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Through the Eye of the Needle: Investigations of Ethnographic, Experimental, and Archaeological Bone Tool Use Wear from Perishable Technologies

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THROUGH THE EYE OF THE NEEDLE:

INVESTIGATIONS OF ETHNOGRAPHIC, EXPERIMENTAL, AND ARCHAEOLOGICAL BONE TOOL USE WEAR FROM PERISHABLE TECHNOLOGIES

BY

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DISSERTATION

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DEDICATION

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ABSTRACT

Perishable technologies – objects made from soft, organic materials that often decay quickly in the archaeological record – are known to be both ubiquitous and abundant in contemporary and historic societies, regardless of variation in social and economic organization or local environment. They are commonly made by women, children and elders, members of society that are often underrepresented in reconstructions of the

past. However, their perishable nature means that these objects are recovered from the archaeological record at low rates, relative to that of more durable materials. Consequently, most evidence for these technologies is indirect.

Use wear on the surface of bone tools provides indirect evidence of perishable materials, as these tools are frequently used in the manufacture of basketry, nets, mats, webbing, and woven fabrics and in the joining of perishable elements to make more complex objects, such as clothing, bags, or structural elements. This dissertation focuses on identifying differences between use wear from plant and animal fibers on bone tools, using a methodologically innovative multi-scalar approach. Analysis is organized at the scale of the working surface and assessed with a predictive tribological model that uses the known properties of different fibers to understand the accumulation of diagnostic attrition. Three kinds of worked bone surfaces are analyzed: experimental, ethnographic and archaeological. While experimentation is standard for use wear analysis, the introduction of systematic, comprehensive, microscopic study of a broad ethnographic sample is significant. Ethnographic and experimental samples demonstrate that function cannot be identified by artifact form and that tribological predictions are a powerful means for identifying wear diagnostic of plant and animal fibers. An archaeological case study from three Magdalenian and Azilian sites in Northern Spain – Entrefoces, El Perro, El Juyo – is presented. Analysis of use wear on osseous artifacts from these sites indicates that both plant and animal fibers were manipulated, a significant result, as evidence for the use of plant fibers at these sites is otherwise absent. This evidence is important for understanding the labor of Late Upper

Paleolithic individuals beyond large game hunting and suggests some activities that may have been carried out by women, children and elders.

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Chapter 1. Introduction

The role of perishable fiber technologies within contemporary, historic, and late prehistoric communities is widely acknowledged to be technologically, socially, culturally, and economically important (Brumfiel 1996; Croes 1997; Drooker and Webster 2000; Hurcombe 2008b, 2010; McCorriston, et al. 1997; Schneider 1987). In nearly every known context, vegetal and animal resources are manipulated into forms that include cordage, leathers and hides, thongs, sinew thread, bags, baskets, nets, mats, clothing, and knitted, knotted, and woven fabrics. These kinds of objects serve a number of utilitarian functions as well as forming rich, malleable media in which gender, social class, occupation, and many other social identities are expressed. However, despite their modern near-ubiquity and marked social and economic importance in many documented contexts, little is known about the early prehistoric manufacture and use of fiber technologies, and in particular of the exploitation of vegetal fibers. This is unfortunate, because the simple presence or absence of such an enormous class of raw materials has vast implications for our understanding of technology, ideology, social relations, economy, and exploitation of the environment.

However, the evidence for the manipulation of plant and animal fibers into artifacts is minimal, especially in Upper Paleolithic contexts. This large gap in archaeological knowledge is driven by issues of preservation, methodological choices, and by the

historic gender imbalance in archaeological research, particularly in the area of Ice Age hunter-gatherer studies. Each of these aspects has distinct roots and each presents real and substantial challenges, however none is insurmountable.

Within the context of Late Upper Paleolithic research, almost nothing is known about the role played by perishable artifacts, especially the various classes of fiber industries. Although references to finds of bone needles typically suggest that this implies the construction of tailored clothing (i.e., Hoffecker 2005; Straus 2005), this is based more on informal analogy than on directed research aimed at elucidating the kinds of fiber industries manufactured during this period. In many archaeological contexts, including the Late Upper Paleolithic, there is poor or no preservation of fiber industries, presenting a barrier to the study of such perishable technologies. However, bone tools are commonly used to work both plant and animal derived fibers, textiles, and hides and often are preserved in sites where there is no other evidence of textile, hide or basketry production.

Late Upper Paleolithic bone tools have been studied as objects of art, chronological markers, or hunting implements, but minimal attention has been paid to other potential uses of osseous artifacts. Due to the elaborate and impressive nature of many worked bone "art" pieces from the Late Upper Paleolithic in Spain and other regions, attention has focused on activities that likely fall outside of quotidian domestic labor. Subsistence studies, the one common topic of Late Upper Paleolithic worked bone functional studies (Knecht 1993, 1997; Letourneux and Pétillon 2008; Pétillon 2005, 2006), have

emphasized the contribution of large game to the Late Upper Paleolithic diet, and by extension, the importance of perishable raw materials that also derive from large mammals, including large hides, sinew, and bone.

This emphasis is partially due to a gender imbalance in the direction of Late Upper Paleolithic studies. While the dietary elements generally assumed to be procured by young, healthy men – large game – are more archaeologically obvious, they are also granted disproportionately more importance in models and reconstructions than contributions of other members of society. This emphasis on men's activities is typically dismissed as an unavoidable consequence of the nature of the Upper Paleolithic archaeological record, predominantly one of stone and bone in caves. Even accepting for the moment that it is likely that 1) Upper Paleolithic groups in Western Europe depended on the hunting of large game for a significant portion of their diet, and 2) that young and middle-aged men were responsible for big game hunting, a major bias that has nothing to do with the nature of the archaeological record is evident. Why do we talk about hunting big game and not discuss questions of preparation and storage? When butchering is discussed, it is frequently assessed in order to determine the priorities for hunters, rather than as a tool for investigating quotidian life within the community; other resources that are identified are seen as either supplements to the big game diet or a curious "alternative" strategy that must be somehow fit into the big game hunting schedule. Big game were clearly an important aspect of Late Upper Paleolithic subsistence in Northern Spain; however, the nature of the archaeological record does not prevent us from considering the role of meat, hide and bones within

the group after the hunt, nor does it dictate that big game hunting was the primary activity around which all other aspects of Upper Paleolithic life were organized.

Many other studies simply consider Late Upper Paleolithic groups as a whole, but in doing so, implicitly elevate the roles of men to represent a greater portion of the overall activities of Late Upper Paleolithic people. For example, Paleolithic groups are often described as “big-game hunters”, a description that may accurately describe the primary labor of young and middle aged men, but is unlikely to encompass the primary activities of other people. The subsistence and economic labor of women, children and the elderly have been glossed over or simply ignored, leaving a large gap in our knowledge of Late Upper Paleolithic lifeways.

In summary, a substantial gap in our knowledge of ancient, and in particular Late Upper Paleolithic, lifeways has been identified. We are constrained by our questioning of the record, not by the information it contains. Despite their demonstrable importance in contemporary and historic contexts, perishable industries have received minimal archaeological attention except in sites of extraordinary preservation where organic materials are well preserved. This gap cannot be attributed merely to the difficulty of studying such industries, given the prevalence of studies of religion and ritual, mobility, and trade, all of which are equally “invisible” in the immediate archaeological record. A focus on the economic and subsistence contributions of young to middle-aged men pervades in Late Upper Paleolithic studies. Because large game hunting explains the largest and most obvious elements of the Late Upper Paleolithic archaeological record,

without an explicit consideration of the range of age, gender and abilities of Late Upper Paleolithic people, other activities that were common but leave less of an archaeological trace have been overlooked.

1.1. Bone Tools and the Manufacture of Perishable Industries

Because of the prevalence of large game bones at Late Upper Paleolithic sites, many with cutmarks that indicate both butchery and hide removal, the assumption that Late Upper Paleolithic people made and used hides and leathers is generally uncontroversial, despite very few studies aimed directly at understanding the details of hide preparation and use. Several current and recent studies are elucidating this activity, however, and demonstrate the importance of soft materials of animal origin in the Late Upper Paleolithic (Amato 2010; Lompré and Negroni 2006). Although we often envision Paleolithic people dressed exclusively in furs and hides as they produce stone and bone instruments, there is extensive evidence that the extraction of plant fibers and the manufacture of textiles and basketry were also, at a minimum, possible. Bone and lithic technologies from the Late Upper Paleolithic are extremely complex and sophisticated; the production of perishable technologies was undoubtedly also highly developed. Climatic shifts at the end of the Pleistocene resulted in the availability of new plant fiber sources. This period is also known for a dramatic increase in the number and variability of osseous tool forms, the function of many of which remains unknown. Of particular

interest is the appearance of the eyed bone needle around 20,000 years B.P., which appears much earlier in Eastern Europe and at the same time and in the same places as the earliest evidence for woven textiles (Adovasio, et al. 2001).

In the ethnographic and historic records, particularly in areas where the use of metal is unknown, restricted or expensive, bone is one of the most common raw materials used to produce tools for the preparation and manipulation of plant and animal fibers. Examples include basketry awls, needles, weaving tools, beamers and hide scrapers and burnishers. The physical properties of bone make it an ideal material for working with fine, smooth, flexible surfaces and fibers. Additionally, bone and fiber industries are both frequently associated with domestic contexts. Coupled with the fact that a large number of common Late Upper Paleolithic osseous tool forms are of unknown use, functional studies of bone tools of fiber industry production may provide information on the roles of osseous and fiber technologies in the Late Upper Paleolithic. Wear, the microscopic and macroscopic attrition accrued through contact with diverse materials, provides a physical marker of use, handling and other treatment of bone tools. Beginning with Semenov (1964), previous studies have demonstrated the utility of use wear on bone tools for identifying the ways that these artifacts were used, including the processing and manufacture of perishable materials (Buc 2005; LeMoine 1997, 2002; Olsen 1984). The research presented here employs the analysis of use wear from soft materials on bone as a way to begin to identify the role of vegetal and animal fibers in the Late Upper Paleolithic.

1.2. Methodological Significance

The archaeological analysis of function relies on strong bridging arguments concerning the material signatures of activities. Traditionally, some of the means of constructing these arguments have been through formal analogy, experimentation, and use wear analysis. This dissertation will challenge some of these forms of argument and clarify the means of pursuing others, with particular attention to the functional analysis of osseous tools.

Foremost, through a study of ethnographic variability in bone tools used in the manufacture of fiber industries, I will argue that the coincidence of form and function is not a reasonable assumption and that form cannot be used as a proxy for the function of archaeological tools. This has significant implications for the ways that archaeological assemblages are organized and analyzed.

Methodologically, I will demonstrate the utility of large-scale materials-based studies of ethnographic tools as a robust means of identifying signatures of use. Importantly, ethnographic artifact collections gain comparative value when studies are done at the scale of working surface, rather than at the artifact or activity scale. I will show how setting the scale at the level of working surface helps resolve some of the well-known difficulties of using disparate – and particularly, older – ethnographic collections to

construct comparative standards for archaeological analysis. This unconventional approach also allows for the comparison of surfaces from different temporal periods, cultural contexts, and economic systems, as the working surface remains the constant unit of analysis.

Secondly, I will present a new model for framing use wear analysis, which draws on tribology, a subfield of materials engineering that focuses on understanding the outcome of contact between materials. The use of tribology allows archaeologists to go beyond documenting the outcome of wear from known contexts and constructing empirically derived standards and allows them to predict and explain variation in wear patterns from different materials, conditions and actions.

Finally, I will look specifically at the relationship between bone tools and fiber industries. I show that the unique physical properties of bone make it a suitable material for tools used in the processing and manipulation of fibers and soft materials of both animal and plant origin. I will demonstrate this pattern in the ethnographic record and argue that many prehistoric tools for perishable technology manufacture were also probably made from bone.

Because bone is uniquely constrained in terms of the possible morphology of tools, the connection between form and function is even more tenuous for osseous artifacts than for some other material classes. Use wear is the best way to identify functional classes in archaeological assemblages, particularly in the absence of chemical residues that

might indicate specific behaviors. At this point in the development of bone use wear analysis methodologies, we have the requisite knowledge to move from identifying the general hardness of worked materials to considering the question of worked material more specifically and to identifying classes of fiber industries created with bone tools.

1.3. Case Studies

The materials studied in this dissertation come from experimental, ethnographic and archaeological sources. The experimental collection is derived both from my own experiments and numerous experiments reported in previous publications. Ethnographic collections, which comprise the largest collection of worked bone artifacts in the study, come from locations throughout the world, with a strong emphasis on North America due to the use of North American museums as the sources for the artifacts analyzed. Archaeological artifacts come from three Late Upper Paleolithic sites in Northern Spain. Entrefoces and El Perro are small sites with a single temporal component while El Juyo is a large site with a series of Magdalenian levels, along with scant evidence of a much later Bronze Age occupation.

These three kinds of artifact collections present distinct challenges and advantages for the study of use wear. These differences will be addressed in detail. However, they have allowed me to begin to address the question that drove the development of this

research problem: identifying evidence for the use of plant-derived fiber technologies in the Late Upper Paleolithic.

1.4. Organization of the Dissertation

The dissertation is organized into 11 chapters. Chapter 1, “Introduction”, introduces the reader to the research questions and broader goals and contributions of the research. Chapter 2, “A Brief History of Bone Technology Studies”, will contextualize this project within a wider framework of archaeological research, focusing in particular on bone tool and use wear studies. Special attention will be given to the history of osseous artifact research at Late Upper Paleolithic sites in Northern Spain as the archaeological case studies were selected from this region. The following Chapter 3, “Perishable Technologies in the Archaeological Record” provides background on the evidence for plant and animal based fiber industries in the Pleistocene and then reviews approaches to the study of these kinds of fragile and perishable materials. Chapter 4, “Tribology”, introduces the reader to the fundamental structure of tribological research, the theoretical framework used here to organize wear studies. A predictive model for wear from soft materials on bone surfaces will be presented, included a detailed discussion of the properties of different organic materials. Chapter 5, “Methodology”, considers traditional approaches to ethnographic, experimental, and archaeological bone tool studies, and then presents the theoretical frameworks for the methods I developed and

employed. Even though three distinct sources are employed, the same observational categories were used, making it possible to unite all of the material for comparative analytical purposes. Chapter 6, “Analytical Protocol”, outlines the research method used to identify and record use wear on bone tools. Chapter 7, “Experimental Program” describes experimental protocols, experiments and results. Wear patterns are assessed against the tribological model developed in Chapter 4. Chapters 8 and 9 contain the study of ethnographic materials. Chapter 8, “Analysis of Ethnographic Collections”, highlights some of the archival and contextual documents that accompany ethnographic collections, discusses the selection of objects for functional analysis and provides some background information on the use of bone tools in the ethnographic and historical record. The collection of ethnographic bone tools is analyzed macroscopically and microscopically. The results of microwear analysis are assessed against the tribological predictions. Chapter 9, “Ethnographic Case Studies” makes use of two kinds of examples to provide a detailed example of the connections between museum objects, documents, bone tool surfaces, tribological studies, and application to the archaeological record. First, beginning from an activity and associated tool, snowshoe needles from North America are examined, morphologically and microscopically. Then, beginning with the tribological predictions, tools with wear consistent with the predictions for contact between plant fibers and bone are isolated. These two cases show two different ways that ethnographic materials can contribute to the analysis of archaeological collections. In Chapter 10, “Archaeological Analysis”, the osseous artifact collections from Entrefoces, El Perro, and El Juyo are described and the microwear analysis is

summarized. Tribological predictions are compared to archaeological patterns. Chapter 11, “Conclusions and Future Directions”, will discuss the utility of the tribological model, the importance of the ethnographic study in a wider archaeological context, and suggest directions for further research.

Chapter 2. A Brief History of Bone Technology Studies

Artifacts made from osseous materials – bone, antler, ivory, horn, shell and other hard animal parts – are a reductive technology that is common in many historic and prehistoric contexts. Bone and antler are the most common osseous raw materials for the production of tools, although the other materials are also regularly used for artifacts. The unique qualities of osseous materials make them appropriate for the manufacture of certain kinds of implements and ornaments. Bone and antler are readily available raw materials in most contexts and come in predictable shapes and sizes – skeletal elements – and have known physical properties. The physical properties of bone and the effect these properties have when tools are made from bone will be discussed in detail in Chapter 4 (Tribology). Here, it is important to note that bone tools, regardless of origin, tend to fall into a fairly narrow range of morphological forms, due to the physical and morphological constraints of the raw material.

Analytically, osseous industries are among the most neglected classes of archaeological artifacts, particularly in North America. Despite their prevalence in most time periods and known archaeological assemblages, specialists in bone, antler and other osseous tools are fairly rare, relative to the number of lithic, ceramic, or even faunal specialists in the archaeological profession. Only in the last 30 years has there been an increase in the kinds of analyses carried out on bone tools and in the overall number of such studies undertaken. This change can be linked primarily to the work of a few individuals who

have increased both the visibility of osseous objects as an artifact class and have worked to enhance communication among bone tool specialists. In the 1970s, Henriette Camps-Fabrer convened the Committee for the Nomenclature of Prehistoric Bone Industry (Camps-Fabrer 1974). Her organization has provided a model for the development of well-defined typologies and forms of analyzing and presenting osseous assemblages. Alice Choyke, Sandra Olsen and Jörg Schibler produced the first large studies that inspired new perspectives on the utility of worked bone for understanding prehistory (Choyke 1983; Olsen 1984; see also LeMoine 2001). Choyke formed the Worked Bone Research Group in the 1990s. This is a semi-independent working group under the auspices of the International Council for Archaeozoology. The work of these scholars, along with many other early bone tool specialists, has resulted in the development of an area of study that cuts across methodological and chronological boundaries and has been increasingly active over time. As a result, a true methodological language has developed through enhanced communication among bone tool specialists.

Although there are many earlier, isolated studies of osseous industries (Barandiarán Maestu 1967; Kidder 1932; Kitching 1963), the contemporary approaches to the study of archaeological bone tools were developed during the 1980s and 1990s, when a number of large-scale studies were done. During this period, several modes of osseous artifact analysis were defined, including chronological-typological studies, and technological approaches that incorporated bone tool analysis into broader understandings of the exploitation of animal resources, functional studies, and social analyses of bone artifacts. Additionally, chronological and stylistic typologies were

refined in many regions. In terms of methodology, many papers concerned directly with methodological advancement and rigor were published, especially in France, while the roles of experimentation, traceological study, and social theory all became established in bone tool research (Adán Álvarez 1997; Bonnichsen and Sorg 1989; Campana 1989; Camps-Fabrer 1981; Choyke 1983; Corchón Rodríguez 1986; Johnson 1985; Knecht 1993; LeMoine 1997; Olsen 1984; Spector 1991). In this chapter, I will provide an overview of the development and most common contemporary approaches to bone tool studies.

2.1. Approaches to the Study of Bone Technology

Because bone tools are common and can be worked into many different forms, the study of archaeological osseous artifacts can provide information on a wide range of human activities, including economic and subsistence practices. Studies of worked osseous materials can address both the technological and social aspects of the use of bone and other materials for artifact production. Here, I discuss some of the most important kinds of archaeological bone tool studies and situate research into the manipulation of soft organic materials with bone tools within the broader field of bone technology studies.

As noted by Christian Gates St-Pierre and Renee Walker (2007), the topics and methods of contemporary bone tool studies are now more widely coherent across regional and temporal boundaries, including bridging differences between North American and European approaches to archaeology. As the field of worked bone studies has matured, the various movements of the last three decades have begun to converge into a more consolidated methodology and perspective. Generally, bone tool studies must be rooted in strong zooarchaeological methods (Choyke and Schibler 2007; Crabtree and Campana 2010; David 2010; Le Dosseur 2010; Olsen 2007). Researchers now agree that the raw material (both element and species), manufacturing techniques, morphology, and evidence for wear are all interrelated aspects of osseous technology that cannot be understood in isolation (Choyke 1997; David 2007b; Scheinsohn 2010). Likewise, the social aspects of bone tool production and use can be more profitably investigated as our basic understanding of the nature of osseous technologies has developed. Like other artifact classes, bone tools can indicate significant social change either in symbolic and stylistic capacities or by providing evidence of changes in economic systems (Brumfiel 2007; Choyke 2006; Dobres 1995; Olsen, et al. 2006).

2.1.1. Descriptive Typologies

As in the early phases of the analysis of all kinds of material culture and in culture history building, one of the primary modes of osseous artifact analysis has been the

establishment of local and regional chronologies and typological schema. Bone and antler technology are frequently used in the definition of chrono-technological phases, particularly in the Upper Paleolithic of Europe where ceramics are not present. The most commonly used typology for bone and antler artifacts in Spain, for instance, is Ignacio Barandiarán's volume (Barandiarán Maestu 1967), which presents a detailed morphological typology of bone tools, emphasizing in particular the decorative elements on different forms. This detailed, comprehensive typology has been used in nearly all studies of osseous artifact assemblages in the Upper Paleolithic and Mesolithic of Spain. Barandiarán was also a prolific writer and analyst and classified many of the bone tool assemblages from major excavations in Spain during the 1960s-1980s (Barandiarán Maestu 1985a, b; Barandiarán Maestu 1981a, b). The use of bone tools – especially antler points or *sagaies* – as chronological markers is especially common during the Upper Paleolithic of Spain, where preservation of osseous materials is often fairly good and small fragments of *sagaies* can frequently be assigned to one of Barandiarán's types.

The classic French approach to bone tool analysis, characterized by a concern with explicit definitions and methodology, is displayed in numerous clarifications and revisions of typological categories and definitions that appear in the French literature. It is exemplified by the work of Henriette Camps-Fabrer, the renowned French bone tool analyst. The Committee for the Nomenclature of Prehistoric Bone Industry was first formed in 1974 at a symposium of the same name convened by Camps-Fabrer and has published a long series of *Fiches Typologiques de l'Industrie Osseuse Prehistorique*,

typological handbooks for different kinds of osseous artifacts. There are currently 10 volumes, that address different morphological forms, including *sagaies*, points, objects of adornment, and retouchers, along with a shorter series of volumes on analytical methodology (Barge, et al. 1992; Camps-Fabrer 1974, 1988, 1993, 1995, 1998; Camps-Fabrer, et al. 1991; Camps-Fabrer and Ramseyer 1998; Camps-Fabrer, et al. 1990; Cattelain 1988; Giacobini and Patou-Mathis 2002; Julien, et al. 1999; Lejeune 1987; Patou-Mathis 1985, 1986, 1989, 1994, 2002a, b; Ramseyer 2001, 2004).

Camps-Fabrer also published prolifically on her own, notably on questions of typology and clear definitions of the terms and categories we use (Camps-Fabrer 1981; Camps-Fabrer 1966; Camps-Fabrer, et al. 1993; Camps-Fabrer and Bourrelly 1974; Camps-Fabrer, et al. 1985; Camps-Fabrer and Morin-Barde 1987). In an early volume, Camps-Fabrer (1966) presented basic information about the classification schema she developed to describe bone tools from Northern Africa, arguing that typologies should be organized functionally, and presented morphological categories that may also have functional significance. She also employed local ethnographic and historic evidence that pointed to a major role for osseous tools in hide working, to interpret some of the potential uses of the prehistoric tools.

Over time, the French paradigm for inventorying and studying bone tools has gradually changed, allowing the introduction of more social and anthropological emphases in their interpretations. However, most French research is still organized around the construction of clear, well-defined morphological typologies as the basis for their work.

The role of typology in archaeological research is repeatedly discussed, critiqued and revised (i.e., Averbouh and Buisson 1996, 2003; Pétillon 2005, 2006; Sidéra 2005). Authors such as Averbouh and Buisson (1996) argue that bone tools have not undergone the same history of classification and reclassification as that of lithic materials, and so, there is not even a systematic and common overarching descriptive terminology for morphology. In order for authors to communicate, a common language is necessary so that different people can understand what is meant when they are describing the same tool type or the same surface patterns.

Following Camps-Fabrer's lead, many French researchers have devoted extensive attention to exploring the utility of typologies to group artifacts by function. Part of the success of this method necessarily lies in the appropriate and detailed definition of categories and attributes. Perhaps no other group of researchers have more clearly defined and refined the typologies used for bone tool analysis. However, as I will show, even very detailed morphological typologies cannot be taken as also representing functional groups.

More recent studies from French researchers have begun to emphasize other approaches to the integration of social and subsistence aspects of the manufacture and use of osseous artifacts. Jean-Marc Pétillion (2005, 2006) began his dissertation research considering the chronological and cultural markers commonly employed in Upper Paleolithic research. Projectile points, both lithic and osseous, are often seen as important diagnostic markers of Upper Paleolithic phases or “cultures” due to their

variation, rapid change, and standardization. Major explanations for this stylistic differentiation include a generalized idea of progress, competition between groups or selective arguments that suggest that changes must reflect increasing adaptation to an environment. However, as Pétillon (2005, 2006) notes, two major points often go unnoted or are not discussed in the literature on projectile points. First, many of these objects are classified as points for hunting based on formal ethnographic analogy, which may be quite reasonable in many cases, but is often left untested or otherwise unevaluated. Second, the range of variation within assemblages is often noted but the implications for human behavior left unaddressed. His dissertation focused on addressing these issues and probing the utility of typological classifications for identifying function and social role of artifacts.

Pétillon reconstructs the life history of the split-based point at Isturitz as:

1. the collection of raw material from the landscape;

2. the production *en masse* of points, which can be effectively made in series from a single antler, leading to both over-production and standardization;

3. mounting and use as projectiles;

4. retrieval of points for repair and reuse.

There is no apparent advantage to either type of point; it may be that the choice to produce split-based points at Isturitz is simply a cultural decision and may be taken as a

marker of an area and a brief time period at the transition between the Middle and Upper Magdalenian.

For the Late Upper Paleolithic of northern Spain, the connection between morphological typologies and temporal periods has been challenged. Manuel González Morales (1986) discusses the osseous assemblage from the multi-component cave site of La Riera and suggests that it has implications for questioning the temporal boundedness of several “diagnostic” types. Excavations in 1976-79 focused on a peripheral portion of the cave, near the back of the vestibule, and, based on the large number of fragments and limited number of formal bone tools, González Morales suggests that this area constitutes a “drop zone” for osseous waste. If this is true, then the artifacts recovered from this zone cannot be taken as representative of the use of bone as a raw material in the entire cave. Overall at the site, bone and antler are scarce in comparison to lithics and the assemblage contains only 336 pieces, including many small fragments. Additionally, osseous material is distributed unevenly over levels, with the majority coming from certain Solutrean (7, 9, 16, 18) and the lowest and highest Magdalenian levels (19, 24). González Morales suggests that bone industry at the site may be more reflective of stylistic choices than chronological or technological variation, because there is a wide range of variation within each functional or typological type.

Overall, *sagaies* dominate the collection, but this class has high internal variability. Certain 'diagnostic' types appear to be 'out of place' at La Riera, indicating that the temporal significance of these forms may be questioned. In particular, bi-pointed,

flattened *sagaies*, often seen as a marker of the late Solutrean, appear in the early Solutrean (level 4) at the site. Single-basal-bevel *sagaies* are also typically viewed as specific to the later Solutrean and early Magdalenian and were recovered from levels dated to the early Solutrean (7, 9, 19). So, both lithic and osseous artifact types with supposed temporal significance appear earlier than expected in the sequence at La Riera.

Summary: Historically, descriptive approaches to the study of osseous artifacts underlie most other analyses that start from the basic categories defined in descriptive studies. These studies are often comprehensive in terms of the description of artifacts commonly encountered in the archaeological record. However, because they are not problem-driven, descriptive studies cannot produce analytic units to answer many questions about the role of bone as a raw material in prehistory. Research questions must precede the construction of analytical types, so that the units of analysis are appropriate to the goals of the research (Ramenofsky and Steffen 1998). Descriptive typologies are not always the most useful organizational systems for understanding bone tools in the past.

2.2. Bone industry as art

Like ceramics, but unlike lithic artifacts, objects from osseous materials may often be highly decorated or may be used as decorative elements such as beads or buttons in clothing or other materials (i.e., Rijkelijkhuizen 2010). This aspect of bone tools opens up another line of inquiry on osseous artifacts: their analysis as art objects. This approach is less common among bone tool specialists, but is rather more commonly under the purview of specialists in symbolic expression or cognitive studies. Objects of bone can be analyzed for patterns of decorative motifs or symbolic forms that indicate their special purpose in ritual (Zhilin 2010) or the meaning of the act of engraving and decorating bone (David 2010). For the Upper Paleolithic of Spain, this approach is exemplified by the work of María Soledad Corchón Rodríguez (Corchón Rodríguez 1971, 1986; Corchón Rodríguez and Garrido Pimentel 2007a, 2007b, 2008) and her students.

Additionally, a number of researchers interested in the development of symbolic expression in the Upper Paleolithic have focused on both the form and manufacture sequence of bone, ivory, and antler objects as part of an overall analysis of the role of symbolism in human communities at the end of the Pleistocene (Farbstein 2010; Goutas 2004; Marshack 1964; Montet-White 1994; White 1992, 2006). Because objects of an apparent symbolic nature are essentially absent in Europe before the Upper Paleolithic, such artifacts have come to be recognized as an important indicator of behavioral modernity. However, the research and opinions on this topic are vast, and not relevant

to the research presented here, so I will not attempt to review this aspect of bone tool studies. For an extensive review of the evidence in Europe and Africa see McBrearty and Brooks or Henshilwood and Marean (Henshilwood and Marean 2003; McBrearty and Brooks 2000). There are many instances of elaborately decorated bone tools from the Late Upper Paleolithic of Europe that have been seen as good indicators for symbolic communication. Work on the symbolic and social aspects of worked bone from Magdalenian sites in Northern Spain will be considered in greater detail in Chapter 10 (Archaeological Analysis).

2.3. Social or Anthropological Approaches

Bone tools are often decorated and are made from the body of a formerly living being. In many cases, bone tools have special social significance and are associated with ritual, gendered identity, socio-economic roles, or group-level identity (Camps-Fabrer, et al. 1991; Camps-Fabrer, et al. 1985; Choyke 2006; Choyke, et al. 2004; Costin, et al. 1998; Dobres 1995; González Morales 2005; Goutas 2004; McGhee 1977; Spector 1991). Osseous artifacts can be used to explore the social identity and relations of the people who made or used them.

Marcia Dobres (1995, 2000) argues that production of technology is a socially grounded process that is guided by, and at the same time creates, social relations. In other words,

technology, or the organization of manufacture sequences, is one arena for the enactment of social identity. Importantly, it is also an activity that has the archaeological advantage of having a material correlate. While research on Upper Paleolithic osseous artifact assemblages has generally been structured around typological concerns and the definition of macrotrends and social norms, Dobres, instead, presents an analysis with the explicit goal of identifying social identities, in particular gendered labor and production, in the manufacture of Late Upper Paleolithic bone technology. Finally, she argues that a gendered approach to the archaeological past does not require that specific gender relations be understood, only that the presence of socially differentiated roles be identified. Although Dobres states that she is departing from typical typological approaches, she bases her analysis on eight formal typological categories, such as harpoons, *sagaies*, needles, and *demi-batons*, and then assigns these groups functional meaning that corresponds with their traditional names. She has created a multi-linear approach to the study of osseous technology overall and her analysis allows comparison at the level of object, group, site, and region. However, Dobres argues that variation in the pattern of deviation from the averages at different sites is evidence for differentiation in social behavior at the respective sites. She does not consider the possibility that variation may arise from different uses for morphologically similar objects and treats each location as a temporally discrete locale and fails to consider the relationships that may have existed between sites.

Genevieve LeMoine (1997) also frames her research in terms of different approaches to style and design, emphasizing in particular Chippendale's definition of archaeology as

the study of past design systems (Chippendale 1986), and Sackett's isochrestic style model (Sackett 1977). The production of any artifact follows a path of various choices made among options. The options are constrained by both explicit or recognized cultural preference and learned motor habits, themselves guided by cultural preferences. This is relevant to the study of bone tools both in terms of their production and in terms of her assertion that use of tools is often repetitive, supporting attempts at functional analysis. That is, production and use are not random. Motor habits are often culturally and behaviorally embedded and not easily unlearned, so actions are standardized and repetitive. LeMoine does not base her argument for use wear analysis on this quality, however, it seems relevant.

2.4. Studies of Osseous Artifact Manufacture

There is a vast literature on the manufacture of bone tools. The production of bone tools is similar to that of lithic tools in that both are reductive technologies – that is, tools are formed through the removal of material (as opposed to the production of ceramics, which is an additive and altered technology). Because of this similarity analysts of osseous technology can borrow some theoretical and methodological ideas from the more developed field of lithic analysis, both in manufacture and use. Additionally, many of the methodological debates have been shared between the two related disciplines. Although much of the debris from bone tool production is too fine

to be recovered from the archaeological record, production and use marks are more visible on osseous material than on flaked stone. The analysis of the use of either bone or lithic tools is made more difficult by the fact that use erases previous marks over time. Analysis of surface traces can only address the last uses of the tool, although this is also a problem faced by most archaeologists on one scale or another. Continued use of tools, sites, and landscapes obscures previous use.

Manufacturing patterns can help identify cultural lineages and learning traditions (Cazals 2005; David 2007; Emery 2001). Manufacture choices may be either conscious or reflect learned traditions of manufacture or local standards (Amin and Roberts 2008; Lave and Wenger 1991). Here, I examine the ways that archaeologists have studied the means by which artifacts are made from bone and other osseous materials. Raw material choice, a significant aspect of bone tool manufacture, will be addressed separately. Distinguishing between human modification of bone and taphonomic alterations is discussed in Chapter 5 (Methodology).

Eva David (2007a, b) has developed a method for identifying technological traditions in osseous materials, with particular attention to the production of artifact blanks using Northern European Mesolithic materials. She argues that, when combined with lithic technological patterns, manufacture lineages can be used to identify broad cultural groups. For example, blank production is often surprisingly varied for similar final forms, indicating different manufacture lineages achieving the same goal (see also Legrand 2005; Legrand and Sidéra 2007; Sidéra and Legrand 2006).

Patricia McComb (1989) wrote her dissertation with an explicit focus on the methodology of the study of bone tools and on identifying production sequences. She examines artifacts made from bone, antler, ivory and tooth from the Upper Paleolithic of Britain and Belgium. The McComb study focuses on the technology of osseous artifact production.

Douglas Campana (1989) explores the conditions under which bone can best be worked through a number of experiments. He begins with a test of fresh, dry, and dry but soaked cattle bone. He finds only fresh bone to be workable; soaked bone is workable only at the outer surface and the revealed surface must be soaked for continued work. He argues that dry bone is virtually impossible to work with flint tools; the lithic tools break before any substantial cuts can be made. Campana finds large scrapers to be the ideal tools for working bone because finer tools break too quickly. The retouched edge of scrapers leaves diagnostic striations on the bone surface. Fine parallel lines and striations can be seen running longitudinally on the surface of bone worked with a stone scraper. Work proceeds more quickly when the bone surface is lubricated with water and this also eliminates chattermarks, series of short, shallow, parallel incisions on the bone surface, which other researchers have identified as diagnostic of the use of stone tools on bone.

Investment of time or energy has been a useful heuristic for thinking about kinds of osseous reduction (Choyke 1997; Legrand and Sidéra 2007; Rabett 2005). Generally, investment in osseous artifact production is identified according to the degree of

modification of tools and kinds of blank production. However, the energy put into the procurement of raw material can also be reasonably considered as an indicator of investment, particularly in the case of antler, which is not always procured from a hunted animal. Raw material choices are considered separately in the subsequent section of this chapter.

Campana (1989) created about 30 bone points with the scraping technique, each taking about 15 minutes after blank production, which was done with a metal saw in the interest of economy of time. He also made a set of 30 tools by abrasion on sandstone. Both cross-grinding, against the grain of the bone and perpendicular to the long axis of the fragment, and axial grinding, parallel to the long axis and with the grain of the bone were employed. He finds that cross-grinding is effective for primary shaping and smoothing, while axial grinding is more useful in the production of sharp tips or symmetrical, round pieces. Bone may be wet, dry or soaked when worked by abrasion, but lubricating water is essential. Faceted sides are diagnostic of cross-grinding while axial grinding produces smooth, curved sides. Production striations are finer than those produced by flint scrapers.

Many studies have been done on the kinds of manufacture techniques employed for specific artifact classes (Averbouh 2001; Averbouh and Buisson 2003; Corchón Rodríguez and Garrido Pimentel 2007 i.p.; Goutas 2004). These studies are often combined with a stylistic or formal typological study. One of the assumptions that underlie many of these studies is that the most "efficient" technologies are always used.

It is critical to remember, though, that tradition often supersedes efficiency as the driver of manufacture patterns.

Hare tibiae were used for needle production in the German Magdalenian (Owen 2005). Usually only one blank was produced per tibia. Fresh tibiae were roughened and then the groove and splinter technique was used to remove a blank. In other parts of Europe the bones of ducks, geese and swans were frequently used for needle production. Jeffrey Flenniken (1978) describes the experimental reproduction of needles from the sites of Lind Coulee and Marmes Rockshelter. He made the needles from hare tibia, which were smashed and twisted in order to create fragments from which blanks of appropriate size and shape were selected. Acute-angled flake knives were used to further shape the bone splinters. When the blank was about twice as wide the desired product, perforations were produced by drilling with a flint drill. Sandstone abraders were then used to further shape the artifact, which resulted in round grooves on the abraders, which are similar to artifacts recovered from the site. Stordeur-Yedid (1979) and McComb (1989) both argue that needle perforation is simple and fast and would be one of the last steps because it is one of the steps least likely to result in failure. They argue that thinning is more likely to break the needle and would be completed before perforation.

Summary: Artifacts are made from osseous materials in a wide range of archaeological periods, cultures and sites. Because they are a reductive technology, later stages of the manufacture process are reflected in artifact surfaces. It has been shown that

techniques of manufacture of bone tools often reflect local traditions. However, the material properties of bone are similar across most bone types and allow us to understand investments of time and energy into bone tool production. Additionally, the basic cadre of bone reduction techniques is similar across temporal and geographic regions and the signatures of these techniques have been documented experimentally and archaeologically.

2.4.1. Raw material use and selection

One of the key issues in the study of bone technology has been understanding the procurement of the raw materials for the production of osseous industries and the articulation of bone tool working with other aspects of animal use and roles in early communities. These studies have been enhanced by the integration of faunal and worked bone assemblages as an interpretive unit, allowing researchers to highlight the connections between body parts used primarily for meat or secondary product procurement, those transformed into tools, and those used in other ways, such as decorative or spiritual uses (Charles 1997; Choyke, et al. 2004; David 2010; O'Connor 1987; Riddler 2003; Scheinsohn 2010).

Descriptive typologies often use species and anatomical body part as the basis for categories, despite evidence from use wear that indicates similar functions. Alice

Choyke (1997), however, argues that viewing tools on a continuum from planned (Class I) to opportunistic (Class II) will better allow us to understand their use and importance in prehistory. Because bone tool typologies are generally based on biological and anatomical aspects of the bone used for the artifact, objects with similar sizes and forms, and potentially, uses, are frequently separated into different groups.

Using Choyke's manufacturing continuum, artifacts can be sorted by the planning involved in production and the importance of "following the rules" in the social organization of production. Highly planned, multi-stage tools are those that are easily and unambiguously recognized as formal tools. The production of such objects is guided and constrained by cultural traditions and practices; these tools may be diagnostic of an area, time, or even specific subgroup within a cultural tradition. These tools were produced in multiple stages of manufacture and were likely to be curated, repaired, and reworked. Non-planned tools, known as expedient, *ad hoc*, or opportunistic, were used as is or only slightly modified. While such tools may have been used extensively, there was little effort put into their manufacture and they are very rarely reworked or were reworked haphazardly. Choyke placed tools in her continuum by plotting use wear and manufacture wear, both scored on an ordinal scale from 0-5.

Investment and raw material selection can be a useful heuristic for assessing the investment and planning of bone tools, although the context of the procurement of bone is certainly a relevant variable that needs to be considered as well. Sex of the animal from which bones are obtained is generally an unimportant factor in the

selection of osseous raw materials unless there is a ritual component (Choyke and Daróczi-Szabó 2010). However, she suggests that in some contexts, the bone from immature animals may be a lower quality raw material for tool production than that of older individuals. Seasonality, availability of materials, and cultural traditions may all result in the use of an "expedient" material in different ways than predicted by the model.

Ryan Rabett (2005) employs Choyke's approach in his examination of bone tools from Southeast Asia. Bone tools are not common in archaeological contexts from the Pleistocene and early Holocene in Southeast Asia, but become more prevalent in middle Holocene coastal contexts. Rabett argues that this increase may indicate that bone tool use is tied to changes in the environment during this transition. In particular, he suggests that bone tools were used to exploit mangrove forests and swamps. Rabett creates a method for recording bone tools in a three-tiered classification:

- point vs. edge-tool, and other miscellaneous categories
  - manufacturing stages and exploitation ratio
    - use wear (function)

Rabett notes that this approach reduces the weight of morphological variation and may mask certain categories but emphasizes history of use and requires a limited number of interpretive decisions be made by the analyst during data recording. The author also

carried out some experimentation, using bone tools as chisels on wood and to dig clay-heavy soil. The wear patterns on one tool from these two materials can be easily distinguished. Bone tools from the two sites examined showed signs of having been used in woodworking. Additionally, there was minimal repair of tools and spent tools were recovered from hearths. Rabett suggests a ritualistic or sub-ritualistic disposal is indicated by this practice.

He notes that the appearance of bone tools correlates with that of mangroves, suggesting a link between the environment and the increased emphasis on bone tool technology. But, once introduced, the presence of osseous artifacts does not decrease with the drying out of mangroves. He notes that there is further work to be done to clarify the function of bone tools at coastal sites but suggests boat-production and harpoon fishing as two areas where bone tools would have been commonly used. He does not, however, address issues of preservation that may also contribute to the patterns of bone tool production and use he identifies.

Vivian Scheinsohn (2010) explores the selection of raw material and variation in morphology of tools produced from an evolutionary perspective. Her study in Tierra del Fuego allows her to examine the process of experimentation with new tool forms in an environmentally circumscribed region. She argues that in this area a period of experimentation is followed by one in which tool types and materials selected are more standardized.

Gema Adán Álvarez (1997) addresses the selection of osseous raw materials in her comprehensive study of Late Upper Paleolithic and Azilian sites in Asturias, Spain. Additionally, she considers the presence of an experimental phase in the production of new osseous technologies at the beginning of the Late Upper Paleolithic. She focuses on situating the selection of raw materials for the manufacture of bone and antler tools within a broader pattern of changes in hunting strategies and technologies along with an increasing territoriality among Late Upper Paleolithic hunter-gatherers.

Summary: The choice of different osseous materials for the production of tools is organized on several scales, most commonly: osseous material used, species, age/sex of animals, and skeletal element. In many cases, because the animals from which bones or other materials are obtained are also food sources, osseous material selection is embedded within subsistence practices. Raw material procurement is also constrained by the composition of the local environment. Choices made by bone tool producers reflect both local traditions of artifact manufacture and the relationship of bone tool production to other aspects of social and economic life.

2.5. Functional Studies

Functional studies are those that deal with the identification of the use of objects in their role in the social and economic lives of the prehistoric users of these tools. There are a number of different types of investigations that might fall under this category, including performance experiments, residue analysis, and use wear studies. Most of these studies focus on some aspect of the used surfaces of tools and the effects of work on these surfaces.

Although I will use the word *function* frequently, in fact this term is a gloss of two related but distinct aspects of tool creation and use: design and use. Intentional design is more frequently reflected in the names that are assigned to objects, such as needle, awl or batten. However, several factors may contribute to the ways objects are used as tools. Tools may be used expediently for a number of other purposes or may have multiple common uses. Secondly, it is important to recognize that the "functional" terms that we use to describe archaeological and ethnographic objects are often fluid and contextual. For example, a "needle" could be a *sewing needle,* used to draw a thread through a fabric, or a *tattoo needle* for drawing an inked thread through skin. It might also denote a large, broad *matting needle* for rushes and thatching or a small, dense *snowshoe needle* for netting leather thongs through a wooden snowshoe frame. Secondly, *use* may not correspond directly to *intention* as is the case in multi-purpose tools or objects that are used expediently for other tasks.

Early functional analyses of bone tools were largely linked to morphology (as discussed above in typology and methodology) and macroscopically visible use wear, which was often not clearly distinguished from taphonomic alterations. James Kitching (1963) produced one of the early worked bone studies at Pin Hole Cave in England. His detailed study provides a great deal of information on the worked bone found at the site, but his interpretations of function are based almost entirely from general morphology.

Functional studies based on performance characteristics and fracture patterns have been particularly useful in understanding tool forms where the use is indicated by form, such as projectile points. Heidi Knecht (1993) discusses the efficacy of different types of Late Upper Paleolithic bone and antler projectile points, as well as considering some aspects of manufacturing techniques. Pétillon (Letourneux and Pétillon 2008; Pétillon 2005, 2006) has demonstrated the importance of fracture patterns for understanding how tools were used. Griffitts (2006) and Scheinsohn (2010) also emphasized performance characteristics. Their work is discussed in Chapter 4 (Tribology).

2.5.1. Use Wear Studies

Sergei Semenov's (1964) important volume on prehistoric technology detailed his method for using experimentation and detailed surface observations to determine the

uses of archaeological artifacts and served to introduce the concept of use wear analysis to the wider archaeological community. Although his work on lithic tools is better known, in fact Semenov and his students devoted significant attention to the production and use of osseous tools. It may be that the unusual osseous forms in the sites he studied were not readily comparable to bone tools from other areas of the world and so his approach to bone tools was less generally applicable and thus, less rapidly assimilated. He also assumed a close relationship between form and function for bone tools, which is now known to be an unsupportable assumption. The relationship between form and function will be considered in depth in later chapters.

The analysis of use wear on bone tools is a powerful tool for reconstructing past economic systems in many cases, but there are significant challenges to the application of such studies, in terms of the logistics of use wear studies, the appropriateness of the approach in some archaeological cases, and the lack of blind testing, coupled with the near-impossibility of identifying all possible contact materials and manufacturing techniques.

It is important to note that the study of surface wear patterns cannot be easily separated from the study of other surface alterations. For this reason, in French and Spanish the preferred term is often traceology (Fr.; *tracéologie*, Sp.: *traceología*). Traceology refers to the study of all surficial traces of human modification, rather than only those developed through use as a tool (Plisson and Lompré 2005). Thus, from the traceological perspective, manufacture, use, handling, curation, and “misuse” cannot be

isolated and can only be appreciated as a whole, in the final product of surface modification. Even in cases where this is not explicitly addressed, the prior preparation of a worked bone surface most certainly plays into the analysis of subsequent use wear.

Use wear studies are time-consuming. There are few widely used standards for assessing use wear patterns, so most analysts must invest significant amounts of time to construct standards for assessing the wear patterns seen on archaeological collections. This is accomplished most commonly through experimental programs, which require significant resources, including time, space for experiments, and materials for experimentation. Few people have the access to these resources to produce large comparative collections, especially when use wear analysts are isolated geographically and intellectually. Additionally, bone tool collections themselves vary widely.

Although she addresses use occasionally, McComb is skeptical about the reliability of wear patterns to indicate the materials worked with bone artifacts. She argues that use wear cannot be used to identify the function of osseous tools or the materials on which they were used because few artifacts preserve original surfaces of high enough quality to identify wear patterns. However, this is likely a specific objection that may be valid in her particular sample, but it is clearly not a valid assessment of the preservation of bone tools in all contexts.

Finally, the methodology for the study of use wear on bone is still being developed (Christidou and Legrand 2005). Standards for magnification, kinds of microscopy, and

filters are lacking. The means of documentation and comparison of wear patterns are irregular, making comparison between studies difficult. Blind tests are virtually unknown in bone tool studies. Concerns about reliability and standardization in use wear analysis will be addressed in Chapter 5 (Methodology), focusing on the relevant work in the field of lithic use wear analysis.

The strongest use wear studies have come from research centers where scholars interested in different aspects of experimental reproduction collaborate, such as the French labs in Paris and MMSH that have long histories of intensive, collaborative experimental studies carried out by faculty, researchers and graduate students. Even in cases where there is substantial support and resources for a large-scale experimental program, it is impossible to test every possible contact material, as Linda Owen has discussed in depth (Owen 1993, 1999, 2005).

The study of use wear is also not feasible in many archaeological contexts (LeMoine 1997; McComb 1989; Vercoutère, et al. 2007). Taphonomic agents may affect the stability of bone on a macroscopic or microscopic scale. In some cases although the morphology of tools in retained, original surfaces are entirely absent or too badly degraded to preserve wear patterns (Figure 2.1: Altamira needle). In other cases, the treatment of bone tools post-excavation includes aggressive cleaning, often with abrasive brushes, that damages or obscures use wear patterns. Museum collections subject to careless handling or storage may also result in damaged surfaces.

Conservation techniques may also present challenges to use wear analysts and will be examined in more detail in Chapter 6 (Analytical Protocol).

Figure 2.1 Needle from Altamira that preserves the original morphology but has no original surface remaining (Altamira CE03960)

By the 1980s, a number of bone use wear and other functional studies had been launched (Campana 1989; LeMoine 1997; McComb 1989; Olsen 1984; Plisson 1993; Runnings, et al. 1989). As more sophisticated methodologies were developed, newer studies were able to better link artifacts and kinds of uses through a number of approaches. The last decade, in particular, has seen a number of important dissertations on bone tool use wear, largely from France. Yolaine Maigrot's (2003) dissertation on Final Neolithic collections from Jura demonstrated the utility of use wear for understanding large assemblages of osseous artifacts of a range of raw materials. Maigrot relied on extensive experimentation, along with the study of some ethnographic tools. Alexandra Legrand (2005) examined Pre-Pottery Neolithic bone tools from Cyprus, considering the role of bone tools in cultural transitions. Janet

Griffitts (2006) studied the intersection of performance characteristics with actual use of bone implements in the Northern Plains of North America. Natacha Buc (Buc 2005, 2010a) has demonstrated that use wear can help distinguish different uses of morphologically similar tools from the Paraná Inferior of Argentina.

Campana (1989), for instance, was able to distinguish between types of manufacturing wear and between use and manufacturing wear. He was also able to determine the manner in which tools were used, although the material on which they were used was frequently ambiguous. Campana's extensive experimentation for his dissertation research was one of the early studies that demonstrated the potential of osseous industries to contribute to the overall understanding of the subsistence and economic patterns of prehistoric societies by means of use wear analysis. His early experiments in the replication of archaeological material were done with the aim of understanding production and to assess the potential of various tools to perform the tasks assigned to them by archaeologists, based generally on formal or ethnographic analogies. Use wear analysis done emphasized surface traces that indicated the direction of use and the general type of material on which implements were employed.

Bone tool use wear has even been used to understand human evolution. Lucinda Backwell and Francesco d'Errico (2001) present an analysis of bone tools from early hominid sites in South Africa that suggests that early hominids used bone tools to fish for termites. They note that "(t)o distinguish between pseudotools and true tools it is necessary to combine taphonomic analysis of the associated fossil assemblages,

microscopic studies of possible traces of manufacture and use, and the experimental replication of the purported tools" (Backwell and d'Errico 2001:1358). Middle Stone Age bone fragments from Swartkrans and Sterkfontein previously identified as tools for digging tubers and working hides were analyzed and through experimentation, were shown to have wear more consistent with termite mound fishing.

Sections of these studies and others that deal with the wear from soft fibers on bone will be discussed in more detail in Chapter 7 (Experimental Program). Here, it is important to note that the kinds of bone use wear studies are varied and increasing in number and have demonstrated relevance for the interpretation of archaeological worked bone assemblages.

Summary: Clearly, then, bone use wear studies can provide detailed information on the technological, social and economic aspects of bone tool use, but the approach is not without difficulty. Some of the challenges will be discussed in greater detail in Chapter 5 (Methodology). Briefly, however, the study of use wear is time-consuming and challenging. There are numerous points in the study of microwear at which interpretative ambiguities enter. Experimentation is costly both in terms of materials and time, and few archaeologists have the resources for large-scale experimental programs. Even when experimentation is facilitated by available time and resources, it is impossible to test every potential use of even one tool form. Secondly, many archaeological artifacts do not have surfaces that are well preserved enough for use

wear analysis and even if those cases where surfaces are in good condition, taphonomic alterations may provide obstacles to use wear observation.

Despite these challenges, use wear studies provide important information on the role of bone tools in past societies. The information from functional analysis cannot be obtained in any other way. As methods improve in bone use wear studies, the role of these studies will only increase in the archaeological analysis of bone tools. The rest of this dissertation will describe my own approach to the analysis of use wear on bone from fiber industries, relying in particular on ethnographic collections to understand the accumulation of wear.

2.6. Summary

Bone tools comprise a significant artifact class that is understudied relative to other raw material classes. The approaches to the study of osseous technologies are varied and can inform on social, economic, subsistence, and technological aspects of past communities. Like other classes of archaeological material, bone tools can be analyzed by morphological, technological, symbolic, or functional attributes. However, bone tools are not as commonly studied as many other kinds of archaeological artifacts. It is often assumed that the taphonomic effects on worked bone are such that analysis of these artifacts is unproductive. However, as has been shown, osseous objects can serve

many different functions and are involved in numerous kinds of social and economic activities. Thus, they can be studied to reveal prehistoric practices that may not otherwise be evident in the archaeological record and are an integral part of understanding cultural, economic and subsistence practices of the past.

Chapter 3. Perishable Technologies in the Archaeological Record

Objects made from plant and animal fibers constitute a major component in the material technology of nearly all known ancient and modern cultures, including contemporary industrialized ones, and are often made with osseous tools. However, soft organic materials preserve only rarely in the archaeological record. In this chapter I will consider some of the ways that perishable materials have been identified in archaeological contexts, through both direct and indirect means, emphasizing in particular wear patterns from fibers on bone tools. I will then focus on evidence of fiber technologies from the Late Upper Paleolithic, demonstrating that there are several distinct lines of evidence that suggest that people of this period were engaged in the production of perishable objects from both plant and animal fiber sources.

3.1. The Importance of Perishable Technologies

It is widely accepted that perishable technologies are ubiquitous, abundant, and socially, culturally and economically important in contemporary, historic and later prehistoric contexts (Barber 1991; Drooker 2001; Schneider 1987). In fact, perishable fiber technologies - objects made from plant and animal soft tissues - may comprise up to 95% of the material culture made and used by contemporary foragers, but are rarely

found archaeologically in most depositional contexts (Hurcombe 1994, 2008a, b). Fibers from plant and animal sources can be used in a wide variety of ways and can be transformed into cordage, mats, baskets, woven cloth, nets, containers, clothing, structural elements, and components for use in compound technologies such as harpoons or tents. Perishable materials can be found in the toolkits for personal dress, cooking, storage, hunting, transportation, and other activities. Additionally, particularly in the case of clothing, woven fabric, baskets, and decorated hides, these objects provide a rich medium for the expression of identity and membership by age, gender, social group, status, occupation, or other social identities (Adovasio, et al. 2007; Barber 1994; Bourque, et al. 2009; Brumfiel 1996, 2007; Burnham 1992; Costin, et al. 1998; Draper 1997; Drooker and Webster 2000; Hayden 1990; Schneider 1987; Soffer, et al. 2000). Given their social and economic utility, perishable industries can provide significant and broad-reaching information about prehistoric groups.

3.2. Perishable Technologies in the Past

Unfortunately, however, despite their ubiquity an importance, we know less about the perishable artifacts of the past than we do about most other classes of material culture. Fiber technologies are frequently archaeologically invisible in two ways: 1) physically, they are perishable, that is, they are organic and frequently not dense and so they decay quickly in most depositional contexts and are thus recovered less frequently from the

archaeological record; 2) intellectually, even when they are present, these technologies are often associated ethnographically and historically with the labor of women, children, and the elderly. Not coincidentally, it is just these members of society who are often omitted from or minimized in our reconstructions of the past (Beck 2000; Conkey 1991; Conkey and Spector 1984; Gero 1985; Gifford-Gonzalez 1993; Hurcombe 1995; Kamp 2001; Lesick 1997; Owen 1994; Querol 2005; Roveland 2000; Shea 2006; Sofaer Derevenski 1994; Soffer, et al. 2000; Spector 1991). These two interrelated factors work in tandem and contribute to the development of a gap in our knowledge about ancient perishable technologies: lack of interest in members of society that are perceived as less powerful – in the past and the present – limits the investigation of these individuals in the past, and the difficulty of recovering this evidence minimizes the attention paid to these material classes.

These issues are especially severe in the Late Upper Paleolithic. In the deep past, the archaeological study of fiber technologies is more problematic because of the extreme rarity of actual exemplars of such objects (Dillehay, et al. 1999; Tuross and Fogel 1994). For example, the dominant view of the Upper Paleolithic provides no room for a role for plant-fiber-based technologies and gives little importance to animal-derived fiber industries. Is this an accurate view of the past or did plant and animal fibers play an important role in the social and economic life of Upper Paleolithic Europe?

Taphonomic factors that remove fiber technologies from the archaeological record increase with time depth, if they are not carbonized. The best conditions for the

preservation of fiber industries are dry caves and rock shelters and permanently waterlogged sites. Neither condition is known for Late Upper Paleolithic sites in Northern Spain.

Linda Hurcombe (1994, 2008b) additionally notes that identifying plant processing is difficult because there is a wide range techniques and uses of plant materials and there is a lack of detail in ethnographic information on organic materials. The low preservation rate of organics creates further difficulty in understanding the role of plants in the past and results in low numbers of archaeologists who specialize in the investigation of organic technologies. Those textiles, baskets, and other items that are recovered from the archaeological record are often fragmentary, making analysis more challenging. Finally, many archaeologists have the impression that early plant fiber technologies were coarse and unsophisticated, with fibers from non-domesticated plant sources being able to be worked only into "burlap" type fabrics.

Hald (1942, 1950), by contrast, provides evidence for the potential fineness of early textiles in her comprehensive review of the use of nettles (*Urtica spp.*) in Danish history and prehistory, supplemented by evidence for the use of nettles in other parts of Western Europe. She includes a number of sources that indicate that both very fine, gauzy fabrics and as rope and other coarser materials can be made of nettle fiber. Overall, the texture of nettle cordage and fabric is similar to that of flax (*Linum spp.*) or hemp (*Cannabis sativa* or *Apocynum cannabinum*). Pictures of various nettle fabrics and costumes are presented. She notes that "nettle-cloth" mentioned in early documents

might refer to any type of bast fiber, as the production sequence is essentially the same. Etymology also suggests an early origin for the use of nettle fibers, in particular “net”. However, there are many means that archaeologists can employ to study ancient economic and artisan activities such as the processing and manufacture of goods with animal and plant derived fibers.

In many archaeological contexts, the presence of plant and animal fiber technologies has been established through both direct and indirect means. This is not the case for the Upper Paleolithic, there has been little discussion of the kinds of perishable artifacts that may have been common, and the detailed study of plant based technologies is particularly limited, despite the fact that numerous studies have highlighted this gap (Owen 2005).

The presence of fiber industries in the Upper Paleolithic should not be a surprise – rather, it would be surprising if they were not part of the Upper Paleolithic cultural repertoire! Here, I will look at the evidence for Upper Paleolithic perishable technologies, beginning with the few direct indications of their presence throughout Europe and then moving on to more indirect indications of fiber use during this period. Although the evidence is scant, it is present throughout much of Europe from the later periods of the Early Upper Paleolithic, suggesting that the lack of knowledge of the use of perishable fibers during this time is due more to preservation and methodological challenges during excavation, rather than their true absence (Bahn 1985).

To begin to study prehistoric perishable industries, a series of issues concerning the development and maintenance of fiber technologies must be addressed. The first issue concerns the likelihood of fiber use within the cultural system under consideration. In both contexts this is not up for debate, but in the context of Late Upper Paleolithic research, where organic technologies are routinely overlooked and their use is not clearly indicated at many sites, this becomes an important first step. What are the baseline conditions necessary for the production of fiber technologies? What constraints might prevent the role of fibers from becoming central in a group's adaptive or social technology? What other materials might fill the roles that are filled by plant fibers in many modern societies? What conditions are necessary for, or conducive toward, the invention and elaboration of plant-derived technologies? While identifying the appropriate conditions for the development of plant-based technologies does not ensure that such technologies were present, it does provide a robust foundation for further investigation.

Secondly, both direct and indirect evidence for perishable technologies must be examined. Direct evidence is fairly straightforward, consisting of those rare instances in which soft organic artifacts preserve, whether in recognizable artifact forms or as tiny fragments. Indirect evidence is more varied. Impressions and casts, especially in baked mud or clay, but also found occasionally in other contexts, can provide clear evidence of the presence and form of fiber industries (Glory 1959).

Organic residues on archaeological artifacts have the potential to establish securely that certain plants or animals were worked with the tools tested. Although there has been minimal attention to the potential for organic residues to preserve over great lengths of time, it is clear that in some cases, the preservation of ancient residues is greater than the preservation of large organic artifacts. Harry Shafer and Richard Holloway (1979) showed that under good conditions organic residues could be recovered from artifacts of fairly great antiquity. Stone tools from Middle and Late Archaic levels dated to 5000-2000 B.P. at Hinds Cave, a dry rock shelter in southwest Texas, contained visible organic residues that were analyzed to determine use of the tools. Plant fibers were visible within the residues under an SEM, so samples were removed from residue buildup and examined under a light microscope, which allowed the identification of some plant remains to the species level. Plant fibers and epidermis of agave (*Agave lecheguilla*) and sotol (*Dasylirion*) were identified, as well as yucca (*Yucca*) epidermal fragments. Animal hair from the residues could generally be identified to major groups (primarily rodents and lagomorphs). Phytoliths were also identified. Combined with an analysis of use wear, the authors conclude that the majority of the tools were multi-use, long-term tools used for the preparation of succulents, small animal butchering and the extraction of plant fibers. Even in the Middle Paleolithic, artifacts of over 100,000 years of age can sometimes retain minute organic residues of surprisingly good structural and chemical integrity, including feather barbules and starch grains (Hardy, et al. 2001).

Residue studies have been rare in Pleistocene contexts. More generally, Odell (2001) argues that the study of plant residues is plagued by greater attention to presence of

such residues, rather than a careful consideration of the meaning of their absence, i.e., is it due to the lack of use on plants, poor or differential preservation, or some other behavioral or taphonomic factor. Essentially, this is another form of direct-confirmation reasoning. He notes that this lack of attention to taphonomy:

> "implies that all those analyses that have been conducted through direct observational methods may be usable only to show the prehistoric presence of a particular plant. They cannot be employed to provide a representative measure of the activities that were practiced in antiquity, because, without a lot more research, we will never know which residues have degraded and which have not." (Odell 2001:62)

Despite Odell's pessimism, the studies discussed here, along with many others, demonstrate that use wear and residue analysis can make important contributions to our understanding of the kinds of plants used in antiquity and the uses to which they are put.

Nuclear magnetic resonance (NMR) is a standard analytical method in chemistry but has not been commonly used to answer archaeological problems. The technique "is a means of classifying atoms within a molecule according to their molecular environment" (Lambert, et al. 2000:176). Resonance peaks are measured and then compared to a standard in order to identify the molecule make-up of a sample. Advantages of the technique include that it is nondestructive and can identify smaller quantities of organic materials than can XRF. Organic structures can be identified more easily than non-

organic material, although ostensibly any material can be identified. The most useful applications of NMR in archaeology derive from the ability of the technique to identify the structure of specific organic materials and identify the makeup of mixed organic and non-organic compounds and samples.

The most successful applications of NMR within archaeology have been with ^{1}H, ^{13}C (useful for organic molecules), ^{31}P (for bone), and ^{29}Si (for silicates). Volatile samples can be analyzed after conversion into gases and liquids, but nonvolatile samples can be characterized as is, in bulk, which is appropriate to many archaeological problems. A pilot study on materials from disturbed deposits probably dating to the Late Upper Paleolithic from the site El Mirón in Spain, however, indicates that the technique has potential for identifying residues on osseous artifacts from the Upper Paleolithic (Rudiger, et al. 2007).

Some kinds of evidence are more closely linked to the production of perishables, as in the case of needles, buttons, or scrapers, or the connection may be more tenuous, as in the case of graphical depictions. The posited link between any indirect evidence for organic technologies must be carefully established. Given the deep time depth of Upper Paleolithic sites and the poor preservation of soft organic materials from ancient sites, few actual organic artifacts are likely to survive under typical conditions, so other means must be used to identify the processing and working of hides, sinew, reeds, and plant fibers during the end of the Ice Age, or in other places where direct evidence is scant. I propose that some classes of osseous tools can provide a good proxy for fiber

processing and may provide direct evidence for this practice through patterns of use-related attrition.

3.3. Archaeological Evidence for Upper Paleolithic Perishable Technologies

If perishable artifacts are common in modern and historic contexts and can be recovered from archaeological sites through a number of means, why then, have they received so little attention in Late Upper Paleolithic contexts, especially in Western Europe? Fiber industries are difficult but not impossible to study and they likely comprise an important element of the material culture – and by extension economic life and organization of labor – of many prehistoric communities, including the Late Upper Paleolithic. There are both theoretical and artifactual indications that fiber industries were produced in Late Upper Paleolithic Spain. Here, I will first consider the theoretical aspect of this question, discussing the background of the "invisible" people and materials of this period. I will then describe the currently known kinds of archaeological evidence for perishable technologies in the Upper Paleolithic from throughout Europe, considering the limited direct indications of plant and animal fiber technologies and then examining other kinds of indirect evidence. It is uncontroversial to suggest that hides, leathers and sinews were important components of Upper Paleolithic technology, but it will be demonstrated that the evidence for animal fiber technologies is no more

direct nor stronger than the evidence for the use of plant fibers. It is likely that both were important sources of material for the production of perishable goods that have long since vanished from the archaeological record.

3.3.1. Who Makes Perishable Technologies?

Ethnographic studies show that in most places gendered tasks are distinct and complementary and allow different members of society to accomplish diverse, time-consuming tasks and develop specialized skills, knowledge, and motor habits (Barber 1994; Brightman 1996; Brown 1970; Draper 1997; González-Marcén, et al. 2008; Hawkes 1996; Lesick 1997; Murdock and Provost 1973). We do not know when and if gender appears as a social category, but it has been argued that by the Late Upper Paleolithic, when human figurines appear widely in the European archaeological record, that gender is a recognized category of human identity (Balme and Bowdler 2006; Beck 2000; Kuhn and Stiner 2006; Lupo and Schmitt 2002; Owen 2005; Soffer, et al. 2000).

Based on Arctic communities, women's products are generally perishable, while many men's products are not. Even if tools of textile and leather production can be identified, associating these artifacts with women is more problematic. Judith Brown's (1970:1077) argument that women's tasks must be "repetitive, interruptible, non-dangerous tasks that do not require extensive excursions" may be used to strengthen gender

assignments; however this argument does not satisfactorily define the constraints placed on all women, but rather women tending small children (Kehoe 1990).

Ethnographically, women and men generally do different tasks (Bird 1999; Brightman 1996; Burnham 1992; Hawkes 1996; Hawkes and Bliege Bird 2002; Kaplan, et al. 2000; Lee and DeVore 1968; Murdock and Provost 1973; Pasternak, et al. 1997; Scelza and Bliege Bird 2008; Wood and Eagly 2002). Brown (1970) argued that the constraints of childcare generally require that women do activities that are repetitive, interruptible, and can be carried out within a restricted radius, so women are often associated with the "domestic sphere," which includes childcare, gathering of plant foods, food preparation, and the production of perishable technologies. Waguespack (2006) contends that as dependence on hunting increases, women's activities shift in emphasis from subsistence to manufacture. In Late Upper Paleolithic Europe, where hunting of large game was a primary subsistence source, then, women should have designated a significant amount of their time to manufacturing, among other things, perishable goods.

Linda Owen (1999, 2005) has documented the importance of women's labor even in places where men bring in the majority of dietary elements. Steve Kuhn and Mary Stiner (2006) argue that women were probably not participating in large game hunting in the Upper Paleolithic. Then, women were doing other things, among them, probably, the production of perishable technologies. Although we don't have data to directly link women, children or elders with specific tasks, given that we can identify numerous

activities beyond large game hunting, it is likely that these members of society were active in some of these areas.

Owen has considered the question of Upper Paleolithic fiber production and gender roles, concentrating especially on the Magdalenian record of Germany (Owen 1991, 1994,1999, 2005). Although her work is not widely cited, she has long made the point that a number of bone artifacts found in the Upper Paleolithic could have been used to sew and create other perishable objects and that these activities may have been the purview of women, children or the elderly. Her point is made most strongly and discussed in the most depth in her 2005 volume, using ethnographic data as a source for analogies for Magdalenian populations (Owen 2005). Owen argues that the bias in archaeological interpretations of the division of labor in the Upper Paleolithic includes both a lack of acknowledgement of the roles of women in the past and an implicit valuation of tasks deemed to be men's tasks as having higher social value and greater contributions to subsistence. Owen argues that in order to identify these tools and activities, interpretation must shift from the level of the artifact to the search for tool kits. For example, rondelles from the Upper Paleolithic may have served as spindle whorls, based on their size, weight and form, while bone "points" may have been basketry awls. Additionally, ethnographically documented groups living in environments and with technological suites similar to those of the Western European Upper Paleolithic tend to rely heavily on net and trap hunting, also suggesting that these practices may have been common in the Upper Paleolithic.

In contexts where such artifacts are rarely recovered, other means must be sought to illuminate their presence in the past. As reviewed above, the vast majority of the material objects made and used by contemporary people are perishable. Additionally, the material culture of bone and stone from the Upper Paleolithic is complex and refined, and many usable plant and animal fibers would have been available in the Upper Paleolithic environment. It can thus be assumed that Upper Paleolithic people were also making sophisticated perishable objects. Castro Curel (1990) notes that the mental and physical capacities required for these types of industries is no greater than that required for the production of microblade lithic assemblages, composite tools such as mounted blades, or osseous tools such as tiny needles. Kehoe (1990, 1994) suggests that the use of animal or plant cordage was probably widespread during the Upper Paleolithic and that archaeological markers of the production, working, and use of these materials have not been documented due to a lack of recognition, rather than their absence in the record. Evidence for perishables production has been improperly assigned to other categories or has been viewed as ambiguous and has not been subject to further examination. The importance of cordage of various sorts to living groups in a range of environments, including the Arctic, suggests that cordage would have been equally important in the Upper Paleolithic (Kehoe 1990; Owen 2005; Soffer, et al. 2000). Kehoe (1999) also argues that ethnographic analogies have been applied inconsistently because models that have been drawn from ethnoanology are constrained by the conceptualization of *sagaies* as projectile points. Even the term bodkin implies use as an awl on skins, rather than use for the production of plant basketry or textiles, despite

the fact that groups living in both the North American boreal forests and the Arctic rely heavily on fiber technologies. The Northern Athapaskan Ingalik, in fact, use cordage in the manufacture of nearly two-thirds of their material culture. Willow bark is the primary source for fiber among the Ingalik and bone awls are used to remove and process the bast portion of the bark.

The information gained from use wear studies of lithic tools has proven useful for considering some of the social and economic aspects of perishable artifacts. Brian Hayden (1990) argues that proportions of lithic tool types and use-wear evidence can help identify 'luxury' vs. 'utilitarian' hide-working, which can then be used to inform on social organization in the past. Hayden bases his argument on ethnographic data from the Pacific Northwest of North America, the Great Plains of North America, Tierra del Fuego, and general patterns throughout Australia. Based on an analysis of ethnographic hunter-gatherer groups of varying types of social organization and complexity, Hayden develops three "models" of hide working which are organized into three progressive stages. Stage 1, "The Basic Cape Model", involves very basic hide working with unspecialized tools and no softening or decoration of hides. Use wear is expected to be prevalent because hide working would be a rare activity and a single tool would be used from start to finish over the entire span of the task. Hide working would occur at the household level. In Stage 2, "The Improved Cape Model", hide production is still only carried out rarely and at the household level, but involves greater intensity of hide processing. A number of new processes, including soaking, tanning, hair removal, and sewing together several smaller pelts to make a larger garment, are introduced at this

point and leave different archaeological markers. However, such processes are generally done outside of the living zone and are rarely recovered archaeologically. Depending on the types of work done, use-wear may be prevalent or nearly non-existent due to an increased range of tools and techniques so that one tool is not used throughout the process. In Stage 3, “Luxury Model Garments”, hide working shifts to being a status signal and the work invested greatly exceeds that necessary for basic clothing needs.

Hayden argues that groups with subsistence based on the exploitation of estuarine or riverine environments, especially when anadomous fish provide a central resource, have a greater ability to produce surpluses and live in semi-sedentary communities with social stratification. He further argues that in such cases hunted meat is still a high-value commodity because hunting is culturally limited so that labor can be concentrated on higher-yield aquatic resources. In such situations, hides become an outlet for the expression of social status. In such a case, specialized hide-working tools, especially endscrapers, become common and hide working may be concentrated in high-status households. Use-wear is expected to be substantial as these tools would be used repeatedly and specifically for hide working.

Hayden then takes his argument and applies it to several archaeological groups. In particular, he suggests that the shift from the Middle to Upper Paleolithic can be seen as an economic shift in which certain Upper Paleolithic groups began to exploit controllable, storable resources that could be used to produce a surplus, such as the

corralling and mass hunting of large herbivores and the exploitation of salmon runs. He argues that a shift in lithic technology from the Middle Paleolithic to the Upper Paleolithic reflects the adoption of Stage 3 hide working, which is supported by the appearance of individualized graves, subsistence shifts, and the appearance of what he identifies as hide-working tools such as needles. However, he states that use-wear on Upper Paleolithic endscrapers has not been noted by many researchers, which he categorizes as "a problem for the future" (Hayden 1990:99).

Another way to look at this, of course, is to consider the possibility that status-signaling clothing was not always made from hides, although, as noted, Hayden argues that hides are the medium of choice for signaling social power in communities where hunting is a high-status activity. This is, however, not universally true. Additionally, is some cases hunting practices may change because of changing uses or importance of hides, as in the case of the Southeastern North America in the Colonial period (Lapham 2005). However, in the Upper Paleolithic, as he notes, hunting shifts include the appearance of mass hunting of herd animals. As he does not note, this may very well be a *group* activity and in this case hunting is *not* limited to high-status individuals, although those individuals could very well be in charge of organizing the hunt. It is unclear how his argument can accommodate communities in which hunting of land mammals is not culturally limited to certain individuals and he has certainly overlooked the possible role of plant fibers in signaling or conveying status.

In the case of large-game hunting, it appears cross-culturally supportable to argue that males nearly always make the kill of large game. However, this may not be a good definition of large-game hunting, as the activities of stalking, sighting, corralling and driving are often done using the labor of women or children, even though men make the actual kill. Owen (2005) does caution against attempts to place women into all hunting activities, as there are divisions of labor that imply the exclusion of one gender or the other from various tasks. Overall, however, the biased nature of ethnographic data, especially coded cross-cultural comparisons has led to a consistent underestimation of the role played by women in hunter-gatherer groups, especially those at high latitudes.

3.3.2. Perishable Artifacts Recovered from Upper Paleolithic Contexts

Direct evidence for Upper Paleolithic perishable materials is mounting, even if the known examples are few and far between. The recent discovery of dyed and twisted flax fibers dated to 30,000 years B.P. preserved in sediment at Dzudzuana Cave in Georgia, is tantalizing, if limited, evidence of fiber technologies in the Upper Paleolithic. The flax fibers were clearly dyed in several colors, some were twisted, and one was knotted suggesting that they had formed part of plied and/or twisted cordage. This interpretation was strengthened by the additional presence of fur from a local mountain goat and fungi, beetles, and moths associated with clothing and skin indicating that perishable clothing had been deposited at the site (Kvavadze, et al. 2009). Finds of

knotted, twisted cordage and bedding from water-logged sites in Israel dated to 19,000 years also indicate the probable wide-spread prevalence of plant fibers in early prehistory (Nadel, et al. 1995; Nadel, et al. 1994; Nadel, et al. 2004). Fragments of twisted rope identified as plant fibers were recovered from the Magdalenian site of Lascaux dated to 17,300 B.P. (Glory 1959; Soffer, et al. 2000). Unfortunately, the fibers have has since been lost, although a cast remains.

3.3.3. Indirect Evidence for Perishable Technologies in the Upper Paleolithic

Thus, the deep time depth of Upper Paleolithic sites means that cases such as those mentioned above, in which traces of fibers are recovered from the archaeological record, are extremely rare. Instead, we must turn to other sources of information to build a more robust picture of the role of perishable technologies in the Upper Paleolithic. Here, I will discuss some other lines of evidence that have been considered in studies of Late Upper Paleolithic perishables. The idea that cordage, weaving, nets or basketry was produced in the Upper Paleolithic is not new and has been discussed casually in the archaeological literature repeatedly (Bahn 1985; Bahn 2001; Kehoe 1999; Tyldesley and Bahn 1983), but few studies have attempted to pursue the question more systematically. Of particular importance is the work of James Adovasio, Linda Owen and Olga Soffer, all of whom have addressed fiber technologies in the Upper Paleolithic indirectly, including a consideration of the role bone tools may play in the production of

perishable materials (Adovasio, et al. 2001; Adovasio, et al. 1996; Adovasio, et al. 2007; Grigor'ev 1993; Owen 1993, 1994, 1999, 2005; Soffer, et al. 2000; Soffer 2000, 2004; Soffer and Adovasio 2004; Olga Soffer, et al. 2000).

Joyce Tyldesley and Paul Bahn (1983) provide a very brief overview of the range of evidence that points to the use of plant materials in the Upper Paleolithic. Wood remains at a few sites indicate that wood was used as a structural material and for the production of spears, possible bows and arrows, or other similar objects since the Middle Paleolithic. The presence of antler and stone artifacts that appear to have been designed as hafted points also suggests that wooden shafts were in use. Digging sticks may also have been in use, as they are relatively common at coeval African sites. Evidence for the use of non-woody plants is scarcer. Dense concentrations of pollen from several French Upper Paleolithic sites suggest that grasses were brought into caves, possibly to serve as bedding or seating. Keeley (1980) has identified use-wear at Hone from the cutting of non-woody plants. There is scattered evidence for the use of berries, nuts, and grains, although many of these examples are subject to doubt as to the artificial nature of their accumulation.

A constraint on prehistorians examining the use of cordage in the Upper Paleolithic is that many fiber products are made either entirely by hand or with tools that are highly unspecialized and either could have, or did, serve multiple functions. Tyldesley and Bahn suggest that use wear on teeth from a range of soft sources could be investigated in search of wear from the working of different materials with the teeth and that use wear

on tools is probably the only way to sort out ambiguities in potential use. Studies focused on bone use wear have already been addressed in the prior chapter, including those that emphasize different kinds of fiber industries.

Within the last two decades, our knowledge about the potential role of perishables in the Upper Paleolithic has advanced dramatically due to the discovery, first at the Moravian Gravettian sites of Dolni Vestonice and Pavlov, and later, at others in Russia, of fragments of fired clay containing impressions of worked fibers (Adovasio, et al. 2001; Adovasio, et al. 1996; Soffer, et al. 2000; Soffer and Adovasio 2004). The imprints of cordage and more complex woven and knotted structures at the Moravian Gravettian sites show that the people living in these groups were producing a diverse range of perishable technologies, many likely from plant fibers. Impressions on burned clay and even antler in at least one case –the Magdalenian site of Gönnersdorf in Germany – establish the presence of cordage, knots, nets, baskets and woven fabrics throughout much of central and northeastern Eurasia in the Upper Paleolithic. The detail visible in some of these impressions is such that patterns of weaving and basketry can be identified in some detail. The implications of these discoveries range beyond the simple knowledge of a previously undocumented category of material culture at the sites. There are eight common patterns for the intertwining of cords or other materials in the production of textiles and basketry; seven of these patterns have been observed in the 49 impressions at the Moravian sites. The textile industry at the sites, in other words, was complex, diverse, and appears to be well established, rather than representing early forays into a new technology.

The identification of evidence for nets derives from a series of impressions of "weaver's knots," knots that are commonly used in the production of nets. Because the knots were identified at spaced series in certain examples, Adovasio identifies their use as hunting nets at a mesh diameter of 4mm. Due to their fineness, these nets could not have been used for hunting large game. This suggestion is supported by the large number of small game found at these and other Upper Paleolithic Eastern European sites. Net hunting may have allowed the development of stable, sedentary communities, as it would have enabled groups to rely on immediately locally available resources over an emphasis on mobile herds of large game. The use of nets for hunting is also suggestive of communal subsistence activities, rather than the typical image of groups of young men bringing home the results of the hunt. As Emily Jones (2006) points out, some kinds of communal hunting of small game in the Late Upper Paleolithic may have been done without the aid of nets or traps. Ethnographically, large-scale net hunting is often associated with aggregation and feasting, which fits in well with the pattern of the Moravian sites which seem to be winter aggregation sites and which also have evidence for ritual behavior that may have helped disperse the social tension inherent in long-term large community living (Adovasio, et al. 2001; Lupo and Schmitt 2002). This example demonstrates the economic importance of perishable objects and the potential explanatory power of a better understanding of the exploitation of plant fibers in the Upper Paleolithic.

Aside from impressions, fairly clear evidence for the kinds of technologies that have disappeared from the archaeological record, depictions have often been studied for

indications of perishable artifacts. Gustave Chauvet (1910 cited in Bahn 2001) argued that incised designs on bone tools and portable art in the Upper Paleolithic may have reflected basketry designs and that the role of perishable technologies in the period was probably large. Zaida Castro Curel (1990) argues that certain depictions from engraved plaquettes from Late Magdalenian levels at Parpallo are images of plant fibers. She argues that images identified as snakes are actually twined cordage. Lines crossed at right angles she identifies as woven textiles. One image of a spiral with diagonal lines extending between the sections of the spiral she identifies as coiled basketry. Several authors have interpreted various Upper Paleolithic female figurines as wearing clothing made from twined fibers (Barber 1994; Beck 2000; Gvozdover 1989; Pales and Tassin de Saint Pèreuse 1976; Soffer, et al. 2000). The well-known female figurine from Willendorf offers one of the most easily recognized depictions of worked fibers in the form of a cap with recognizable stitches. Other figurines display the same headgear (Soffer, et al. 2000). Woven straps or bandeaux are present on a number of figures from central and Eastern Europe, while belts are common on those from central and western Europe. Particularly important is the figure from Lespugue that wears a string skirt hanging from her belt; the detail of the engraved skirt allows the identification of the construction method of both the cordage and belt (Soffer, et al. 2000). Figurines dressed in apparent hooded garments of hide have also been identified, lending credence to the interpretation of woven and twisted fibers as elements of clothing rather than “decoration” (Gilligan 2010; Hoffecker 2005), although see Soffer, et al.

2004 who argue that positive identification of these garments as hide and fur is debatable).

Sites with impressions are few and figurines and depictions are relatively rare, but there are other potential indicators of perishable industries that are far more prevalent. Although many tools that can be used to manipulate leathers, hides, hair and sinew can also be used to work plant fibers, there are some tools that are used primarily on plant resources. In the Upper Paleolithic, where wool from domesticated animals is not present, fibers that can be worked into a continuous cord can be derived from animal tendons or from plant sources. Sinew is an unlikely choice for weaving flexible fabrics; so woven threads were likely to have been of plant origin. Weaving tools such as battens were probably used on plant fibers.

That animal hides, hair and sinew were used in the Upper Paleolithic and earlier to make clothing, containers and cordage is widely accepted. Faunal remains and hunting equipment indicate that animal products were available and well known to Upper Paleolithic people. It has been suggested that the presence of small carnivores in Upper Paleolithic sites may indicate their exploitation primarily for furs rather than for food (Charles 1997; West 2001). Willendorf 9 has also been identified as a specialized fur procurement site based on the high proportions of fox and other fur-bearers (Therrius 1956-59 in Montet-White 1994). Indirect indications of the use of animal fibers are numerous. Butchering patterns can indicate an emphasis on hide and tendon removal (West 1990 in Montet-White 1994; West 2001). Sinew is an important source of thread

in many contemporary northern groups because it swells when wet so it can be used to make waterproof seams and may have served a similar purpose in the past. Horn and hoof decay very rapidly and are virtually unknown from the Upper Paleolithic, but depictions of both suggest that they may have been used as raw materials (Owen 2005). Conkey (1991) has argued that Magdalenian harpoons indicate the use of cordage of some sort.

3.3.3.1. Lithic Tools and the Production of Perishable Technologies

Despite the lack of controversy concerning the exploitation of processed animal fiber technologies in the Upper Paleolithic, the best evidence for their use can be found in the tools used to make them. Stone and bone tools make up a large portion of the Upper Paleolithic archaeological record and may provide insight into the production of perishable technologies. Stone hide-scrapers are a commonly identified tool in Upper Paleolithic sites, and use wear and performance studies indicate that some of them were used on hides (Banks 1996; Cazals 2000; González-Urquijo and Ibáñez-Estévez 2003; Odell 1988). Bone scrapers, beamers, and smoothers are also frequently identified. In the Upper Paleolithic the presence of the bone needle, in fact, is often cited as evidence of the production of “tailored clothing” (Gilligan 2007, 2010 Hoffecker 2005; Straus 1992, 2005).

Lithic tools, then, can provide information on both the kinds of perishable materials produced, and possibly, the importance of those industries. Lithic artifacts are ubiquitous in Upper Paleolithic sites and have the potential to inform on Upper Paleolithic exploitation of organic materials. Stone tools are the most durable and ubiquitous kind of archaeological evidence. Sylvie Beyries (2002) argues that because stone and bone tools used to work hides are the most permanent evidence that remains in most archaeological sites, the questions of the hide-working process can be approached from the study of such implements. The same is true of evidence of the manufacture of objects from plant fibers and elements.

Linda Hurcombe (Hurcombe 1992, 1994, 2008a, b, 2010) has long focused on the utility of use wear analysis of stone tools to identify organic, and especially plant derived, technologies in the Mesolithic and Neolithic. Wear may accumulate on stone tools from many different activities in the production chain of basketry, textiles, cordage, and cordage by-products like nets. In general, the sources of variation in plant use can be grouped: plant species worked, plant portion worked, plant portion harvested, harvest season, and intended use. For some of these activities, tools are unnecessary. She also notes that tools may be made of stone, bone, antler or wood, further complicating the task of identifying wear diagnostic of a particular task by any one analyst, as few archaeologists work across raw material categories.

Because wear from soft materials develops more slowly than that from hard materials, there is another level of difficulty to the reconstruction of plant-based technologies

beyond the usual challenges of use wear analysis. Soft material polishes also tend to resemble one another, especially at low magnification, and, in some cases, it may be impossible to identify the source of wear beyond the classification of 'soft material' or 'ambiguous.' Owen (1994, 2005) suggests that while 'hide polish' is "identified" on many Upper Paleolithic tools, this may be due to the conflation of different soft material wear patterns and many such polishes may indeed be attributable to the working of plants. Without sufficient comparative experimental collections with a range of plant-working examples, these kinds of errors are unavoidable. She also suggests that the large incidence of "unused" tools may be due to the use of tools on plant materials that leave no diagnostic wear. Plants may also have been worked with unmodified flakes and blades, rather than with "formal tools," further reducing the likelihood of identifying wear, as formal tools are tested more extensively for use-wear. The use of unmodified flakes to work plant materials is well documented in North America (Kornfeld, et al. 1990). Owen has identified polish on Magdalenian backed bladelets in Germany that she believes may have resulted from the combing of fibers in cordage production.

Juel Jensen (1994) focuses on the role played by silica in the production of wear by plants on lithic tools and showed that plants with higher silica content produce wear on lithic tools more quickly. Unfortunately, levels of silica in plants are more variable and higher than is generally recognized. Among the silica-rich plants tested by Juel Jensen, were reeds and nettles. Reeds rapidly produce heavy, distinctive wear. Nettles also

produce fairly substantial wear, which varies somewhat with the maturity and water content of the plants.

3.3.3.2. Bone Tools and the Production of Perishable Technologies

Osseous tools are a second common class of artifacts that can provide information on the production of fiber industries. As noted previously, there are many kinds of bone tools that are associated with the production of organic, and in particular plant-based, technologies. In the Upper Paleolithic there are a number of common osseous artifact forms that have no commonly accepted functional attribution. Here, I will discuss some interpretations of some of these objects as tools for perishable object manufacture and then briefly summarize the potential for bone use wear to indicate plant and animal products no longer preserved in the archaeological record. Bone use wear studies have already been discussed in Chapter 2 (A Brief History of Bone Technology Studies).

Bone tools such as needles, awls, battens, shuttles, and net gauges are commonly used in the production of nets, baskets, weaving, hide-working, and the production of other perishable goods in contemporary, historic and prehistoric contexts (Barber 1991; Giffen 1930; Mason 1988 (1904); Osgood 1970; Rafel Fontanals 2007). These kinds of tool forms are common in the Upper Paleolithic. Owen (2005) argues that sharp points were probably used for working hides, while more rounded points were used in textile and basketry production. She suggests that most Upper Paleolithic points are quite sharp,

having been reworked or discarded when they became dulled or broke during use. Those that were discarded when dull may indicate leather working. The link between sharpness and leather, however, is not supported in all cases, as basketry awls are often extremely sharp and stone awls can be used to perforate hides that are then worked with duller bone tools (Legrand 2005; Mason 1988 (1904)). Thus, the contents of tool kits alone cannot be used to determine if fibers from both plant and animal sources were used in the Upper Paleolithic.

Studies of bone use wear from perishable materials in other contexts have already been reviewed. Use wear on bone tools can also provide information on the use of leathers and hides in the Upper Paleolithic. Aliette Lompré has examined the hide-working process, from skinning through sewing by studying the bone tools used in the various stages of hide processing (Lompré and Negroni 2006). Penelope Amato (2010) has looked at the kinds of tailoring and decoration that was employed in the Upper Paleolithic through a study of bone needles and awls. In the following chapters I will describe my approach to examining the kinds of soft materials worked with bone tools in the Upper Paleolithic.

Kehoe examined several Upper Paleolithic artifacts in comparison to tools used ethnographically for the production of leather and woven cloth. Based on formal similarity, Kehoe interprets bone tools as having been used in the production of nets, bags, mats, and snowshoes. She suggests that the polish found on *bâtons du*

commandement and other (unidentified) bone and antler tools may derive from plant fibers (Kehoe 1990).

Interestingly, the appearance of the eyed needle may also be associated with plant fibers. Sinew can be, and ethnographically often is, sewn without the aid of a needle (Amato 2010; Owen 2005; Speck 1911), as hardened sinew can be threaded through a hole made with an awl. In fact, this technique allows for a finer perforation, only as wide as the thread. Although hide has some ability to recover from a perforation, for fine work and waterproof garments, smaller perforations would be desirable. Unlike sinew, plant fibers cannot be easily sewn without a needle, excepting self-needled plants such as the agave with its hardened spine at the end of a set of strong fibers. Such self-threading plants are rare. It may be more than coincidence that early Upper Paleolithic eyed needles are found at sites such as the Moravian ones where there is additional evidence for the processing of plant fibers. Zaida Castro Curel (1990) argues that the smallest needles at Parpalló would be ineffective for sewing hide and so also indicate the use of plant fibers. Alice Kehoe (1990) argues that the use of functional terms, such as *sagaie*, in place of descriptive terms, obscures interpretative thought and leads to an unquestioning acceptance of what are functional assignments that have not be rigorously tested. Gilligan (2007, 2010) suggests that eyed needles would have been used in the construction of delicate undergarments of skin and would have been most important for fine work. This is not consistent with either experimental or ethnographic studies of fine sewing with sinew (Amato 2010; Burnham 1992; Issenman 1997; King, et al. 2005). Thus, tool form alone gives very little information on the choices of fiber

sources in the Upper Paleolithic, but where it does provide some insight suggests that plant fibers could have been exploited in the European Upper Paleolithic.

Soffer (2004) presents evidence for the production of woven fabrics during the Upper Paleolithic in the form of use-wear on antler artifacts that may have come from use as a weaving batten. Soffer began her study by considering the previous research she and others have done on Upper Paleolithic textiles and basketry, including research into casts, imprints, female figurines, pollen and a few preserved fragments. Perishable technologies that have been identified include cordage, netting, plaited basketry, simple and diagonal twined textiles, and plain woven textiles. The widespread occurrence of the eyed needle and evidence from burials also attest to the creation of tailored clothing. Soffer and colleagues (2000) have already argued that the sophistication of textiles imprinted on clay fragments at the Pavlovian sites indicate that this was not a new technology at the time. Soffer states that the materials that made the impressions "were clearly made of plant rather than animal fibers" (Soffer 2004:407) but does not elaborate on the method of identification. Fiber-producing plants commonly identified in Upper Paleolithic pollen spectra include alder (*Alnus*), yew (*Taxus*), milkweed (*Asclepias*), and nettle (*Urtica*).

She began with an ethnographic study emphasizing hunter-gatherers living in northern latitudes, but including other groups to increase her sample size. She examined a wide range of tool types but did not include needles or awls because although they are both commonly used for textile production, they can also be used on skins and hides.

Although the majority of the tools were made of wood, bone, antler and ivory weaving implements were produced by groups in northern North America and Siberia. All tools were studied with magnification no greater than that of a low-powered microscope.

Soffer identified a pattern of parallel or subparallel striations, and occasional crossing striations, perpendicular to the working edge of the tool. She then turned to the archaeological record in search of similar patterns on bone and antler artifacts that had either previously been identified as projectile points or whose function remained unclear. Soffer notes that a great number of the pieces she saw had diagnostic use wear indicative of textile production. By region:

- *Moravia*: Gravettian industries at 28,000-22,000 years ago included weaving battens and hatchels of ivory, mammoth ribs, and bird and cave lion bones

- *Russia*: industries from about 22,000 years contained weaving battens made from mammoth ribs, ivory and bird bone, along with possible spindles

- *Germany*: Aurignacian industries dating to 32,000 years old contained mammoth rib needles probably used in the production of mats, beveled sagaies with textile production wear and batons from ~13kya which have use wear and are formally analogous to spinning tools used in Iceland and Portugal

- *France*: collections from the Aurignacian through the Magdalenian contain rods, polishers, batons, sagaies, spatulas, and plaquettes that may have served as battens, weaving sticks, mat needles, and net spacers

Soffer argues that the results of her preliminary study call for the reexamination of osseous artifacts from throughout the European Paleolithic. She suggests that higher magnification may yield better results, notwithstanding the positive results obtained with low-power magnification. She also suggests that the study of residues on osseous tools may help resolve certain ambiguities of use wear studies and advocates the study of needles. She concludes with an assertion that Upper Paleolithic weaving and the production of perishable technologies can be associated with women's work based on ethnographic data on hunter gatherers and on iconography from throughout the Upper Paleolithic.

Louise Heite (1998) argues that pierced batons were used as spinning tools rather than spear straighteners, the most common functional interpretation. She argues that straight branches are easy to find; even in the Arctic, where trees are generally gnarled and short, straight branches grow in summer months. Heite argues that it is "contrived" to view these objects as spear straighteners because it is difficult to imagine people choosing to straighten a curved branch rather than simply seek out a straight one. Second, she argues that batons are not an appropriate tool for the shaping of wood.

She states that wood, not being highly plastic, must be boiled or heated and steam treated before being shaped. After the wood has been made more pliable through these processes, it must be set in a mold and kept there until fully dry. Clearly, a pierced baton would not be the tool for this task. Heite notes that pierced batons may have been used to remove twigs from branches, but in her view this would only be necessary in cases of mass production of spears. She also states that if these artifacts were being used to shape wood, they would need to have been fitted with microblades for shaving off excess material. She argues additionally that the tools are over-engineered for the working of wood.

Heite offers an alternative explanation for the function of the pierced batons: half of a two-part spinning tool. She bases her interpretation on formal analogy to the *madman*, or *vitleysingur*, a tool used in Iceland to this day for the spinning of coarse animal hair into rope. The tool consists of a handle and a spinner. The spinner is very similar to Upper Paleolithic batons in both size and shape. Hair prepared for spinning by rolling it into a cylinder is known as a *rolag*. Hair pulled and arranged so that the hairs are basically parallel forms a *roving*, which is an alternative form of fiber preparation. The *rolag* or roving is spun so that hairs are twisted together into cordage, forming a stronger structure. To use the *madman*, the hair is tied to the shaft of the spinner which is fitted onto the handle so that the spinner can be twisted to form cordage. Heite did not conduct use wear analysis on any artifacts, but argues that the distribution and form of wear should indicate whether the batons were used in spinning. If this were the use of the pierced batons, there are several types of diagnostic wear that can be

anticipated. At the center of the baton there should be wear from the fastening of the cord, the perforation should show wear from spinning on the handle, and the end of the spinner should show polish from sliding off balls of cordage.

3.4. Summary

Upper Paleolithic people had both the available resources and the cognitive and physical ability to produce a range of perishable objects, as indicated by the complexity of other kinds of Upper Paleolithic material culture. Ethnographically and historically, perishable objects make up a substantial component of the material goods produced and used by all people. Thus, it is to be expected that Upper Paleolithic people also made use of organic materials to produce clothing, bags, nets, baskets, storage containers, structural elements, and other objects. The few examples of direct evidence for perishable technologies support this assertion, but due both to the nature of taphonomic agents in Upper Paleolithic sites and the emphasis in Pleistocene research on lithic and osseous materials, we still know very little about Upper Paleolithic use of fiber technologies. Fortunately, there are a number of sources of indirect evidence for these industries, the most ubiquitous being the stone and bone tools used to process and manipulate plant and animal products into artifacts. Numerous small, focused studies have already indicated the potential of functional analyses of bone and stone tools to provide information on the production of perishable technologies. In the remaining chapters I

will describe my own methodology for use wear analysis of bone tools and the role that ethnographic collections can play in understanding the use of osseous implements for perishable artifact production.

Chapter 4. Tribology

4.1. Defining Tribology

Archaeologists are not the only researchers interested in the physical consequences of contact between two materials at work. The development of wear or attrition is important in the fields of engineering, physics, and a number of other smaller disciplines, although their interests relate to other concerns, generally to the reduction of wear for performance enhancement. The interdisciplinary area of study that deals with contact, friction and wear is known as *tribology*.

The basic foundations of tribological research indicate that the physical properties of two contact materials help determine the outcome of different types of contact. Thus, the known properties can also be used to predict some of the wear patterns that might result from contact. In this chapter, I discuss the properties of bone as a raw material for tool production, then the properties of different plant and animal derived fibers. Finally, I present a tribological model that I developed from these properties, that predicts differences in wear from plant and animal fibers on bone tools. This model will provide the basis for my analysis of experimental, ethnographic and archaeological osseous artifacts.

Tribological analysis seeks to identify the outcome of contact between two surfaces and draws heavily on mathematical models developed to explain the interaction between force, pressure, and friction (Bhushan 1999; Rabinowicz 1965, 1970). Tribology is a cross-disciplinary field and can aid archaeologists in understanding use wear accumulation, by revealing both the theoretical and the mathematical basis for the occurrence of attrition resulting from work. The theoretical insights from tribology, most influentially introduced to the bone industry literature by Genevieve LeMoine (1997), can provide a stronger framework for understanding reduction and alteration of osseous artifacts throughout their life history, and over the processes of manufacture, use, re-use, transformation into other forms, repair, handling, storage and taphonomic alterations.

Although tribological analyses comprise an independent discipline, we can isolate a number of key findings that are relevant to archaeological analysis of wear patterns on artifacts. Tribological research can inform on the study of the manufacture and use of archaeological artifacts by providing guidelines and models for understanding and predicting the material outcomes of wear and contact on a physical level. Much as Johan Kamminga and Brian Cotterell (Cotterell, et al. 1985) argued that the nature of lithic raw materials should inform our study of lithic artifact manufacture, I suggest that the basic qualities of the raw materials used to create objects with bone tools can contribute to the construction of object-level analogies for identifying different events in the long life history of those same osseous artifacts.

Knowledge within the field of tribology explains how and why wear occurs as a result of contact between two materials and justifies the basic assumption underlying all use wear analysis: ***different materials and actions cause distinct patterns of wear on tools***. Wear is defined within tribology as "the removal of material from solid surfaces as a result of mechanical action" (Rabinowicz 1965:109). Mechanical wear is due to the action of friction. Although the basis for friction is still not completely understood, current theories hold that friction is due to the shearing off of minute surface irregularities or asperities.

The challenges of equifinalities inherent in use wear analysis are well-known (d'Errico 1993; Hurcombe 1988; Odell and Odell-Vereecken 1980). Experimentally derived patterns of wear that appear to be diagnostic of particular uses or materials can be mimicked by materials or contexts that are quite distinct. However, it is in just these cases that tribology can contribute to archaeological use wear analysis. Because tribological predictions are developed based on the characteristics of the contact materials, they should be able to identify potentially similar patterns as well. This is not to say that tribology is a panacea for the many challenges of use wear analysis, but rather that it provides an independent perspective from which to assess competing hypotheses for artifact use. Tribological predictions must be embedded within an understanding of social and economic context and used along with the analysis of artifact form, use-related breakage, evidence for hafting or other composite elements, and spatial indications of working areas or tool kits.

However, simply put, the nature of the contact materials and the kind of contact determine the characteristic wear of any particular action. In order to predict or understand wear patterns, we must consider the physical make-up, structure and properties of the contact materials, the force, direction and mode of contact, as well as any contextual details, such as the condition of the materials, presence of lubricants or adhesives or the compounded effects of long-term stress. Thus, the first step in developing a tribological model for wear patterns on tools is a consideration of the material properties of the raw materials and then of the context and kind of forces involved in the use of these tools.

4.2. Osseous Materials: the tools

Bones form the structural foundation for the placement of muscles and other connective tissue within the body of animals with interior skeletons. The outer portion of the bone or antler is known as the cortical, compact, or laminar section and is hard and dense. The inner portion is known as spongy or cancellous bone and is characterized by a porous structure, which, in the living state, is filled with marrow (Figures 4.1, 4.2) (Christensen 2004).

Figure 4.1 Cross-section of Seri bone awl made on a metapodial, showing the dense, outer cortical portion and the inner spongy section (NMAI 112161)

Figure 4.2 Cross-section of mule deer antler showing the dense, outer cortical portion and the inner spongy section

The dense cortical portion of long bones or antler is most commonly used for artifact production, although small areas of the cancellous part of bones may still remain at times. Many other elements can also be used to make artifacts.

Compact bone contains haversian or nutrient canals, the osteons, around which are deposited layers of calcitic bone matrix. Osseous materials in the living state are composed of both organic and inorganic materials. Living bone contains 75-90% inorganic material, providing a framework in which organic matter is embedded. However, only about half the weight of fresh bone is mineral while much of the other half is collagen. The inorganic portion of living bone is primarily composed of the mineral calcium hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$). The organic portion contains collagen, a complex protein structure, with the remaining portion being made up of protein, lipids and carbohydrates. Type I collagen, the most common organic component, has a triple-helical structure with an amino acid sequence in which every third location on the structure is glycine, a very small molecule that allows compact folding and twisting of the chain, resulting in a flexible macrostructure (Child 1993).

Bone has unique material properties, being a brittle material but with a very high tensile strength, especially relative to its compressive resistance, i.e., it is highly anisotropic – different planes have different responses to stress (Currey 1964 and references therein). This anisotropy has been attributed to the distinct properties of the two primary components of bone: collagen providing good tensile resistance and apatite contributing to compressive stress resistance. John Currey (1964), however, argues that

bone is best thought of as a two-phase material. Two-phase materials have emergent properties derived from the interaction of the materials, in our case a matrix of flexible, resilient collagen in which are embedded crystals of brittle, strong apatite, that exceed the properties of either material individually.

In bones, collagen is arranged in long, aligned fibrils, and this may also contribute to bone's anisotropic properties (Hedges 1987; S. O'Connor 1987; T. P. O'Connor 1987; O'Connor 2000b). Long bones in particular are structurally designed to withstand substantial impact along the long axis through a combination of flexibility and strength. Most bone tools are made from the thick compact bone at the center of the diaphysis, or shaft, of ungulate long bones, although many other skeletal elements can be made into tools. Near the center of the diaphysis, osteons are approximately parallel and splay out toward the epiphyses, or ends, so that bone is more anisotropic at the center of the shaft and becomes increasingly isotropic toward the ends. Division of the long bone will tend to split parallel to the osteons, so that long blanks can be extracted longitudinally with relative ease through a number of techniques. These blanks will be strong along the long axis.

4.2.1. Mechanical Properties of Bone

In order to understand the ways that bone tools and surfaces respond to stress and wear, the mechanical and performance qualities of bone should be taken into consideration. In one early study of bone mechanics, Eileen Johnson (1985) argued that many of the debates concerning the agents of bone modification at archaeological sites arise due to a substantial lack of understanding of the physical fracture properties of fresh, dry, and mineralized bone. Force that affects a material may be either static or dynamic and bones are affected by various forces throughout their use as skeletal elements, and through taphonomic factors that affect them after discard.

Fresh bone retains moisture, which affects its response to force, as it is not brittle, but viscoelastic (deformable) and ductile. After the loss of moisture, bone becomes brittle. How this change affects artifact manufacture is not completely clear (Campana 1989; O'Connor 1987, 2000). Certain variations among different kinds of bone may have minimal consequences for the performance and wear accumulation on tools from these different osseous materials. In terms of hardness and ease of working, Campana (1989) notes that fresh bone has a Rockwell hardness number of 7 when wet and 35 when dry; working wet bone is significantly easier than dry specimens. However, it is by no means *necessary* to work bone when wet (see chapter 7, Experimental Program).

Antler, technically a specialized kind of bone external to the body, is macroscopically different from bone (see Chapter 5 for a further discussion of identifying bone and

antler). Wear accumulated on bone and antler may vary due to the macroscopic differences between larger pieces of these materials. Among bones from different large mammal species, Griffitts (2006) argues that there is no notable difference in wear from similar activities. She has, however, documented different wear patterns on turkey bones, possibly indicating that the bones of large birds are distinct enough from large mammals to warrant separate analysis. Because there are few artifacts from large bird bones in the Late Upper Paleolithic, I did not pursue this difference further.

Some of the mechanical properties known to affect the movement of force through inorganic material (i.e., lithics) are applicable to bone, although the limits of this analogy have not been thoroughly tested. Johnson (1985) likens the spiral fracture of fresh bone to the conical fracture of lithics as an identifiable feature with a known cause but that may be caused by artificial or natural factors. This distinctive fracture pattern is directly attributable to the fibrous, anisotropic structure of green bone.

Among the range of potential techniques for the production of bone tools are (Provenzano 2004):

- blank creation by
    - percussion, direct or indirect (Figure 4.3)

○

Figure 4.3. Direct percussion on bone

Figure 4.4. Indirect percussion of a rib with a lithic wedge

- groove and splintering (Figures 4.5-4.6)

Figure 4.5. Groove and splinter technique

Figure 4.6. Groove and splinter extraction and nucleus

- longitudinal sawing (Figure 4.7)

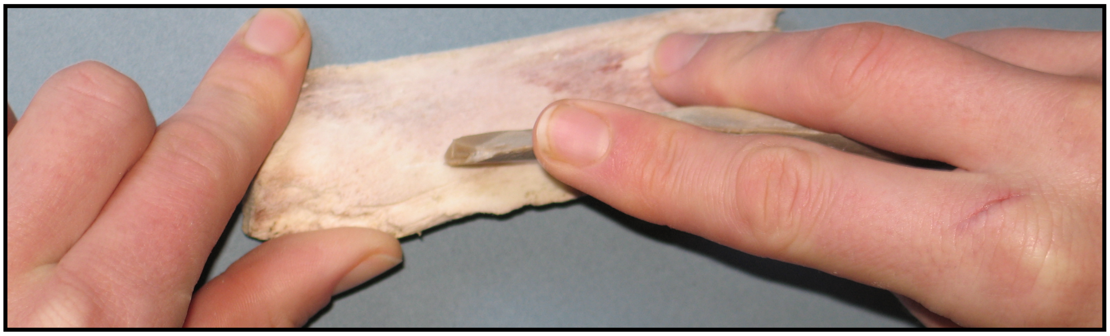


Figure 4.7. Longitudinal sawing with a burin

- sawing and snapping (Figure 4.8)

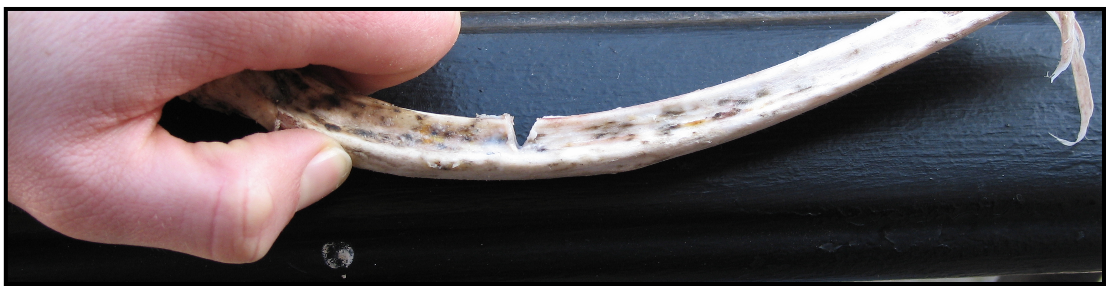


Figure 4.8. Sawed rib prepared for snapping

- modification by
  - scraping (Figure 4.7)

Figure 4.9. Scraping

- pressure flaking

- grinding (Figure 10)

Figure 4.10. Grinding against sandstone

- polishing

Figure 4.11. Polishing with an unmodified flake

- perforation by
    - drilling
    - scraping

These techniques can introduce new properties to osseous artifacts that are not inherent to unmodified bone. Modified bone surfaces are often compacted during the process of manufacture, as the pressure and abrasion not only shear off fragments of material, but also compress the remaining material, closing off osteotones and reducing variation in the most exterior surface. This produces a smoother surface that can then

be more refined through polishing or other finishing techniques. Notably, smoother and harder surfaces are less prone to friction, shearing, and snagging, which can reduce the attritional effects of wear. Prolonged handling and use can also contribute to a smoother, more compressed surface. However, the more compact surface may also provide an advantage to archaeologists as the decreased absorption of loss of water may slow decay, sometimes lending bone tools a greater chance of preservation than unmodified bone, even under the same depositional conditions.

The physical properties of bone, particularly long bones, derive primarily from its role in living animals. The ways that bone performs while in a living animal condition the use of osseous resources as a raw material for tool production. These characteristics may also have an impact on the accumulation of manufacture and wear traces on the surfaces of tools, as well as affecting the preservation of such artifacts.

Summary: Bone is a readily available raw material in most contexts and is not difficult to reduce into many tool forms. The structure of long bones is anisotropic, strong, hard and flexible on a macroscopic level, which makes it conducive toward particular shapes and modes of work, particularly elongated shapes, rather than broader forms. Flat bones such as the mandible, scapula or pelvis or short bones such as phalanges and astragali deviate somewhat from the characteristics of long bones, resulting in their conversion into different artifact forms from those typically made on long bones. Here, I focus on the qualities of long bones as they are the predominate source of raw material for the artifacts studied. Osseous tools are appropriate for piercing,

burnishing, and other activities that require sustained, lighter pressure and make use of the resiliency of bone. Some tasks that introduce shorter and sharper stresses may be more successfully carried out with antler, which has a less dense structure that more ably absorbs shock, but frequently has a rougher final surface texture (Knecht 1997). However, this does not indicate that bone can never be used for tasks that involve sharp impact (Christidou and Legrand 2005). Bone is still strong and resilient and can be used even for hunting points.

Microscopically, worked bone surfaces are often denser, more even, and less porous than unmodified bone. These traits reduce friction and may make use-related attrition difficult to identify. However, this sometimes results in greater preservation of compressed surfaces. There are deviations in actual artifact manufacture and use from the predictions that could be generated from each of these generalizations; material properties can still be used to model and predict general patterns of bone object performance under different conditions.

4.3. Plant and Animal Fibers: the worked materials

Bone tools are used in many tasks, but one of the common kinds of uses of osseous artifacts is in the preparation and production of soft fiber products, including hide-working and modification, weaving, basketry, sewing, bark processing and mat-making.

Sources for fiber in prehistory can be divided into two categories: animal and plant. Despite wide variation within these two categories, there are fundamental differences between soft materials from plant and animal sources. Additionally, it is important to remember that the wear from materials that are pliable and softer than bone will share certain general wear markers. These are discussed in more detail in Chapter 7 (Experimental Program). Here, I focus on the properties that distinguish plant- and animal-derived fiber classes.

Fibers are cells that are many times longer than they are wide, allowing them to be spun and twisted. "Fibres have been defined by the Textile Institute as units of matter characterized by flexibility, fineness, and a high ratio of length to thickness" (Morton and Hearle 1975:3). As will be discussed, both the major classes of plant and animal soft materials are composed of fibers, but the nature of those fibers and their alignment and distribution vary. In order to be suitable for cordage, textiles and other soft artifacts, the fiber must be both strong and flexible, allowing it to survive twisting, folding, manipulating during manufacture and use of the end product. Additionally, most kinds of fibers have individual filaments that are tiny, have a length/width ratio of 1000:1, and are stable and strong despite their shape and size. There are many kinds of fibers, yarns, and fabrics, each with varying mechanical properties. Fibers vary by their molecular structure, the number of internal components, and the arrangement of cells and fibrils. Yarns vary in the way that they are composed and constructed, while fabrics may be even more varied, including webs, nets, mats, woven cloth, knitted cloth, braided structures, felts, cords, and plaited or coiled baskets (Backer 1969).

Although hide, skin, sinew, reeds and plant fibers are similar in their basic structure, there are fundamental differences in their internal organization. Understanding the function fulfilled by each type of fiber in its original living context will assist in identifying salient differences in make-up, performance, resistance and malleability as artifacts. These characteristics – embedded within social understandings of the nature and importance of materials and within manufacture traditions – underlay the choices made by prehistoric people in selecting raw materials for object manufacture. More importantly, the basic qualities of these varying raw materials may also result in characteristic wear patterns on osseous tool surfaces. Understanding the physical qualities of raw materials does not provide a direct means of predicting the way that they were used, but is essential to predicting the physical outcome of contact between the bone and different kinds of fibers. Thus, the first step in developing standards for archaeological wear patterns is to clearly understand the physical differences in the wearing materials in order to identify the kinds of attrition that might be expected from the contact between bone and diverse fibers.

According to J. Gordon Cook (1968), several attributes can be defined that allow the assessment of the quality and utility of a fiber. Those that might have an especially important bearing on the resultant wear patterns on bone tools are:

- structure and appearance
- initial modulus or resistance to stretching

- average stiffness

Initial modulus refers to resistance to stretching and small extension of the fiber under pressure. Modulus corresponds to flexibility – high-modulus fibers will be brittle while low-modulus ones tend to be flexible. Initial modulus describes the resistance over the short term, rather than resistance over time under continuous pressure. Average stiffness relates to the quality of the fiber alone and can be defined as the "ability of a fiber to carry a load without deformation" (Cook 1968:xxiii). The structure and appearance of fibers relate to their original selection as raw materials – a characteristic that might be exaggerated in periods of experimentation with new fiber sources – and on a gross scale may indicate both the suitability of a particular fiber source for a given goal, as well as the kinds of attrition that it might cause on tool surfaces, such as the presence of nodes or burrs, pigments, and the size or shape of the fiber or fiber bunch. As I will discuss below, these qualities differ between plant and animal fiber sources.

Summary: Beyond their basic structural similarity, different classes of fiber have distinct physical properties that affect their selection for modification into perishable industries and also govern their interaction with osseous tool surfaces. Differences in flexibility, initial modulus, macroscopic structure, and composition between plant and animal-derived fibers drive the differences in wear patterns from soft materials on bone tool surfaces. Beyond the characteristics of raw materials, factors ranging from accidental

inclusions such as dirt, intentional additives such as lubricants or dyes to the state of the tools and raw materials, and working conditions will also contribute to variation in wear patterns. Aspects of the raw materials chosen for manipulation into perishable technologies may also affect the species and skeletal element selected for manufacturing the osseous tools used to transform plant and animal elements into objects.

4.3.1. Plant fibers

Fibrous material and other elements for the production of perishable technologies can be obtained from a number of plant sources. Although classifications of plant fibers vary, there are a few main groups into which most fiber sources can be divided:

- *bast and bark fibers*: the fibrous bundles that form the inner bark or phloem of dicotyledonous plants
- *leaf fibers*: fibers along the leaf of monocotyledonous plants; complete leaves may also be used as elements in some kinds of constructions
- *seed hair fibers*: fibers found in seeds and fruits; most seed fibers are derived from domesticated sources, such as cotton

- *complete plant elements*: stems, leaves, grasses, reeds, rushes, or other unmodified or minimally modified plant parts are employed in many kinds of structures, particularly baskets and mats

As elements of a living plant these materials all serve particular functions in the plant. These functions constrain their physical form. Additionally, all plant fibers are composed primarily of cellulose, which has a long, chained molecular structure, are tapered at both ends, and have thick cell walls. Cellulose itself is made of small threads called microfibrils or fibrils, which may be arranged in a number of ways depending on the plant in question. Cellulose cells have hard walls and a rigid cell structure. Fibers of plant materials are generally aligned internally. The cell wall is layered, with each layer one microfibril wide. The microfibrils are oriented parallel to each other in each layer. Successive layers spiral around the overall fiber structure in different directions and angles. This layered, spiraling structure is responsible for the overall form of fiber strands (Preston 1963).

Compared to plant fibers, animal hides and tendons generally require more preliminary processing and may be cleaner, because they tend to be found under layers of softer, less orderly matter that comprises the green portions of plant stems and leaves. They are then typically used in artifact manufacture in a bundled, ordered way. Because of the wide range of plant elements that can be converted into artifacts, different classes of plant fibers will be discussed individually.

4.3.1.1. Bast fibers

One of the most commonly used types of plant fibers are the fibrous bundles of bast or stem fibers found along the stems and trunks of dicotyledonous plants. Bast fibers lend themselves to the production of string because they are already comprised of long, tough, flexible phloem cells: the vascular cells that draw water up from plant roots and distribute it to different parts of the plant. Thus, at a cellular level, they present a form that is elongated, slender, and flexible, and therefore, are amenable to being aligned to each other and then twisted and joined into cordage.

Bast fibers are formed of long, over-lapping, thick-walled cells that run along the entire length of the plant. The individual cells are cemented together by non-cellulosic substances. Additionally, bast cells are often bundled together in a plant's structure and can be used in these larger, sturdier natural bundles as well (Figure 4.12). Bast fibers grow in bundles around the woody stem, forming an inner bark. The number and size of the microfibrils varies between fiber bundles in the same strand, so bast fibers are not uniform. Bast fibers are smooth but have crossed marks and fissures along the surface (Bailey, et al. 1963). Cells are long, with tapering ends and a polygonal cross-section. Cell walls are thick with the central hollow, or lumen, representing only a small portion of the fiber. The fiber surface is considerably smoother than that of animal fibers. Nodes at irregular points on the stem are a diagnostic trait of these fibers. Variation in

the lumen and distribution of nodes are often diagnostic of species. For example, nettle (*Urtica dioica*) cells may be 5cm long and the surface is generally somewhat irregular or distorted. The lumen, the hollow space within a filament, is small and the ends of the fibers, which may reach up to about 2m in length, are rounded. The cell cross-section is oval with thick walls (Cook 1968).

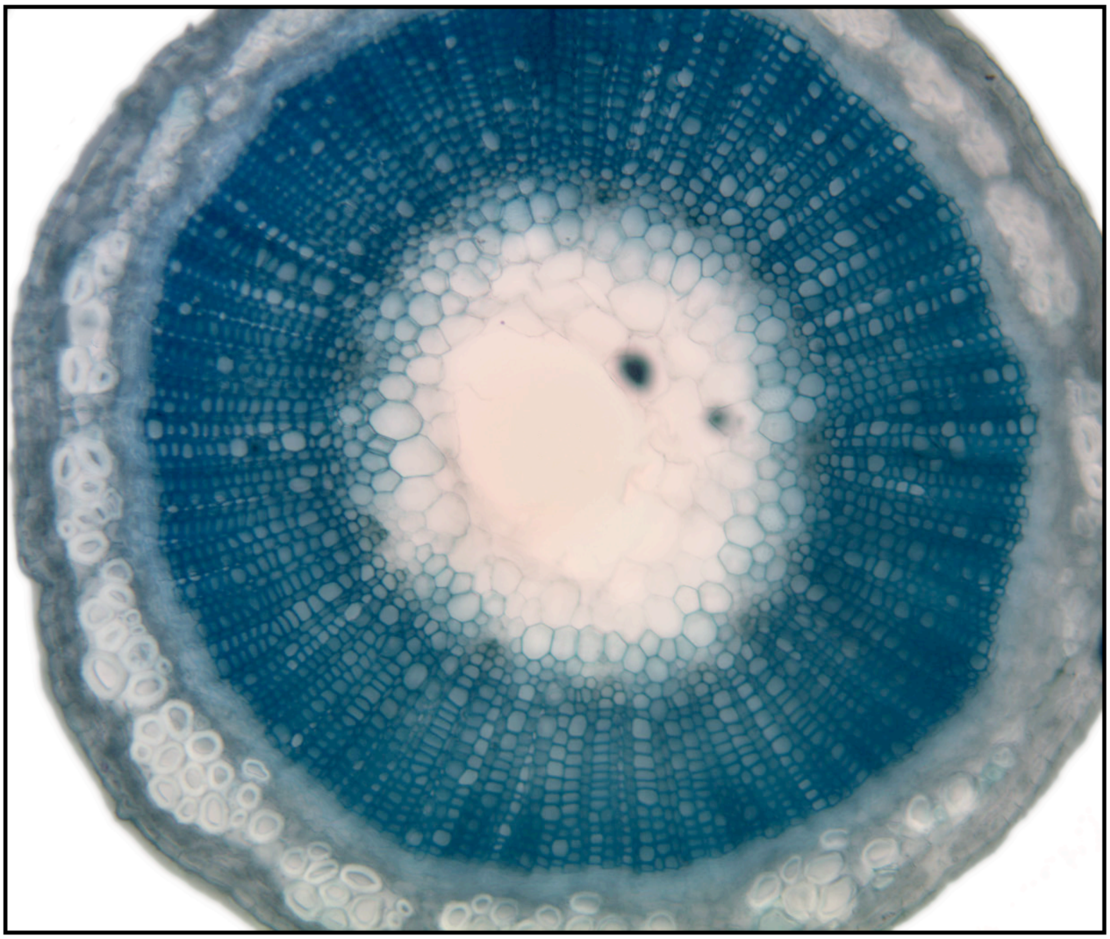


Figure 4.12. Cross section of flax, showing bast bundles (white)

Bast fiber is extremely strong, due to its physical structure. However, considerable processing may be necessary to obtain the finest bast fiber. The quality of bast fibers for textile production also varies with the plant's growing conditions. Plants that grow in crowded conditions yield finer fibers. To obtain fine, high-quality fibers, plants should be harvested just before the plant goes to seed (Grieve and Leyel 1931). To maximize fiber quantity, plants should be harvested after seeds have ripened, but these fibers are coarser and more difficult to process because they cling to the stem.

Plants are pulled up and left to dry a few days, generally on the ground, and then seeds and leaves are removed, often using a large comb (this process is referred to as *rippling*). Bast-producing plants are generally retted, which is the process of soaking in water to remove soft, fleshy material. Plants can be retted by dew-retting or water-retting. Dew-retting consists of leaving plants in open fields 4-8 weeks. Water-retting is done in either running or still water, generally inside crates or sacks for 10-20 days. Retting can be done in basins or, if plants are attached or weighted down, can be carried out in slow-moving water, which can make later processing of the fibers simpler as the running water washes away matter as it decays and loosens from the stem and bast fibers (Hess 1936). Plants can also be weighted down by other means, including stones or soil. After all types of retting the stalks are dried and then cleaned by *breaking* and *scutching*. Breaking is the breaking up of the stalk into small pieces while scutching is the removal of the stem and primary ordering of the fibers, generally by beating (Hess 1936). Fibers that are less clean and still have considerable amounts of stem and outer flesh clinging to them can be obtained by simply stripping dried stems and working the

fiber bundles over a board or stick to increase their flexibility. Sometimes, nettle may be boiled before hackling to ease the removal of small bits of stem. Bast fibers may also be oiled or dampened before spinning.

Examples of bast fibers include: jute (*Corchorus spp.*), flax or linen (*Linum spp.*), hemp (*Cannabis sativa* or *Apocynum cannabinum*), sunn (*Crotalaria juncea*), ramie (*Boehmeria nivea*), and nettle (*Urtica spp.*). Bark fibers are also bast. Of these fiber sources, nettle and bark would certainly have been available to the Late Upper Paleolithic inhabitants of Northern Spain. Of the many nettle species, today the most commonly used for textile production are *U. dioica*, the common nettle or great nettle, *U. urens*, the small nettle, and *U. pilulifera*, the Roman nettle.

Bark fibers are also a type of bast fiber, but given their unusual make-up can be considered as a distinct group or sub-group. Bark fibers are obtained from the bark of trees and are located only on the exterior of the living organism, unlike vascular cells found within the protected interior of the plant body. Thus, bark fibers are exposed to changes in humidity and temperature, as well as attack from any number of parasites and plant consumers, during the lifetime of the plant. Bark from dozens of trees are used in the production of fiber technologies, with the some of most common being cedar (*Juniperus spp.* and *Chamaecyparis nootkatensis*), juniper (*Juniperus spp.*), willow (*Salix spp.*), birch (*Betula spp.*), kenaf (*Hibiscus cannabinus*), fig (*Ficus sur*) and spruce (*Picea spp.*).

4.3.1.2. Leaf fibers

Leaf fibers run along the leaf of monocotyledonous plants. Leaf fibers are harder than most bast fibers and may be larger. Strands of individual fibers are smooth but do not display the cross-marking of bast fibers. Tips are flat and often pointed. Of particular note are the leaf fibers of desert plants such as the needle-tipped agave (*Agave spp.*). The manufacture of goods with these kinds of self-needled plants may leave very little trace in the archaeological record.

Figure 4.13. Prepared raffia fiber (Sage Ross)

4.3.1.3. Seed Fibers

Seed fibers form around a growing seed. The most well known example of a seed fiber used industrially is cotton (*Gossypium spp.*), although other sources include milkweed (*Asclepias spp.*) and kapok (*Ceiba pentandra*) (Figure 4.14). Seed fibers are soft and short and must be spun in order to create lengths of thread. Most that are in use today are domesticated and were not available in Late Upper Paleolithic Europe.

Figure 4.14. Kapok seed with fiber (J.M. Garg)

4.3.1.4. Complete Plant Elements

Finally, the whole or partial leaves of plants or entire grasses, reeds or rushes are used in many cases for the production of a range of artifacts and structural elements. There is a large range of variation in this last category, as it is not of the same type as the previous three. When we consider plant parts used with minimal modification, then the structural role of the object and its physical characteristics will vary given the plant, its ecology, and the particular element employed. Small saplings or stems are commonly used as elements in coiled basketry. These small, woody stems may be perforated or separated to allow the moving basketry element or stitch to pass through the foundation. Generally, such stems are made of woody, strong cellulose and will be worked when green, with a high moisture content allowing flexibility for manipulation into forms that stiffen as the stems dry and harden. The ways of preparation of complete plant elements also range considerable (Hurcombe 1994, 2008a).

Rushes, grasses and reeds warrant special consideration in this category, as they are notable for their extremely high silica content. However, many other plants also contain substantial amounts of silica. Activities involving tool contact with silica-rich plants, include basket making using many different materials and techniques, weaving, harvesting grass seeds; processing yucca (Russell 1908), agave (Parsons, et al. 1990), nettles (Gustafson 1980:73) or other plants for fiber; and net making. Grasses also contain hard silica phytoliths (Lewin and Reimann 1969). Silica is hard and can be slightly angular, causing it to be fairly abrasive. This natural abrasive may contribute to strong

bone tool attrition patterns when tools are used against silica-rich plants. On a macro level, silica is often concentrated in the leaf, stem nodes and shoots. On a smaller scale, silica is often found in just those parts of the plant likely to be used in artifact construction: vascular (bast) cells and in the cell walls of the exterior layer of plant elements (Lewin and Reimann 1969).

Summary: The plant sources for fiber and artifact manufacture elements in the Late Upper Paleolithic of Northern Spain might have included bast from nettle, bark from willow and birch, and twigs, roots, and saplings. Plant fibers are characterized by a rigid cellulose cell wall and generally by a smooth exterior surface of the individual fiber. The most common plant materials used to construct perishable artifacts are long and flexible. The presence of varying degrees of silica in different plant species should affect attrition from wear due to its strong abrasive, angular character.

4.3.2. Animal fibers

Mammals provide the second major source for fibers for the production of perishable technologies. Animal-derived fibrous materials include hair, fur, true wool, hides, gut and sinew. With the exception of sinew and gut, these materials share the quality of once forming part of the barrier between the inner organs and skeleton of an animal

and the outside world, while sinew, made from tendon, and gut were never exposed to external conditions but found within the body. The animal parts that are exposed to varying exterior conditions all exhibit durability in changing temperature and humidity, as well as being highly flexible. Soft perishable materials from animals can be grouped into three primary classes:

- *Skin*: skins, furs, hides, rawhide and leathers are composed of animal skin and are subject to various kinds of treatments before being converted into usable materials

- *Hair*: fur, hair and wool grow out of the skin and are kinds of hair, although the properties of wool are distinctive

- *Sinew*: worked tendon

Like plant parts, animal parts, despite their variety, share certain cellular traits. Animal cells derive from the same kind of stem cell and differentiate during development, which imparts certain shared qualities. Animal cells lack the rigid cell wall found in plants and cells are bound by an extracellular matrix of collagen, which is calcified in hard animal parts such as the skeleton or shells. Keratin and collagen have softer cell boundaries and less orderly arrangement of cells than that found in plants (Cook 1968). This softer and more irregular cell structure lends different wearing properties to animal products. In fact, even the osseous materials share some of these qualities at the cellular level. Here, though, I will focus on the soft animal parts. Macroscopically,

animal fibers and soft parts have unique qualities that affect their interactions with worked bone surfaces and other materials.

4.3.2.1. Skin and hide

Mammal skin is made up primarily of collagen fibers, but rather than being aligned, they are interlocked and matted, much like a felt. The skin is divided primarily into the epidermis and the corium. The corium is made up of interlocking collagen fibers that are matted together without any predominant order (Bailey 2003). This dense, disorderly, flexible structure can be perforated through the division of fibers to make space for an element to pass through or by breaking fibers to create a gap. Both actions are typically involved in the perforation of hide with a bone awl or needle.

Figure 4.15. Worked and painted hide from Knife River Historic Site (Chris Light)

Additionally, internal inclusions in animal hide may be of varied size and material and should result in striations and gouges of unpredictable form. During their lifetime, animals, especially large herbivores, brush up against thorns, twigs, dirt particles, and other hard materials in their environment. Many small pieces of wood or other materials become lodged in the skin and remain there without harming the animal. Some may eventually work their way out of the skin or become dissolved over time, but

at the time of death, small inclusions are common in animal hides. Skin can also develop irregularities from scarring during the life of the animal.

4.3.2.2. Fur and hair

Animal hair fibers are all made of keratin, but vary widely in form, especially among domesticated animals. As in plant fibers, the cortical cells that make up keratin fibers are much longer than they are wide. Hair fibers have four layers and have a distinctive scaly outer surface. The size and form of scales varies by animal and hair type. The outer surface, the epicuticle, is a fine membrane that may impart a resistance to soaking up water, although it is permeated with small pores. The epicuticle forms a thin membrane over animal fibers, but it does not seem to limit friction, which is pronounced in the distal-to-proximal direction of a hair (Sikorski 1963a). The next layer is the scaled surface that consists of large, overlapping, flat cells and gives hair its diagnostic appearance. Non-domesticated animals tend to have irregular cortex scale patterns (Ryder 1963). The interior layer, or cortex, is composed of smaller fibrous bundles of fibrils. The cortex bundles are polyhedrons that pack closely together in some regions of the cortex. In some cases, such as domesticated wool, these fibrils are uneven and spiral around each other, which gives wool its crimp. However, in straight hairs the fibrils are aligned to each other. The bundled microfibril structure is the primary structural element responsible for the functional qualities necessary in textile

fibers (Sikorski 1963b). The interior hollow cavity is the medulla and varies greatly in size and form among hair types. The medulla may be broken or unbroken, each having a number of possible forms. The cross-section and length of hairs vary by species and hair type (Cook 1968).

Figure 4.16. Needle with wool, Hopi Pueblo (NMNH E166613)

Fur, if attached to a skin, is arranged in an ordered way, through the natural patterning of hair follicles. Some processing to clean fur and remove loose hairs may have been carried out with bone tools. More typically, however, animal hair is worked into some

kind of cordage. In the case of human or horse hair, mane and tail, long, strong individual fibers are available for twisting into longer lengths. Prior to the domestication of wool-bearing caprines, spinning fur and hair into string would likely have presented difficulties, given the short length and minimal crimp of non-domesticated fur.

4.3.2.3. Sinew

Sinew is made from tendon, the internal collagen bands that bind muscle to bone. The fibers that make up tendon are arranged in large, parallel groups that bind into sheaths that wrap around each other to form the tendon (Issenman 1997). In the living body, tendons serve as highly elastic elements that bind muscle to bone and absorb and store energy in a spring-like action. Untreated sinew is not very useful as a fiber, as it has limited flexibility and durability (Choyke and Duffy 2011). Sinew can be treated in different ways to conserve flexibility or to allow hardening and may be the fibrous material that is most altered by different treatments. Worked sinew can be twisted into strong, flexible cordage (Figures 4.17-18). Sinew worked when damp and allowed to dry with the fibrils aligned and untwisted may harden in place. Sinew exposed to heat shrinks and permanently loses all flexibility.

Figure 4.17. Freshly extracted tendon and hide

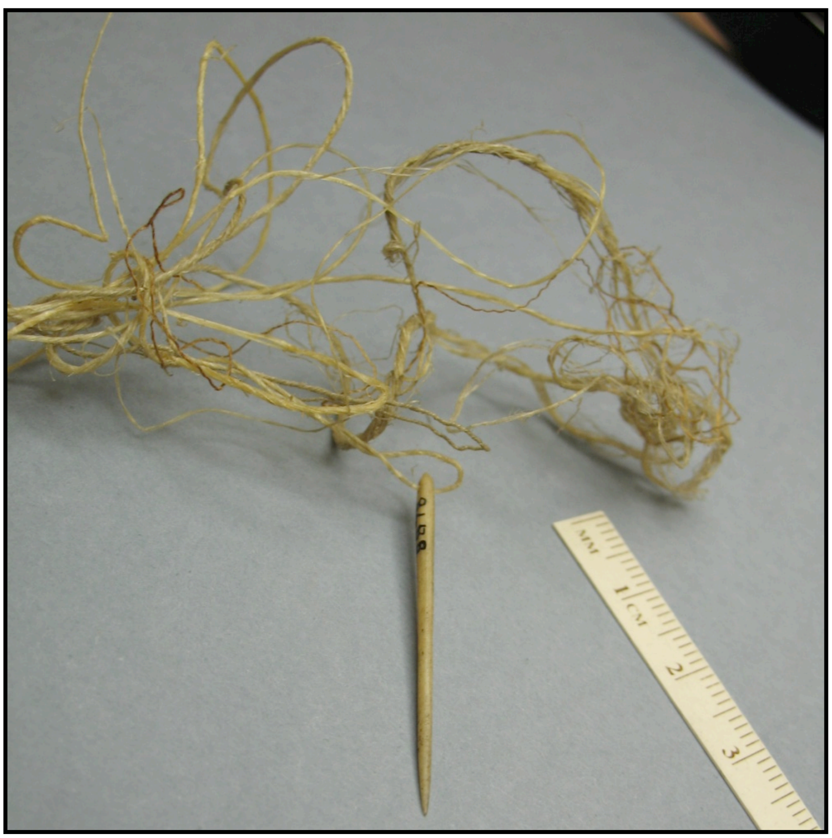


Figure 4.18. Bone needle with sinew thread, Montagnais or Innu (NMAI 028878)

Figure 4.19 Bone needle with gut, Eskimo Nuwukmiut (NMAI 53175)

Summary: Sources for animal fibers are somewhat less varied than those for plant fibers, but the class still represents substantial internal variability. Hair, fur and skin formed part of the protective barrier around living animals, while gut and tendon serve functions within the body. However, despite functional variation within living mammals, animal cells all derive from developmentally early stem cells and thus share certain properties. They lack a rigid cell wall and are joined to each other by a cellulose matrix, which is not ossified in the kinds of cells that make up hair, skin, and tendon and so, is soft and somewhat malleable.

4.4. Use wear on Bone from Fiber Materials

In order to model the expected outcome of different kinds of contact, the various forces at work between and on contact materials must be understood. Studies in tribology have established that friction, adhesion and shearing are some of the main factors that result in the alteration of materials due to contact during the course of work (Buc 2005). In this study, I began with the generation of tribologically based expectations based on the differences between plant and animal fibers. These predictions were tested empirically against experimental and ethnographic surfaces with known use history. I then evaluated the utility of tribological principles for predicting use wear characteristics. The outcome of these tests will be discussed in chapters 7 (Experimental Program), 8 (Analysis of Ethnographic Collections) and 9 (Ethnographic Case Studies); here I will present the model for wear based on the prior discussion of the physical properties of bone and plant and animal-derived fibers.

First, I consider the performance of the bone and fibers in question, with particular attention to the factors that govern reactions to stress that lessen or increase wear from contact. Then, I examine the interaction between surfaces in motion and the ways that archaeologists have understood the accumulation of wear. Finally, I use the insight from tribological principles to develop models for wear from classes of plant and animal fibers on worked bone surfaces.

4.4.1. Bone and Fiber at Work

Bone and plant and animal-derived fibers each have distinctive physical properties that govern the interactions between these materials and contribute to the patterning of wear on osseous tools. I now turn to some of the factors that help us understand the performance of fibers and the ways that they may create wear on contact materials. Structural and mechanical engineering provide us with some basic information about the ability of fibers, yarns and fabrics to withstand pressure and stretching, and thus, have the potential to inform on their predicted effectiveness as wearing materials or their propensity to cause attrition in osseous surfaces. When the mode, intensity, duration, direction, and gesture of tool use can be identified, this can contribute to the inference of tool function.

Each of these aspects of variation in tool use can be explored through an understanding of the influence of worked material reactions to contact on the attrition that can accrue on tools. Tensile resistance is the primary variable in determining resistance to breakage, while elastic recovery would contribute to resistance to wear. Friction, shearing, and adhesion are the primary driving forces behind attrition.

In this study, I have focused on differences in wear patterns due to material worked, and to a much lesser extent, duration of work. However, a comprehensive tribological model would necessarily include all of these variables. As each requires a different kind of comparative sample, I selected one kind of variable as the first test of the utility of

tribology in archaeological analysis. The material worked can be modeled with clear expectations for diagnostic differences between classes, so this was the aspect of wear variation that I examined here. Additionally, the original archaeological question of interest related to the use of plant fibers, so raw material was an obvious choice for the tribological model developed.

4.4.1.1. Performance Characteristics of Bone as a Material for Tools

Michael Schiffer (1979) introduced the concept of performance characteristics as a useful way to evaluate tools use. Janet Griffitts (2006) employed this method to order her functional analysis of bone as a raw material and of bone tools in a number of modern, historic, and ancient contexts (Schiffer 1972). She notes that performance characteristics are different from material properties in that performance characteristics are specific to a particular task. This poses a challenge for the archaeologist attempting to *determine* function of archaeological artifacts. However, Griffitts assesses the performance characteristics of a number of artifact classes and suggests that the performance characteristics in certain tasks may help explain the replacement of bone tools with metal or wooden forms in the late historic period (Griffitts 2006). Heidi Knecht's study of projectile point performance characteristics allowed her to suggest some of the reasons for the predominance of antler over bone in hunting point manufacture in the Late Upper Paleolithic (Knecht 1997). Antler's structure and makeup

allow it to absorb shock more effectively, so antler resists breaking on impact more readily than bone.

Vivian Scheinsohn (2010) assessed the material and performance properties of different skeletal elements and species in her study of bone material selection in Tierra del Fuego, noting that variation among bone sources could contribute to manufacture choices. She found that the choice of elements for tools for different tasks reflects general properties that distinguish skeletal elements and the bones of different taxonomic groups from each other. In particular, the bones of large birds, terrestrial camelids, and cetaceans (ocean-dwelling mammals) were used in different ways depending on their strength and resilience. Scheinsohn created a proxy measure for these properties by measuring load-bearing capacity, stiffness or resistance to deformation, elastic energy absorption capacity, and elastic modulus, which is a compound measure that describes the relationship between force exerted on a surface and the amount of deformation resulting from the pressure.

4.4.1.2. Other Factors Affecting Artifact Surfaces

Beyond the basic factors of raw material and mode of contact, several other factors affect the presence and form of use wear on archaeological artifacts. The functional living role of the plant and animal elements worked into artifacts places constraints on these materials that translate into distinct material properties, as has been discussed.

The preparation of fiber elements for the manufacture of products can also contribute strongly to the characteristics of the final fibers that are worked with bone tools. For example, unmodified sinew is brittle and stiff but sinew can be worked into strong, flexible cordage (Choyke and Duffy 2011).

The condition in which the manufactured elements were worked also contributes to the nature of the wear patterns created, particularly in altering the role of friction on surface modification. When examining bone tools it is important to remember that lubricants, such as fats, reduce friction and thus wear. The presence of fats on either bone tools or the materials on which they are used can minimize wear. The surface attrition seen on a tool may be the surface of wear from the material that is being worked, or from other products that are involved in the manufacture process, such as slurries, lubricants, dyes, or abrasives added intentionally by the craft-worker or grits, greases or liquids in the environment inadvertently introduced between the tool and worked material (Plisson 1993).

When investigating use wear on archaeological specimens, the conflation of use, manufacture, handling, repair and taphonomic processes is a potential source of bias that can limit our ability to infer action from wear patterns. After deposition, bone tools may be subject to abrasion from the depositional matrix, water flow, or other taphonomic agents. Treatment during excavation and in the lab may also obliterate or compromise surface wear patterns through vigorous washing, consolidation or other

treatments. Additionally, the deteriorated and fractured condition of most osseous artifact surfaces may prevent the identification of wear.

4.4.2. Properties of Thread and Fabric under Mechanical Stress

Mechanical manipulation such as twisting, spinning, or twining is necessary for use of most fibers because the individual strands are small and fine and cannot be used for thread, cord, or more complex structures. Although the term "yarn" is used colloquially in a more circumscribed sense, a yarn can be defined as "any assemblage of fibers or filaments which has been put together in a continuous strand suitable for weaving, knitting, and other fabric construction" (Emery 1966:10). To facilitate the use of short fibers, the individual filaments must be lined up and then twisted. This introduces lateral tension that creates friction between individual strands and holds them together. The internal friction between individual fibers introduced by twisting is what keeps the fibers together in a coherent yarn (Hearle 1969b).   Twist decreases strength in individual filaments, but increases resistance to abrasion and damage and increases overall strength in the final yarn. Thus, twisting is necessary to create long, strong yarns from short fibers, that have emergent properties due to the process of fiber manipulation. Thus, a higher twist will result in a yarn that is denser, stronger and will produce more wear on tools. Strength increases with twist, up to an optimum.   When twisted too much, or beyond the optimum, the specimens will double back on

themselves. This undesirable condition is known as crepe twisting. Longer and finer fibers produce stronger yarn because they decrease slip (Hearle 1969a). So, physically, the fibers selected for yarn production must have long-chain molecules to prevent the loss of strength during the twisting process, somewhat parallel arrangement that allows for alignment and manipulation, lateral forces that create cohesion in the structure (often, this is twist), and some freedom of molecular movement for flexibility, as well as the absorption of water or dyes. It is important to remember that while individual fibers may have certain defined mechanical properties, preparation of fiber sources and working of the fibers into cordage can alter the unmodified characteristics substantially.

Tensile properties are the reactions to stress, force, and deformation along the fiber's axis, particularly the elongation, and ultimately breakage, due to increasing force loads. There is a temporal component to elongation: under force, there is immediate elongation to a certain point, followed by slower, gradual elongation until breakage:

$$\text{tensile strain} = \text{elongation}/\text{initial length}.$$

As fibers are subjected in tensile strain they extend, resulting in a narrower fiber. This means that in cases where high tensile strain is exerted, such as in tugging a thread with an eyed needle, the zone of contact with the tool is decreased. If we are looking at a resistant fabric then the tensile strain on the thread should be higher and the zone of contact in the eye of the needle might be smaller. The varied degree of tension (stretching length-wise) and lateral pressure (the space available for a thread between

others on either side in the fabric) contribute to the ultimate cross-section of the yarn within a fabric and under stress (Backer 1969). After deformation, elastic recovery of different fibers can be assessed through the amount of permanent damage to the fiber (stress) and to the proportion of length recovered after the removal of strain.

Studies on the tensile properties of different fibers have shown that bast fibers do not recover length well but do withstand stress with minimal permanent damage. Wool and hair have a yield point but display substantial recovery even close to the breaking point (Morton and Hearle 1975). Unfortunately, studies of the tensile properties of sinew are unavailable. However, experiments suggest that worked sinew also has significant recovery and withstands stress well; this is also indicated by the use of sinew for tasks such as bowstrings, which withstand substantial and repeated extension and stress. This suggests that when different kinds of fibers are available, people will select a fiber for a particular purpose based on availability and the appropriateness of its physical traits for the given task.

4.4.2.1. Fiber friction

In terms of performance, friction must be high internally, to allow the cohesion and stability of a twisted strand, but friction between the fiber and other materials causes damage to the cordage and may result in attrition in contact materials as well. This combination of damage and attrition is the basis for the accumulation of use wear.

Friction is thus critical to the development of wear and can be understood in terms of three basic laws (Morton and Hearle 1975:612):

1. frictional force is independent of the size of the surface area of contact
2. friction is proportional to the normal force between the two surfaces in contact
3. there are two types of friction: static friction resists initial movement and kinetic friction resists continued movement; kinetic friction is independent of the speed of sliding

However, fiber friction is complicated by the fact that a cordage strand will have numerous crossed fibers that form individual points of contact. Additionally, the roughness of a surface has considerable impact on effective friction due to its effect on points of contact. Thus, the net outcome of these two factors is often such that it *appears* that the second law of friction is not always obeyed. As our understanding of friction has progressed, it also appears that friction may be due to the union of two substances and to subsequent breakage of that union. In fact, friction varies with the roughness of the surfaces, the capacity for deformation, and the shearing force needed to break unions.

Stanley Backer (1969) shows that greater strength and resilience of cordage may cause heavier or more rapid accumulation of wear, as the fiber is more resistant to fraying, breakage and volume loss. In those fibers that have surface directionality – i.e., scales –

there is a directional frictional effect (Morton and Hearle 1975). This explains the propensity of wool to felt and suggests that we can expect significantly different interactions between hair and osseous surfaces than between other fibers and bone.

4.4.3. Wear and Attrition

At microscopic scales, damage from contact between fiber and bone occurs on both surfaces. Additionally, there are a range of different types of wear that may be present at a microscopic scale including material fracturing, displacement, and adhesion (Del Bene 1979). Adhesion may be particularly important in contributing to the use wear produced by the action of a softer material against a harder material. Striations can also result from adhesive wear, which involves actual bonding of atoms from one material to those of another; wear produced by soft materials on harder ones may be primarily adhesive wear. Bonding may be chemical, electrical or due to the action of surface tension.

LeMoine (1997) argues that most wear encountered on archaeological osseous material is abrasive wear, resulting from contact between surfaces of differing hardnesses. Particle shape and size of the harder material affect the form of striations made in the softer material. The particles that wear against bone may be part of the worked material as in the case of surface asperities on reeds or temper in ceramics, may be

introduced accidentally as dirt and grime, or may be a component of an intentionally introduced substance such as lubrication to ease work, mineral or organic dyes, abrasives for smoothing, or fats worked into hides, among many other examples. Angular particles cause fractures along the groove while spherical particles cause plastic deformation of the material resulting in a groove with “pile-up” along the edges. Among angular particles, small particles may also cause plastic flow and pile-up without fractured edges; as size increases, fracturing occurs and large particles cause only fracturing and no plastic flow. Greater force will increase the creation of striations. Polish is now generally seen as a type of very fine-scale abrasion, possibly on a molecular scale, but may also involve the deposition of grains of material such as phytoliths (LeMoine 1997).

Most striations and polishes are assumed to have been formed through the mechanical removal of material. This can apply to attrition related both to manufacture and use. Mechanisms of mechanical polishing can be grouped into abrasion (loss of material from the surface) and surface translocation (movement of material from raised areas to depressed areas, forming a smooth, even surface). Abrasion models for the accumulation of use polish are predicated on the assumption that so many tiny striations build up that to the unaided eye the area appears smooth. Use wear includes the presence of polish, which is produced by the sustained contact of bone with a softer material, resulting in a localized area with a smooth, reflective surface. Pitting, crushing and striations can also be caused by use and are generally found on the working edge of the tool and parallel to the long axis of the bone (Buc 2010a; LeMoine 1997).

Thus, we can determine that the different microscopic surface patterns characterizing osseous surfaces worn with hard and soft materials are a function of a few primary factors:

- hardness and resilience of both contact materials, along with any other inclusions
- shape and form of both surfaces and any inclusions
- amount of friction between the surfaces
- force exerted
- duration and intensity of use

Both manufacture techniques of reductive technologies, including bone, and the phenomenon of use wear depend on these factors. By identifying the differences in these factors among different tasks, gestures and materials, a model for use wear can be developed.

4.4.4. A Model for Wear on Worked Bone from Plant and Animal-Derived Fibers

In the previous discussion of the properties of bone, and plant and animal-derived fiber, I have identified differences between plant and animal fibers that should result in different forms of use wear on bone. The most salient differences are the rigid cellulose cell wall present in plants but absent in animal cells and the differences in the macroscopic arrangement of plant and animal fiber bundles. Particularly in the case of animal hide, the irregular structure of the matted fibers contrasts strongly with the long, parallel bundles of bast fibers in plant stems. Overall, plant fibers are stiff, ordered, and often lack inclusions of other materials. Animal fibers are softer, vary greatly in their internal organization, and may have small inclusions present within the material or adhering to it. Thus, the following predications can be made for the differences between plant and animal fiber wear:

Plant fibers have a durable, rigid cell wall and often used in bundled or twisted groups. The cells of plant fibers have a lower initial modulus and are less likely to deform to the microcontours of the contact surface of a bone tool. Thus, wear from plant fibers should be characterized by:

- planar attrition
- non-invasive polish
- orderly stria are possible

- edge rounding may not be present

Animal fibers, on the other hand, are often internally less ordered than plant fibers on both a macroscopic and microscopic scale. Cells of animal fibers have a soft cell boundary and may deform to the contours of a worked bone surface. Finally, animal fibers are more frequently worked with abrasives and lubricants than plant fibers. Based on these properties, wear from animal fibers on bone tools should be characterized by:

- rounded borders
- attrition that deforms the original surface
- invasive polish
- striations may vary substantially in size and orientation

By plotting these expectations in a table, we create a grid of wear predicted from plant and animal materials:

Table 4.1: Tribologically Derived Expectations for Wear on Bone from Contact against Plant and Animal Fibers		
Variable	Plant Materials	Animal Materials
Polish invasiveness	Non-invasive	Invasive
Microtopography	Flat or planar	Rounded
Presence of striations	Yes	Yes or No
Striation organization	Patterned	Irregular
Striation size	Similar to each other	Varied
Volume loss	Variable	High
Presence of pitting	Yes or No	Yes

Pitting is the only variable in this simplified model that was not selected based on my understanding of the properties of the contact materials, but rather on its prevalence in the literature as a reliable indicator of hide-working (i.e., Griffitts 2006).

In the following chapters it will be shown that these predictions are supported in the ethnographic record of osseous tools and in experimental programs. Although this model is highly simplified and cannot provide direct rules for identifying kinds of use wear, it demonstrates the utility of tribological investigation as a framework for archaeological use wear analysis and shows that further research in this area may allow us to refine the criteria for this model to allow greater specificity and broader application. It also indicates that a consideration of some of the other primary

tribological variables, such as direction and mode of work, should allow the incorporation of new dimensions to this tribological model for use wear accumulation on bone.

4.5. Summary

There are many ways to structure a functional study of archaeological artifacts. In my research I have employed insights from the field of tribology to help me predict the ways that bone will act as material for producing tools for the construction of perishable technologies and the kind of wear that will develop on worked osseous surfaces during different kinds of work on varying materials. Tribology provides a useful framework for this kind of analysis because tribologists are interested in precisely the same variables as use wear analysts: the attrition caused by moving contact between two surfaces. Although tribology was developed to help contemporary industries reduce the wear and tear on moving parts in machines and other tools, we can modify and apply these models to predict and classify wear on tools.

Tribological studies indicate the factors that cause wear and that differentiate kinds of wear from different materials. Among the primary factors are the form, hardness and resiliency of both materials, indicating that different materials will produce distinct wear patterns under similar conditions and modes of contact. This provides the basis for

archaeological use wear analysis. Drawing on this, I have developed a preliminary predictive model for the differences in use wear from plant and animal-derived fibers. The cellular and macroscopic structure of fibers varies between plants and animals more than within these classes, so it should be possible to distinguish wear from these two kinds of sources. Relying particularly on the fact that plant cells have a rigid cell wall that is lacking in animal cells and that plants are primarily composed of cellulose while animal fiber cells are protein-based, I suggest that attrition from plant fibers will be less invasive and contain more orderly striations while animal fibers will conform to the tool surface and leave more invasive, rounded wear.

Chapter 5. Methodology

As discussed in Chapter 2 (A Brief History of Bone Technology Studies), although bone tools are relatively frequently encountered in the archaeological record of the Late Upper Paleolithic of western Europe and many other places, until recently the approaches taken in the analysis of osseous artifact assemblages have focused on manufacture and typology. There have been very few studies specifically focused on investigating perishable materials through use wear on bone tools. Chapters 2 and 4 (A Brief History of Bone Technology Studies & Tribology) introduced the field of bone tool analysis and a tribological model for analyzing use wear on osseous artifacts. Here, I focus on the functional analysis of worked bone surfaces. The study of material culture, especially of archaeological artifacts, can be organized at many scales. The most common scales employ the artifact or regional assemblage as the unit of analysis. I have already presented an overview of bone tool studies, emphasizing studies at the artifact and assemblage scale, as well as behavioral scales.

In Chapter 4 (Tribology) I proposed an alternative framework for structuring the analysis of attrition patterns: tribological modeling. Observations that will be assessed through tribological principles must, by necessity, be comparable at the scale of the contact surface. In this chapter I focus on aspects of bone technology that can be studied at the working surface level. I begin this discussion by reviewing some of the identification and classification problems in bone tool analysis. I will discuss the three kinds of collections

used – experimental, ethnographic, archaeological – and identify differences in these samples, the unique challenges presented by each collection, and the ways that the three samples complement each other within the framework of functional analysis. I describe the nature of each sample, both in terms of the inherent qualities of each kind of worked bone collection and in my sampling strategies, which varied by collection, given the unique opportunities and challenges of studying disparate and often older collections housed in museums. I then shift my focus to functional analysis of artifact surfaces, emphasizing bone tool studies. I discuss different approaches to use wear analysis, especially the question of level and kind of magnification. Surface replication techniques are an important part of large-scale use wear studies and provide another means for data sharing, so common replication techniques will also be reviewed. I will outline some methods that were attempted and discarded or were omitted from this study. The following chapter will provide an overview of the steps I followed in my analysis.

5.1. Worked Bone Collections

This analysis of function of bone tools relied on three kinds of collections: experimental, ethnographic and archaeological samples of worked bone. In each case, I analyzed surface attrition patterns and morphological variation. All three collections are made up of worked bone used in various manners and contexts, but the life histories of artifacts

from each group are distinct. Data that contextualizes the accrual of use wear varies for the three collections. There are advantages and drawbacks to the use of each kind of collection, and in particular, the use of ethnographic and experimental collections for the construction of comparative standards helps balance the strengths and weaknesses of each. Given the differences in origin and uselife of objects from the three collections, they are not comparable at all scales. However, analysis at the object-surface level allows robust comparisons, as will be discussed in detail after the collections are described. Below I will discuss the utility of these kinds of collections and the challenges inherent in each. I will close this section arguing for the comparison of experimental, ethnographic and archaeological collections at the scale of artifact working surfaces.

Experimentation allows the greatest control over context and life history variables pertaining to manufacture and use. These categories include the materials worked and their condition, as well as the types of tasks that might create wear. For ethnographic assemblages, the geographic, environmental and cultural origins are key, as is the history of use. In many cases, the history of use for an object or collection might contain information about age, gender, or social status of the object's owner, its function, and the materials worked, and in extraordinary cases, actual descriptions of the activity carried out. Archaeological data on the context of use includes the site, its geographical location, and pertinent environmental information, including pollen, phytolith, and faunal studies, and chronological information such as absolute dating and typological assignation. For both ethnographic and archaeological samples, information on post-

use history, including taphonomic alteration, and repair, cleaning and consolidation in the laboratory or museum context is also important, but is not always available.

5.2. Comparative Standards for Use wear Analysis

5.2.1. Experimentation

Both within the field of worked bone studies and more generally in functional analysis, experimentation has long been the primary means by which surface traces and other patterns of attrition diagnostic of use have been identified. Experimentation is standard practice among specialists in traceological analysis across material types and study areas (Legrand and Sidéra 2007; Semenov 1964). Experimentation is essential to understanding the patterns that develop from the manufacture and use of objects as it allows researchers to establish direct causal links between actions and attrition patterns.

There are many ways that experiments facilitate the construction of robust standards for the assessment of archaeological assemblages. Through experiments, archaeologists are able to isolate and control the variables that are of most interest. Those variables might include: raw material of the tool used to make an artifact of interest or as the object of work, gestures, duration of use, condition of the object or the contact

material, context of work (dirty, damp, etc), techniques of manufacture or use, or taphonomic agents. By varying only certain variables in each experiment and making standardized observations, the experimenter can begin to distinguish between the different factors at work in creating the features of the final surface and can isolate proximate causal relationships. Another advantage is that conducting experiments allows the analyst to observe the process of wear accumulation. This can provide insight into the nature of use-related attrition. Experimentation, then, allows the traceological analyst to establish the grounds for arguments about the life history of archaeological artifacts, using known causal relationships that structure the development of surface attrition.

Experimentation has also been critical to the development of use wear standards, beginning with the work of Semenov (1964), as discussed in Chapter 2 (A Brief History of Bone Technology Studies). Semenov developed his standards for assessing use wear through experiments and many analysts followed his lead. The outcome of this early emphasis on experimentation was a strong reliance on empirical observations of wear patterns on experimental pieces to develop standards for use wear on archaeological artifacts. Generally, this has proved a workable and reliable approach to use wear analysis. However, as noted in Chapter 4 (Tribology), use wear specialists lack a coherent theory to predict and understand the wear patterns identified on experimental objects. An understanding of the impact of individual variation, context and many other variables would strengthen the application of experimentation in use wear studies. Additionally, there is a lack of blind-testing among bone tool use wear specialists.

Employing blind tests would allow analysts to test their methods of wear identification (for lithic use wear seeHurcombe 1988; Newcomer, et al. 1986; Odell and Odell-Vereecken 1980).

As discussed in Chapter 2 (A Brief History of Bone Technology Studies), experimental reproduction of osseous artifacts has been used to build up our understanding of the possibilities of shaping bone and antler, thus contributing to our knowledge of the manufacture of osseous artifacts. For example, Hind Sadek-Kooros (1972) found that metapodial awls can be formed by simply striking the center of the bone and then twisting the ends. Researchers including André Billamboz (1977) and Jörg Schibler (2001) have found experimentally that antler can be soaked in cold or boiling water for easy workability. Michel Dauvois (1974) found chattermarks diagnostic of scraping bone and antler with flint tools (see also Campana 1989). Mark Newcomer (1974) and André Rigaud (1972) distinguished between bone worked by abrasion and flint. D'Errico and colleagues (d'Errico, et al. 1984) have published criteria for identifying manufacture traces on bone. These and other experiments provide great insight into the process of bone tool production and have allowed the development of robust analyses of manufacture sequences.

5.2.1.1. Experimental Design

Experiments can be designed in a number of ways, according to the varied constraints and goals of the research. There are two primary approaches to designing and organizing experimentation, which I gloss as "task-based" and "action-based" and which reflect two types of analogies for comparison to archaeological collections. Task-based experiments are those that replicate an entire task, or some portion thereof, in order to replicate the wear patterns produced by the completion of this task. Tasks might be as simple as chopping down a tree or as complex as sewing and decorating a dress (Maigrot 2001; Mathieu, et al. 2004). Essentially, the experimenter creates a behavioral analogy within the experimental collections, as the observations are organized at a task – or behavioral – level.

Task-based experiments provide information on the overall patterns of attrition resulting from specific, goal-oriented behaviors, as well as informing the researcher, in an informal or qualitative way, on the efficiency or ease of tool use. The wear patterns from task-based experiments may be expected to be fairly similar to those found on archaeological tools that were used in comparable tasks prehistorically, as a variety of movements, angles, pressure and speed will generally be employed during the process of completing a complex task. Experience with the tools and worked materials, however, is a critical element in task-based experiments, and contemporary archaeologists may not have the appropriately developed motor skills and knowledge of production techniques to successfully imitate the gestures and practices of prehistoric

practitioners. People who grew up using bone tools from an early age in a socially structured environment to create complex perishable goods have developed motor skills once they reach adulthood. Both neurological and fine and gross muscle development are different in adults than in children (Thelen 1995), so archaeologists who take up bone working or basketry at an older age may never develop the same refined, automatic gestures and habits. In some cases, archaeologists do become quite skilled – even virtuosic – in the production of certain kinds of artifacts. More rarely do archaeologists become proficient in the production and daily use of artifacts not used in contemporary contexts. Additionally, archaeologists are employed in a particular way: *archaeology*. Few archaeologists designate hours per day, every day, to the creation and maintenance of tools and goods from bone, hide, and plant fibers. Instead, they pursue these activities as part of isolated experiments in an artificial context. Nonetheless, task-based research remains the dominate model for use wear experiments, as it yields comparative surfaces that are most likely to closely mirror those of used archaeological tools and the argument can be more easily made for the relevance of the experiments to the social questions that ultimately underlie archaeological research.

Unlike the behavioral analogies that structure task-based experiments, the scale of action-based replications is at the surface or object level. Action-based experiments isolate one particular gesture from the overall operative chain and replicate only that action. Actions selected may be more or less directly related to a hypothesized activity, but the overall task is not replicated. Action-based research can be more explicitly and

simply linked to tribological models as these experiments seek to isolate the direct result of one particular type of contact between two materials, where the direction, pressure, context and contact surface are all held constant for the duration of the experiment. While in a task-based experiment the synthetic unit might be the completion of task, for action-based cases, duration of use is another necessarily controlled variable. Action-based experiments have the advantage that the connection between gesture and surface patterns is explicit and direct, but these extremely simplified conditions mean that the surface patterns are unlikely to have strong similarities to those identified on archaeological artifacts that have a long and complex history of use, even when only used to complete one kind of task in the past. However, action-based experiments carry the additional advantage of allowing the researcher to potentially identify actions that were not originally envisioned among the likely activities or procedures in the past.

The advantages of experimentation for understanding the accumulation of wear and constructing standards for the assessment of archaeological tools are clear. First and foremost, experiments allow the researcher to document the link between wear patterns and the activity that resulted in those patterns. Because the state of the artifact before use is documented and then compared to the surface after a known treatment or series of treatments, the causal relationship in attrition patterns is transparent. Additionally, variables can be controlled and isolated, allowing more precision in the links that are identified between activities, materials, and attrition. Finally, because the experimental tool can be observed at several points during its

uselife, the gradual accumulation of wear can be documented in increments. This is a powerful factor when examining the archaeological record where uselife of tools is always unknown. In some cases, the uselife for an archaeological artifact can be suggested, based on condition, evidence for repair, and handling wear; in other cases the duration of an artifact's uselife is nearly impossible to determine.

There are some difficulties that arise from relying solely on experimentation for the production of standards and for the understanding of the range of variation in use and end condition. One basic problem in determining the basic parameters of an experimental program is defining the boundaries of the experimentation. It is, of course, impossible to test every possible idea, material, and action conceivably carried out using a bone or antler tool, throughout time and space. In effect, all experimental archaeology is fundamentally grounded in the original decisions made about the possibilities that will be tested and those that will be ignored. This nearly always leads to certain consequences, including the identification of patterns in archaeological assemblages that cannot be positively linked with any known pattern determined through experimentation.

More importantly, it means that biases that arise both from our cultural context and from the conventional wisdom of the archaeological community have a strong formative effect on the outcome of research in a very real and observable way. For example, if we assume that we "know" that there are no vegetal fibers used in the Paleolithic, these materials are excluded from experimentation and so the assumptions are not tested.

This underlies the importance of avoiding what I have termed “direct-confirmation experimentation.” Direct-confirmation experimentation describes those experiments in which a hypothesized use for a tool is replicated and the wear patterns produced are compared to those on the archaeological tool in order to assess the hypothesis (c.f. Owen 1994).

Direct-confirmation experiments are useful in isolated cases, and particularly when the overall knowledge base is small, they provide a starting point for understanding the life history of a tool. On the other hand, they do not display the rigor needed in an experimental program (in fact, they do not constitute a *program* at all) and are prone to the subtle incorporation of ethnocentric, androcentric, and historical biases. These pervasive influences on archaeological research generally govern the kinds of research that take place and may guide the original assumptions made by investigators about the likely or unlikely uses of objects recovered from the archaeological record (Kehoe 1991; Owen 1999). These types of biases are unavoidable, although they can be partially controlled through the complementary use of ethnographic documents (see Chapter 8: Analysis of Ethnographic Collections). Another is by careful, periodic assessment of the gap between our knowledge of the past and our interpretations of that knowledge, in particular of the constraints placed upon prehistoric individuals by their social, economic and physical environment.

Another difficulty is that experimentation simplifies objects’ life histories. Experiments limit the number of variables relevant to understanding artifact use so that causal lines

can be established. Although these types of controls and limits are essential to generating use wear standards, the kinds of surfaces that are typical of experimentally used tools may not be typical of those found on objects that have long and complex life histories. Used objects may be subject not only to much longer uselife than we can replicate in the bounds of short research programs (particularly dissertations), but also to more handling, carrying, storage conditions, expedient uses, and different owners. Recent experiments by Alice Choyke and Paul Duffy suggest that use wear on bone ornaments may accrue very slowly, especially in terms of volume loss (Choyke and Duffy 2011).

The varied contexts and conditions of use that a typical object might encounter over its uselife are also impoverished in the experimental context. These aspects of the history of objects used in a dynamic living environment are extremely difficult to replicate experimentally but may have significantly impacted archaeological tools, thus making the interpretation of archaeological surfaces difficult.

These problems, however, are almost by definition inherent to the very basis of experimentation: simplification of the variables in order to establish the effects of isolated variables. We must, therefore, be aware of the potential impact of oversimplification on our archaeological analysis even though this may often be an only minor problem. Clearly in other cases oversimplification can pose a significant challenge to understanding and applying experimental results. Once again, the use of complementary ethnographic research can mitigate this simplification by providing a set

of contrasting standards that allow us to understand the outcome of long and complex artifact life histories.

A final difficulty in experimental research is the lack of developed motor habits and skills on the part of experimenters. Although most experimenters have developed great familiarity working with their materials, wear patterns produced by a highly skilled adult worker may be distinct from those of a learner or even a relatively experienced experimental archaeologist, so the analogue is not perfect. Additionally, how does our focus on producing wear subtly affect the ways that we wield replicated tools? As with the other caveats on experimental programs, I argue that our best tool for correcting this possible deficit in our experimental collections is the complementary study of ethnographic materials. In Chapters 8 and 9 (Analysis of Ethnographic Collections & Ethnographic Case Studies) I will discuss my own ethnographic research and show its relation to my experiments. Chapter 7 (Experimental Program) describes experiments conducted with bone and antler tools and the use wear standards that can be constructed from the outcome of these experiments.

5.2.2. The Value of Ethnographic Data

Given the difficulties with the direct application of experimentally produced standards to the analysis of archaeological collections, objects collected from living people can

provide another important sample for constructing comparative archaeological standards. Although descriptions of ethnographic tool use and other ethnographic documents are often employed to understand overall social patterns of tool manufacture and use (Beyries 2002; Binford 1980; Kehoe 1999), they can also be used to produce object-level analogies about wear and attrition.

There are a number of advantages to constructing standards for archaeological analysis from ethnographic collections. The two kinds of collections complement each other by providing different kinds of object life histories, each strengthening the interpretation of the other. Ethnographic materials provide an alternative and complementary comparative collection for the establishment of standards for the assessment of archaeological patterns in several ways. Ethnographic objects were created and used by individuals or working groups with learned, life-long developed motor habits and were used in living contexts in which they are tools with particular uses, but may also have been used expediently in diverse ways. Often tools were used either by one person or by several people within the same learning tradition and context (Choyke 2006, 2009). They are also subject to handling, storage, and transport over their life history, which is generally quite different from experimental specimens. The complex surface attrition patterns on ethnographic tools may provide a good model for archaeological surface patterns. Wear on these objects was accumulated through use, handling, transport, repair, storage, and alternative uses of tools in a lived context. Finally, the form, kinds and conditions of artifacts in ethnographic collections are not the result of decisions made by archaeologists based on prior knowledge of the kinds of artifacts seen in the

archaeological record. By forming collections based on use or other behavioral attributes of interest, the range of variability in tools used in certain capacities can be observed.

Experimental tools, on the other hand, are curated in special ways in order to best maintain the surface that reflects contact with a specified material and in a particular manner. Additionally, the goal of producing wear on experimental tools may subtly affect the way these artifacts may be used, while ethnographic tools accrue use wear incidentally, through the use of the implement, in the same way that archaeological wear develops.

There are essentially two ways to think about the selection of appropriate ethnographic materials for a comparative archaeological study. The differences between these two strategies lie in the one being true *ethnographic analogy* while the other is based on the construction of c*omparative standards*. As noted by Alison Wylie (1985), most archaeological reasoning is analogous in nature but the analogies are constructed on different scales. Both have their place in archaeological studies, but the underlying logic is different and thus, different choices are made about appropriate criteria for sample selection.

When constructing a true ethnographic analogy, the archaeologist seeks to understand the ways that different aspects of material culture and behavior interact with each other and with the social and physical environment. The aims can be quite varied, including,

for example, looking for tools that are similar to an archaeological tool of unknown function, examining large-scale patterns of parent-child dynamics, or identifying social mechanisms that help people deal with stress (Keeley 1999; Moerman 1998; Murdock and Provost 1973; Wobst 1978). Ethnographic analogies can be culturally specific or cross-cultural.

Culturally specific analogies developed through ethnoarchaeology are well known to most archaeologists, particularly from the American schools (Binford 1978, 1980). Ethnoarchaeology provides a way of linking material patterns with the activities of living people as a way of understanding patterns found in the archaeological record. Lewis Binford (1962) argued for the use of indirect model-building analogies based on strong similarities in environmental context. This approach has been adopted in Upper Paleolithic studies (i.e., Owen 2005).

Several authors (Pasternak, et al. 1997; Peregrine 2001, 2004) have argued that cross-cultural research may provide more useful analogies for understanding archaeological patterns because synchronic similarities across groups of diverse cultural origin and tradition may reflect common human behaviors that can be extended diachronically, rather than mirror historically and socially situated and constrained behaviors. For a very useful overview of cross-cultural comparisons and the application of the conclusions of such comparison to the archaeological record, see Peregrine (2001) and Wylie (1985). Here, I will only briefly revisit their arguments.

Local history and cultural traditions always play a major role in determining cultural and social behavior and may alter the expression of common human behaviors. Nonetheless, there are still some behavioral and cultural similarities among people. Thus, archaeologically we can assume certain kinds of categories and activities were likely to be present in most, if not all, human groups. Gendered identities is an excellent example of one such category. Gender is recognized cross-culturally, but the number and make-up of genders vary (Brightman 1996; Doucette 2001; Gellar 2009; Hawkes 1996; Murdock and Provost 1973; O'Gorman 2001; Pasternak, et al. 1997; Rosenblum and Travis 2006; Wood and Eagly 2002). Often cross-cultural anthropological studies are done at a holistic or behavioral level and do not necessarily involve the close study of physical objects. In this study, I employed this approach occasionally, in an expedient or unsystematic way, as I studied archival records, published accounts of tool use, or more extensive documentation of cultural groups whose tools were included in my study.

The second form of study of ethnographic objects is one aimed at constructing comparative standards for the assessment of archaeological objects. The utility of the record of ethnographic material culture for understanding use wear and other attrition patterns has been largely overlooked, in favor of behavioral analogies. Studies of ethnographic artifacts can be combined with behavioral studies in some cases, although generally one or the other approach predominates.

Steven Brandt and Kathryn Weedman (2002), for example, developed a two-year ethnographic program in Konso, Ethiopia to document the use of stone tools in hide working and then performed use wear and residue studies of stone tools from the project in order to create standards for archaeological analysis. Their study indicated much greater variability in the organization of hide-working labor and in the kinds of tools used in the task, probably owing to their broad approach.

Many uses of the ethnographic record in archaeological interpretation are not made at comparable scales between the ethnographic and archaeological patterns. While the interpretation being drawn is behavioral, the comparison is based on morphology at the artifact level, rather than at the worked surface. This ignores social context when addressing the archaeological record and is based on the demonstrably unreliable assumption that form is indicative of function.

As described earlier in this chapter, I examined ethnographic artifacts at the scale of the working surface without considering the social or economic context of use. This decision was deliberate. Samples of ethnographic objects that are selected based on a behavioral analogy can provide information on patterns of manufacture, use and discard of tools, as well as the social and physical context of these activities, but are of utility primarily when the archaeological activity in question has been established through other means. If there are substantial gaps in our knowledge about the ways that objects were used, then a sample of ethnographic tools based on morphology or other

characteristics may be more useful as there is no *a priori* assumption made about the relationship between form and function.

There are few morphological analogs for Late Upper Paleolithic archaeological tools in the ethnographic record. So, rather than selecting ethnographic samples based on morphological similarity, functional attributes either of the artifact or its use can also provide the means for sampling. Here, I selected tools used to work plant and animal fibers, but the selection could equally have been based on a particular kind of bone, manufacture technique, or some other aspect of bone tool manufacture, use and discard. By studying objects that display attrition or other signatures of a known mechanical interaction, then the cultural process at work – manufacture, use, discard, repair – can be understood by means of assessing the physical outcomes of the artifact's uselife. Thus the relationship that is the focus of the study is not between people and objects, but rather between the objects themselves or between objects and other forces. The cultural context must still be known in order to correctly identify the culturally mediated processes and interactions of interest, but is not the main focus of study. This was the type of study that I carried out with ethnographic objects in order to construct comparative standards for understanding the patterns that result from use of bone tools in contact with soft, fibrous materials.

Archival documents are the true key to using ethnographic and ethnohistoric collection if the goal of research is to link object and action. These documents and other ethnographic literature may contain information about the broader social and cultural

context of labor, the individuals who are responsible for different tasks, and the meaning and role of objects within a social context. However, such documents can never be taken at face value, but must be viewed in their historical context (Galloway 2006). They range in quality and format and can include formal reports, publications, letters, inventories, interviews, and other kinds of records. The documents often contain descriptions that are anecdotal in nature and were designed to give the readers back in a museum or government headquarters an impression of the lives of indigenous peoples, including their daily activities and general information about their technology. The reports that arose from the first anthropological expeditions were also designed to contextualize the physical collections acquired for the Smithsonian and other museums and institutions as part of the mission of early ethnographers and historians but were not directed at recording the production and use of artifacts. Hence, the emphasis of early ethnographers lay in identifying extremes: the most exotic behaviors and those behaviors that seemed most familiar to them, with little in between and with minimal attention to the historic processes that contributed to the configuration of social structures (Wobst 1978).

Additionally, early ethnographers were predominantly male, interested in male activities and had minimal or no analytic focus on or access to women's work. Researchers frequently came to the conclusion that women played little role in the social and economic spheres of indigenous communities. This bias resulted in less complete documentation of women's activities than that of men's tasks, particularly

when women's tasks have a ritual component that precluded the presence of men (Conkey and Gero 1997; Kehoe 1990; Querol 2005; Sweely 1999).

Although not used in this way here, ethnographic and ethnohistoric records can reveal some of the ways that objects and different raw materials have meaning within a social world filled with diverse actors and actresses. The social and ritual meaning of things can have direct impact on the choices that people make in terms of the ways that seemingly similar materials and tools are used (Choyke and Daróczi-Szabó 2010). Bone, for example, is linked to living animals and this may or may not have significance for the way that bone is employed as a raw material. Although these patterns cannot be extrapolated directly to the archaeological record or to cross-cultural ethnographic patterns, they can help explain idiosyncrasies in the use of materials and tools. The relationship between tool makers and users and the social status of each can also help explain some kinds of variation among and between tool collections.

Other kinds of information relating to the manufacture, use, maintenance, and discard of osseous artifacts are of greater direct relevance to the construction of comparative standards for the study of archaeological collections. The most obvious and concomitantly most essential data relates to the names and functions of tools, including the amount of tolerated variation in alternate uses of tools. Some kinds of tools have very specific functions while others are generalized tools in both theory and practice, even if they have names that might imply to outsiders that they have a particular and bounded use. Additionally, the methods and social, spatial, or temporal context of

manufacture, use and maintenance are often identified in accompanying documentation.

5.2.2.1. Ethnographic Museum Collections

Despite many advantages, the use of ethnographic artifacts is not without difficulties. Tools from ethnographic contexts have complex life histories. This complex uselife is an advantage in terms of the similarity of surface traces to archaeological tools that also have complex life histories. However, as tools are used, stored, reused, repaired, used expediently, handled, curated, moved, dropped, reworked, collected and prepared for museum curation, or any other treatments that might take place over the full life history of an artifact, patterns of manufacture, wear, and handling can be obscured or altered by many other kinds of contact with diverse materials. This can result in complicated and difficult to decipher sequential attrition patterns. Additionally, the nature of many of these “secondary” contact situations is not known because these activities fall outside of the prescribed use of the tool, so the analyst has no way of separating standard use from other wear, aside from using large samples and determining the form of the working surface relative to the documented activity.

Research in museums with ethnographic collections can center on two sources of information: archival and object-based. Because the utility of ethnographic artifacts for archaeological study relies on the link between objects and known life histories, the

documentation that accompanies ethnographic collections is critical to their study. There are significant difficulties in obtaining the requisite detailed information. The kind and amount of detail can vary significantly within and between ethnographic collections, ranging from simple identifying names, such as “Awl nut pick” (NMAI 021719.000) to detailed information on the owner, context of use, and meaning, such as “Bear bone awl used in making bark utensils” (NMAI 164196.000).

Accompanying documentation varies more widely. Despite the disparities in detail, broad patterns can be identified, allowing us to recognize patterns of wear, handling or breakage that appear archaeologically. With attention to the potential for error or bias and a systematic research design, most of these difficulties can be overcome and the information that can be gained from ethnographic material justifies their study.

Ethnographic collections are not direct representations of the tools made and used by a particular group of people any more than archaeological records are a direct reflection of the range of materials found in the past. Nonetheless, a vast amount of information can be gleaned from the combination of physical collections and written documentation that accompanies them. Judicious use of ethnographic materials requires that the units of comparison be clearly delineated in order to determine the basis for accepting and eliminating objects and various kinds of data.

A serious limitation on the use of ethnographic collections for comparison to archaeological assemblages relates to the range of variation between objects from two

contexts that are usually distant from each other culturally, temporally and geographically. When ethnographic studies are undertaken with the goal of informing on a specific archaeological problem concerning a known range of archaeological tools, it becomes clear that many tool forms that were common in prehistory have no modern analogs. The converse is also true: some ethnographic tool types bear no formal similarity to archaeological tool types. ***If we can gain one insight from the study of ethnographic material culture on a broad scale, however, it is that the correspondence between tool form and function that commonly underlies archaeological interpretations of tool use is not upheld in the ethnographic record***. This indicates that the lack of a formal analog *cannot* be interpreted as the lack of a behavioral similarity. This difficulty will be explored in more details in Chapter 9, Ethnographic Case Studies. The range of variation in the uses and roles of tools that are morphologically similar to tools for fiber manipulation, but have distinct functions, such as nut picks that are morphologically similar to hide-piercing awls (Figures 5.1 and 5.2), or needles, bag pins, wound plugs, and bodkins that share a general morphology (Figures 5.3-5.6), can also be described through the study of ethnographic collections. Use wear and other performance and functional studies are the only way to determine what activities were carried out using the archaeological artifacts that are morphologically similar to functionally diverse tools.

Figure 5.1. Hide-piercing awl, Patagonia, Fuegian (NMNH E131222)

Figure 5.2 Nut pick, Comanche (NMAI 021719)

Figure 5.3. Ottowa needles (NMAI 084605)

Figure 5.4. Montagnais or Innu Tobacco Bag Pin (NMAI 127197, 1 of 11)

Figure 5.5. Eskimo Angmagsalik Wound plugs (NMAI 177112)

Figure 5.6. Eskimo Tigera or Tikeramiut Bodkin (NMAI 126770)

5.3. The Study of Artifacts in the Museum Context

Museum collections of ethnographic and archaeological material contain vast amounts of understudied artifacts with great potential for informing our studies of the past without the additional expense and destructive aspects of excavation. However, museum practices affect the ethnographic and archaeological samples available for study and the methods that can be applied to the different collections. There are numerous logistic and theoretical challenges to integrating the data from collections of diverse histories. Differences among museums can also contribute to the difficulty in comparing samples. Additionally, museum practices aimed at the proper care and curation of artifacts can come into conflict with standard archaeological analytical practices, so in some cases, modifications to archaeological protocols must be enacted.

Here, I discuss some aspects of the museum collections research. Some problems are specific to either ethnographic or archaeological collections, while others are common to collections research in general.

Museum practices contribute to the availability of objects for study. In this way, museum access is one aspect of collections research that can introduce error or bias into a study's sample. Because museums serve multiple constituencies, there are numerous demands placed on curators when determining how and when artifacts can be studied or used for other purposes. Clearly, exhibitions, both local and lending, are one of the primary uses of museums artifacts that may conflict with access for study.

Logistical concerns can also present challenges to the study of museum collections. Study of microwear on ethnographic collections requires the appropriate microscopy and photography equipment that may not be available in many museums. Maintaining a study collection outside of the main repository for a substantial period of time may also be problematic. Finally, for archaeologists, the procurement of funding for collections-based research is more difficult than obtaining funds for excavation and laboratory analysis, posing an additional barrier to large-scale collections-based projects. Fortunately, in the case of this dissertation, funding the museum work was not a difficulty.

The ways that study collections are constructed must also be considered. Museums name, sort and organize collections in ways that can structure the sample that is

included in study, as objects are typically located through database searches before they are studied. In many cases, the nature of databases is such that artifacts cannot be selected based on morphology, which is the primary way that artifacts are sorted in archaeological collections. This difference in sorting constitutes another incompatibility between the make-up of archaeological and ethnographic samples. Ethnographic collection databases are typically organized by functional names but the reliability of these attributions is not consistent. Names may sometimes be derived from informants (sometimes, but not always, the people who made or used the tools, from the ethnographer or other collector, or sometimes from museum professionals either at the time of acquisition or later. It is rarely clear by whom and when the names were assigned to the objects. Many museum collections were compiled in an arbitrary manner during the course of ethnographic fieldwork. There are few systematic collections of material goods and of those that exist, few focus on the manufacture of objects for daily life, such as the tools of textile, basketry, or leather production used in this study. Thus, systematic comparison of elements in these collections requires the reorganization of objects into larger groups that necessarily gloss over myriad contextual and social variables. As will be discussed in more detail in Chapters 4 (Tribology), 7 (Ethnographic Artifacts) and 8 (Ethnographic Case Studies), the ethnographic study here has demonstrated that a one-to-one correlation of form and function is not always present, and can never be assumed archaeologically. Thus, morphological groups are not the best way to sort ethnographic artifacts. As will be

shown in Chapter 9 (Ethnographic Case Studies), sorting objects by use material groups and then by use wear patterns is more useful for developing archaeological standards.

In the case of names and types in archaeological artifacts, the assumption that certain archaeological – i.e., morphological – types constitute functional groups can result in similar constraints on the artifacts available for a functional study. The materials available for study are often constrained by the typologies used by excavators to sort artifacts before they were accessioned in a museum. Only in rare cases can all the artifacts from a particular area be studied. Additionally, if more than one project has been done at a site or area, the criteria for sorting into groups often vary. The difficulty imposed when some bone tools are stored with large faunal collections has already been noted. Even within worked bone from one excavation, however, sometimes only certain kinds of artifacts are made available for study. In this project, for example, only certain morphological classes were released from the smaller sites.

There is also a suite of processes that physically affect artifacts during and after recovery or collection, but before analysis (Galloway 2006). The treatment of artifacts after recovery can affect the success of use wear analysis. This is especially the case of bone artifacts that are submitted to a change in environment when they are excavated. Washing techniques or attempts to stabilize the physical structure of bone tools may destroy surface wears. Traces of wear on artifact surfaces can be damaged in the course of cleaning and preparation for curation. Conservation techniques can also be detrimental to surface analysis in some cases. Jessica Johnson (1994) argues that any

researcher attempting to analyze museum collections must understand the conservation history of the material in order to properly interpret the artifact's characteristics. Otherwise, modern additives may be interpreted as residue, polishes or other traces of wear or manufacture. In his discussion of the nature of archaeological data, Terry O'Connor (1996) draws a parallel between diagenesis or decomposition and recovery techniques as the two factors affecting the integrity of a faunal assemblage:

> "In a sense, these two things are parts of the same process, even though one can be controlled (to some degree) by the bone specialist, while the other cannot. Both, however, are stages of data attenuation, a reduction of the information inherent in the assemblage at the point and time of deposition" (O'Connor 1996:8).

This is equally true in the case of bone tools in the ethnographic or archaeological samples. Many archaeologists studying wear patterns exclude consolidated material from their analyses, which is due both to problems resulting from conservation techniques and a lack of thorough knowledge on the part of archaeologists of the chemistry, mechanics, and reversibility of common consolidants. Patricia McComb (1989), when selecting material for her dissertation on Upper Paleolithic osseous tools, found that she had to omit from microscopic analysis those specimens that had been treated with consolidants. Olga Soffer (2004) likewise found prior treatment of an object by a conservator to be grounds for omission from her study of Upper Paleolithic bone implements. Douglas Campana had a similar experience: "Unfortunately, these

implements had been conserved by consolidation with a plastic binding agent and were not suitable for wear-pattern analysis" (Campana 1989:21). Both McComb and Soffer were attempting to analyze material with low-powered light microscopes; the problem is amplified at the level of magnification achievable with an SEM (e.g.: Campana 1989; LeMoine 1997; Runnings, et al. 1989).

The practice of directly labeling artifacts, common in both archaeological and ethnographic collections, can also obscure worn or worked surfaces especially since people writing on these surface often chose the most worn, smooth surfaces which are very often exactly the zone around the working edges. Threads for labels run through needle eyes or tied around objects can also obscure surfaces and may produce new wear patterns.

5.3.1. Artifact Casting and Replication

Conservators at large museums must evaluate the benefit from new knowledge generated through artifact studies against the long-term stability and care of the objects. This concern is most serious when destructive or potentially damaging techniques are used in the study. In this project, casting artifact surfaces was originally envisioned as a cost-effective way of allowing the study of museum objects with several different microscope systems. One of the major problems that has faced use wear

analysts of both lithic and osseous tools is the difficulty of transporting artifacts to locations with better microscopy equipment than that found at many museums or university labs that do not have a current emphasis on microscopic analysis.

The kinds of microscopes used to study manufacture and use traces are not the more common kinds of microscopes found in many labs, and preferences vary between researchers as well. One solution that has been examined by many traceological specialists is creating casts of stone and bone surfaces that can then be studied in the analyst's own laboratory, thus eliminating the need to duplicate expensive equipment where it will not be used regularly and increasing the availability of artifacts to different researchers. However, despite numerous suggestions, no perfect casting technique has been found for bone tools, as many of the techniques used on stone cannot be used on organic objects. They leave behind inert residues that are harmful to the long-term stability of the bones.

As early as 1979, Jørgen Ilkaer (1979) advocated the use of casts for the study of use wear based on the following eight qualities:

- the surface can be coated without damaging the artifact
- the cast can be made to be very thin so that it can be "unfolded" so that curved surfaces can be viewed easily without losing depth of field

- the cast can be “unfolded” to facilitate the comparison of edges and broad surfaces as the cast can be manipulated so that the edge is “flat” on the same plane as a flat surface

- small pieces can be cut out and mounted for easy viewing with a range of microscope types including the SEM

- documenting use wear is easier on casts as areas can be marked for photography and comparison

- experimental replication and use is made more useful, as casts can be made at several stages throughout the process and compared

- use wear can be studied early in the excavation and analysis stage because casts can be made and sent out to laboratories or saved for later examination in the laboratory without transporting artifacts

- the same artifact can be studied by multiple people and in different locations at the same time as several casts can be made and can be transported easily

Casting also permits data sharing with other specialists, allowing direct observation of wear patterns outside of the original museum, but without requiring the transport of artifacts. Silicon molding products are the standard for replicating lithic surfaces for use wear study (Banks 1996; Banks and Kay 2002; Ilkjaer 1979; McComb 1989; Runnings, et al. 1989). LeMoine (2002), however, found that all silicone based products are

inappropriate for use on archaeological osseous materials because they stain and leave an inert oil that prevents the uptake of humidity and can result in uneven expansion and shrinking, leading to cracking and flaking. At AMNH, with the assistance of a curator, I found that a test with silicone-based casting materials left immediate and macroscopically visible stains on archaeological bones from unprovenienced collections.

This presents a challenge for analysts who rely on microscopy to study museum specimens of osseous technologies (Johnson 1994). However, other means of casting artifact surfaces are available. Acetate peels are a standard method for replicating worked bone surfaces on archaeological artifacts. Acetate tape has several distinct advantages in that it: 1) leaves no stains; 2) sets in less than 1 minute so there is no prolonged contact with archaeological material; 3) is transparent but can be darkened to be made opaque, so it can be used in many types of microscopes; 4) is inexpensive enough to allow several impressions to be made of any tool and is affordable on most budgets. However, the tape is very thin and cannot be used on surfaces with high relief, or fragile or exfoliating surfaces and is ineffective for points or holes. Acetate tape is also used in other contexts to collect residues, so it cannot be used on any tool that might be tested for residues. It is also somewhat difficult to learn how to correctly use acetate tape on bone surfaces, but once learned, the technique is simple and effective (Buc 2005). Work with the Museum Conservation Institute (MCI) at the Smithsonian was carried out to assess the safety of using acetate peels on ethnographic bone tools from the NMNH and the NMAI. MCI conservators determined that acetate can leave a residue on bone surfaces. It can also damage surfaces that are in any way friable.

Because acetate can leave residues on artifact surfaces, remove residues from surfaces, and damage friable surfaces, alternative means of casting were sought as well. The requirements of a casting technique are that it be detailed enough for the purposes of study, stable, and not damaging to the artifact. Reversible hydrocolloids, developed for use in dentistry, meet the requirements for safe use on bone and antler. Reversible hydrocolliods have an extremely high resolution, appropriate to the study of microwear (Federick and Caputo 1997). More importantly, hydrocolloid impression materials leave no residues on bone and will not cause any damage to the surface of specimens selected for casting.

Dupli-coe-loid, from GC America, is the reversible hydrocolloid that I used for casting artifacts at the Burke Museum. The product was heated in a double-boiler to 140° F so that it can be poured into a container to hold the mold. Plastic tupperwares were used to hold molds, as the hydrocolloid separates easily from the plastic without the aid of any other type of lubricant. The hydrocolloid was poured into the Tupperware at 140° F and allowed to cool about 30 seconds, until the hydrocolloid begins to hold its form. Then the object to be cast was gently pressed into the mold. Allowing the hydrocolloid to cool before casting the object serves two purposes: 1) the cooler temperature is safe for bone and antler objects; 2) allowing the hydrocolloid to stiffen before pressing in the object results in the casting of fine detail from the inner ring of perforations and other areas of high surface topography. The object was left in the hydrocolloid until set, approximately 10 minutes. Once set, the hydrocolloid separates easily from bone and

antler surfaces. This allowed the microwear study of artifacts from the Burke Museum at a later date in a lab equipped with an appropriate microscope.

Figure 5.7. Casting experimental artifacts with Dupli-coe-loid

Figure 5.8. Casts of artifacts in Dupli-coe-loid

5.3.1.1 .Summary: Museum Collections Research

There are a number of well-known and considerable challenges to the study of artifacts housed in museums of ethnographic or archaeological collections. However, these collections also represent a vast, rich resource with unique qualities for answering many kinds of questions about tool manufacture and use. I have argued that the different histories and kinds of accompanying information that are associated with different collections make comparison at the assemblage (i.e., collection) level impossible and at the artifact level difficult. As I will discuss in the final portion of this chapter, comparisons at the level of working surface are still robust and demonstrably productive for constructing standards for archaeological research.

5.3.2. Archaeological Collections

Artifacts of worked bone and antler from the archaeological record of the Late Upper Paleolithic of Northern Spain comprise the archaeological component of the case studies in this dissertation. Initially, published literature on all sites with collections of worked osseous material from the Late Solutrean and Magdalenian available for study was examined. Certain morphological/typological artifact forms were selected: needles, needle fragments; pointed forms including pins, awls, fine points, *sagaies*; *varillas* and spatulate tools. These correspond to the following types from the 1967 Barandiarán classification used in most osseous industry analyses and publications in Spain:

- needles: types 55.1-3; most are 55.2 (Figure 5.9)
- pointed forms: fine points (*puntas finas*) or pins: type 11: gracile bi-point (Figure 5.10); type 12: gracile point with double edge)
- *sagaies*: types 1-10 with subtypes (Figure 5.11)
- *varillas*: types 26-30 with subtypes (Figure 5.12)
- spatulate tools: types 31.1-4; most are fragmented and can only be assigned to type 31 [Figure 5.13]).

Figure 5.9: Barandiarán type 55.2: Needle with rounded or truncated head: Complete needle from El Juyo (941239 #357)

Figure 5.10: Barandiarán type 11: Gracile bi-point: Nearly complete punta fina from El Juyo (11M #22)

Figure 5.11: Barandiarán type 4.3: Point with a single-bevel base, square or polygonal cross-section: Nearly complete small sagaie from El Juyo (10Q8 #6208)

Figure 5.12: Barandiarán type 30.3: Decorated varilla with linear decoration: Mesial portion of an antler varilla from Entrefoces (#162)

Figure 5.13: Barandiarán type 31.1: Spatulate tool with a rounded base: El Juyo (11N #96)

A translation of the Barandiarán typology noting the types used here can be found in Appendix II. A more detailed description of these artifact forms is found in Chapter 10 (Archaeological Analysis). I examined only those artifacts that seemed to have potential as tools for fiber processing or manipulation. I based this primarily on ethnographic

models and on standard assumptions among Upper Paleolithic archaeologists, such as the assumption that the eyed needle is used for sewing. In retrospect, after completing my ethnographic study, I would not use the same sampling strategy, as I have since been convinced that the connection between form and function is not consistent. However, at the onset of my research, I focused on these artifact forms. They are morphologically variable enough to provide some idea of the variability of osseous tools being created and used at the archaeological sites studied.

There are a number of factors that affect the nature of the collection of archaeological artifacts available for study, including use and discard strategies, taphonomy, excavation strategy and study logistics. Understanding the different processes that have affected an artifact is an essential facet of all archaeological analysis. Because burial environments are extraordinarily complex, estimating preservation from the composition of the matrix is reliable only on an extremely gross scale (Bolker, et al. 1998; Child 1993; Dowman 1970; O'Connor 1996, 2000a; Sease 1994). Bones deposited in the archaeological record are subject to a wide range of taphonomic processes that can impact our understanding of human interactions with animals in the past. While many factors work to shape the types of bones that will be deposited, diagenesis, the transformation and deterioration of buried organic material, works to alter the actual content and form of the bone, including complete decay.

As a raw material, bone is in equilibrium with its environment in the living state and is then extracted by humans to be made into artifacts. After deposition, bone undergoes

changes until it comes into equilibrium with the new, changed environment. These changes include the shift from the living to the non-living state. During that process water is lost, the proportion of organic to inorganic components shifts, and the physical and mechanical properties of bone are changed. After the artifact is discarded and enters the archaeological context, it must once again come to equilibrium with the new environment. The changes that take place during this period are more difficult to predict, being based on local soil chemistry, but may include the loss or uptake of minerals, the loss of organic material to microorganisms, the loss of material due to mechanical abrasion by both water and sediment, physical movement connected to subsequent human or animal occupation, and chemical exchanges with the environment that may affect the overall makeup of the object (Child 1993; Hedges 1987).

Archaeological sites often produce vast amounts of bone that may be in a considerably weakened state, especially at very ancient sites. Bone may be fossilized, mineralized, or partially mineralized. Worked bone appears to preserve at a higher rate in certain conditions. While the mechanism for this preservation is not well known, it is likely related to the compression of worked bone surfaces, which makes the artifacts more resistant to absorbing and losing water. Polished objects often have better preservation than those that are not polished, which may be related to microscopic changes in the bone surface, although these changes are not fully understood (LeMoine 1997). It has been suggested that during bone tool manufacture the exterior surface may be compressed or even slightly melted, creating a more resistant surface that is less prone

to the absorption and loss of moisture, as well as being less susceptible to microbial agents (Child 1993; Johnson 1994). This is not so clearly the case with antler. Antler artifacts are often extremely fragile and have more poorly preserved outer surfaces than bone artifacts from the same sites. This introduces another bias to our sample of osseous artifacts.

Archaeological excavation and recovery practices also introduce bias into the sample of artifacts available for study. The Late Upper Paleolithic sites that have been excavated in Northern Spain and in most other areas are mostly located in caves. This is a natural result of the better preservation and greater contemporary accessibility of these sites, but such sites are probably not representative of the entire suite of Late Upper Paleolithic sites – and activities and people – that existed in distant prehistory. Given their relative geological scarcity on the landscape and their distribution only in certain places, prehistoric people must have been using a much greater range of locations and kinds of sites to carry out their lives. Thus, we are almost certainly lacking in our understanding of Late Upper Paleolithic land use and resource exploitation. In this study, all of the archaeological artifacts were recovered from cave contexts. Recent excavations in northeastern Spain and southern France of Late Upper Paleolithic open air sites are beginning to provide information on some of the activities that took place outside of caves, but organic preservation at these sites is poorer than in caves and osseous assemblages are more limited.

Excavation methodologies also contribute to differences in the recovery of worked bone from different sites. The differences may have to do with excavation strategies such as stratigraphic control or the use of flotation and screening. Samples collected under different strategies are not directly comparable (Freeman, et al. 1998; Nagaoka 2005). For example, Les Freeman and Joaquín Echegaray and colleagues (Freeman, et al. 1998) emphasize the importance of screening for recovering tiny artifacts such as needle eyes. The sample of broken needle eyes from El Juyo is remarkably large and this can be directly linked to the consistent use of flotation, which is not replicated at other Late Upper Paleolithic sites in this study. In neither case can the statistical representativeness of the sample be assumed.

5.3.2.1. Identification of Worked Bone

There are a number of methodological concerns that relate to the basic identification of archaeological osseous artifacts, all of which affect further research into these collections. Identifying objects as anthropogenic and determining their identity to the fullest extent possible are important first steps to any analysis. Taphonomic alterations can also be confused with human modification of bone surfaces (Patou-Mathis 1997b; Vercoutère, et al. 2007). This is particularly the case when identifying expedient or minimally worked bone tools. The study of expedient or minimally worked bone tools is also focused primarily on separating cultural from non-cultural modification. Trampling,

breakage for marrow extraction, and gnawing can modify bones into "pseudotools" (Binford 1981; Fiorillo 1989; Hill 1989; Patou-Mathis 1997a, b; Vercoutère, et al. 2007).

Many early North American studies of bone artifacts were focused on the question of differentiating human modification from natural predepositional and taphonomic processes. Expedient tools and minimally modified artifacts were of particular interest to many early worked bone specialists in North America. Lewis Binford (1981) documented many of the ways that trampling and gnawing can result in bone modification that mimics human intentional modifications. Eileen Johnson (1985) reviewed current approaches to the analysis of bone modification with a strong emphasis on determining the role of humans in bone breakage and then used these techniques to evaluate the role of humans in breaking bone and creating expedient bone tools at a Folsom site. This is still the only chapter in Schiffer's extensive and well-known series, *Archaeological Method and Theory*, to directly address osseous artifacts in any way, indicating that this emphasis has remained dominant in much North American research. Robson Bonnichsen and Marcella Sorg's volume *Bone Modification* (1989) collected a number of early studies of bone modification in the context of early human populations in the Americas. The volume included a number of important methodological studies that helped illuminate the ways and circumstances under which bone breaks and linked the study of bone modification to faunal studies and the study of human antiquity in the Americas.

The size and number of anatomical features that are preserved in a bone object also contribute to the ease of determining whether a bone has been humanly modified. For example, microfaunal long bone elements or fish fin ray bones are often identified as needles. Particularly in the case of small artifacts such as the mesial sections of needles, worked bone can be difficult to identify macroscopically, given both the minimal nature of the reduction of some tools and the effects of taphonomic agents to polish, scratch and stain bone (O'Connor 2000; Patou-Mathis 1997; Vercoutère, et al. 2007). The easiest way for the non-specialist to distinguish a worked section from the smooth, even surface of a microfaunal long bone is with the aid of magnification. The surface of a worked fragment will display fine striations and frequently a smooth, polished surface (see Figure 5.14). Microfauna, on the other hand, will have a surface with even, regular, large pits, having an almost "honeycombed" appearance (see figure 5.15). This can be observed at 50x and is thus achievable in most field or research laboratories.

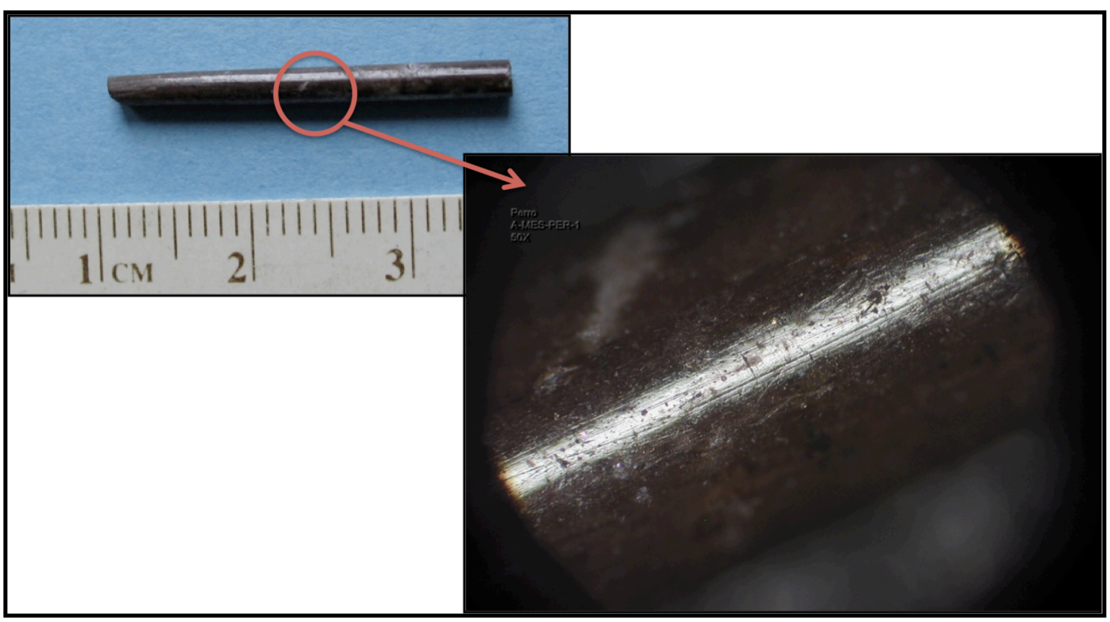


Figure 5.14. Worked bone surface without magnification and at 50x (El Perro #A-211)

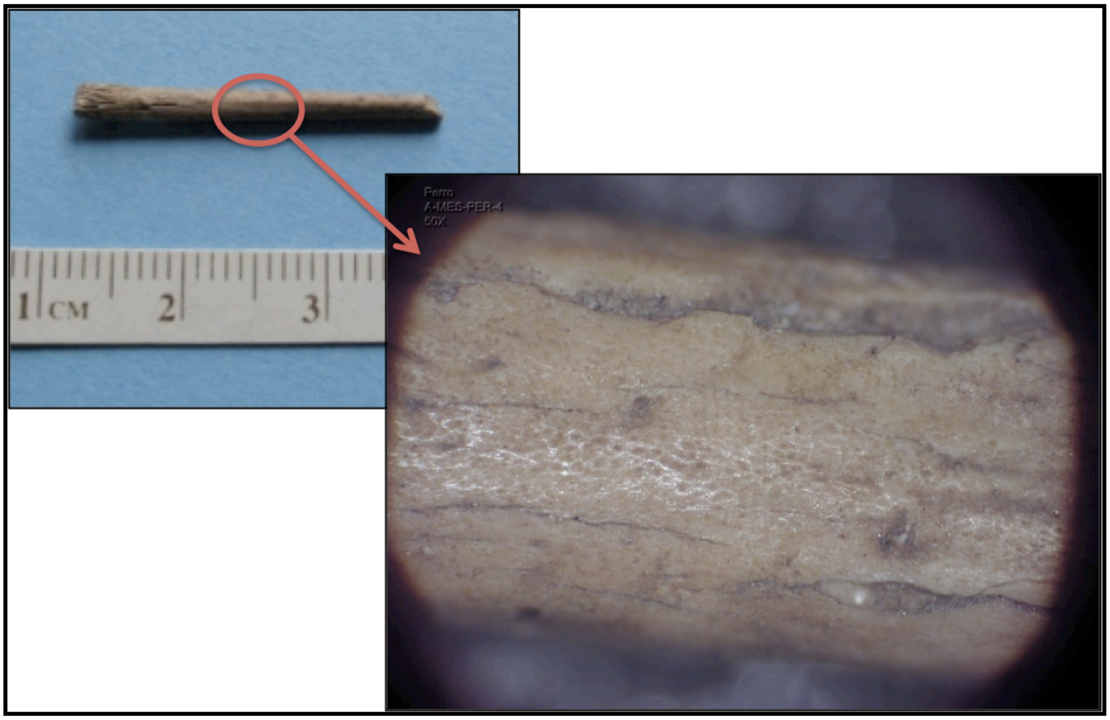


Figure 5.15. Microfaunal long bone without magnification and at 50x (El Perro #A.211)

Jean-Baptiste Mallye and Véronique Laroulandie (2004) also note the importance of determining whether apparent modifications are actually features of the natural bone, such as muscle or feather attachments. Root etching can also occasionally imitate modification (Grayson, et al. 1988).

5.3.2.2. Antler vs. Bone

A second identification issue is differentiating between bone and antler as the raw material for artifacts. Other osseous materials, such as tooth, ivory, horn and shell have

distinct make-ups are not kinds of bone. These materials are generally identifiable at a macroscopic and microscopic level. However, as identified in Chapter 4 (Tribology), bone takes two primary forms, antler and bone, which are indistinguishable at a cellular level, but can be easily differentiated macroscopically as complete elements. Because antler is a specialized form of rapidly growing bone, it is not always clear whether an artifact is made from antler or bone at first inspection. Microscopically, bone cells in antler are often more variable and less organized.

However, the difference is marked in terms of manufacture and use decisions. Antler is procured in different ways, and often at different times than bone. It therefore has a different pattern of availability. Antler can be obtained both from living animals and gathered from the landscape as shed antler. Shed antler is also essentially a seasonal resource, as antlers are shed at predictable times and are best used for tool production when fresh.

Antler is available all year long from one of the two species, as their growth cycles are dissimilar (Tuohy 1999). The two main sources for antler in Late Upper Paleolithic Northern Spain are red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*). Red deer antler is a preferred tool material because of its more compact form. Red deer prefer open terrain but may be found in various habitats, including mixed forests. Group size is dependent on habitat, with larger herds forming in open zones. They are seasonally migratory. The red deer sheds its antler from March to May and as it regrows the antler is soft and covered with skin and hair. During this period, antler is

unusable as a raw material. By August, growth has terminated and by September the antler has hardened completely. Roe deer, although said to be adapted to woodland and shrubby ecozones, readily adapt to a variety of environments. Group size may be small, but varies. Roe deer shed antlers from October to December with the new antlers fully grown by April.

Additionally, antler is highly resilient and thus more appropriate for certain tool types, such as projectile points, that will be subjected to high impact (Currey 1964; Knecht 1993, 1997; MacGregor 1985; McComb 1989). In terms of the treatment of bone and antler as a raw material, bone is greasy and may be cleaned by boiling, maceration in water or scraping before working while antler does not necessarily require such treatments. Some researchers feel that soaking aids the workability of antler (Campana 1989; McComb 1989), but this may be a matter of personal preference. In my experimental work, I did not find this to be the case. Thus, distinguishing between bone and antler, when possible, is helpful to understanding raw material acquisition and bone tool manufacture sequences and to identifying use.

Antler differs from other bones in that it grows quite rapidly and does not usually develop osteotones, which are tubes of highly mineralized bone that form along blood vessels running lengthwise on the bone. Antler also contains more collagen and less mineral content than bone. Terry O'Conner argues that neither of these factors can be used to differentiate the two materials as they essentially the same material (T. P. O'Connor 1987). The cancellous portion of antler, the medulla, has a honeycomb

structure that expands in size toward the edges of the antler while cancellous bone is more angular. In larger artifacts some diagnostic features may be retained, but on artifacts made from only the compact section of bone or antler it may be difficult or even impossible to identify the basic raw material.

Bone matures over time, resulting in a more ordered structure but antler is shed before this process can take place. The reordering of bone can be identified by the presence of concentric arcs and long, straight lines on the surface of the bone running parallel to the long axis. Mature bone will break along distinct lines revealing the laminar character of bone growth as layers of compact bone. Additionally, secondary osteotones, while not unknown in antler, are generally present and regularly spaced in mature bone, so their presence in relatively great numbers suggests that the raw material is bone rather than antler. Subjectively, one can argue that the microstructure of holes and spaces on the surface of an artifact is more regular and uniform on bone than on antler.

As suggested above, the best differentiating measure may be artifact function, as antler is tougher and more resilient than bone and was sometimes selected preferentially for shock-absorbing artifacts. Antlers have tapering tines and the beam to which they are attached. Beams can be used to produce flat artifacts while the shape of the tines restricts the types of artifact blanks that can be removed from them. However, because of antler's high collagen content, it can be soaked and the shape altered considerably; this is less successful with bone. So, while macrovariation allows the identification of raw material and sometimes species of large or fairly intact/unmodified specimens,

microscopic examination of osseous artifacts does not allow differentiation of raw material or species. Other more subjective factors include antler having a more "woody" surface appearance and bone being more easily worked to a high polish. Articular surfaces indicate bone and may also allow element or species identification. The presence of a marrow cavity also indicates that one is dealing with long bone compacta. The cancellous section of bone is more compact with larger holes than that of antler. Raw antler is grey while raw bone is white, although taphonomy may equalize these color differences.

5.4. Artifact Surface Use Wear Analysis

Once identified as cultural material, osseous artifacts can be analyzed in numerous ways. There is an extensive literature on the analysis of manufacture of bone tools that has been discussed in Chapter 2 (A Brief History of Bone Technology Studies). Here, I focus on the functional analysis of bone tools through use wear patterns. Traceological analysis, particularly use wear studies, is based on the idea that different materials and gestures have diagnostically distinct effects on contact materials. The use of tribological principles to identify properties salient to distinguish material surface alterations from different activities has been discussed in depth in Chapter 4 (Tribology). Properties of different materials were identified and the kinds of attrition from wear on bone were predicted. Simple tests against ethnographic and experimental studies demonstrated

the utility of this model for understanding wear patterns. Here, I will present a methodology for the observation and documentation of use wear on bone tools at the scale of the working surface and the assessment of these observations with the tribological model.

Campana emphasizes the assessment of function at the assemblage level, in order to identify associations between form and function within a particular assemblage (Campana 1989). He argues that toolkits found in association allow for a stronger interpretative link between tool forms and overall function. This association, however, can be problematic in a variety of ways. He notes that the inferences made about function proceed in levels, each less secure than the previous. The first level of inference is that of identifying the direction and force of use along with the relative hardness of the worked material. The second level involves using the inferred type of work done with the artifact and determining specific jobs that fit the identified criteria. The third level requires that the possibility of treating a group of similar objects as a population in terms of function under assessment. Campana identifies three factors that complicate the study of a large assemblage with low levels of morphological variation. When many artifacts in an assemblage are morphologically similar:

1) it is likely that similar objects served several, possibly related, functions

2) specimens probably display wider variation in degree of use and contingencies of life history, i.e.: loss, repair, recycling, etc

3) “misuse” of a tool, i.e.,: use for purposes other than that for which it was intended, becomes more likely.

Bordes (Bordes, et al. 1969) has argued that misuse will produce less ambiguous use wear than “proper” use, an argument that seems difficult to support.

Here, instead of analyzing artifacts at the assemblage level, I have set the scale of analysis of wear patterns at the working surface in order to allow for productive comparison of experimental, ethnographic and archaeological surfaces. These collections are distinct in many ways, because they have different use lives, kinds of available documentation, present conditions, and thus, different utility for understanding the accumulation of use wear on bone surfaces. The kinds of information that can be obtained from each collection are distinct, both in terms of scale and level of detail. Although, direct comparisons cannot be made between collections, activities, or even artifacts, setting the scale of analysis to the artifact working surface, rather than behavioral level, allows more effective comparisons of archaeological and ethnographic attrition patterns. This scale of comparison can be made useful in cases where a reasonable behavioral analogy is not clearly evident from artifact form. It also permits a more precise empirical understanding of the physical outcome of contact between two known materials under known circumstances through both experimental and ethnographic examples. When working in deep time this approach is particularly useful, as we have a limited understanding of the social and economic life of people in the very ancient past.

There are certain variables that affect the surface of worn artifacts but that have not been sufficiently covered here. As noted by Sidéra and Legrand (Legrand and Sidéra 2007; Sidéra and Legrand 2006), the shaping mechanisms and tools used to manufacture bone tools may have a strong effect on use wear development. However, despite the wide recognition of this fact, little systematic experimentation or other studies have addressed wear variation by original surface preparation. Thus, although I documented the means of manufacture and surface preparation for experimental tools and for ethnographic and archaeological artifacts when possible, this variable was not included in later analysis. The second critical factor is the effect of taphonomy. Taphonomic alteration can have substantial impact on deposited bone (Averbouh 2001; Giacobini and Patou-Mathis 2002; Patou-Mathis 1997). Taphonomic studies were originally proposed as part of this project but were not logistically feasible. Taphonomy is addressed in more detail in Chapter 10 (Archaeological Analysis).

5.4.1. Magnification

There has been considerable debate, particularly among early lithic use wear analysts, regarding the ideal magnifications for the study and identification of use wear. The debate over high vs. low-powered microscopes in the lithic microwear literature has its own parallel in the field of bone tools (see Plisson and Lompré 2005). As recognized by many analysts (González-Urquijo and Ibáñez-Estévez 2003; Gordon 1988; Legrand and

Sidéra 2007; LeMoine 1997; Sidéra and Legrand 2006) wear patterns vary with the scale of observation.

There are three primary approaches to use wear analysis: low power, high power and SEM. Low power analysts prefer magnifications of 25-100x, where flake scars and striations are the primary evidence of use. Low-power light microscopes do not require the use of replicas and allow greater depth of field than high-power microscopes and the working distance between the lens and the object is large, allowing easy manipulation of large objects. The high power approach is the most common and involves higher magnification and a greater emphasis on polishes as signals of use. The majority of use wear analysis on lithics has been done with high-power binocular light microscopes, generally with a magnification of 100x-400x. SEM analysis has higher magnification, resolution and depth of field, however, the use of the SEM can be economically prohibitive in terms of both time and money (see LeMoine 1997). Advantages of the SEM include the superior quality of photomicrographs which have a much greater depth of field under the SEM than under a light microscope, making features easier to identify.

Contemporary approaches to the study of use-related attrition on osseous artifacts generally include aspects of both the high-power and low-power observation methods, in an attempt to consider all available surface patterning. This is a reflection of both the increasing recognition that the original surface has a strong influence on the development of wear and that attrition takes different forms at different scales of

observation, as well as, at least in osseous industries, the incorporation of use wear studies in the larger field of traceology (Gordon 1988; Grace 1989; LeMoine 2002; Odell 2001; Plisson and Lompré 2005; Ungar 2003). Bone tool analysts, especially, have typically employed analysis at several levels of magnification, as manufacture and volume loss from use or taphonomic agents is visible at lower magnifications while use wear is more reliably assessed at higher resolutions (Averbouh 2001; Buc 2005, 2010; Legrand and Sidéra 2007; LeMoine 1997; Sidéra and Legrand 2006). LeMoine, for example, looked at every tool with a low-power microscope in order to study manufacture and to assess each piece for general characteristics and for appropriateness for examination with a high-power microscope or SEM. McComb (1989) examined artifacts on three scales, sampling fewer examples at each level of increasing magnification. Hand lenses at x8 and x15 magnification were used on all artifacts to identify manufacturing traces and to select artifacts to be viewed at higher magnification. An optical microscope with magnification up to x100 was used on certain artifacts and experimental reproductions to identify areas for SEM examination. Most analysts follow a similar approach.

In terms of magnification, there are divergent opinions on the importance of standardizing the magnification at which observations are made. While one school of thought leaves the level of magnification to be determined by ease of observation (LeMoine 1997; McComb 1989), others argue that magnification for different attributes should be predetermined (Christidou 2008; Legrand 2005). Early personal experience when learning to analyze bone use wear lead me to assign observations to a particular

magnification level, as it seemed that wear patterns might be labeled differently at higher or lower levels because of the difficulty of determining invasiveness at low levels of magnification or continuousness of wear at higher levels with a smaller field of vision.

However, it was clear that it would be useful to be able to determine, in fact, if magnification had any measurable impact on observations. If the magnifications that I had set were determining the kinds of results found, it would be imperative that the level of magnification for each kind of observation be set prior to study and only studies at the same levels of magnification would be comparable. If, on the other hand, magnification had no measurable effect on observations, then bone use wear analysts could more reliably compare observations despite variation in analytical methods.

To this end a small study was developed, as this question has not been addressed systematically in the bone tool literature. Of the ethnographic artifacts from the NMNH that were characterized microscopically with the metallurgical microscope, 91 were documented photographically at the same sample site at all three magnifications used: 50x, 100x, and 200x. A larger sample of artifacts were studied microscopically, but some artifacts were missing micrographs at some magnification, or the sample site was slightly offset due to the microscope being bumped, artifacts slipping from their position on the stand, or some other problem. However, 91 artifacts is a sufficiently large sample for a preliminary assessment of the question. Nine microwear attributes, as well as a qualitative assessment of best clarity level, and the use material group (animal or

vegetal) and the sample location were recorded. The structure of the observations appears in Table 5.1.

Table 5.1 Variables Measured Across Magnification Levels		
Measured at the artifact level	Use Material Group	
	Sample Location	
	Clarity Best Level	
Count of Striations Across Midsection 50x	Count of Striations Across Midsection 100x	Count of Striations Across Midsection 200x
Homogeneity 50x	Homogeneity 100x	Homogeneity 200x
Polish Connectedness 50x	Polish Connectedness 100x	Polish Connectedness 200x
Polish Invasiveness 50x	Polish Invasiveness 100x	Polish Invasiveness 200x
Polish Invasive (Y/N) 50x	Polish Invasive (Y/N) 100x	Polish Invasive (Y/N) 200x
Striation Depth 50x	Striation Depth 100x	Striation Depth 200x
Striation Organization 50x	Striation Organization 100x	Striation Organization 200x
Striations Patterned (Y/N) 50x	Striations Patterned (Y/N) 100x	Striations Patterned (Y/N) 200x
Attrition 50x	Attrition 100x	Attrition 200x

In this sample, about 60% of the 2730 observations (30 observations each for 91 artifacts, including nine observations made at all three levels of magnification) showed no difference across the three magnification levels. Of the remaining observations,

about half of them varied at the 50x level, an unsurprising result, as this level of magnification is rarely used for bone use wear studies. At 50x there is insufficient detail visible for the assessment of many kinds of wear patterns. At higher magnifications of 100x and 200x, however, these 20% of the cases showed agreement (see Table XXX). In only 3% of cases were the observations of wear different at all three magnifications, bearing in mind that this is impossible for those kinds of observations with only two possible states.

Initially, these data suggest that while magnification has some effect on the observations of wear patterns, this effect is not strong enough to indicate that observations made with different methodologies are incompatible.

Table 5.2: Counts of observations that differ at each magnification

	No difference by observation	Observations different at 50x	Observations different at 200x	Observations different at 100x	All observations different
Observation					
Homogeneity	50	12	15	8	1
Connectedness	63	19	2	2	0
Polish Invasiveness	37	21	17	4	7
Polish Invasive (Y/N)	56	13	13	4	0
Stria Depth	48	21	8	5	4
Stria Organization	38	27	10	5	6
Stria Patterned (Y/N)	63	13	8	2	0
Attrition	65	11	8	2	0
mean	52.5	17.125	10.125	4	2.25
median	53	16	9	4	0.5
% showing this difference	61	20.	11.6	5	2.5

The safest and most reliable approach is probably the use of several different magnifications because different scales of observation provide different types of information. The major problem for the analysis of bone surfaces at high magnifications, however, is the problem of depth of field limitations at these magnifications. Because many worked bone surfaces are fairly uneven due to manufacture techniques, it may be challenging to observe the worn surface. In the case of many of the smaller or more highly worked objects, such as eyed needles, however, the worked surface is highly polished and undulation or channeling from manufacturing traces is a negligible factor.

5.4.1.1. Questions of reliability

In 1974 Lawrence Keeley argued that most (to-date) use wear studies were flawed by common, yet correctable, errors. Keeley defines the goal of use wear studies as the reconstruction of the "primary economic activities of prehistoric groups" (Keeley 1974:323). From this, two correlates are drawn: the conclusions from use wear studies should be both *accurate* in terms of identifying function, and the range of activities identified should be as *complete* a reflection of the prehistoric range as possible. Keeley found the lack of control over the difference between attrition from use, taphonomic variables, and manufacture the most serious problem confronting most use wear

studies. He also noted a lack of experimental studies. Most experimentation involves what he refers to as “direct verification” (Keeley 1974:329): archaeological wear is studied, guesses are made as to the source, and experiments with those guesses are carried out, offering confirmation but no information on whether or not the wear is diagnostic. He notes the lack of complete, ecologically accurate, extensive experimental programs as the base of use wear assessment.

George Odell (Odell 1975, 1988; Odell and Odell-Vereecken 1980) addressed both wear and breakage patterns through experimentation and assessed the success of interpretations through blind tests. Recognition of wear patterns in blind tests is less accurate for retouched tools than it is for unmodified edges. Odell notes that further experimentation is helping this problem. He also notes that experimentation shows that a projectile point must be shot an average of 3.65 times before wear can be recognized, so some points may not display wear diagnostic of their use. However, given the high number of points with evidence of use for woodworking, Odell concludes that the equivalency between morphology and function is not upheld for these objects.

Debates between Keeley and Odell, along with others, developed over several years as they critically examined a range of use wear analysis methodologies and the construction of experimental research programs. The concern over reliability continues to present itself among use wear specialists, but there have been several ways that the issue has been tackled.

5.4.2. Quantification or standardization of observations and concerns about reliability

Use wear, manufacture and traceological studies in anthropological research have all been criticized because of the lack of reliability of qualitative analyses and high inter- and intra-observer error rates (Gordon 1988; Grine, et al. 2002; Stemp, et al. 2006). Because of the difficulties of comparison, the quantification of wear has been recognized as desirable in the analysis of worn surfaces. Additionally, as noted by many use wear analysts (Backwell and d'Errico 2001; González-Urquijo and Ibáñez-Estévez 2003; Gordon 1988; Grace 1989; Grine, et al. 2002; LeMoine 2002; Lerner 2007; Ungar 2003), the lack of standardized descriptive categories for observations of use wear has meant that new investigators must be trained in apprenticeships, which creates strong methodological lineages that often have difficulty communicating with each other. Plisson and Lompré (2005) argue that the publication of photos is an essential component of traceology and present a number of suggestions for the production and preparation of micrographs. Gordon (1988), however, notes that photographs taken from the SEM are both imperfect and biased in their representation of surfaces, especially if the object is tilted slightly when the photo is taken and do not provide a good mode for the communication of surface attributes..

Gordon (1988) proposed a system for the description of wear on dental surfaces. In his system, microwear is generally characterized as pits (1:1 – 1:2 axes with no discernible orientation), scratches (<1:2, orientation identifiable) and gouges (<1:2, sinuous, without discernible orientation), which are compared based on the relative frequency of these types and by the degree of parallelism displayed among scratches. However, the cutoffs for distinguishing these groups are not consistent between researchers and it has been argued that the same actions (compression and shearing) in different degrees result in the different trace types, so cutoffs are, by nature, arbitrary. Sampling and observation strategies also vary – and can have large impacts on results. Examination at different levels of magnification essentially constitutes different samples of the same surface because different features are visible with changes in magnification, so these variable must be standardized for data to be comparable.

Documenting surface patterns through photographs (also known as micrographs) is standard for most bone wear analysts. These micrographs serve to document patterns for later comparison, but also allow observations about surface wear to be made at the time of observation and then reassessed and refined later from photographs. Photos taken with the microscope can then be processed with the program Helicon Focus (Krebs 2007) which allows several photos to be merged into a single, final image. This is helpful because in most cases one photo of a microsurface cannot capture the entire field in focus, due to variation in surface topography. During physical observation this does not present a problem, as patterns can be followed visually as minute focusing is done. However, switching between several photos in order to understand an overall

pattern is not very effective and photo-stacking allows for useful images to be generated (Plisson and Lompré 2005).

González Urquijo and Ibáñez Estévez (2003) report on the use of digital image analysis to group polishes on lithic tools. They note that the approach they propose is based on the assumption that texture, pattern, and development of a polish on a surface are the defining characteristics that distinguish between patterns left by different materials and actions. They argue that the degree of wear development, and hence, the length or intensity of use, can be measured, and thus, that this variable can be used to distinguish between polishes that otherwise appear very similar. The technique consists in the analysis of pixel variability on a digital image. A threshold is determined, based on the luminosity of pixels on an unused portion of the surface and those pixels that show greater luminosity are considered to be polished. The pattern of linkage of polished pixels is related both to the material worked and to the degree of polish development. The frequency of unpolished pixels within polished zones can indicate the intensity of use. A number of variables pertaining to polygon form, size, frequency and position, as well as average and maximum luminosity values of individual pixels can be used to statistically group surfaces. Pilot studies show a high degree of reliability of the statistically derived groups as reflections of function.

Microware 4.0 (Ungar 2004) is software designed to aid in the measuring and recording of wear patterns detected with an SEM. *Microware* allows the analyst to identify two axes along each striation, which are marked at the four points of greatest extent. Wear

traces marked this way can be compared statistically in terms of size and dimensions. The technique maintains the subjective aspect of most SEM studies in that the analyst must identify all striations and determine their endpoints, and is prone to some degree of error, even when tested by researchers with extensive experience recording use wear both with and without *Microware* (Grine, et al. 2002). However, *Microware* is a more reliable method of recording and comparing wear patterns than simple description and has been used effectively in functional studies of archaeological bone tools (Backwell and d'Errico 2001; d'Errico and Backwell 2003). *Microware* may be more applicable to tools that are used in a very limited range of motions and angles of contact, as it was designed for the analysis of teeth, which meet contact materials in highly constrained ways. Archaeological tools that have many potential modes of use may present wear patterns that are too variable to be effectively analyzed with the Microware program.

Another technique that can be used to assess surface characteristics is scale-sensitive fractal analysis (SSFA). Worn surfaces are measured with a tandem confocal scanning microscope (TCSM). The TCSM produces 3-D coordinate values at regular points on the surface of the bone, resulting in a "topographic map" of the artifact. SSFA is then used to characterize the roughness and degree of anisotropy of the surface by repeatedly fitting fractal patterns to the topography, running in iterations until the fractal value has reached an asymptote. Essentially, if a straight line is drawn across an uneven surface, the line is not a good approximation of the distance covered by the surface. If the line is broken into smaller sections that fit the surface more closely, the line will be longer and will more closely approximate the contours of the surface. Eventually, breaking the line

into smaller sections will no longer greatly alter the total line length and at this point the surface has been characterized satisfactorily. SSFA can be run with the Sfrax program (Brown 2006). SSFA has not been used to assess archaeological osseous material, but has been applied with success to paleoanthropological studies of dental wear and preliminary studies of lithic use wear (Stemp, et al. 2006; Ungar, et al. 2006; Ungar 2003; Ungar, et al. 2006). Additionally, pilot tests I did on worked bone and antler surfaces show that SSFA can measure variation at a level appropriate to the study of use wear on osseous materials. However, the difficulty of obtaining access to a TCSM and bringing museum artifacts to an exterior lab with such a microscope made pursuing this kind of analysis impossible for research undertaken for this dissertation.

Summary: The analysis of use wear patterns is largely qualitative and subjective. Efforts to increase the replicability of use wear assessments and to use means of quantifying use wear patterns have not yet had major effect on the practice of use wear analysis. Quantifying methods generally either rely on the measurement of striation measurements or on ways of assessing the smoothness of a polished surface. Although to date these methods are not widely used, use wear analysts continue to refine methods of recording and analyzing worn surfaces.

5.4.3. Assessing Surface Patterns

There are two major steps in the assessment of use wear on bone tools. First, it is essential that manufacturing traces and use-traces be distinguished. In most cases, an artifact will be produced with a material that is harder than itself and used on a material softer than itself. Thus, we can apply the principles of tribological analysis to aid in classifying manufacture and use traces as well. Tribological predictions based on the physical properties of the contact materials are supplemented by considering the gesture and direction of work. Campana (1989) suggests that use-wear may be expected to be patterned because of the gestures associated with some kinds of tool use. However, it is useful to bear in mind that the gestures used with tools are often learned in such a way that they are not universal but reflect culturally specific patterns of artifact production and use. Use wear should also be distributed irregularly on the tool, unlike manufacturing traces that may be more prevalent on all tool surfaces, particularly finishing treatment such as polish. Polish that is smooth, satiny, and lacks fine scratches, but is not distributed uniformly across a surface is likely to be from handling and holding. In cases where use wear and handling wear are difficult to distinguish, the distribution of attrition may not be a useful indicator of working surfaces.

In many classes of artifacts, use zones can be determined based on the use wear. Overall, use wear and handling wear are expected to obliterate, soften or unevenly smooth manufacturing traces, especially near the working ends. Scratches, stains and

polishes from taphonomic agents must also be identified. Polish resulting from manufacture or from use on soft materials may be indistinguishable unless its distribution indicates that it likely derives from use, as the materials that are used in polishing – hides, ochre slurries, or very fine abrasives – may also be worked under other circumstances with bone tools. Taphonomic agents may be distributed irregularly across tool parts or may be uniform regardless of working areas. An analysis of the condition of non-modified bones in the associated faunal assemblage can also be helpful in identifying taphonomic alterations.

After use-related attrition has been isolated, it can then be assessed for indications of the contact materials and actions that created the wear patterns. Generally, it is known from numerous experiments and other traceological investigations that there are identifiable traits produced by contact between bone and hard vs. soft materials. Bone manufacture and wear specialists use agreed upon standards for this primary separation. The standards are discussed in detail in Chapter 7 (Experimental Program) and used in subsequent chapters. As outlined in Chapter 4 (Tribology), tribological principles were used to generate theoretical predictions of wear patterns from distinct raw materials.

5.5. Summary

Several ways for understanding the accumulation of use wear on bone tools have been outlined in this chapter. The central link between all of these seemingly varied approaches to functional analysis of archaeological artifacts lies in the physical nature of osseous materials. As skeletal elements composed anisotropically of mineral and organic components, bones share certain material qualities and these qualities are fundamentally what determine the behavior and reactions of these objects to all outside forces that are brought to bear upon them. Thus, we can understand common aspects of manufacture, wear, and taphonomy from the perspective of material sciences. The very qualities identified by western science were undoubtedly the same qualities that made bone a favored tool material source for prehistoric people. Consequently, these attributes are relevant both on a material and social level. By focusing first on the physical aspects of bone as a raw material, analogies for assessing the life history of archaeological artifacts can be created through ethnographic, experimental, and tribological research, all of which are connected by their common emphasis on the material outcomes of the interaction of bone with other materials.

This theme will structure the dissertation research to be described in the following chapters and constitutes the framework by which disparate information sources have been integrated to allow a rigorous study of the basis for modification and attrition on osseous industries. In the following chapter (Analytical Protocol) I describe the

analytical protocol I used for observing and recording use wear on bone surfaces from experimental, ethnographic and archaeological artifacts.

Chapter 6. Analytical Protocol

In this chapter I take the tribological principles of Chapter 4 (Tribology) and the methodological considerations described in Chapter 5 (Methodology) and integrate them to create an analytical protocol. I will describe the methods I used for observing and recording use wear on worked bone surfaces from experimental, ethnographic and archaeological collections. The same observation method was used for all three collections for microscopic analysis. Macroscopic observations varied based on the distinct life histories of the different kinds of artifacts.

6.1. Observation Method

Osseous artifacts from experimental, ethnographic and archaeological collections were analyzed on both macroscopic and microscopic scales. In developing an observation method for the recording of artifact surfaces, there were a number of key requirements. A systematic method had to be developed that would be flexible enough to be appropriate for a variety of objects and collections, yet still permit the collection of comparable data. The approach had to be conceptually sound, taking into account the research goals and the multi-scalar nature of the study.

6.1.1. Macroscopic Observations

Macroscopic data is similar for archaeological and ethnographic collections. Macroscopic observation began with several simple means of describing osseous objects. General morphological descriptions and measurements were recorded.

Camps-Fabrer (1966) laid out standards for the orientation of pieces that are still commonly employed in the publication and description of osseous artifacts and most of this protocol was followed here. Bone objects were arranged longitudinally. The superior face was defined as that with greater polish or the outside of the original bone, while the inferior face is that which corresponds to the inner portion of the element. In some cases, it was impossible to distinguish the two faces. Camps-Fabrer labeled the distal end as the "used" end, and the proximal end as that corresponding to the handle. This final standard has been since challenged, given that it may at times require the *anatomically proximal* end to be the *distal end* of the tool (i.e., Buc 2005; LeMoine 1997). I find this an important point and also avoid the use of the terms *distal* and *proximal*, unless I am referring to anatomical orientation of the original bone element. Rather, I have used artifact morphological components: tip, mesial section, perforation, handle (Figures 6.1 and 6.2). Not all of these components are found in all artifacts. The tip refers to any working zone located just at the ends of a longitudinal tool; generally these areas are pointed or beveled. The mesial section refers to the center of the tool and is not generally a working zone on pointed implements, although it may have strong handling wear. On perforated tools, the perforation is of particular interest as it will

have contact with threads passed through but will not be subject to as much handling, transport or drawer wear; wear in this zone should reflect the use material clearly. Some artifacts have an identifiable handle, frequently an area of the bone that is not modified.

Figure 6.1. Artifact sections on a needle (Altamira CE03960)

Figure 6.2. Artifact sections on an awl (Burke 9.3E494)

Basic measurements were made on tools from the ethnographic and archaeological collections in order to have a simple description of each object. Metric data on length, maximum width, maximum thickness, and position and diameter of perforations was included on all macroscopic data sheets. These data are primarily descriptive, as metric data are difficult to use in determining the original form, typological class or function of bone tools. Points or other parts may have been recut or resharpened many times over the uselife of a tool, continuously transforming the tool morphologically and functionally (see Touhy 1999). Tools may be transformed over their uselife through a number of social and economic processes (Choyke and Daróczi-Szabó 2010). Unlike the experimental specimens, ethnographic artifacts vary in size. Although dimensions were documented, these data were not analyzed in any way. The dimensions of bone tools are more likely to represent aspects of raw material form (Ramseyer 2004) and repair (Tuohy 1999) than function.

Macroscopic indicators of use were also recorded. Use can result in breakage and tool failure, breakage and repair for continued use, or breakage that does not impair use. Evidence of reworking and resharpening was identified when possible. Reworked needles may present an older eye base above a second perforation. Resharpening is difficult to identify, but in rare cases can be indicated by a more expedient, uneven tip where the workmanship is notably different than that on the rest of the piece (Figure 6.3).

Figure 6.3. Needle from Rascaño displaying both resharpening and reperforation (Altamira CE 13478)

Additionally, wear can result in asymmetrical volume loss or in macroscopic polishes and striations. Macroscopic striations are a good indicator of the direction and gestures of work, particularly if use was highly patterned and repetitive, as in the case of some basketry awls (Figure 6.4).

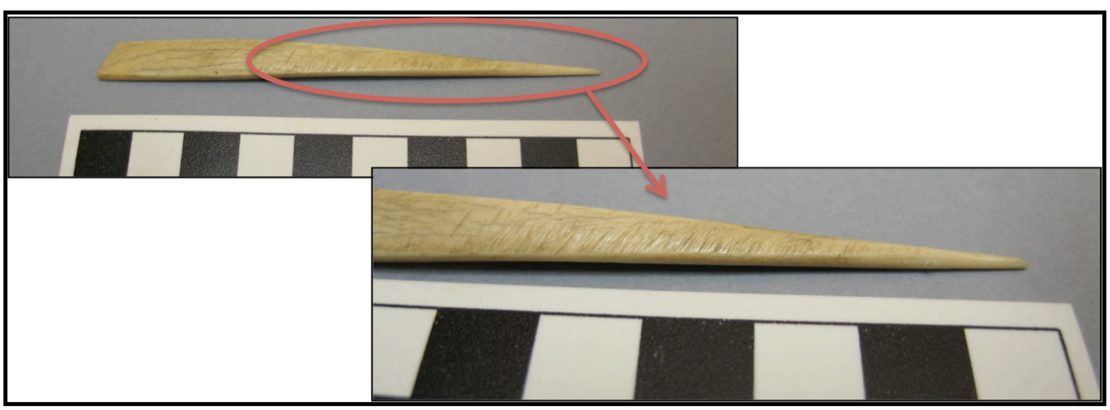


Figure 6.4. Basketry awl, Hopi Pueblo, AZ (NMAI 090624)

Information on conservation, consolidation, restoration and general taphonomy was also noted. These data are key to the identification of appropriate bone tools for microscopic study. Tools that have been aggressively cleaned or restored are sometimes useless for use wear analysis as their surfaces are either obscured or wear patterns have been compromised through later chemical and mechanical cleaning. Similarly, tools stored in bags together with other bone tools or other artifacts may have compromised surfaces. Treatment by a conservator, however, is by no means a necessary indicator that an object should be excluded from a study. In certain cases the layer of consolidant is so thick that the surface cannot be clearly seen and polishes are often obliterated by such treatment (Figure 6.5: a *varilla* from Entrefoces with the surface completely obscured).

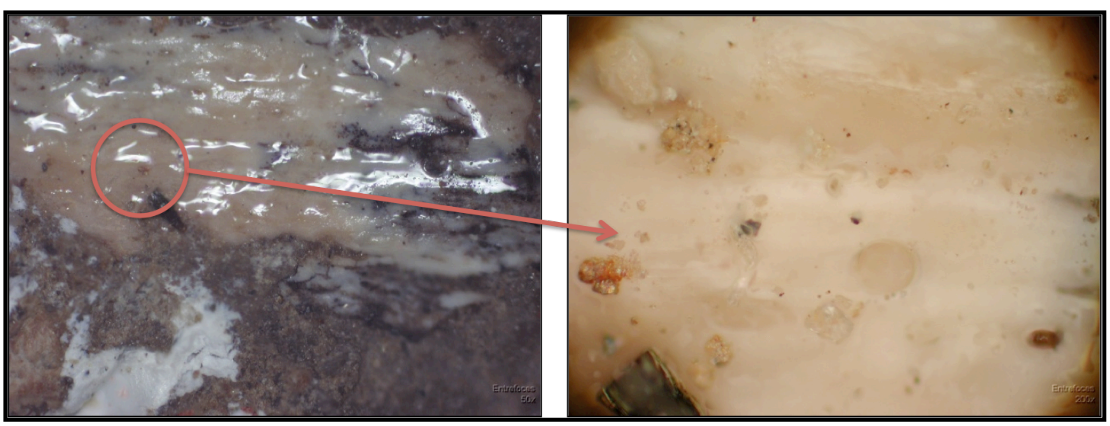


Figure 6.5. Varilla from Entrefoces with the surface completely obscured, 50x, 200x (A-60)

However, a well-done, lightly consolidated object can often still be studied for striations, crushing, edge-rounding and microtopographical erosion (Figures 6.6-6.7). Unfortunately, in older assemblages, the conservator's notes are usually missing or non-existent, and in newer collections the records may be isolated from other object records, preventing a true assessment of all of the processes through which an artifact has passed or the later removal of thick consolidants and the assessment must be made based on the object's appearance. However, where a conservator's treatment has no visible impact on the object, it is unlikely to compromise its study. This is then a viable strategy for selection of materials.

Figure 6.6. Fish stringer, Siberia, lightly consolidated, upper face, 50x (NMNH E046249

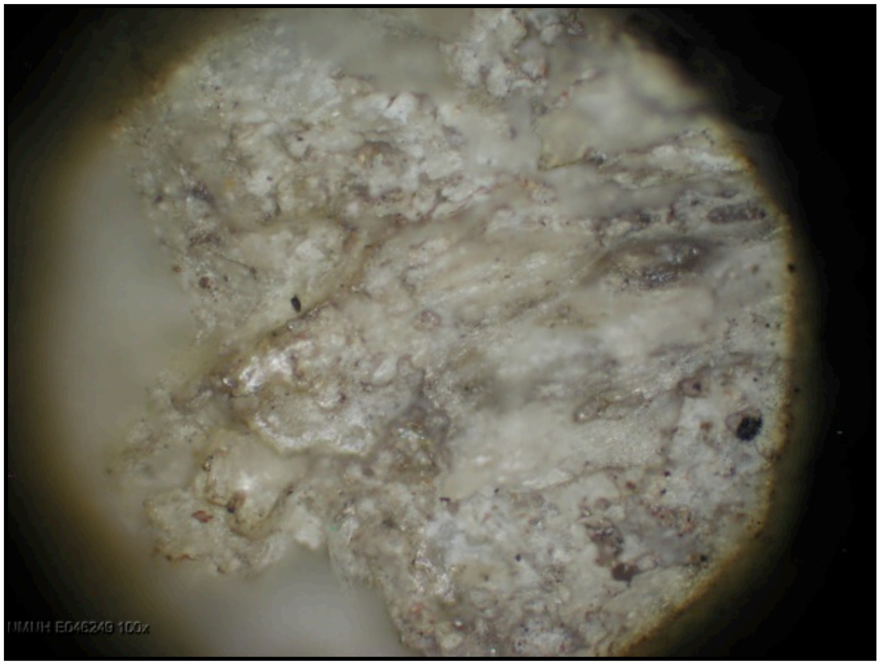


Figure 6.7. Fish stringer, Siberia, lightly consolidated, eye, 100x (NMNH E046249)

After this general assessment of the artifact, traces of manufacture were recorded, focusing on variations in the preparation of the working surface, as different beginning states will affect the development of use wear. Highly smoothed surfaces may develop wear less quickly, as friction is reduced. Additionally, a very compact surface is stronger. Surface finishing techniques that produce rough microtopography will develop polishes first on the high points in most cases as there is a greater physical difference between difference points which can constitute a barrier to actual contact with the worked material (Figure 6.7).

Manufacture information can also be important in the comparison of archaeological sites, allowing the overall similarity of bone technology to be taken into account.

Manufacture patterns are among the most important indicators of social learning traditions (Amin and Roberts 2008). Overall typological and technological similarities or differences may have a number of root causes, among them being site function, seasonality, cultural variability, manufacturing tradition, and change over time. Clearly the demographic and sociocultural makeup of the group that created the settlement will have critical influence on the activities completed, the tools used, and abandonment and disposal practices. While it is not the goal of this dissertation to study all of these variables, they nonetheless will have an important impact on the composition of the original assemblage and on the activities that were carried out with bone and antler tools, as they reflect how people make and use bone tools and the roles played by different raw materials in their lives.

Although different morphological categories were not used for functional analysis, different datasheets for macroscopic observation correspond to the following rough-sort morphological categories: eyed needles, awl (all large pointed tools, including *puntas finas* or gracile points and pins), *sagaies* (beveled antler points), rib or spatulate tools, mesial fragments, pointed or tip fragments, and “others”. Datasheets used in this analysis can be found in Appendix III. This is similar to the strategy used by Campana (1989) in analysis of Natufian and Zagros Protoneolithic bone tools. Campana separated artifacts into broad formal categories that might have functional significance, rather than relying on typologies. A separate data sheet with some of the same categories of information was created for experimental pieces. Ethnographic objects were recorded

on similar sheets, with history of use and provenience replacing the excavation, site, and chronological information on the archaeological data sheets.

In summary, the macroscopic phase of study included the classification of each object in terms of basic morphology, completeness, size, and indications of reworking.

6.1.2. Microscopic Observations

After macroscopic observations were completed, tools that appeared to have good preservation and the potential for use wear patterns were studied microscopically. Here, a multi-stage process was used to analyze use wear on artifact surfaces. Observations were begun with the aid of a 10x magnifying loupe used to identify areas of macroscopically visible luster or striations from use. The overall surface was assessed to determine methods of manufacture, in particular finishing, and this evidence was used as the basis from which areas with variable textures, sheens, or striation patterning were isolated for further study. For this project, a binocular metallurgical microscope, Olympus BH, was used for the analysis of nearly all collections. The microscope was fitted with objectives of 5, 10, 20, and 80x, along with the eyepiece objectives of 10x, resulting in possible magnifications of 50, 100, 200, and 800. The 800x setting turned out to be of no use for the study of these collections as the depth of field is too limited to allow easy observation and the area sampled is too small for patterns to be

identified. 200x is sufficient for the identification of wear patterns. 50x was also used only minimally, as the subtle variations in wear types are better distinguished at 100-200x. As show in the magnification study, differences between observations made at different magnifications do occur, but do not appear to represent a significant source of error.

6.1.3. Recording Use wear Observations

Data sheets (Appendix III) were used to allow observations to be recorded in a consistent manner. These data sheets also indicated the level of magnification used for the observation of different surface characteristics. By collecting data in this way, observations could be made before all experiments were finished or before ethnographic assemblages were fully studied. Standardizing data collection allows the production of comparable data among the three collections and will facilitate later comparative work between colleagues and with material from other archaeological, experimental or ethnographic collections. Data sheets were developed with the aid of Aline Averbouh, MMSH (see Appendix III). Those variables presumed to have functional significance given our current knowledge of the use of bone tools in contemporary, historic and archaeological societies, were recorded. General morphological and technological descriptions were also included, as these are important for the original selection and sorting of material and provide the basis from which wear patterns can be

distinguished. The datasheets also contain basic descriptive information of more general interest, as described above.

A separate data sheet for the recording of microwear from all three of these collections was used. An example of all datasheets can be found in Appendix III, while an example – archaeological needles – is located below, along with the microwear data sheet. This system permitted the flexibility required for different types of collections and objects while still providing a consistent structure for the collection of comparable data from the distinct groups. Definitions of analytical terms can be found in Appendix IV.

Observations were transferred from datasheets to an Access database designed for this project. The database reflects the same categories found on the datasheets (see Figures 6.8-6.13). Although the database was not created until after observations were completed, the structure of the database was in place from the earlier stages of the study, through the datasheets. Once the database was created, data forms could be eliminated and observations entered directly into the database. The use of a database simplifies the standardization of data as it defines the attributes that are observed and the descriptive categories employed. This is particularly important when the majority of the data is qualitative, as is the case in this project, as names, terms, and categories are predefined.

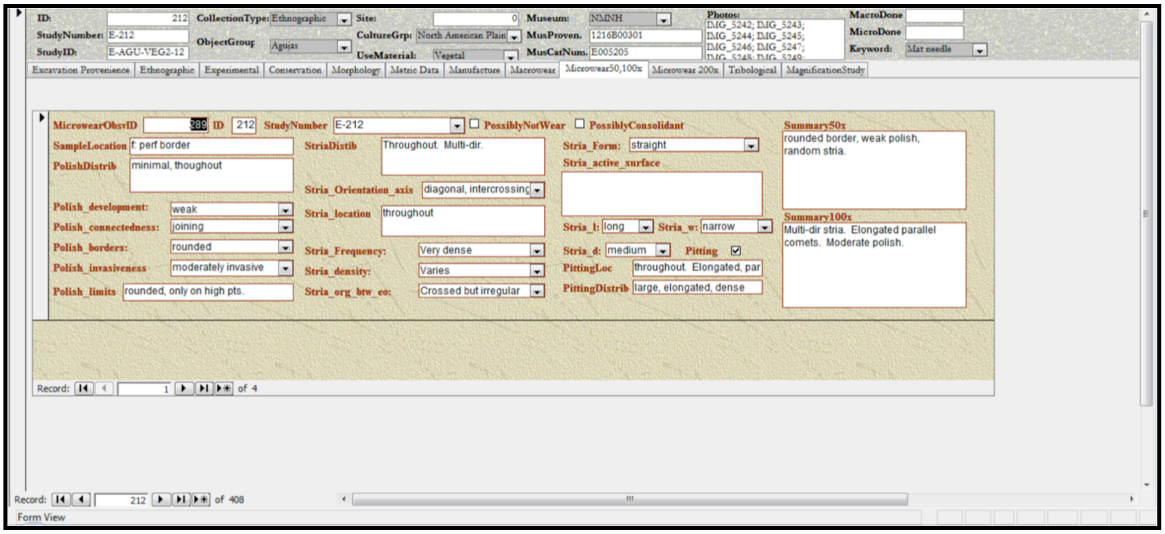


Figure 6.8. Database, observations at 50x and 100x

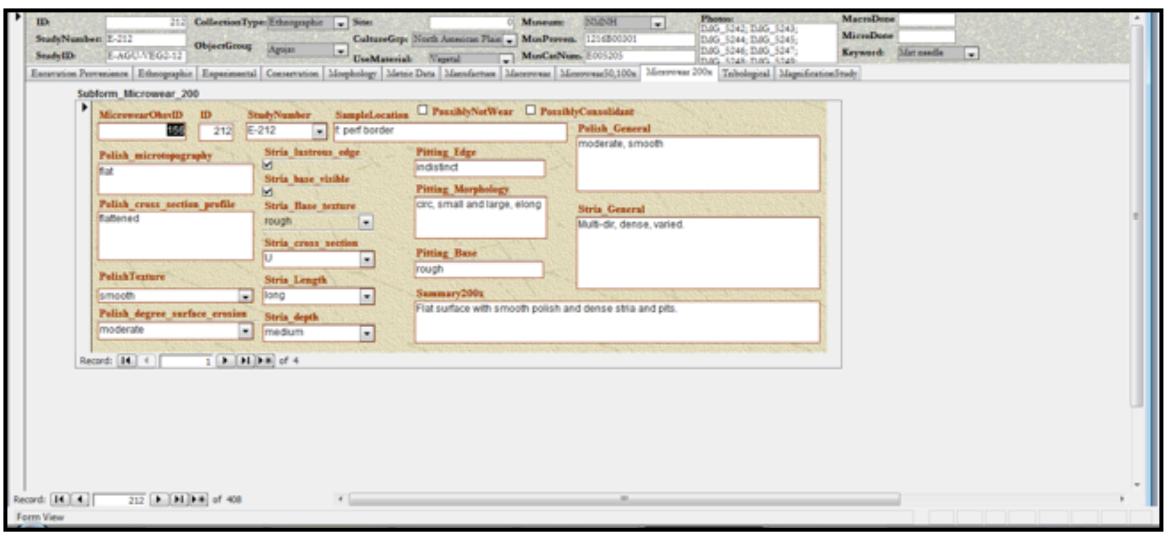


Figure 6.9. Database, observations at 200x

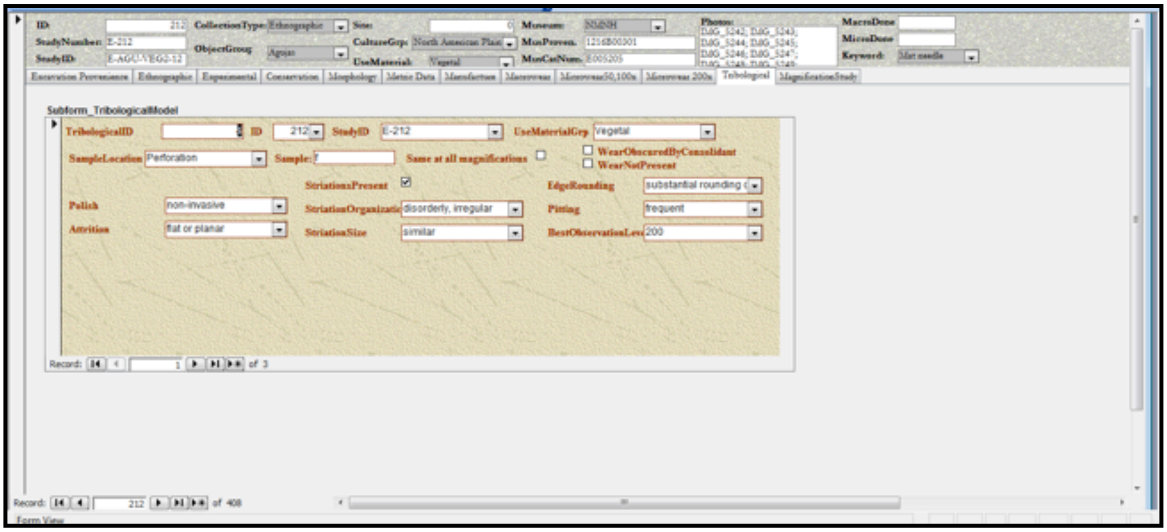


Figure 6.10. Database, tribological observations

Micrographs were also produced to record surface patterns. Photographs were stacked with Helicon Focus. Good micrographs can allow the analyst to revisit surfaces and assess wear patterns fairly effectively. Observations for the magnification level study were done on micrographs, as the study was conceived long after fieldwork ended. Photographs also allow data sharing and as such are an important part of data recording.

Micro:
Macro done:

Data Form
AGUJAS, ETC.

Site data
Name:
Location:
Chronology:

Artifact excavation lab number:
Excavation provenience:

Artifact museum catalog number:
Museum provenience:

Study number:
Photos: IMG_; IMG_;

Descriptive data
Typological grouping:
- Barandiarán:
- Stordeur-Yedid: prox: mesial: distal:
- cross-section: mesial: perforation: point:
-

Metric data:
- length:
- max width:
- max thickness:
- width at perforation:
- perforation: length: width: distance from end:

Other information:
- state: blank, partially formed, finished/complete, finished/broken
- portion of piece:
- shape of perforation:
- position of perforation:
- decoration:
- condition:
- conservation history:

Figure 6.11. Datasheet for macroscopic observations on needles, page 1

Micro:
Macro done:

Technological data

Raw material:

Blank production:

Shaping/Forming:

Perforation Production:

Finishing:

Object state: Finished tool/ Tool in Production/Debris:

Macroscopic functional data

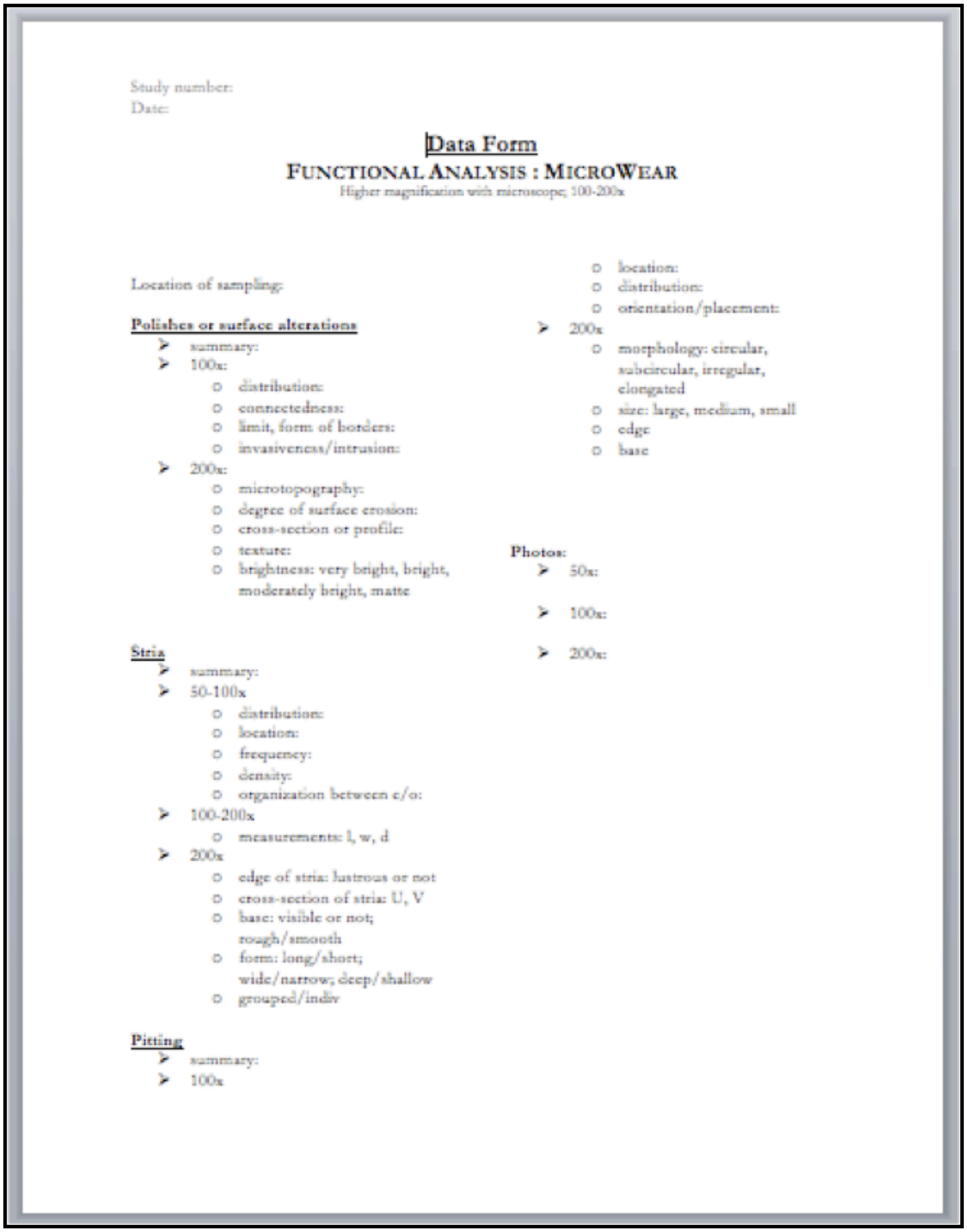
Summary:

Polish/Luster:
- perforated (1°) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Striations:
- perforated (1°) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Chipping, fractures, etc:
- perforated (1°) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Figure 6.12. Datasheet for macroscopic observations on needles, page 2



Study number:
Date:

Data Form

FUNCTIONAL ANALYSIS : MICROWEAR

Higher magnification with microscope; 100-200x

Location of sampling:

Polishes or surface alterations

- summary:
- 100x:
  - distribution:
  - connectedness:
  - limit, form of borders:
  - invasiveness/intrusion:
- 200x:
  - microtopography:
  - degree of surface erosion:
  - cross-section or profile:
  - texture:
  - brightness: very bright, bright, moderately bright, matte

Stria

- summary:
- 50-100x
  - distribution:
  - location:
  - frequency:
  - density:
  - organization between e/o:
- 100-200x
  - measurements: l, w, d
- 200x
  - edge of stria: lustrous or not
  - cross-section of stria: U, V
  - base: visible or not; rough/smooth
  - form: long/short; wide/narrow; deep/shallow
  - grouped/indiv

Pitting

- summary:
- 100x
  - location:
  - distribution:
  - orientation/placement:
- 200x
  - morphology: circular, subcircular, irregular, elongated
  - size: large, medium, small
  - edge
  - base

Photos:

- 50x:
- 100x:
- 200x:

Figure 6.13. Datasheet for microwear observations

6.2. Summary

Data was collected at both macroscopic and microscopic levels. The observation methods were essentially the same for all collections and analysis was done at the artifact working surface level. These measures allow for comparability of what are fundamentally different kinds of bone tool collections.

Chapter 7. Experimental Program

The background of experimentation in worked bone studies has already been discussed in Chapter 2 (A Brief History of Bone Technology Studies), while the basic contours of the experimental program conducted for this study have been discussed in Chapter 5 (Methodology). In these prior chapters I also described some of the many approaches to experiments designed to create use wear to aid in archaeological study. In this chapter I present my experiments, the larger experimental protocol I designed, and the results of use wear analysis, both descriptively and compared to the tribological predictions. I also present some results of other people's experiments, in order to supplement those obtained through my experimental program.

7.1. Experiments in Bone Use wear Studies

Experimental archaeology has traditionally provided the standards for use wear analysis of archaeological artifacts. Experiments allow the researchers to identify the outcomes of specified chains of events. In the case of archaeological studies, experiments are generally aimed at elucidating one of two goals: 1) performance of an object under certain conditions to test the feasibility of a proposed process or action; 2) the material signature of a particular action; both are relevant to functional studies (see Sidéra and

Legrand 2006). Performance characteristics were addressed in Chapter 4 (Tribology) (Griffitts 2006; Knecht 1993, 1997; Pétillon 2006; Scheinsohn 2010). Experimental studies aimed at understanding osseous artifact manufacture or taphonomy and other aspects of bone use wear have also been already addressed in Chapter 2 (A Brief History of Bone Technology Studies). Here I will focus on studies of the production of wear on osseous surfaces from plant and animal fibers and soft materials.

Because the number of kinds of soft materials known to be made ethnographically with bone tools and the great diversity of forms encompassed by these technologies are vast, it would be useful for archaeologists to be able to distinguish the kinds of perishable materials that were worked with osseous implements. To this end, researchers have developed comprehensive experimental programs in order to test for differences in wear patterns generated by different soft materials. This problem represents a challenge for archaeologists in terms of the kinds of experiments that are developed to assess wear patterns. Linda Owen (1993) provides an overview of various materials for which there is ethnographic evidence of working but which are often overlooked in experiments aimed at the production of comparative samples for use in the identification of use-wear. Owen argues that broad research frameworks are essential for experimental programs carried out with the aim of identifying use-wear because they provide different possibilities against which archaeological markers can be compared, especially in cases where there is limited knowledge about the use of tools. Many bone tool specialists have tried to do just that, creating large databases of a range of artifact materials.

Because it is impossible to test for every possible contact material, choices have to be made to define the parameters of a useful archeological experimental program. This ensures that the results can be incorporated into broader research goals, and that the experiments will constitute a cohesive program, or in the terms of Michael Schiffer and colleagues (Schiffer, et al. 1994; Schiffer and Skibo 1987), *experimental archaeology*, that builds on itself, rather than a collection of unrelated experiments. There are a number of avenues that can be utilized to determine appropriate possibilities to test in an experimental program. Four in particular were primary in the study presented here:

- *research emphasis*: the emphasis of this project is the expansion of our knowledge concerning the use of *plant fibers* in the Late Upper Paleolithic, and as such, plants and other soft materials were the focus of a large portion of the experimentation. The majority of previous research on use wear on Late Upper Paleolithic osseous surfaces has focused to a large extent on wear from use as hunting tools or body ornamentation; the results from these studies have been incorporated into the comparative collection without the necessity of excessive replication of previous studies.

- *ecological data*: using the available knowledge of ecology and environmental conditions of the Late Upper Paleolithic of Northern Spain, plant types that were likely to have been present and culturally recognized were selected as primary working materials

- *archaeological evidence for perishable technologies*: as described in Chapter 4 (Perishable Technologies in the Archaeological Record), evidence for perishable technologies is present in the archaeological record of the Upper Paleolithic of Europe in a number of forms, including textile impressions, depictions of clothing and plants, and the very implements that are the subject of this study.

- *ethnographic data*: the above sources were all compared to a wide sample of bone tools from the ethnographic record, which provides both further clarification of the range of possible uses of plants, techniques of production of perishable technologies, and cautionary tales pertaining to the functional variation of morphologically similar objects.

These four complementary kinds of variables contribute to my ability to define the experimental program in such a way as to maximize the productivity, as well as both the reliability and accuracy of the results. They are the same parameters that many investigators use to frame their experimental choices. Additionally, these parameters can be used to sort other people's studies so that their results can be effectively incorporated into my own framework for assessing archaeological tools.

7.1.1. Use wear experiments reported in the literature

A number of studies have provided information on bone use wear accumulation essential to the development of my research, and my experimental program.

Douglas Campana's analysis (1989) began with a simple consideration of the tasks that could feasibly be carried out, given the morphology of different tools. Pointed implements may have served a number of functions, but these are all characterized by the action of piercing or impressing some material with the point. Possible uses include: projectile points, hide-working, weaving, basketry, and lithic retouching, along with clay decoration in areas and periods with ceramics. Bone perforators used on hides seem nearly ubiquitous in cultures that make leather products. Bone awls are known from many ethnographic contexts, especially in North America and were often used for both hide-working and basketry and textile production. Tools were often used by the same people interchangeably for these purposes, which can complicate the analysis of use-wear. Bone tools have been preferred to metal or other materials even in historic periods for use in basketry and some hide-working because bone is unlikely to tear the material being pierced. Bone projectile points should show use-wear from both the penetration of hide and impact with bone and from missed shots that come into contact with dirt, sand, stones and other abrasives (see also Knecht 1997 and Pétillon 2006).

Campana (1989) noted a number of bone tools that may have been associated with basketry, sewing, or weaving in Neolithic and Protoneolithic sites. There is one fairly

complete bodkin-like implement and several other fragments. The more complete artifact was probably a netting or matting needle. The tip is elliptical and well-rounded and well-polished, without any chips. The perforation is broken, but shows some wear on the tip end. Another similar tool has two perforations, next to each other and aligned perpendicular to the long axis of the tool, along the base. These holes are highly rounded and polished on the basal side, with fine scratches, suggesting wear by a cord. Several other perforated objects have been interpreted as thong-stretchers due to heavy wear on the hole in the form of polishing, rounding and fine scratches.

In an innovative approach to test the uses of spatulate-ended implements as hide-scrapers, Campana devised a mechanical device that he used to simulate hide-working. “An experimental tool was made in order to simulate the wear expected on a tool tip from prolonged friction with leather or hide that would occur if the implement were used as a hide compressor, dresser, or rubber…. (The) tool was mounted on a wear-producing apparatus consisting of a reciprocating motor-driven arm, hinged in such a way as to simulate as closely as possible the motion of the human arm. This arm moved the tool approximately axially back-and-forth with a 10 cm stroke about 2.5 times a minute. The arm was initially weighted to produce 1 km of pressure at the tool tip” (Campana 1989:59). Although this device cannot replicate complete activity wear it can be used to test action-based wear and to understand the sequential development of wear. This system allows control over a number of variables so that specific variables can be isolated for the purpose of understanding wear accumulation processes.

Campana used his mechanical arm to test a perforated cow scapula as a thong stretcher. He found that the overall form and distribution of wear on these tools is consistent with friction from hide, but that on the experimental tool, after wearing through three leather strips 4mm wide, manufacturing traces could still be seen, while these were completely obliterated on several of the archaeological specimens. This led Campana to conclude that prolonged contact displayed by the artifacts could only have been produced by the suspension of these tools by a cord, not by their use as hide-processing tools. Preliminary work by Alice Choyke and Paul Duffy, however, indicates that suspension may not result in heavy wear (Choyke and Duffy 2011).

Experimentation in Campana's study also included the perforation of leather with bone points and he sought to identify the range of ideal diameters for bone tools so that perforation could be achieved with relatively little force (requiring a sharpened tip) but where breakage and failure were minimized (requiring a thick, broad tip). Because of these constraints, it was suggested that very finely tipped tools were used on fine or loose materials, such as woven fabrics, while tools with thick tips were probably used on leather or other strong materials. Because repeated pressure is placed on a bone perforator, the tips of tools used in such a manner quickly develop rounding and abrasive polish. If abrasives such as silt or sand are present, abrasion builds up more quickly and includes larger scratches, indicating the direction and manner of use of the implement. Tools used for basketry and weaving would develop wear behind the tip rather than at the tip, but wear typical of such activities included varied motions and may be difficult to characterize aside from general placement on a tool. If materials like

reeds, which contain natural abrasives, were manipulated, diagnostic wear should be readily identifiable.

Campana (1979) has also considered how to differentiate between shaft-straighteners and thong-smoothers. In his Neolithic assemblage a perforated scapula had been interpreted as either a shaft-straightener or a thong smoother. Campana created another mechanism to reproduce wear on an experimental replica of the tool. He found that the wear, which is distributed in four lobes, lying perpendicular to each other, around the hole, is consistent with use as a shaft-straightener. Lobes diagonally across from each other are symmetrical in depth and angle. The wear is angular, rather than rounded. The latter would be more consistent with use on leather strips. He also found that the diameter of the shaft can be estimated based on wear and the Natufian example was probably used extensively on shafts about 8.5 mm in diameter.

There are many other classes of broad or round tipped artifacts that may indicate the working of plant materials at archaeological sites. Long-handled osseous combs have generally been interpreted as having been used to beat up the weft when weaving on a warp-weighted loom or hide or fiber processing. For sites from Iron Age Britain, Touhy (1999) interprets antler combs as having been used to braid leather and weave starting borders and possibly for the insertion of ornaments such as beads or feathers into woven pieces. There are many instances of breaks or chips on teeth that were then smoothed down by further use. This evidence suggests that the worked materials were tough and would have resisted snagging, indicating that leather might have been the

worked material. Woven basketry is discarded as a possibility as wear is not consistent with this use, except on the under side of the teeth. Campana (1989) suggests that the production of matting, basketry, and textiles are all technologically similar, both in terms of the use of tools and in the conceptual aspects of these tasks, making it difficult, if not impossible, to distinguish within these task categories based on artifact form or wear patterns. However, there are many differences in the production sequences of different perishable technologies that can create different wear patterns on bone tools.

Legrand (Christidou and Legrand 2005; Legrand 2005, 2008; Legrand and Radi 2008) has done extensive experimentation with bone tools used to manipulate fibers as part of her analysis of bone needles from the aceramic Neolithic (7^{th} – early 6^{th} millennium) at the site of Khirokitia, Cyprus and bone points from the Early Neolithic site of Colle Santo Stefano, Italy. Legrand undertook experiments on hide in various states, bone, wood, bark, reeds and flax fibers. Her action-based experiments consisted of perforating, scraping, cutting, and smoothing materials, while her task-based experiments encompassed sewing, basket-weaving, and chopping wood (Legrand 2005). Legrand (2008) assessed 67 archaeological needles from the aceramic Neolithic 7^{th} – early 6^{th} millennium site of Khirokitia, Cyprus. She notes that many display significant deformation at the tip and are asymmetrical from use. On the other hand, chipping and crushing are rare. About a third displayed middle deformation of the eye. Craters and scratches visible at low magnifications are also much more common than in the experimental assemblage. Craters were also worn at the base in certain cases.

Legrand's study was seminal in distinguishing wear from the production of a range of perishable artifacts. More generally, there are a number of observations about different kinds of use wear signatures that can be drawn from the literature. Because both use wear analysis and experiments are time-consuming and logistically complicated, sharing results is essential to the development of more systematic and widely applied bone use wear studies (Sidéra and Legrand 2006). Terminology within bone tool studies, and especially functional studies, is relatively standard but varies somewhat from author to author. Here I will attempt to rephrase all of the use wear descriptions to match the terminology that I have used throughout this study in order to facilitate comparison of wear observations.

Soft materials from a range of sources produce rounded volume loss that adheres to the overall contours of the original tool form (Buc 2005, 2010; Griffitts 2006; LeMoine 1997; Sidéra and Legrand 2006). This attrition pattern can be due to handling, transportation in a flexible container, or use against a soft material.

Wear patterns have two main attributes: polish and striations. Unlike the case for the analysis of lithic use wear, most bone tool use wear analysts privilege striations as more diagnostic of worked materials than polish, although both contribute to the pattern of wear on bone tools (Buc and Loponte 2007; Christidou and Legrand 2005; Griffitts 2006; LeMoine 1997; Sidéra and Legrand 2006). Microtopography, the form of the microscopic surface and the degree of roughness or rounding of surface peaks and valleys, can also reflect worked materials (Christidou 2008; Griffitts 2006; Sidéra and

Legrand 2006). Tool morphology is also frequently cited as a key indicator of function (Buc and Silvestre 2007; LeMoine 1997) although this is not a secure means of identifying function.

Wear from both handling and working leathers is often macroscopically and microscopically rounded, with irregular striations (Griffitts 2006; Sidéra and Legrand 2006). Short, smooth, intercrossed striations with rounded borders may indicate contact with hides (Buc and Loponte 2007; Buc and Silvestre 2007; LeMoine 1997). Smooth or polished striation bases are also documented from hide-working (Buc 2005, 2010; Legrand 2005). Griffitts (2006) suggests that handling can be distinguished from use wear on soft hides based on a more irregular distribution and shallower cross-section of the striations. Microscopic and macroscopic edge-rounding can be created from use against hides and leathers. Polish is invasive, extending into the low points of the osseous microtopography. Pitting is frequently identified as diagnostic of leather and hide working, although Griffitts indicates that pitting may not be apparent at magnifications below 100x and is best viewed at 200x or above magnifications (Griffitts 2006; Lompré personal communication).

Natacha Buc (Buc 2005; Buc and Loponte 2007) argues that the differentiation of use wear between soft hides and soft plant materials based on use wear can be based on the form of striations. Striae that are shallower and organized parallel to each other indicate plant materials, while deeper and intercrossing striations indicate working

animal materials. Legrand (2005; Sidéra and Legrand 2006) also associates shallow, fine striations with plant working.

Griffitts argues that more important than whether a fiber is of plant or animal origin is the amount of silica in certain plants. Although she groups soft cordage from animal and plant sources, she places silica-rich plants in a separate category. She identifies the wear from silica-rich plants as non-invasive and planar, with volume loss also frequently planar rather than rounded. Griffitts finds that striation organization and distribution varies substantially among activities involving plant elements and fibers, as striation position is contingent on the gesture of work.

Alexandra Legrand's experiments included weaving and sewing flax, reed, bark, and hide. Overall, she notes three dominant patterns of wear that she attributes to soft plant materials and bark. She distinguishes bark wear based on heavy smoothing of high points on the bone surface. Weaving was carried out for 50 hours with a needle. It is unclear what kind of movement was used – the needle appears to have served as the shuttle from the picture, but it is unclear if it was also used as a batten. Wear from weaving accumulated gradually. The perforation shows no clear wear even after 50 hours of work. The tip has lost substantial volume to chipping. At 200x high points on the bone surface are "varnished with a flat or domed aspect and smoothed texture. Numerous micro-pits and multi-directional, short, fine (less than 1mm), superficial, straight and continuous striations were also observed" (Legrand 2008:447).

Sewing flax fabric produced faster and more developed attrition. "Scratches progressively appear on the needles eye zone. Chippings progressively invade the faces of the tip and highly modify the original volume. At high magnification, the original surface topography was progressively regularized. The rises became varnished and smoothed with domed or flat aspects and grainy or smooth textures. Striations were longitudinal, long or short, fine or broad (between 1 and 2 mm), superficial, straight, organized, continuous. The largest striations had smoothed edges and were partially affected by the polish. Toward the end of use, craters appeared while micro-pits progressively disappeared" (Legrand 2008:447). Variations from patterns noted experimentally lead Legrand to conclude that the archaeological needles were used for sewing with some other soft plant fiber other than flax.

Wood-working was not considered in this study, but the signatures of wood-working include a moderately invasive polish (Griffitts 2006). Griffitts also found that tools used to weave commercial, domesticated cotton acquired a very bright polish and surface cracking.

Microtopography provides further information. LeMoine (1991) and Griffitts (2005) both note that dampness can result in wear that isolates osteotones as raised ridges, regardless of the worked material. Legrand identifies planar, homogenous attrition from contact with bark, with more rounding present after working hide, especially in the primary zone of contact (Sidéra and Legrand 2006). The distribution and orientation of

striations results more from different gestures than from variation in worked materials (Buc 2005, 2010; Buc and Loponte 2007; Buc and Silvestre 2007; Legrand 2008).

Summary: There is general agreement on differences in polish and microtopography resulting from wear from plant and animal fiber (see Table 7.1). Despite assertions that striations are a better diagnostic indicator of material worked, the patterns of striations identified as characteristic of different fiber classes are more variable among researchers. Striations may be more indicative of manner of work, rather than contact material, as suggested by Griffitts (2006).

Table 7.1. Summary of Use Wear Signatures of Plant and Animal Fibers Reported in Previous Publications

Material worked	Polish	Striations	Other markers
Plant	Non-invasive; Planar (especially silica-rich plants)	Shallow; Long; *Fine OR variable; Parallel OR variable*	Smoothed microtopography;
Animal	Invasive	Irregular; Rounded shape; Smoothed or polished base; Crossing; Short; *Shallow OR deep*	Pitting; Rounded microtopography
General to soft materials			Rounded volume loss

*Italics indicate disagreement on diagnostic patterns for different kinds of wear

From: Buc 2005, 2010a, b; Buc and Loponte 2007; Christidou and Legrand 2005; Griffitts 2006; Legrand 2005, 2008; Legrand and Sidéra 2007; LeMoine 1997; Maigrot 2000, 2001, 2003; Sidéra and Legrand 2006

7.2. Experimental Program Design

Here, I will discuss some of the variables that are relevant to identifying the kinds of fibers worked with osseous artifacts in the Upper Paleolithic. Most of these parameters are pertinent to the study of soft materials worked with bone tools in any location or time period, but the advantage to studying the Upper Paleolithic in terms of designing an experimental program is the absence of domesticated animals or plants, limiting the kinds of fibers available to Late Upper Paleolithic people. The possibilities that could be tested in an experimental program, even one that is well-defined and directed at a narrowly bound question, are nearly infinite. Additionally, the fiber sources in any area are determined in part by the local climate and biotic community. This basic outline could be enlarged to include domesticated wools and hairs and domesticated plant fiber sources in other contexts where such fibers were available. Here, though, I will focus on non-domesticated plants and animals available in Western Europe in the Late Upper Paleolithic.

A number of kinds of variables affect the accumulation of wear, including the form of the tool, the tool material and condition, raw material worked, preparation of raw materials to be worked, additive products including lubricants, grits, dyes, grime, and adhesives, gesture of work, duration and intensity of work, skill of the artisan, and activity being carried out. None of these variables acts in isolation and all can provide

information on the ways that bone tools were used in the past. However, in order to productively target variation in wear that is indicative of specific variations in use, most experimental programs emphasize one of these classes of variables. My experimental protocol is designed to identify different kinds of wear associated with plant and animal fibers. I aimed to isolate variation caused by differences in raw material that might be useful in the context of Late Upper Paleolithic bone tool use, rather than in gesture, condition, task, or other variables.

Materials to be worked in experiments were selected based on the factors outlined above: an emphasis on documenting wear from plant materials, as animal materials are more amply documented in published literature; plants present in the Late Upper Paleolithic of Northern Spain as documented in pollen spectra and suggested by environmental reconstructions; plants that have documented use for the manufacture of perishable technologies in the ethnographic record; archaeological indications of plant fiber use broadly in the Late Upper Paleolithic (Boyer-Klein and Leroi-Gourhan 1985; Boyer-Klein 1981; Carrion, et al. 2000; Freeman and Gonzalez Echegaray 1995; Leroi-Gourhan 1986; Moerman 1998; Owen 2005).

Experiments were first devised based on activity groups and then organized by morphological groups (Table 7.2). In Table 7.2 I present the overall experimental program that was developed. Only those experiments that are bolded were carried out at this time. Many bone tool specialists have found it useful to organize experimentation

and analysis by morphological groups, while all along recognizing that the connection between form and function is indirect (Buc 2010a, Legrand 2005).

Table 7.2. Experimental Program by Morphological Group

Artifact Group	Goal	Position	Movement	Material	Material form	Pertinent Activities
Points 	Perforation	• **Perpendicular** • **Angled**	• **Straight** • **Twisting**	• **Woven nettle fabric** • **Skin – fresh** • Skin – dry • Skin – tanned	• **On frame** • On surface	• Sewing • Weaving
	Insertion	• **Perpendicular** • **Angled**	• **Straight** • **Straight, then twisting** • Straight, then lateral • Angled • Angled, then twisting • Angled, then lateral • Bilateral	• **Pine needles** • Pine roots – boiled • Pine roots – fresh • Spruce roots – fresh • **Retted nettle fiber – 4 & 8 weeks** • Splitting bark – willow, spruce, birch, oak • Saplings – fresh • Saplings – soaked • Sinew – knotted • Hide thong – knotted	• **Bundled** • **Twisted**	• Basketry • Weaving • Fiber preparation • Netting

Table 7.2. Experimental Program by Morphological Group						
Artifact Group	**Goal**	**Position**	**Movement**	**Material**	**Material form**	**Pertinent Activities**
Perforations 	Guiding (friction)		• **Cordage moves** • Tool moves	• Sinew – twisted • **Sinew – straight** • **Sinew – twined** • Nettle – twisted, stripped • **Nettle – twined, retted 4 & 8 weeks** • Nettle – twisted, retted 4 & 8 weeks • Nettle – plaited, retted 4 & 8 weeks • Willow – twined • Willow – plaited • Pine root – straight • Pine root – twisted • Pine root – twined • Hide thong – tanned • Hide thong – dried	•	• Sewing • Weaving • Basketry

Table 7.2. Experimental Program by Morphological Group

Artifact Group	Goal	Position	Movement	Material	Material form	Pertinent Activities
Needles 	Sewing	• Varies with movement	• Varies – includes perforation, pulling, insertion	• Skin – tanned; sinew straight • Skin – tanned, sinew twined • **Nettle woven fabric, nettle twisted cordage** • Nettle woven fabric, nettle twined cordage • Birch bark; nettle twined cordage		• Sewing

Table 7.2. Experimental Program by Morphological Group

Artifact Group	Goal	Position	Movement	Material	Material form	Pertinent Activities
Spatulate tools 	Contact – face	• **Parallel (flat)** • **Highly acute angle** • **Wide angle**	• **Parallel to axis – unidirectional** • **Parallel to axis – bidirectional** • **Perpendicular to axis -- unidirectional** • **Perpendicular to axis – bidirectional**	• Nettle – woven fabric • **Skin – fresh, inner** • **Skin – fresh, outer** • **Skin – dry, inner** • **Skin – dry, outer** • Skin – tanned • Bark – on tree • Birch bark	• On frame • **On surface**	• Hide-working • Weaving • Fiber processing
	Contact – borders	• Perpendicular – lateral • Angled – lateral • Angled – end	• Scraping – unidirectional • Pushing – unidirectional • Bidirectional	• Nettle cordage – stripped & twisted • Nettle – stripped & twined • Nettle – retted & twined • Skin – fresh • Skin – dry	•	• Weaving • Hide-working
	Weaving	• Perpendicular	• **Beating**	• **Nettle – stripped, twisted** • Nettle – retted, twined	• On loom	• Weaving

Appendix V lists some of the kinds of experiments that could be pursued in order to address the use of bone tools in the Late Upper Paleolithic of Western Europe, organized by morphological artifact group. The primary variables that were selected were artifact group or morphology, goal, position, movement, material and material form. Because many of these actions are associated with a number of more complex production sequences, the types of activities that could employ each action were also identified. This table is not exhaustive, but serves to indicate the complexity and true impossibility of the challenge of creating a useful experimental program that will establish standards for the assessment of archaeological wear patterns. Not only is it important to precisely define the parameters of the experimentation, and explore numerous variables, but it is also important to repeat experiments more than once to confirm the recurrence of wear traits under the same conditions.

After establishing the parameters of the experiments to be carried out, the tools to be used in experimentally must be produced. For this study, some blanks were produced using methods available to Upper Paleolithic people, such as fracture and groove and splinter. Bone tool blank production with flint tools can be quite time consuming, so other blanks were cut with a band saw in order to speed the process. However, all tools were shaped and finished with stone tools, including unmodified flakes, lithic scrapers and drills, and sandstone, limestone and shale grindstones.

My experimental collection of thirty-two pieces was created primarily at the Maison Méditerranéenne des Sciences de l'Homme **(**MMSH) under the direction of Aline

Averbouh. Following Buc (2010, 2006) and others (Campana 1989; McComb 1989), I identified three morphological forms to replicate and use to create wear. These forms are pointed, spatulate, and perforated (see Table 7.2). Because needles were the original focus of the archaeological study, I also replicated needles, which have both a point and a perforation. Although I made many of the tools, individuals with varying degrees of experience or expertise in the manufacture and manipulation of bone and antler tools were included among the artifact producers. This allows some consideration of the role played by custom and skill in the development of wear patterns. The sample, however, is skewed, of course, toward individuals with low skill levels. No pattern was detected in the utility or wear patterns on tools made by different people. Several of the artifacts have two working ends that were used in different ways and there were some pieces that were not used, so the number of experiments does not correspond exactly to the number of tools created.

7.2.1. Experiments

7.2.1.1. Action-based Experiments

The majority of the experiments were action-based. I deliberately created a certain kind of contact between two materials. The primary variables in the experiments were raw materials worked, gesture, and raw material state. As discussed in Chapter 5

(Methodology), action-based experiments do not replicate any particular task, only certain kinds of contact. However, although designed by action, these kinds of experiments can inform on the outcomes that may be expected from certain activities. One strong advantage of action-based experiments is that the skill level required to complete them is less relevant. However, actions isolated from a goal may not be as patterned as those within a complex task.

Actions were selected based on the gestures and materials involved in a range of tasks in the manufacture of perishable technologies. Appendix V presents the organization of experiments based on activity, and grouped into activities involved in the exploitation of animal fibers and those associated with the exploitation of plant fibers. Each activity is matched to known forms of archaeological artifacts from the Late Upper Paleolithic of Northern Spain. These artifact forms were used to select the forms of artifacts used in the experiments. The primary actions were perforation or insertion and unidirectional or bidirectional rubbing. Bone tool forms of different types were tested.

7.2.1.1.1. Results of action-based experiments

Action-based experiments were carried out primarily on pointed and spatulate forms. Here, I will highlight a few of the results from materials that are unrepresented or absent from the ethnographic sample. Assessment of the full collection with tribological principles is found later in the chapter.

X-1, sample area A, the rounded end, is a rib tool used to clean dry deer fur, running the tool perpendicular to the surface of the fur-bearing side of the hide. Macroscopically is has a bright, strong, highly developed polish and extreme smoothing. Striations run perpendicular to the axis (along the direction of work) and are subparallel to each other. Striations are extremely dense, small, short, and shallow. A few small, sub-circular pits with abrupt edges are present. Where macro-polish is less strongly developed, striations are deeper. Sample area B, the squared border, displays a bright polish with no striations and many small pits. The polish is extremely invasive.

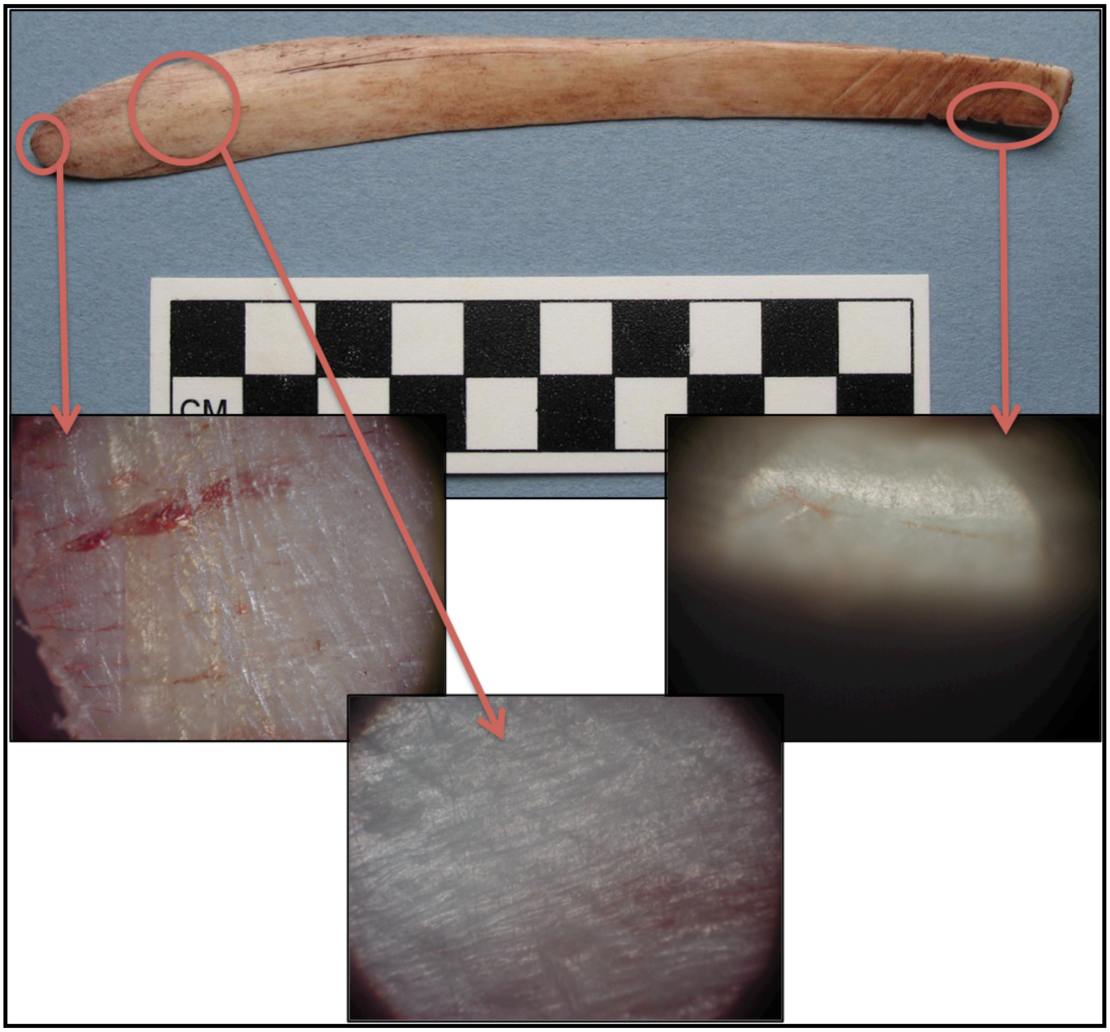


Figure 7.1. Spatulate tool used to clean fur (X-1)

X-5 is a pointed tool used to perforate fresh hide perpendicularly for 30 minutes. A moderate sheen is visible macroscopically. Microwear is bright and invasive, with no notable striations present. There is limited pitting present.

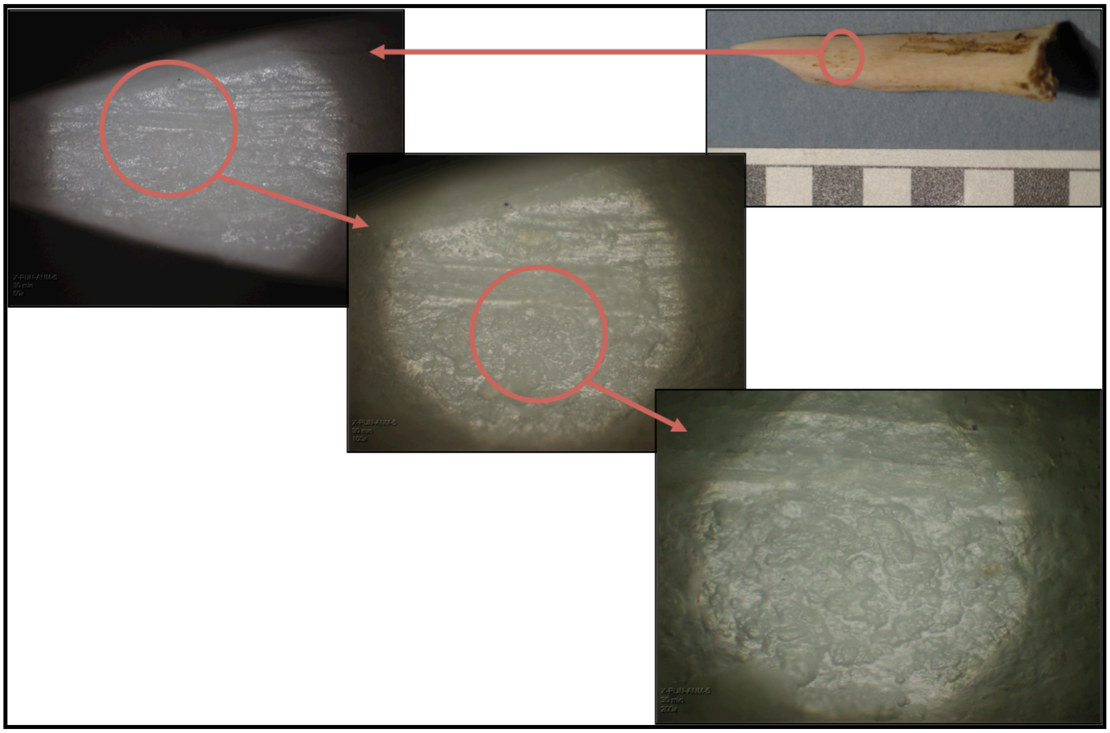


Figure 7.2. Point used to perforate fresh hide (X-5)

X-25 is a pointed tool used to perforate a bundle of fresh pine needles at an angle of 45º for 15 minutes. The planar polish is thin and somewhat invasive. Striations are all about the same size, and arranged longitudinally along the axis and parallel to each other. There are a few small pits and limited edge rounding.

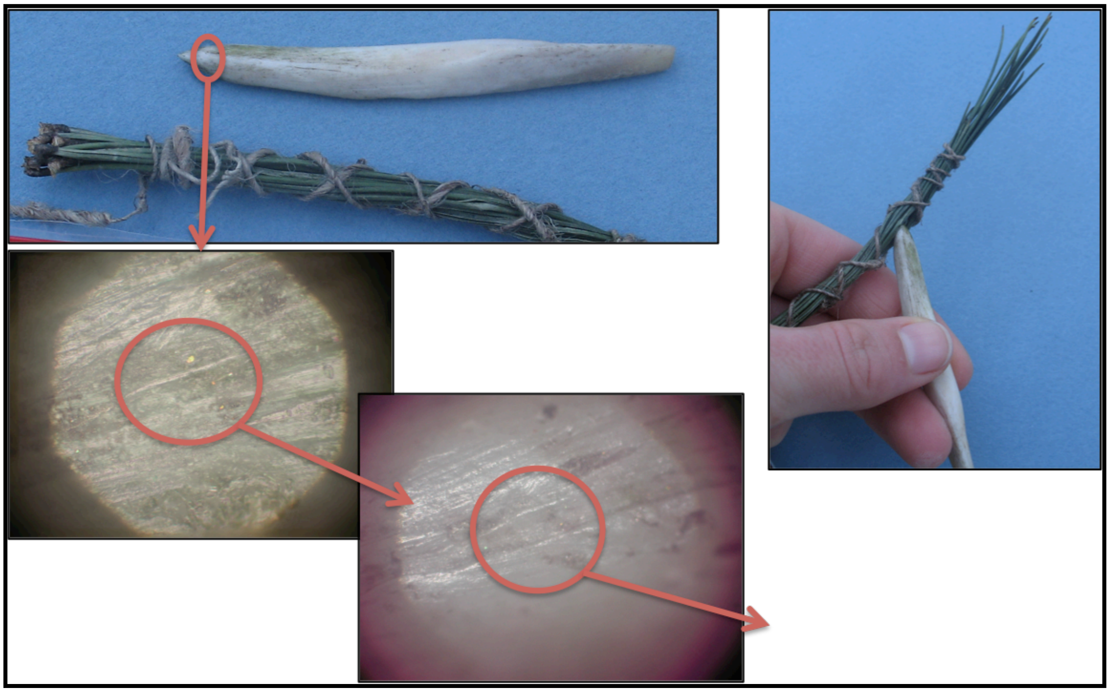


Figure 7.3. Point used to perforate fresh pine needles (X-25)

X-30 is a pointed tool used to perforate fresh, twisted pine needles for 30 minutes. Bright polish is rounded and non-invasive. Dense, long, shallow striations intercross along the axis. At the point on the mesial section of the awl where it was most deeply inserted into the pine needles and then removed, curved striations show the change in direction of movement. The difference noted between X-25 and X-30 serves to demonstrate that the preparation and arrangement of the worked materials can have a significant impact on the development of wear in experimental settings. At this time it is difficult to determine whether this effect varies with longer duration of use. Repeated use, though, may mute this effect, given minor variation in material preparation and organization with each instance of use.

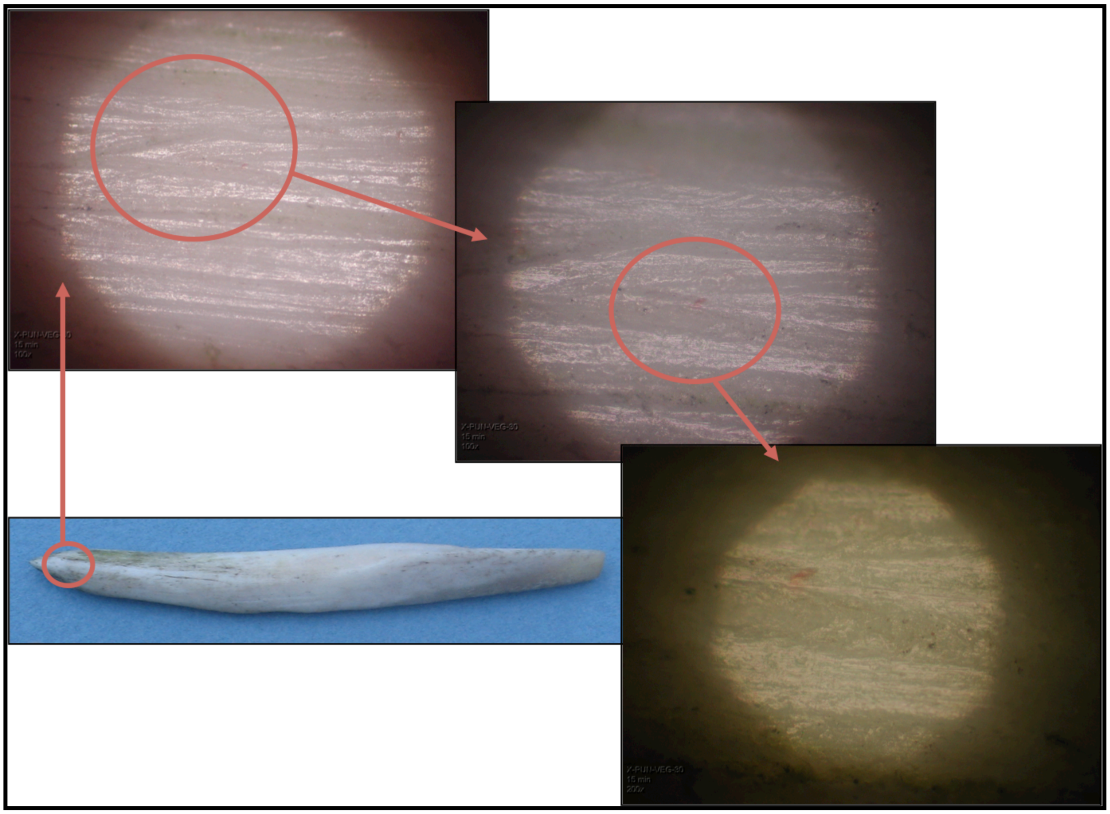
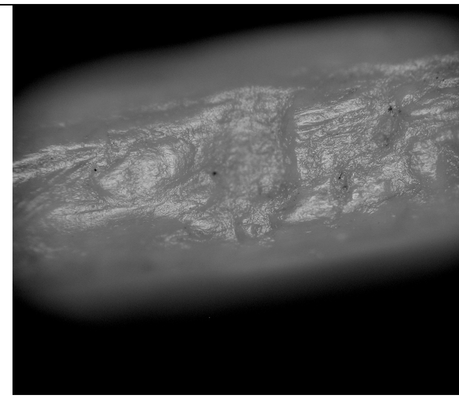
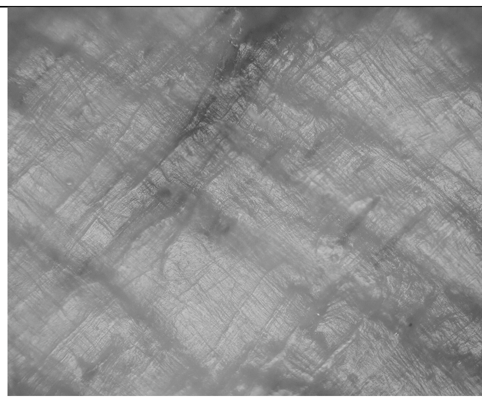
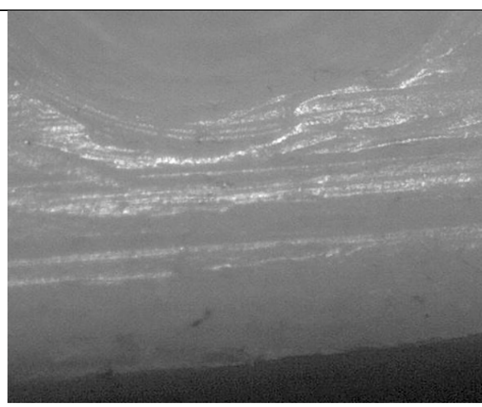
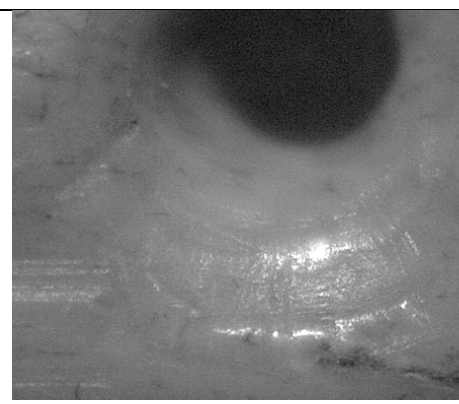


Figure 7.4. Point used to perforate fresh pine needles (X-30)

As has been reported earlier (Stone 2009), action-based experiments also indicate that there are some differences between materials of differing hardnesses among fiber classes. In Figure 7.5 it can be seen that all of the animal fibers produced invasive wear and edge rounding, while plant fiber wear is smoother with planar attrition. Striations are absent in nearly all of these specimens.

Table 7.3 Use Wear on Experimental Surfaces from Soft Organic Materials by Material Form		
	Animal Materials	Plant Materials
Very soft: Fur & nettle bast fiber		
Medium soft: Dry, fresh hide & fresh pine needles		
Cordage: Sinew & retted nettle bast fiber		
*From Stone 2009:227, Figure 37.5		

7.2.1.2. Task-based Experiments

A small set of task-based experiments were included in this study to complement the action-based experiments and to help in understanding the ways that bone tools perform in different conditions.

One of the challenges of experimental archaeology concerns the skill level and motor habits of the practitioners. This has already been discussed in detail in Chapter 5 (Methodology), but here I will simply identify my skill level at each of the tasks, as this could have a significant impact on the results, although this impact is extremely difficult to measure. First, the manufacture of bone tools, although not the aim of these experiments, is a relevant step in which skill may well affect outcomes. I primarily taught myself to make bone tools and later, was instructed in some other tool manufacture technique by other archaeologists.

7.2.1.2.1. Weaving

I learned how to weave as a child, but am not an accomplished weaver. However, I am familiar and comfortable with weaving and with the different kinds of tools that can be used to create woven cloth. My skill level is intermediate, which may be an acceptable skill level for comparison with archaeological tools, especially in the case of weaving, which is an extremely repetitive task with gestures strongly dictated by the constraints imposed by the activity.

X-2 is a spatulate tool made on a split deer rib and used to weave stripped, twisted nettle cordage on a non-heddle loom (Figures 7.5-7.6). The tool was used as a shuttle and batten to guide and tamp down the warp. X-2 was used for a total of five hours. At the end of this period, polish is not macroscopically visible and striations from manufacture are still visible throughout the surface. The polish is bright and somewhat invasive microscopically. Striations are frequent but not highly patterned. They intercross irregularly but are of a similar size. Rounding is pronounced on the borders but not on faces.

Figure 7.5. Weaving nettle cordage with spatulate tool

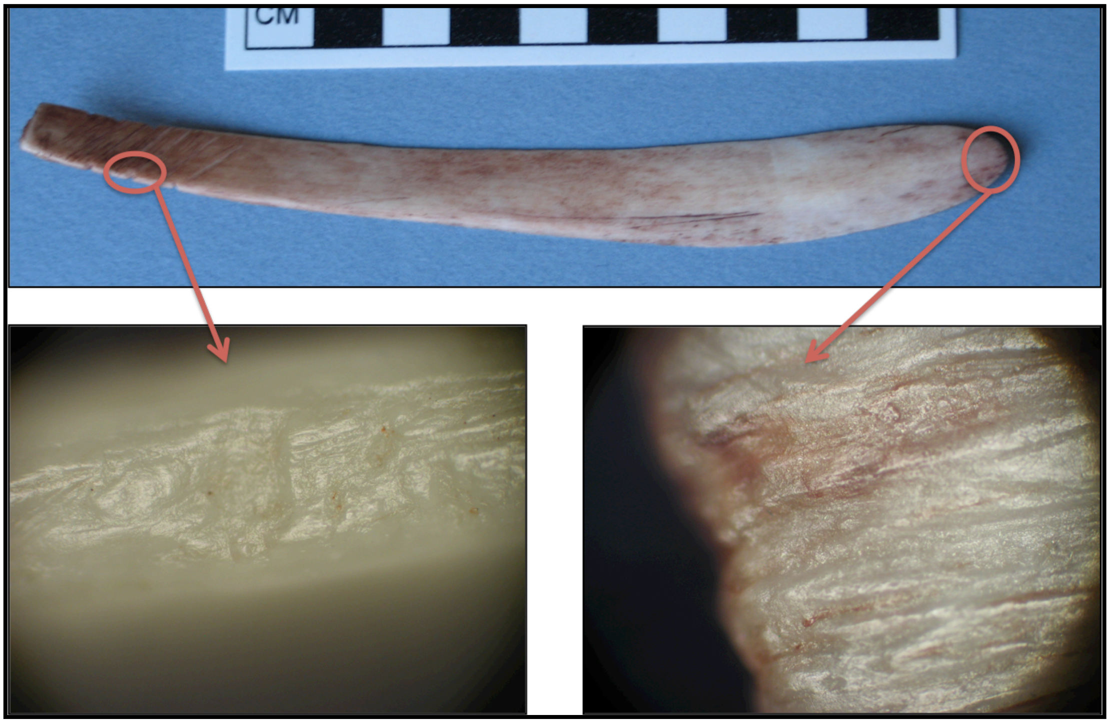


Figure 7.6. Spatulate tool used for weaving nettle cordage with use wear on the border and tip (X-2)

7.2.1.2.2. Hide-scraping

This was my first attempt to prepare a hide. I was given some advice by a friend from the Alamo Navajo reservation who has done brain tanning, although using modern tools. I was assisted in the long and laborious process of hide-scraping by my father, who had also not previously attempted hide-scraping. Although the process seemed quite easy to learn and the outcome was satisfactory, the skill level represented here is extremely low. This undoubtedly affects the pattern of wear accumulation and likely contributes to a less regular pattern of wear.

Four spatulate tools were used in hide-scraping (X-16, X-17, X-19, X-32). Three were made from split and shaped ribs of bull while the fourth was made from a full deer rib with a beveled end. Wear on the tools was similar; here I will only describe one. Tools were used for about 50 hours each. Notable macroscopic volume loss progressed rapidly, particularly on the specimen (X-19) that was a full rib. This suggests anecdotally that splitting and smoothing ribs may contribute to a longer tool uselife. Wear after hide-scraping is macroscopically visible as a bright, smooth sheen. Microscopic polish is bright, invasive and rounded. Few striations are present and they are oriented irregularly. Substantial rounding of the microtopography has taken place and there is substantial pitting.

Figure 7.7. Hide-scraping with a spatulate tool made from a modified rib (X-32)

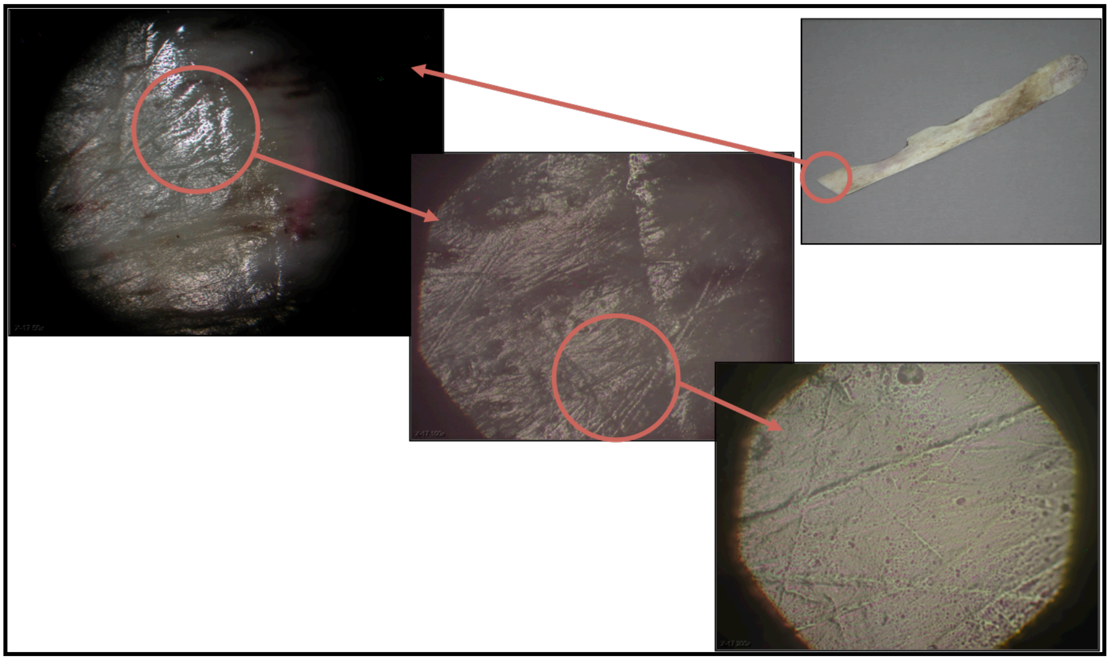


Figure 7.8. Spatulate tool with use wear from hide-scraping (X-17)

7.2.1.2.3. Sewing:

Sewing is a task I regularly complete for repairs and patches, although only rarely for more complex tasks. My sewing level is intermediate. Unlike weaving, there is more variation in the gestures used in sewing, but because the needle passes through the sewn material, wear patterns are more strongly affected by this action, which varies minimally with skill level.

Two needles, (X-24, X-28) were used in sewing experiments. The wear on the needles is similar; I will only describe one of them here. X-24 is a needle used to sew fabric made from twisted nettle in a simple weave. The fabric was sewn with twisted nettle cordage that is coarser than the cordage used to weave the fabric. After 45 minutes of use, a

bright, invasive, rounded polish is present on the eye. There is minor rounding of microtopography, with very limited pitting. Striations are not present. On the mesial face of the needle, a similar bright, rounded polish is present, but is non-invasive. There are no striations or pits and microtopography is not notably smoothed.

Figure 7.9. Sewing nettle fabric with twisted nettle cordage (X-24)

7.2.2. Tribological Assessment of Results

The results obtained through experiments were also assessed with the tribological model. Although the surfaces used against animal fibers generally fit the predictions for animal fiber wear, plant fiber surfaces yielded more variable results (Table 7.X). Both striation organization and the form of polish deviated from the predictions in numerous cases. As has been noted, there is little agreement among bone tool use wear analysts of the kinds of striations that are characteristic of different fiber classes. The results from experimentation here indicate that this may be because striations are not strongly patterned by material class. The lack of agreement in polish roundedness or flatness is surprising, but may be related to duration of use.

Table 7.4: Tribological Assessment of Experimental Surfaces

Study ID	Use Material Group	Polish	Attrition	Striations Present	Striation Organization	Striation Size	Edge Rounding	Pitting	Total: Tribological Predictions for Animal Wear	Total: Tribological Predictions for Plant Wear	Total: Neutral Tribological Predictions
X-1	Animal	invasive	rounded	Yes	regular, patterned	similar	substantial rounding or volume loss	few or none	3	2	2
X-1	Animal	invasive	rounded	Yes	disorderly, irregular	vary	limited rounding or deformation	few or none	4	1	2
X-5	Animal	invasive	rounded	No	NA	NA	limited rounding or deformation	frequent	2	1	4
X-7	Animal	non-invasive	flat or planar	No	NA	NA	limited rounding or deformation	few or none	0	3	4
X-16	Animal	invasive	rounded	Yes	regular, patterned	vary	substantial rounding or volume loss	few or none	4	1	2
X-17	Animal	invasive	rounded	No	NA	NA	substantial rounding	frequent	4	2	1

Table 7.4: Tribological Assessment of Experimental Surfaces											
Study ID	Use Material Group	Polish	Attrition	Striations Present	Striation Organization	Striation Size	Edge Rounding	Pitting	Total: Tribological Predictions for Animal Wear	Total: Tribological Predictions for Plant Wear	Total: Neutral Tribological Predictions
							or volume loss				
X-17	Animal	invasive	rounded	Yes	regular, patterned	similar	substantial rounding or volume loss	frequent	4	2	1
X-19	Animal	invasive	rounded	No	NA	NA	substantial rounding or volume loss	frequent	4	0	3
X-32	Animal	invasive	rounded	Yes	disorderly, irregular	vary	substantial rounding or volume loss	frequent	6	0	1
X-2	Plant	invasive	rounded	No	NA	NA	substantial rounding or volume loss	few or none	3	0	4
X-2	Plant	non-invasive	rounded	Yes	disorderly, irregular	similar	limited rounding or deformation	few or none	3	2	2

Table 7.4: Tribological Assessment of Experimental Surfaces

Study ID	Use Material Group	Polish	Attrition	Striations Present	Striation Organization	Striation Size	Edge Rounding	Pitting	Total: Tribological Predictions for Animal Wear	Total: Tribological Predictions for Plant Wear	Total: Neutral Tribological Predictions
X-3	Plant	invasive	rounded	No	NA	NA	substantial rounding or volume loss	few or none	3	0	4
X-24	Plant	invasive	rounded	No	NA	NA	limited rounding or deformation	few or none	2	1	4
X-24	Plant	non-invasive	rounded	No	NA	NA	limited rounding or deformation	few or none	1	2	4
X-25	Plant	invasive	flat or planar	Yes	regular, patterned	similar	substantial rounding or volume loss	few or none	2	3	2
X-26	Plant	non-invasive	flat or planar	Yes	disorderly, irregular	similar	substantial rounding or volume loss	frequent	3	2	2

Table 7.4: Tribological Assessment of Experimental Surfaces

Study ID	Use Material Group	Polish	Attrition	Striations Present	Striation Organization	Striation Size	Edge Rounding	Pitting	Total: Tribological Predictions for Animal Wear	Total: Tribological Predictions for Plant Wear	Total: Neutral Tribological Predictions
X-28	Plant	non-invasive	flat or planar	Yes	disorderly, irregular	vary	limited rounding or deformation	few or none	2	3	2
X-28	Plant	non-invasive	flat or planar	Yes	disorderly, irregular	similar	limited rounding or deformation	few or none	2	3	2
X-30	Plant	non-invasive	rounded	Yes	disorderly, irregular	similar	limited rounding or deformation	few or none	2	3	2

*Yellow indicates tribological prediction for animal wear; Green for plant wear; Blue for neutral states

7.3. Future Work

The experiments described here can only begin to help define use wear standards for archaeological analysis. There are many other variables that need to be addressed. As will be presented in the next chapter, the microscopic study of ethnographic collections can provide further and complementary data to help close this gap in the standards for use wear analysis. However, many other variables should also be incorporated into future experimental work to expand on this experimental program. Most importantly, working reeds and bark was not attempted here and represents an important gap in the materials studied. Work of longer duration is also clearly necessary. As discussed, the duration of work appears to have a strong effect on microtopographic rounding in this experimental collection, a result not reported elsewhere. Finally, experiments need to be replicated, so that variation related to factors other than wear can be isolated, and the association of surface attrition with use can be demonstrated more reliably. Thus, further study and experiments are necessary to understand this pattern and determine if it is a robust pattern or due to some other variable.

Chapter 8. Analysis of Ethnographic Collections

In this chapter, I present the analysis of ethnographic artifacts, that comprises the largest sample in the project. In Chapter 5 (Methodology), I argued that ethnographic materials provide a powerful complement to experimental archaeology for constructing use wear standards for the analysis of archaeological collections. Here, I describe the ethnographic artifact and archival collections selected for analysis and aspects of the cultural and ecological background of the groups represented in this sample. I describe the strategy I employed when selecting ethnographic specimens for study. I then discuss morphological patterns in ethnographic tools, emphasizing that form and function have no one-to-one correlation. Finally, I will present the use wear analysis of ethnographic tools and assess the attrition patterns against the predictions derived from the tribological model for wear of fibers against bone. I will compare the results from the experimental and ethnographic use wear analyses and identify modifications of the tribological model that are indicated by the results. Use wear traces indicate that the majority of the predictions developed through the tribological framework and described in Chapter 4 (Tribology) were borne out in the ethnographic sample. This will allow me to construct standards for the assessment of archaeological use wear patterns.

Finally, I identify ways that the detailed study of ethnographic museum artifacts can inform on questions of interest to archaeologists, ethnologists, and museum professionals. The use of ethnographic museum collections for archaeological research

is a controversial topic, and many researchers are unsure of the validity of these collections for scientific study. I outline in more detail the commonly identified problems with these collections and the basis on which I argue that, indeed, ethnographic materials constitute a valuable and extensive resource for the production of comparative standards for the assessment of archaeological artifacts. I close the chapter with suggestions of some other kinds of research that might also employ ethnographic museum collections to answer archaeological questions.

8.1. Goals of the Study of Ethnographic Collections

By *ethnographic collections*, I am referring to objects collected from living people in the modern or late historic periods, along with the contextualizing documentation that accompanies these artifacts. Thus, the objects have an age that ranges from a few years to about 200 years, but come from documented use contexts. Unlike ethnoarchaeological collections, ethnographic artifacts were not obtained or documented with archaeological goals in mind, but were the result of ethnographic research. Finally, in this context I am referring to objects that are curated in museums of indigenous culture, anthropology, or natural history, although there are many other sources for ethnographic material culture.

My decision to use ethnographic materials in this study is framed by three goals:

1) begin to investigate the range of variation documented in the known record of worked bone use, including aspects of the manufacture, use, and social roles of bone tools, their users and their makers;

2) provide a sample of use wear with known history of accumulation that complements experimental studies and assists in the creation of comparative standards for attrition on bone artifacts recovered from the archaeological record;

3) test the tribological model that was designed to help predict kinds of bone use wear created with different materials.

The largest collection of the three kinds of specimens studied in this project consisted of tools made of bone, antler, and occasionally other osseous materials from ethnographic collections housed in US museums. In total, 952 objects were originally considered, based on morphology and documentation, of which 581 were selected for macroscopic study after assessing their accompanying documentation, while a smaller sample of 129 was studied microscopically.

8.2. The Study of Material Culture in Ethnographic Museums

There are many museums in North America and worldwide that house collections of artifacts with documented histories. As archaeologists aim to use material culture to understand the past, these collections represent a large data source. Despite the wide availability of ethnographic artifact collections, archaeologists have not regularly incorporated these resources into their studies. There are a series of objections raised to the study of ethnographic artifacts for archaeological purposes. These objections fall into two main groups: 1) concerns about the nature of documentation; 2) concerns about the objects. The concerns about the documentation of object use arise because of the suspicion that the documentation of ethnographic collections is:

- *Insufficient*: the documentation is highly normalized and does not reflect true use patterns

- *Unreliable*: the ascribed uses do not reflect cultural practices

- *Nonexistent*: there is minimal documentation of the questions that tend to interest archaeologists or other students of material culture

- *Biased*: historical attitudes, lack of communication, and resistance to colonization all skew reports of object life history and use and result in significant gaps and some errors

Regarding the objects themselves, there are concerns that artifacts housed in museum collections:

- *Are not representative of the range of certain tool types and constitute a biased sample*: people are unlikely to give up their most important tools or their most prized objects, so those pieces that end up in ethnographic collections constitute an impoverished sample that does not represent the kinds of objects found in a living context

- *Have been subject to excessive handling and consolidation*: the objects have been treated as art objects rather than as material documents of cultural practice

- *Have complex life histories*: even if reported and documented functional names can be trusted, in practice tools and object are subject to non-ascribed uses, repair and reclamation practices, and other practices that alter the linear connection between function and condition at the time it was collected

While there is some truth to each of these concerns, none of these issues are insurmountable. The ethnographic and ethnohistoric artifacts and documents housed in museum collections provide a rich source of information on material culture and the role it plays in human lifeways. By emphasizing the study of physical objects with the methodologies developed within archaeology, useful comparative standards can be constructed from ethnographic collections.

Given the overarching aims of this research, I focused on use-related attrition on bone tools used in a very limited set of tasks. However, the study of objects in museums can be broader than the task-based research presented here, as many kinds of data can be obtained from these collections. An understanding of the morphological variability of osseous tools in the ethnographic and ethnohistoric record strengthens and enriches our approach to other analyses of archaeological tools, but variability is not the only information that can be obtained from the study of ethnographic artifacts.

The patterning in tools in the ethnographic record includes form, use, wear, repair, discard, and museological aspects of tool condition and attrition. These data can inform on the analysis of archaeological material at the artifact level by providing information on the relationships between morphology, manufacture, use, condition and meaning. Information on the variation of morphology within different tool types and on manufacture and raw material choices can be obtained, which not only contributes "cautionary tales" that reduce the simplicity of archaeological understanding of material culture, but also enrich our ways of thinking about objects and people. These analyses help indicate ways that archaeologists can make useful analogies about behavior through artifacts.

If the function and history of the tool is fairly well-known, handling and wear patterns can be linked with material and gesture. The condition of the object at time of discard can be recorded, although given the diverse ways that objects enter the museological record, this cannot indicate anything beyond the level of the individual tool. From a

meta-analysis of methodology of museum collections, the study of these collections lends itself to understanding museum practices of curation and conservation and identifying changes in museum practice that might affect both ethnographic and archaeological collections. Finally, in some cases, the information generated through experimentation and archaeological study might help clarify the history of some ethnographic objects, as the assigned names and functions can be assessed based on artifact surface attrition.

Many of the objections raised to the applicability of ethnographic museum collections to archaeological studies are resolved when the unit of analysis is scaled at the working surface or artifact zone. As discussed in Chapter 5 (Methodology), observations were carried out in the same manner as those used for archaeological and experimental materials, which provides comparative robusticity.

8.3. Ethnographic Museums Collections Studied and Criteria for Specimen Selection

This study of ethnographic materials was aimed at constructing standards for the surface attrition patterns resulting from the use of bone and antler artifacts to process fibers, weave, make basketry, work leathers and hides, and sew. On a higher scale, the aim was to distinguish between wear from fibers of plant and animal sources, while

finer grained information was also anticipated. Given this goal, the social and physical context of use represented important information but did not constrain my artifact choices. I was interested in contact between bone and soft surfaces, regardless of other cultural variables.

As I am considering artifacts from an archaeological population with no direct or evident cultural links to any living peoples, I draw analogies of worn artifact surface similarity, organized through the lens of tribological principles. That is, I am comparing *attrition*, not *artifacts*. Because there are no direct analogs for Upper Paleolithic tools in museum collections of objects of contemporary and historic origin, I employed a sampling strategy based on contact surfaces, focusing on osseous tools used to manipulate plant and animal fibers during basket-making, weaving, netting and hide-working in order to understand the wear patterns that result from contact between bone and soft fibers of diverse kinds. The benefit of this approach is that it resulted in an increase the range of artifacts studied, along with a larger overall sample, because I considered artifacts from any historical or contemporary group where bone tools were used to modify plant or animal fibers.

Additionally, because I was interested in identifying subtle differences in wear patterns, I needed required use history records. Unfortunately, such documentation is fairly rare in most museum collections, with the result that the potential sample was small, even without restricting my research on the basis of region or socio-economic patterns. All bone tools used in the production of plant or animal perishables were considered for

analysis and objects were selected based on accompanying archival documentation and surface condition. To maximize the sample size, objects were selected only by the amount of wear present and the presence of artifact life history information.

Because of the importance of bone and antler tools in the processing of plant and animal soft materials, the presence of such tools may be indicative of the production of perishable artifacts that are themselves no longer present in the archaeological record. However, because many of the functional tool types vary significantly in both morphology and precise function, *there is no one-to-one correlation* between archaeological artifacts and specific fiber technologies. When considering the kinds of perishable industries that might have been produced in the past, it is also important to remember that one of the difficulties in reconstructing their production is that many of the steps in the procurement and processing of fibers and the manufacture of cordage, baskets, nets, or woven cloth require few implements and many can be accomplished entirely by hand (Adovasio 1977; Hurcombe 1994, 2008a, b, 2010; Mason 1988 (1904)).

I selected four museums, based on their large collections and the logistical feasibility of visitation: the American Museum of Natural History in New York City (AMNH), the Smithsonian Institute's National Museum of Natural History (NMNH) and National Museum of the American Indian in Washington, D.C. and Suitland, MD (NMAI), and the Burke Museum of Natural History and Culture at the University of Washington in Seattle, WA (Burke). The decision was also guided by the size of the bone tool assemblages housed at these museums and the logistics of travel. From each museum, I

requested a database search for all bone needles, awls, battens, and weaving implements from ethnographic collections. Using the list, I eliminated those objects that fell outside of the defined set – tattoo needles, for example – and those objects that did not have a clear indication of use. Sewing needles I retained so that I could check archival records upon arrival for more detailed information on use. Many tools have names that suggest the material they were used on: snowshoe needles and mat needles are the best examples. Before examining the physical objects, I consulted published and unpublished museum archives related to the collections, which also helped eliminate those objects whose function appeared to be ambiguous or attributed by the collectors, rather than the people who made and used the objects. Ultimately, this process allowed me to exclude the vast majority of artifacts from study based on missing information or attribution. Once I began to study tools, I had a small subset of the objects originally identified in the database search (see Table 8.1 for a summary of these objects), but I was sure of at least some of their life and use history.

Table 8.1: Ethnographic Collections Studied																
Museum	Origin Area	Eyed Sewing Needles	Eyed Snowshoe Needles	Eyed Mat Needles	Eyed Fish Needles; Large Needles Use Unk.	Completely Worked Awls	Articular Awls	Basketry Awls	Weaving Awls & Batens	Net Needles & Guages	Bone Points	Pins, Bodkins	Wound Plugs, Pegs	Hide Scrapers	Worked Rib Tools	Total
AMNH	Arctic		5		8	14	5				11	1	1			45
	Calif. Coast						9	1								10
	NE N. Am.		2			1	6						5			14
	Pacific NW			1	1	7	27				4		12			52
	N. Am. Plains	1	4	10			2		1							18
	SW N. Am.					2	9	1	8							20
	Total AMNH	**1**	**11**	**11**	**9**	**24**	**58**	**2**	**9**		**15**	**1**	**18**			**159**
Burke	Arctic	7							3	3						13
	Pacific NW	1		24		2		1		12						40
	SE Asia							1								1
	SW N. Am.							5								5
	Oceania			7			9									16
	S. Am.							1		1						2
	Total Burke	**8**		**31**		**2**	**9**	**8**	**3**	**16**						**77**

Table 8.1: Ethnographic Collections Studied

Museum	Origin Area	Eyed Sewing Needles	Eyed Snowshoe Needles	Eyed Mat Needles	Eyed Fish Needles; Large Needles Use Unk.	Completely Worked Awls	Articular Awls	Basketry Awls	Weaving Awls & Batens	Net Needles & Guages	Bone Points	Pins, Bodkins	Wound Plugs, Pegs	Hide Scrapers	Worked Rib Tools	Total
NMAI	Arctic	4			6		4				6	11			5	36
	Calif. Coast			1	1	2	2				2	1	13		1	23
	NE N. Am.	8	66	21	4	8	10				2			2	1	122
	Pacific NW			6				4			1					11
	N. Am. Plains	2		22	1	4	2				1		4	1		37
	SW N. Am.						13									13
	S. Am.	1					6	4	2							13
	Total NMAI	**15**	**66**	**50**	**12**	**14**	**37**	**8**	**2**		**12**	**12**	**17**	**3**	**7**	**255**
NMNH	Arctic	21	7		1		2				1		4			36
	Calif. Coast						1	1								2
	NE N. Am.	10		1												11
	Pacific NW			1			1	2								4
	N. Am. Plains			5												5
	SW N. Am.	1				5	2	3	3							14

Table 8.1: Ethnographic Collections Studied

Museum	Origin Area	Eyed Sewing Needles	Eyed Snowshoe Needles	Eyed Mat Needles	Eyed Fish Needles; Large Needles Use Unk.	Completely Worked Awls	Articular Awls	Basketry Awls	Weaving Awls & Batens	Net Needles & Guages	Bone Points	Pins, Bodkins	Wound Plugs, Pegs	Hide Scrapers	Worked Rib Tools	Total
	S. Am.	2				1	1	1								5
	Oceania			3	1		2	4	1							11
	Siberia				2											2
	Total NMNH	**34**	**7**	**10**	**4**	**6**	**9**	**11**	**4**		**1**		**4**			**90**

*types drawn from museum catalogs; **AMNH = American Museum of Natural History; NMNH = Smithsonian National Museum of Natural History; NMAI = Smithsonian Museum of the American Indian; Burke = Burke Museum of Natural History and Culture; Am. = America; Calif. = California

Several contemporary and historic bone knitting needles, awls, and one bone handle for a metal awl were also included in the ethnographic collection. These were acquired from a friend whose mother had knitted with bone knitting needles and from purchases made in antiques stores and online. Although there is no information on the use history of the objects from the antiques stores, they provide an interesting addition to the collection, as they represent some artifact forms that were not studied in the ethnographic collections. The bone handle and the handled end of the knitting needles, in particular, help document handling wear, a kind of wear pattern that was overlooked in the initial planning of the ethnographic study and so was not directly accounted for in any way among the ethnographic artifacts.

8.4. Bone Tools and the Manufacture of Fiber Technologies in the Ethnographic Record

The ethnographic and ethnohistoric records demonstrate that osseous tools are frequently employed in sewing, weaving, basket weaving, and hide-working (Amato 2010; Densmore 1929; Mason 1988 (1904); Murdoch 1892). Because individual ethnographic case studies cannot be taken as representative of broad patterns of human behavior, I highlight broader patterns that describe some cross-cultural aspects

of bone tool use in the ethnographic record. I examined local practices concerning the production and use of bone tools for perishable industry manufacture; in many cases the use of bone tools in similar activities does not vary across region or population. The primary kinds of artifacts used in this dissertation are needles for sewing, snowshoe-netting, and mat-making, awls for hide-working, basketry and weaving. There are other common classes of osseous artifacts also involved in the production of perishable technologies, that were not selected for study. In particular, there are many kinds of artifacts involved in making nets and snares that were excluded from study (Figures 8.1-8.3), in part because formal analogs are absent from the Late Upper Paleolithic record.

Figure 8.1 AMNH Anthropology T-22457

Figure 8.2 Eskimo net mesh gauges, Alaska, CapePrince of Wales (NMAI 226999 & 226976)

Figure 8.3 Net needles of varied origin (Burke 2158, 1.2E1335, 2732, 2779, 1746, 1682, 2350, 1308, 2747, 1313, 2743)

As reported by Campana (1989), ethnographic evidence corresponds well to our understanding of the mechanical and physical properties of bone. If blanks need to be cut out, bone is often used fresh or soaked or steamed before working (groups cited: Maori, Salish, San). Blanks for bone tool production can also be produced by somewhat less controlled means: bones can be heated quickly in a fire, leading them to shatter longitudinally (Micmac awls, Salish needles), or can be struck with a hammer, also

producing long fragments. Blanks can then be shaped by cutting and scraping (Andaman Islanders, Arande, Copper Eskimo) or abrasion (Aleuts, Andaman Islanders, Micmac, New Guinea Highlanders, Ojibwa-Chippewa, Ona, Salish, Yaghan). Perforations may be made with mounted flint drills (Maori) or rodent teeth (Kuma of New Guinea). Polishing is a common final step and can be done with many materials, including pumice, sharkskin or with horsetails (*Equisitem nymale*), which contain silica, an abrasive (Aleut, Salish) (Campana 1989). In North America, the introduction of metals by Europeans may have also lead to some changes in the ways that bone tools were made and used (i.e., Speck 1911 on the Huron; Griffitts 2006; see Olsen 2003 for an older example of the same phenomenon at Iron Age Fiskerton). Before the development of metal-working technology, needles and awls of diverse forms were typically made from bone in a wide range of archaeological and ethnohistoric contexts (Kidder1932; Griffitts 2006).

These tools can take many forms and many of these shapes can also be employed in other tasks, meaning that the analysis of tool morphology is only the first step in determining tool function and the production sequences of perishable industries. Despite the utility of osseous materials for creating tools for working flexible organic materials, other materials are also commonly used. Wood is frequently used in the same ways as bone; the choice may be based on raw material availability, tradition, or may be random (Choyke 2005; Scheinsohn 2010). In the following chapter (Ethnographic Case Studies) I examine the case of snowshoe needles in great depth. As will be shown, most snowshoe needles are made of bone, but even within the same

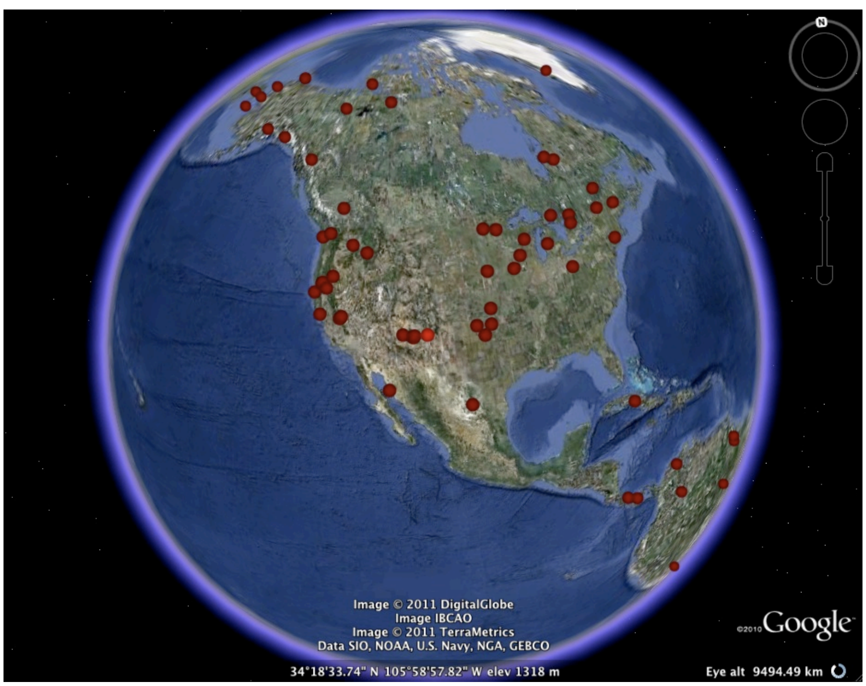
community and at the same time, needles of the same shape and use are sometimes made from wood and steel. This is true of many ethnographic tools and is undoubtedly the case in the past as well.

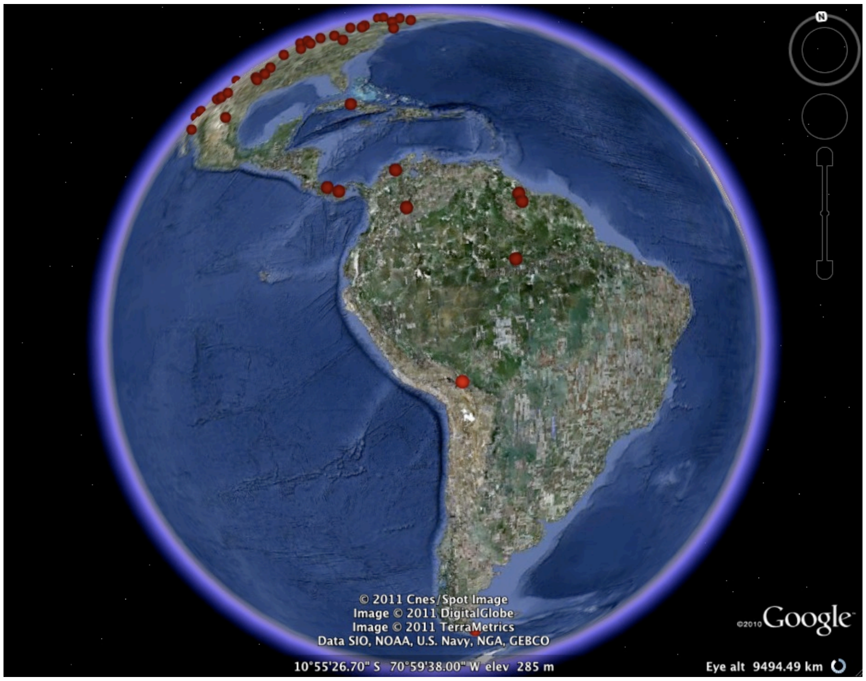
8.4.1. Ethnographic Background by Region

To facilitate comparisons among and between groups, I assigned the ethnographic collections to geographic groups, reflecting both broad environmental variation and the diverse histories of bone tools use among different peoples. Here, I consider some of the patterns of bone tool use by region. The similarities among the populations within the groups reflect both the constraints and opportunities inherent in different environmental and ecological contexts along with the history of ethnographic research in these various regions. Because the ethnographic sample was large and unevenly distributed, I will discuss only those regions that contributed significant samples to the ethnographic study. These brief descriptions should not be taken as suggestions for how bone tools were used by the Late Upper Paleolithic people of Northern Spain but rather situate the use of these tools in living historical and cultural context.

There are some redundancies in the collections but museums have different strengths or focuses, resulting in the unique make-up of each collection. Furthermore, osseous technologies are, of course, more common in some places than in others, due to

cultural histories and well as the availability of other materials to make the same tools, so the distribution of the study is geographically uneven. As can be seen in Figures 8.4a-c, the majority of the collections studied come from groups in North America. All of the museums that were included in the ethnographic portion of the study are from the US, so while there are artifacts from throughout the globe, the vast majority are from North America. Africa, in particular, is highly underrepresented in the sample, even though the osseous industry, basketry, bark working, weaving, dying and hide-working industries from many parts of Africa are renowned (Camps-Fabrer 1966; Perani and Wolff 1999).





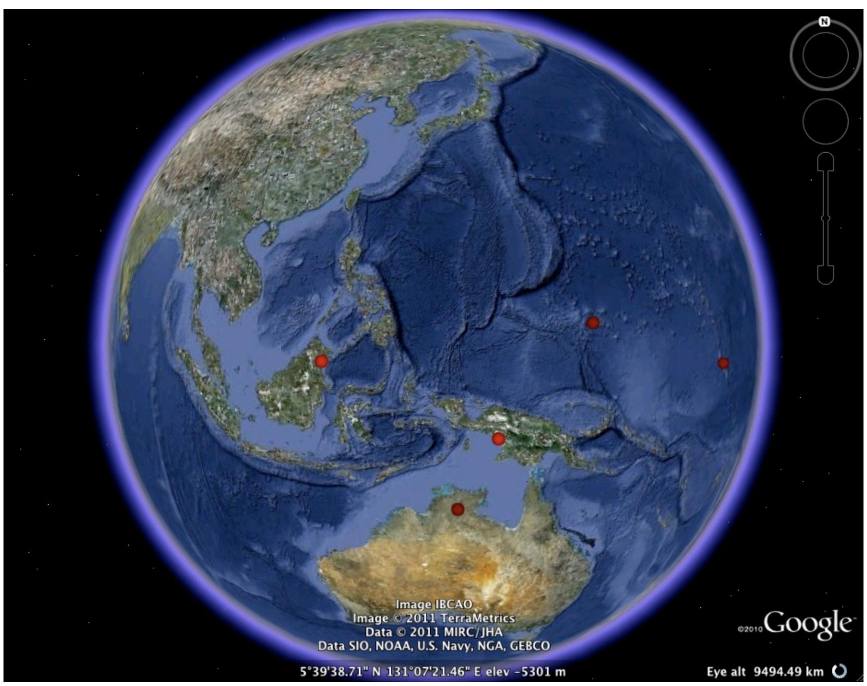


Figure 8.4a-c. Locations of origins of ethnographic artifacts studied

Because these are the largest collections, the following discussion will focus on American indigenous use of worked bone. Some people in most of the regional groups discussed below continue to engage in traditional artisanship but metal and plastic have replaced bone in many cases. The process and reason for the replacement of osseous technologies are not central here and I will not address this complex topic. For a study of this phenomenon in central North America, see Griffitts (2006). I will focus my discussion on the use of bone tools to produce soft organic technologies without temporal reference.

8.4.1.1. The Arctic

The detailed, complex, virtuosic bone-working of people in Arctic communities is well-known (Damas 1984; McGhee 1977; Meade and Fienup-Riordan 2005; Osgood 1970). Although ivory figurines are among the more famed artifacts, the bone and antler industry of many Arctic populations is large, diverse and sophisticated. Many osseous artifacts made in the Arctic were employed in the production of perishable technologies: needles, awls for hide working and basketry, shuttles, and net gauges are among the most common (Figures 8.5-8.9). Sewing needles were reported to have been made from hare teeth sometimes, but later ethnographers suggest that these were actually awls (Hoffman 2002; Owen 2005). Needles were made from the bones of large birds such as gulls while needle cases, drinking straws, and beads were made from the

tubular long bones of many birds. Fish bones were also occasionally made into needles and awls.

Figure 8.5. Net mesher, Eskimo Nuwukmiut, Point Barrow, Alaska (NMAI 047003)

Figure 8.6. Eskimo awls, Northwest Alaska (AMNH Anthropology 60/1717 and 60/1718)

Figure 8.7. Needle, Eskimo Nuwukmiut, Point Barrow (NMAI 048457)

Figure 8.8. Awl and sinew twisters, Eskimo, Northwest Territories, Canada (NMNH E001321)

Figure 8.9. Needle case with two bone needles (NMAI 021807)

The hide and gut clothing made in the Arctic is also famed, especially for its utility and effectiveness as protection against extreme conditions (Burnham 1992; Gilligan 2007, 2010; Issenman 1997; King, et al. 2005). Women were primarily responsible for making clothing, a task that occupied a good deal of their time. However, all men also knew how to sew and had to be prepared to repair clothing that rips when away from home. Seal gut and caribou leather and hides were the most common materials for making clothing. However, many other animal products were converted into clothing and objects. Hare skins were used to make a variety of clothing items, although their skin is so thin that when used as boot liners or other extensively worn items, they had to be replaced every few days. Making a robe of rabbit skin twisted around cordage to strengthen the fabric could take 100 skins for an adult and 40 for a child. Small carnivores such as the fox and wolverine were also trapped, although primarily for their

fur and their importance increased dramatically with the fur trade with Westerners. The skins of waterfowl were made into clothing, blankets, and other items. Feathers could be used as insulation or decoration. Fish skins were sewn into clothing to provide better water resistance (Owen 2005).

Archaeological evidence from the later prehistoric period suggests that perishable industries have long played a major role in Arctic life. In terms of craft activities, although it is difficult to weigh the importance of crafts based on their tool kits, Murdoch (1892) argues that leather working and basketry or textile production both seem to have been among the most common tasks in many historic and prehistoric communities at Point Barrow, based on the prevalence of such artifacts.

8.4.1.2. North American Desert Southwest

The deserts of the North American Southwest are and have been home to numerous populations with diverse subsistence, economic and socio-political strategies. However, the tasks that are completed using bone tools do not reflect this broad cultural diversity, but rather are somewhat similar across cultural boundaries. The local raw materials available to these peoples are similar, leading to similar ranges of contact materials worked with osseous tools.

Perishable industries are important crafts in the Southwest. Hides and leathers, baskets, and woven textiles are all produced in large quantities and today constitute an important economic resource through marketing the product of these industries. The ethnographic collections of bone tools from these regions reflect the role of perishables in the production systems in the Southwest. Seri collections, for example, yield dozens of basketry awls. Bone tools had no less importance historically (i.e., Kidder 1932). One interesting aspect about basketry and weaving awls from the Southwest is the great morphological diversity of the tools used for essentially the same purposes. Awls for weaving and basketry both vary substantially across communities (Figures 8.10-8.12).

Figure 8.10. Hopi Pueblo, basketry awls (NMAI 090624)

Figure 8.11. Zuni Pueblo, weaving awl, (NMNH E234480)

Figure 8.12. Basketry awls, Seri, Sonoma, Mexico (Burke 3-12314-12318)

8.4.1.3. North American Plains

North American Plains indigenous groups are numerous and diverse, however, there are some common activities and tool types found in the region. Plains cultures are particularly known for virtuosic hide working traditionally done by women and which make use of several kinds of bone tools (Densmore 1929; Lapham 2005; Speck 1911; Spector 1991). One common tool from this region, the snowshoe needle, will be examined in depth in Chapter 9 (Ethnographic Case Studies). The bone industry of the Plains is large and includes a wide range of tools used in the manufacture of perishable industries, especially hide working: scrapers, beamers, awls, sewing needles, mat needles, and others (Griffitts 2006) (Figures 8.13-8.16).

An extraordinary resource for understanding bone tool use in the historic era of the Plains is the work of Frances Densmore. Densmore did fieldwork among the Chippewa (Ojibwe) in the early 1900s for the Smithsonian and produced large collections now housed in both NMNH and NMAI which contributed numerous specimens to this study (Densmore 1929, 1974). She was particularly interested in basketry but provided documentation on other aspects of daily life. Additionally, she spent a good deal of time documenting women's lives and tasks, making this a valuable and unusual resource. She notes common use of the following animals for hides and sinew: moose, deer, rabbit, and less commonly, otter and muskrat. Sinew was used for sewing hides; an awl of bone, metal or wood, or an unmodified thorn was used to pierce the hide and the sinew

was dampened in the mouth and threaded through the hole. Hides were commonly prepared by brain-tanning or by smoking. Rabbit hides needed no tanning and were left to dry outside in the wind, which blew off hair that was not tightly attached to the hide. Sinew was also used for bowstrings.

Plant materials were also widely used for sewing, weaving, and the production of household objects. Nettle fiber was woven into cloth, knotted into fishing nets, and used for a number of other purposes. Generally the fiber was extracted from stalks that had been allowed to mature, die, and dry in the field and were picked as needed. Another common plant fiber was made from the inner bark of the basswood tree, which could be processed in a number of ways. Generally it was retted in a pond for about 10 days and could then be twisted. Basswood fiber treated this way could be used for a number of different tasks, depending on the thickness used. When a very strong twine was needed, the cordage could be boiled to strengthen it. Bark fibers could be softened and separated from woody sections by being drawn through a bear pelvis. Untwisted fibers were also used for some purposes, although they were more difficult to prepare as they had to be processed without being allowed to dry out and were not as strong. Aside from these two fiber sources, various other plants were used. The bark of slippery elm or cedar could be twisted into a fiber, as could the root covering of bulrushes. Bulrushes and cattails were used for the production of floor mats. Awls and bone needles were sometimes used in mat-making. Mats for the sides of wig-wams were often made from cattails using basswood fiber sewn with a long, flat bone needle (Figure 8.16). Bags were made from a wide range of materials, including roots, and

slippery elm, cedar and basswood bark fiber. Blankets were sometimes woven of rabbit skin. When Densmore was with the Chippewa, trade goods such as yarn, broadcloth, woven blankets, and beads were common and these materials were readily incorporated into the production of clothing and household goods.

Figure 8.13 Awl, Winnebago (AMNH Anthropology 50.1/2236)

Figure 8.14 Awl, Comanche,Oklamhoma (NMAI 021396)

Figure 8.15. Awl, Modoc, Oklamhoma (NMAI 193315)

Figure 8.16. Mat needles, Winnebago, Nebraska (NMAI 141091)

8.4.1.4. Summary

Bone tools are common in the ethnographic record and are frequently used in the manufacture of plant and animal fiber technologies. Bone is a widely available raw material and the properties of bone are conducive toward its use for the production of tools for procuring, processing and manipulating soft materials into objects. Although the kinds of perishable technologies produced, the tools used to make them, and the social organization of production vary, the general association of bone tools with perishable industries is robust, if not completely uniform. Patterns in the ethnographic record suggest that wear on bone tools may provide evidence of perishable technologies that no longer preserve in the archaeological record.

8.5. Documentation and Archives in Ethnographic Museums

One of the key factors in determining the potential of an ethnographic collection or an item for incorporation into an archaeological study is the presence and nature of accompanying documentation. Documentation can take the form of accession records, collector's notes, comments and analysis from source communities, interviews with the creators and users of the tools, published synthesizing reports, or later publications based on the objects or collections. Currently, many of these sources are combined into the primary artifact database for museums and are available from the early stages of

project planning. For example, AMNH allows researchers to search both objects and selected archival documents online. This compression of sources can occasionally lead to problems as the reliability of data is more difficult to assess. The attribute most likely to be unreliable, however, is the name ascribed the object. I have generally discarded the name since it is uninformative if it is the only information available.

The facilities available to archaeologists at museums vary, but most ethnographic and natural history museums do not have the equipment necessary for microscopic study of artifacts. Archaeologists who wish to carry out such studies are advised to plan on providing their own equipment. Some means of creating micrographs is also recommended for later consultation. Portable microscopes are expensive, unwieldy, and difficult to obtain. Although I was able to bring my metallurgical microscope to NMNH for the microscopic study of a subsample of artifacts, time and budgetary concerns prevented me from returning to all of the museums with this instrument. One alternative that allows at least some level of magnification and picture-taking ability comes from an unlikely source: children's toys. The Digital Blue Q5 children's microscope, despite its bright purple exterior, can be used to take photographs at 60x that can document volume loss and the distribution and orientation of larger striations (Figures 8.16-8.17). Although not a replacement for a true microscope, this is an economical, lightweight, durable and easy to transport means of preliminary study and would probably be sufficient for many studies of manufacture, use-related fractures, or decoration.

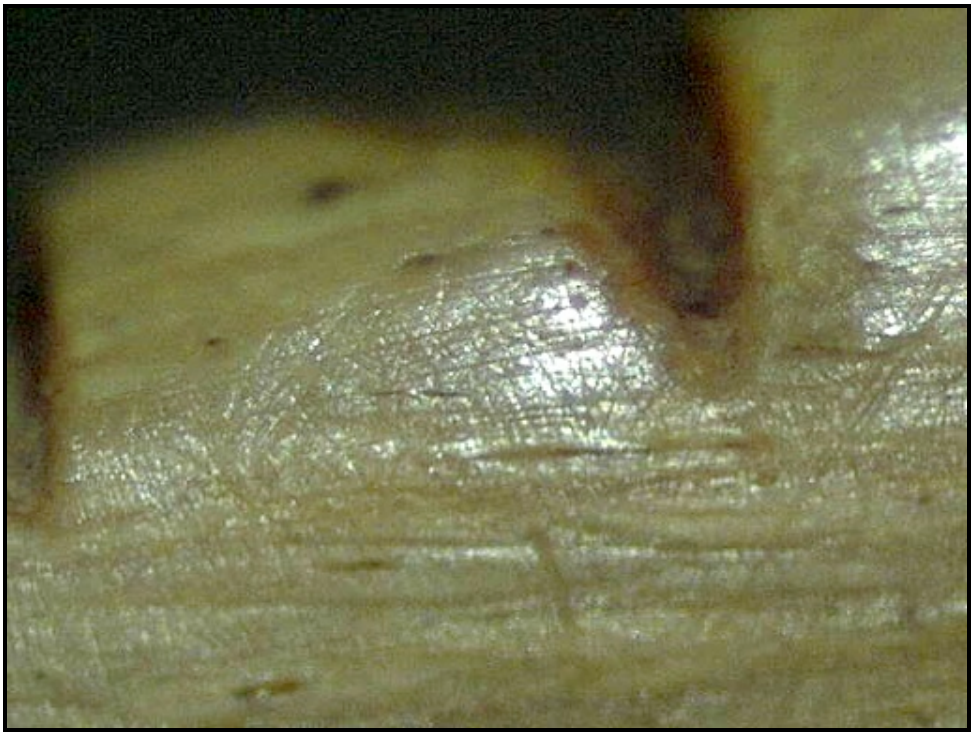


Figure 8.17 Hawikuh weaving batten, 60x (NMAI 066490)

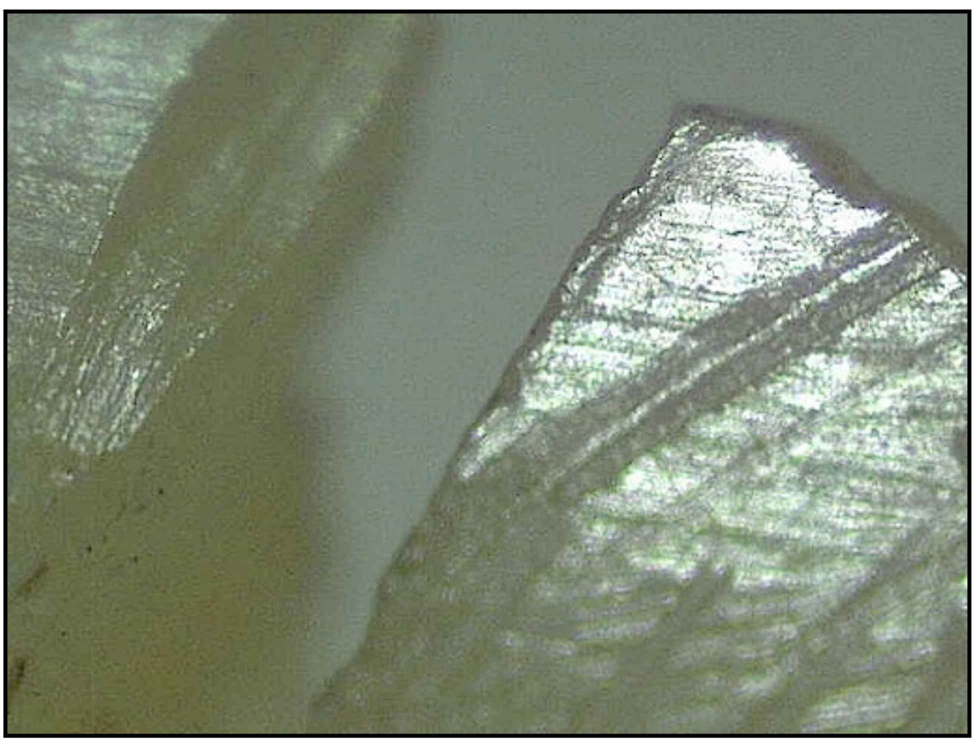


Figure 8.18 Cree hide-scraper, 60x (NMAI 253335)

8.6. Results

There are three main kinds of results that were obtained from the ethnographic study: information on macroscopic variation in bone tools used for the manufacture of perishable technologies; microscopic and tribological data on the wear patterns resulting from contact between worked bone surfaces and soft organic materials; implications for the use of ethnographic objects as part of archaeological studies. I discuss each in the following sections.

8.6.1. Morphological and Macroscopic Variation in Ethnographic Tools

Initially, the study of ethnographic and historical tools focused on the morphological variability of tools used for different purposes related to the production of perishable technologies. I focused in particular on whether there is a correlation between form and function. Then I defined some aspects of the range and kinds of variation in bone needles, awls, and other tools.

Morphological groups, such as those that typically drive archaeological typologies, could be constructed for ethnographic artifacts, but it is clear that these groups would not reflect function. Tools for the same purpose may vary substantially in form, to the extent that archaeologists would rarely group them together. Most groups based on use

would contain numerous morphological types. Most morphological groups would contain artifacts from more than one functional group. The degree of variation in form of tools used for similar or the same tasks varies widely. Study of ethnographic collections clearly shows that there is no *a priori* correlation between form and how an object is used. The factors driving the degree of variation within a morphological type are unclear.

Weaving battens are a good example. Weaving battens from New Mexico and Alaska, demonstrate approaches to accomplishing the same task, each with a distinct morphology (Figures 8.19-8.21).   The raw material, dimensions, and shape of each tool is distinct. Macroscopic and microscopic wear patterns indicate the similar gesture and materials of use for these tools, despite very different morphologies.

Figure 8.19 Alaskan Arctic weaving implement (Burke 1996 49/12)

Figure 8.20 Zuni weaving needle, New Mexico (AMNH Anthropology 50.1/8790)

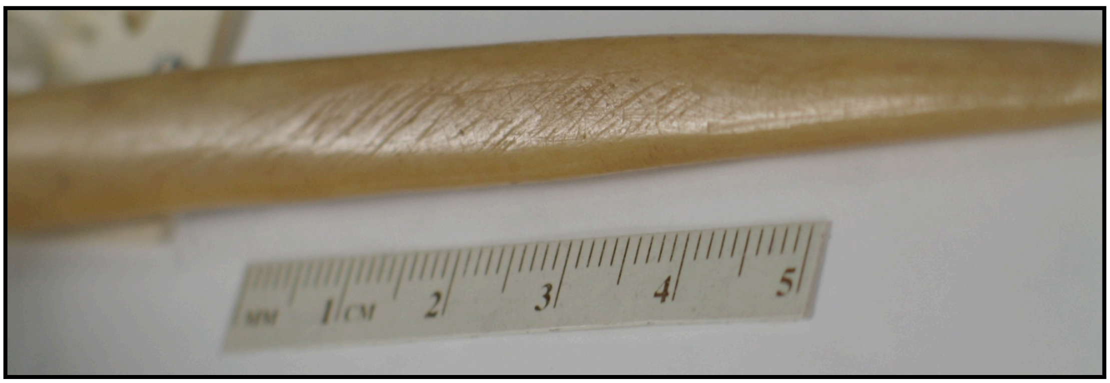


Figure 8.21 Zuni weaving needle, New Mexico, working zone (AMNH Anthropology 50.1/8790)

In rare cases, form and function align strongly, as in the case of bone snowshoe needles, discussed in depth in the following chapter (Ethnographic Case Studies). Found throughout the northern portion of North America, snowshoe needles are usually made of bone, although examples in wood and metal are also known. Although they vary somewhat in size, and the form of the central perforation varies, overall, snowshoe needles – flat, wide, bi-pointed, and centrally perforated – are remarkably similar.

Conversely, the simple “sewing needle” for use with sinew thread varies more dramatically, even within the same region and broad cultural group. Alaskan sinew-sewing needles vary in dimension, curvature, form, and can be made in ivory, bone, or later, metal (Figures 8.22-8.25). Thus, in the case of the sewing needle, despite serving only one general function, form can vary, while the snowshoe needle is more morphologically constrained.

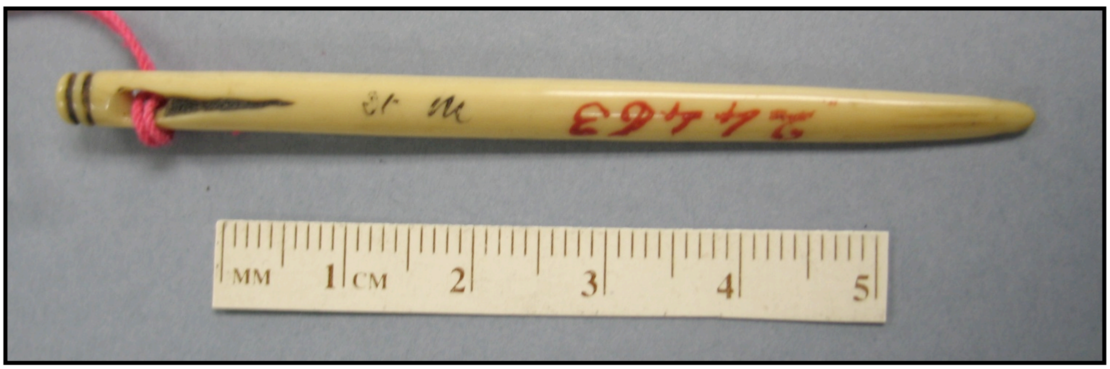


Figure 8.22 Eskimo needle, Norton Bay (NMNH E024463)

Figure 8.23 Eskimo needle and thimble, Northern Alaska (NMNH E089392)

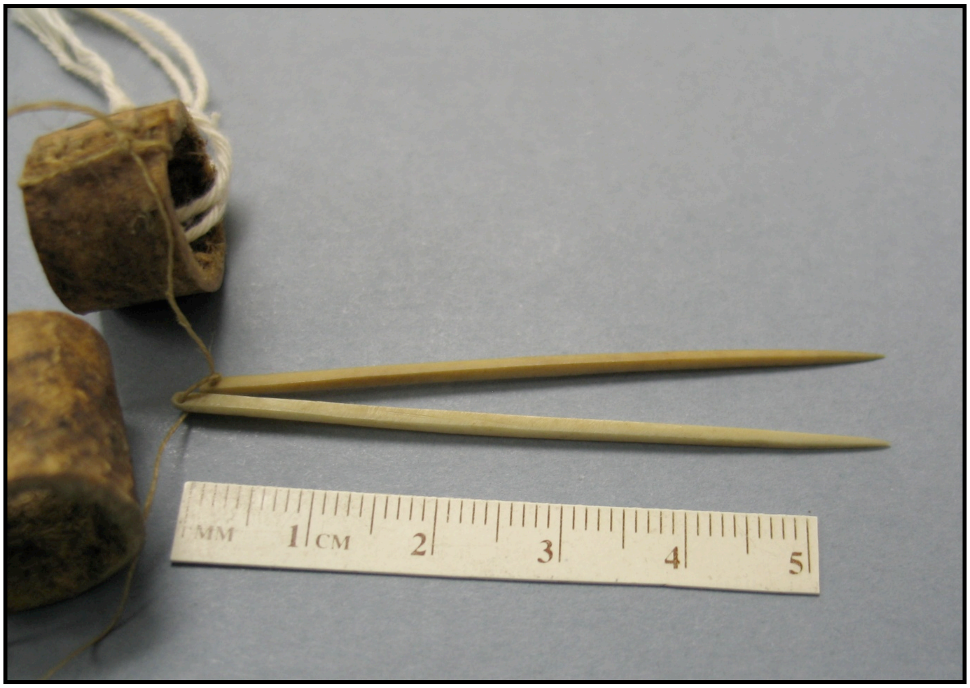


Figure 8.24 Eskimo needles and thimbles, Northern Alaska (NMNH E089394)

Figure 8.25 Bone needles in case (NMAI 021807)

More commonly, a shared form can be assigned multiple names and serve multiple purposes, particularly in less-elaborated shapes. The ubiquitous small and pointy forms that we see in both the ethnographic and archaeological records can fall into numerous ethnographic categories, among them leather pricking awls, thread-manipulating weaving awls, knitting needles, bag pins or toggles, and more surprisingly, lice scratchers, pipe cleaners and nutpicks (Figures 8.26-8.31). Context of recovery and attrition patterns would be necessary to discern difference of use in archaeological forms.

Figure 8.26 Dyak basketry awl (NMNH E249050)

Figure 8.27 Montagnais or Innu (Canada) Bear bone pipe cleaner (NMAI 101433)

Figure 8.28 Projectile point, Eskimo, Canada (NMAI 070932)

Figure 8.29 Salish head scratcher (NMAI 098609)

Figure 8.30 Needle case with pin, Eskimo Tigara or Tikeramiut (NMAI 077747)

Figure 8.31. Composite fish hook, Montagnais Naskapi or Innu, Canada (NMAI 121735)

8.6.1.1 Implications for Archaeological Analysis

The most important implication of the macroscopic study of ethnographic tools for archaeological analysis is clear: form ≠ function. We cannot use formal similarity in the archaeological record as a stand-in for functional parity. This is specifically demonstrated in Chapter 9 (Ethnographic Case Studies).

8.6.2. Microscopic Wear Patterns

Wear patterns on ethnographic artifacts reflect the life history of the object, including manufacture, use, handling and curation. Curation can produce drawer wear or can be reflected in conservation techniques. Conservation has already been discussed in Chapter 5 (Methodology). Here, I only note that some artifacts were excluded from microscopic analysis because of thick consolidant or ink that obscured the surface. Additionally, threading a cord for the accession label through the eye of needles is a common practice that both makes observation of the perforation difficult or impossible and can incur use wear from the movement of the string. Many manufacture techniques are documented in the artifact surfaces and were described minimally but were not included in further analysis.

Generally, tools for different tasks have markedly different surface attrition patterns. Some kinds of activities result in more diagnostic patterns than others. Wear from mat-

making, for example, is fairly regular from artifact to artifact (see Chapter 9: Ethnographic Case Studies).

8.6.3. Assessment of the Tribological Model for Plant and Animal Wear

Tribological analysis of wear indicates that the tribological model predicted many of the aspects of wear patterning correctly, demonstrating that the application of tribological principles to archaeological studies of attrition can have predictive and explanatory power. Narrative and photographic descriptions, along with the long data form for use wear analysis have already been discussed. A second aspect of my analysis of the ethnographic tools consisted of recoding the data created with the lengthy data form for use wear recording and assessing the seven variables identified in Chapter 4 (Tribology) for the basic tribological model of wear. These variables are: polish invasiveness, microtopography, presence of striations, striation organization, striation size, presence of pitting, and volume loss. Each of these variables is defined in detail in Appendix IV. As discussed in greater detail in Chapter 4 (Tribology), the tribologically derived expectations were:

Table 8.2: Tribological Predictions for Plant and Animal Fiber Wear on Bone Tools		
Variable	**Plant Materials**	**Animal Materials**
Polish invasiveness	**Non-invasive**	**Invasive**
Microtopography	**Flat or planar**	**Rounded**
Presence of striations	**Yes**	**Yes or No**
Striation organization	**Patterned**	**Irregular**
Striation size	Similar to each other	Varied
Presence of pitting	Yes or No	Yes
Volume loss	Variable	High
*Variables in bold were statistically significant in the ethnographic sample.		

The model was heavily simplified in this test, to determine the utility of this approach for the analysis of bone use wear. Thus, I could not expect the model to fully predict use wear patterns nor to explain all aspects of use wear variability, but rather to indicate general trends in wear patterns that result from the material properties of the different fibers under consideration. Once again, the inclusion of pitting was not based on material properties, but rather the prevalence of this attribute in bone tool use wear literature as an indication of hide working (see Griffitts 2006; Legrand and Sidéra 2007; LeMoine 1997; Sidéra and Legrand 2006).

The data were coded for these variables and outcomes were tested with chi square tests to indicate whether the distribution of results could be explained by random factors or was due to sample size. Although the sample size is small and the model

highly simplified, the chi square tests indicate that some patterns in the data support the tribologically derived predictions.

Polish invasiveness, one of the variables clearly expected to vary by fiber class, is slightly significant (p-value 0.07), suggesting that invasiveness is partially determined by cellular structure, but we should expect that other factors also influence the invasiveness of polish. The form of microtopography, however, the second variable associated with differences in the cellular structure of plant and animal fibers, is more highly significant (p-value 0.02), indicating that cell structure may more strongly affect small-scale volume loss than it does polish distribution. Both the presence of striations (p-value 0.000) and, in the case of their presence, the orderly patterning of those striations (p-value 0.02) are associated with plant wear at a statistically significant level.

Other variables, however, do not reflect the expectations generated for differences between plant and animal fiber wear. The size of striations shows no correlation with fiber source, indicating that this variable is not linked to raw material, but may be indicative of other factors at work in the accumulation of wear. Likewise, overall volume loss is not associated with either fiber type, a result that makes intuitive sense given the range of conditions or preparation of fibers that can be associated with different kinds of fiber-working activities.

The presence of pitting, however, displays a distinct pattern. Pitting does not correlate statistically to either use material, but rather varies by tool part (tip, mesial or

perforation), indicating that this attribute may be more indicative of handling than wear from any particular worked material. No other variable tested in the tribological model varies with tool part in a statistically significant way.

8.6.3.1. Implications for Archaeological Analysis

The explicit tribological model proposed in this dissertation is powerful for understanding the accumulation of wear on bone tools. Ethnographic artifacts have wear patterns that reflect the use history of these tools in ways that are predicted by tribological principles. This indicates that further exploration of the detailed predictions possible in a tribological framework may have significant benefits for archaeological use wear analysis of both osseous tools and artifacts of other materials. Tribological predictions are based on standard material properties and much of the work to discover and document these properties has already been done. The knowledge about use wear patterns generated through experimentation by numerous authors is supported and positioned within an explanatory framework that allows us to make predictions about kinds of contact that may be difficult to replicate. Tribological studies may also help archaeologists seek agents for novel wear patterns located only on archaeological specimens.

8.6.4. Comparison of ethnographic and experimental wear patterns

A comparison of wear patterns on ethnographic and experimental collections shows some similarities in attrition patterns and other characteristics that diverge. As expected, ethnographic artifacts yielded wear patterns that were not found in the experimental collection. Some experimental results are not replicated in ethnographic materials. In other cases, experimental and ethnographic wear patterns display similarities. When these similarities match the predictions of the tribological model, we have a strong basis for using these results to construct standards for the analysis of archaeological wear patterns.

8.6.4.1. Macroscopic Patterns of Use-Related Attrition on Experimental and Ethnographic Specimens

Experimental tools were generally used for a limited amount of time and none were used for more than 50 hours, in the case of four hide scrapers. The tool used for the longest duration on plant fibers was a weaving batten used for 5 hours. None of these tools was depleted; only one showed significant volume loss. This result suggests that the tools from the ethnographic sample may have been used for substantially longer time. However, it is very difficult to know the duration of use of ethnographic tools, even in cases where other kinds of information are quite detailed. So, duration of use may be substantial in some ethnographic cases but brief in others. This is one aspect of

ethnographic artifact life history that likely mirrors that of archaeological specimens. Many archaeological tools probably entered the record when intentionally discarded, ending their uselife because of depletion, replacement, or sometimes loss (Choyke and Daróczi-Szabó 2010; Schiffer 1972; Spector 1991). Although this may be slightly later in the uselife cycle than the point at which ethnographic artifacts were obtained by ethnographers, the condition of tools may still provide a good model for use wear after significant and sustained use.

On the macroscopic scale, visible surface modification and volume loss varies between ethnographic and experimental samples, but is also significantly varied within each collection. Macroscopically visible wear is common on ethnographic objects, although it is not ubiquitous by any means. Experimental objects also displayed macroscopic indications of use in many cases.

On ethnographic artifacts, polish, smoothing and sheen are often notable and can indicate work and handling zones. This is also true of many experimental pieces, especially those used on animal products, which is not the case in the ethnographic sample. It is not clear what may be driving this difference in macroscopic polishes, as experimental tools were washed gently in both acetone and alcohol to remove fatty or greasy residues. A bright shine was identified on some ethnographic hide scrapers. In general, polishes on experimental pieces displayed more marked boundaries, which would probably have softened after repeated uses with slightly different placement of contact zones or slight variation in the dimensions of materials worked.

Attrition can take place in the form of volume loss or striations and scratches. Experimental hide scrapers displayed significant volume loss, most notable on the nearly unmodified rib. However, hide scrapers from the ethnographic collections do not show signs of heavy volume loss, although it is difficult to judge in retrospect if any resharpening has taken place. Volume loss may have taken place in the eye of ethnographic mat needles, although this is once again difficult to measure. No other artifacts from either collection displayed significant volume loss. Macroscopic striations on ethnographic basketry awls are often apparent and may be quite marked. No true basketry was attempted in the experimental collection, although replications of the gestures in basketry did not result in any macroscopically visible striations. This suggests that attrition on basketry awls may build up over an extended period of use, especially since the addition of abrasives or significant amounts of grit are highly unlikely, as opposed to the case of hide preparation.

8.6.4.2. Microscopic Use Wear

The use wear documented microscopically on ethnographic and experimental collections also revealed both similarities and differences. Because of the extensive number of observations, comparison between the two collections was carried out with the results of the variables in the tribological model.

The association of planar attrition with plant working is quite strong in the ethnographic collection but was not supported for experimental specimens. This result was unexpected and is difficult to explain. It may be due to the duration of use, as most experimental pieces may not have been used extensively enough to develop the microscopic volume attrition that creates planar wear. Further work with experiments of longer duration are necessary to clarify this question.

8.7. Conclusions

Ethnographic collections are a rich source of information on bone tool use at several scales and the detailed study of material culture can play a role in research beyond archaeology. Here I have described some of the kinds of osseous artifacts that are housed in museums in the U.S., with attention to both macroscopic patterning and use wear signatures. Additionally I demonstrated the utility of these studies for constructing standards to frame archaeological analyses. Finally, I argued that material culture studies have broad applicability in museum practice, ethnographic study, and anthropological approaches to technology and economic and social production.

8.7.1. Microwear Study of Ethnographic Materials

The study of ethnographic collections was extremely productive and provided insight into the kinds of uses that can be made of bone tools in the area of perishable artifact manufacture. I approach the analysis of wear from a tribological perspective at the scale of the working surface. These results are used to construct standards for archaeological analysis. Analysis of use wear patterns on ethnographic tools used to prepare and manufacture plant and animal fibers supports many of the predictions made with the tribological model of attrition caused by contact of fibers against bone. This indicates that the tribological predictions reflect a material reality about the contact of bone with other materials and is a useful avenue by which further research on bone tool use wear patterns might be organized.

The ethnographic study also established that the relationship between form and function is nonlinear. Form cannot be taken as a reliable proxy for function. Although this observation has been repeatedly made in the archaeological literature (i.e., Buc 2010), in practice form is still frequently used as a stand-in for function.

Use wear and residue studies are the best means by which to establish artifact function for lithic and osseous artifacts (Buc 2010a, b; Banks and Kay 2002; Christidou and Legrand 2005; Hardy, et al. 2001). Especially in the case of elongated bone tools, where the form of the artifact is strongly constrained by the form and characteristics of the raw material, the correspondence of form to a specific function is even more tenuous.

8.7.2. The Role of Ethnographic Collections in Archaeological Research Design

Basic standards can be defined for surface patterns diagnostic of different contact materials by creating experimental collections or studying wear on ethnographic objects, as demonstrated in this and the previous chapter, and as is well established in the archaeological literature. The emphasis on experimentation, coupled with a tendency to restrict ethnographic research to secondary, written sources, has limited the potential for the creation of usable standards for use wear analysis. Ethnographic collections cannot simply be replaced by thorough experimentation; the approaches are complementary. While experimental results are simpler to analyze and understand, ethnographic collections provide different data that can help correct some of the bias in experimental assemblages. Ethnographic objects may document long use-life histories by skilled or unskilled practitioners. Experimentation by archaeologists takes place in isolation from cultural practice and features wear produced by one or a few people. Long object life histories can rarely be effectively replicated in the short time frame and with the novice motor skills of most archaeologists.

However, many archaeologists are hesitant to make extensive use of ethnographic materials because they are unsure about the validity of the links between surface attrition patterns and activities. There are serious and realistic challenges to defining a reliable ethnographic sample and to determining the reliability of the links between

archival documents, publications, and artifacts. However, I have shown here that it is possible to select a sample that contains artifacts with detailed and accurate uselife histories. Ethnographic collections at museums across North America are vast and the artifacts curated therein have widely divergent kinds and levels of documentation. It is true that not all the ethnographic artifacts at any one museum are likely to be usable for the documentation of use wear standards, but there are a sufficient number of artifacts that this should not present a barrier for most projects.

Documenting ethnographic objects has allowed me to maximize the variability of my comparative surfaces and provides a strong, culturally rooted source of wear patterns. Thus, despite my research being archaeological in nature, there is no foreseeable end to my work with ethnographic collections; rather I see limitless possibilities for expansion and enhancement of the project.

The topic of research addressed in this dissertation concerns the use of bone tools to produce perishable industries from plant and animal fibers. There are a number of other topics that can also be explored with ethnographic museum collections. Many aspects of object uselife are documented in the objects and archives in museums, including information on cultural curation processes, manufacture patterns, repair and maintenance strategies, and decorative elements or techniques.

8.7.3. The Contributions of Artifact Level Study to Museum Collections and to Ethnography

Ethnographic studies, broadly conceived, can include a consideration of the role of material culture in human lifeways and choices (i.e., Densmore 1974; Lemonnier 1986, 1993; Osgood 1970) Beyond the area of archaeological use wear standards, the study of ethnographic collections serves an end in itself and may be relevant to ethnographic and historical studies of the populations whose material I am documenting. Archaeological methods used to conduct the microscopic analysis of ethnographic collections can contribute to museums' knowledge about their own collections. Many objects have accompanying documentation, but others lack basic information about how tools were made and used.

Social and economic production and the social organization of technology are broad concerns within the discipline of anthropology (Dobres 1995, 2000; Lemonnier 1986, 1992, 1993; Lemonnier and Pfaffenberger 1989; Schleher 2010). One of the barriers to greater use of ethnographic collections within archaeological research projects is the lack of familiarity of many archaeologists with the kinds of ethnographic material culture housed in museums. Another obstacle is a general assumption that using museum collections is a self-evident process, free of theoretical or practical difficulties. Because archaeological training and research funding structures emphasize fieldwork and excavation, most students are poorly prepared for work with museum material.

The study of material culture of contemporary and historic origin with the methodology of archaeological research provides a powerful means of understanding some of the ways that tools are used in a socially meaningful ways. This dissertation represents only a preliminary consideration of the question of how people use bone tools to manufacture other goods within a social and cultural context, as the research was more heavily focused on use wear analysis methodology. The case study to follow (Chapter 9: Ethnographic Case Studies) will give some indication as to how the social and behavioral aspects of tool use might be more fully explored.

For ethnographic collections to gain greater currency in archaeological research, we must assess their validity for understanding the material outcomes of complex, situated cultural practice that includes the use – and mechanical accumulation of wear – of these objects. This work was predicated on testing the assumption that ethnographic objects with documented histories of use can be employed as standards for the assessment of surface wear patterns to identify the function of archaeological artifacts. This assumption is frequently cited anecdotally in archaeological literature (i.e., Kehoe 1999; Soffer 2004). Here, it has been demonstrated that this assumption is supportable. Setting the scale of analysis to the artifact surface level has been shown to be useful for the study of use wear.

Summary: Ethnographic collections constitute an important, but underutilized, resource for scientists interested in identifying the function and performance of tools. Questions of validity and a desire to avoid simplistic analogies have discouraged archaeologists

from incorporating ethnographic collections into studies. However, many of these difficulties are linked to the use of direct analogies for archaeological tools. Without relying on direct behavioral analogies, we can use the physical and material characteristics of bone and animal and plant fibers to link worn surfaces across temporal and cultural boundaries. This information can both inform archaeological projects and contribute to ethnographic and historical studies of the manufacture of perishable objects.

Chapter 9. Ethnographic Case Studies

The case studies in this chapter demonstrate the results discussed in Chapter 8 (Analysis of Ethnographic Collections) in more detail. The case studies demonstrate the relationships between documents, artifacts, and wear patterns and indicate ways that these relationships can inform an archaeological study. In particular, I emphasize that while form, function and wear coincide in some cases, in others they do not. I also show that while some ethnographic tools do not have a formal analog in the archaeological record, information on the scale of the working surface can still be relevant to archaeological analysis. This is because, as shown, form cannot be used to identify function. An unknown or unfamiliar form may still perform a known function that can be identified through use wear analysis.

Archaeologists seeking to identify economic and subsistence activities in the past often rely on the identification of the function of artifacts. There are three kinds of groups frequently involved in this identification: morphology; use wear or residues; and function. The end goal is to group artifacts by function, but one of the first two sorting methods is used to approximate function. Archaeologists, then, are faced with two equally feasible possibilities to create the first artifact sort. Typically, artifacts are sorted by morphology and these groups are then tested for variable indications of use from

attrition or residues. Alternatively, however, groups could be created from wear patterns and then morphological variation within these groups could be examined.

To demonstrate the utility of ethnographic analogy at the scale of the artifact working surface, I have selected three distinct case studies. First, I use a tool type that has limited morphological variability and has a well-documented function: snowshoe needles. This is useful in considering those cases where form and function coincide. Additionally, since most archaeological collections are sorted by morphology as a first analytical step, it demonstrates that kind of variability of use wear patterns that might be expected in a group of tools that share both morphology and function. Archaeologically, however, this link between form and function is generally assumed, rather than established independently. My second case study demonstrates the difficulty of assuming that form and function always align. Here, I select a sample of tools based on shared use wear patterns and examine the morphological and functional variability within the sample. The third example examines an artifact with two kinds of wear on different tool zones, demonstrating the importance of working surface level analysis.

9.1. Case Study I: Snowshoe needles in northern North America

The snowshoe needle is a common artifact type found in ethnographic collections from throughout the northern portion of North America. The needles are used in to draw thongs or rawhide through a frame and weave them in through each other, creating the webbing for the base of the snowshoe (Bourque, et al. 2009; Speck 1911). Snowshoe needles are morphologically similar throughout a wide portion of northern North America, despite being found in a wide geographical area across many cultural and linguistic groups and in a fairly diverse range of environmental contexts.

9.1.1. Environmental and cultural background

Snowshoe needles are found historically in nearly all areas of North America where webbed snowshoes were used, from Alaska to Quebec and down through the northern portions of the Great Plains. This encompasses egalitarian foragers such as various populations of Inuit speakers and more stratified societies practicing both foraging and horticulture such as the Huron (Wyandot) (Speck 1911) and members of the Wabanaki Confederacy (Bourque, et al. 2009) However, it has been suggested that the use of the netted snowshoe is a recent introduction to Arctic groups from the Northern Plains groups (Birket-Smith 1930). The use of snowshoes by indigenous peoples of North America is documented in historic accounts as early as 1672 (Denys 1908) and

archaeological snowshoe needles indicate their use in late prehistory as well (Davidson 1937).

The tasks of making snowshoe needles and snowshoes are frequently gendered, but there is no clear pattern in the assignment of these tasks. Among the Huron, snowshoe needles were used by men during the winter to prepare snowshoes, although the rawhide thongs were prepared by women. For the Chippewa and Wabanaki, however, men made the wooden frame of the snowshoes and the snowshoe needles, but women used the needles to net the mesh from rawhide (babiche) (Birket-Smith 1930; Bourque, et al. 2009). Among the Ojibwa, women made snowshoe needles, along with all other tools made from bone (Rogers 1962). Regardless of the ethnicity or gender of the maker, the process of snowshoe manufacture appears to be relatively similar. A wooden frame is formed of dampened wood. After the frame is hardened, rawhide or sinew is threaded through the holes in the frame and netted into a mesh with the aid of the snowshoe needle, which is used to both guide the cord and pull and tighten the mesh.

9.1.2. Macroscopic and microscopic analysis of bone snowshoe needles

Morphologically, snowshoe needles are remarkably standardized. Eighty-four snowshoe needles were studied macroscopically and a subsample of 15 were assessed for

microscopic use wear. They are made on a bipointed bone blank with a central perforation. They generally measure 8-12cm in length and around 1cm in width at the center. There is little variation in size or form across regions or cultural groups. The variation present among these artifacts is primarily found in manufacture and finishing techniques and in the form of the perforation. Bone snowshoe needles may be carefully finished and polished or may retain substantial amounts of manufacturing traces. Perforations may be gouged or drilled and may be circular, oval, or irregular. Snowshoe needles are occasionally made in other materials, namely wood and metal, and these needles also take the same form and size of the bone ones. This formal standardization suggests that the morphology of snowshoe needles is strongly constrained by their function (Figures 9.1-9.7).

Figure 9.1. Snowshoe needles, Abnaki Penobscot, Maine (NMAI 029201)

Figure 9.2. Snowshoe needles, Cree Tete de Boule (NMAI 142089)

Figure 9.3. Snowshoe needle, Menomini Wisconsin (NMAI 092012)

Figure 9.4. Snowshoe needles, Algonkin Maniwaki or River Desert, Canada (NMAI 153039)

Figure 9.5. Snowshoe needle, Eskimo, Bering Strait, Alaska (NMNH E044335)

Figure 9.6. Snowshoe needles of bone and wood, Montagnais or Innu, Lake St. John, Canada (NMAI 028877, NMAI 032427, NMAI 118114, NMAI 101415)

Figure 9.7. Snowshoe needles, Eskimo, Yukon Alaska (NMNH E036681, NMNH E036693)

Because snowshoe needles have very little strong contact with worked materials, the level of macroscopically visible wear is generally low. Some needles have light polish at the tips and many display rounding on the periphery of the perforation, the location of the most intensive contact with the leather thongs.

Perforations, points and faces of snowshoe needles often display microscopic wear traces characteristic of use against animal soft materials. Microscopic wear is often pronounced on snowshoe needles. Microtopographic surfaces are rounded and polished. Polish is thick and often highly invasive, reaching both high and low points of the microtopography. Striations are often present but are frequently distributed without any discernible pattern (Figures 9.9 use wear on the perforation of E-221; Figures 9.109.12 use wear on both ends and the perforation of E-231).

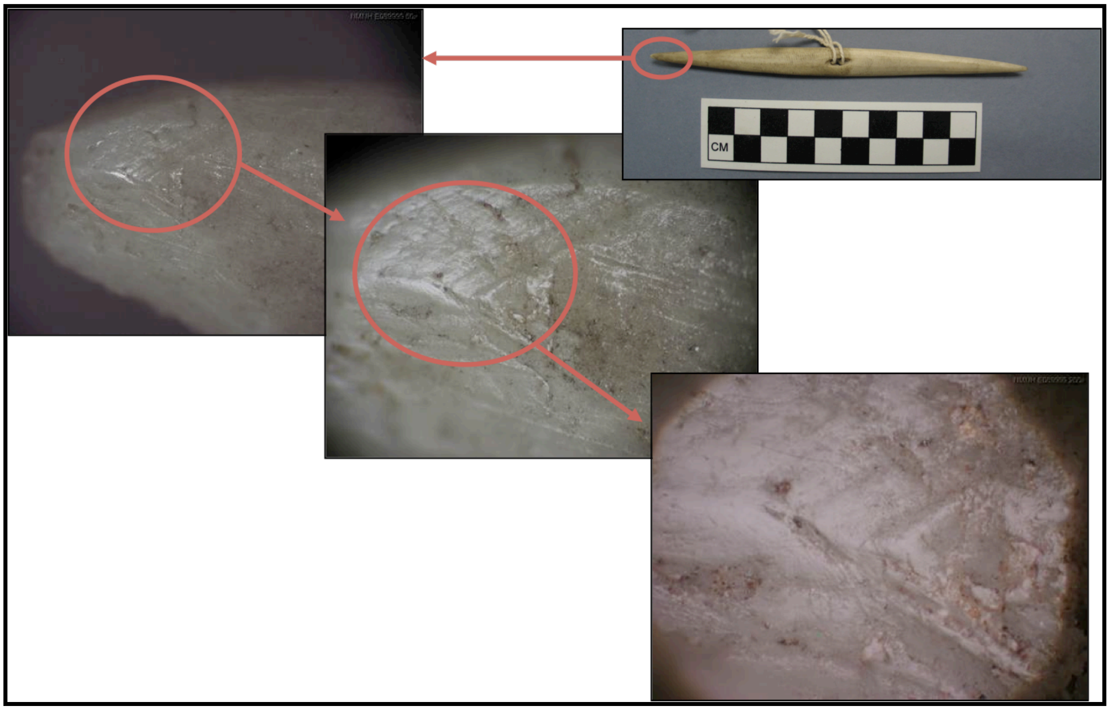


Figure 9.8. Snowshoe needle with use wear on the tip, Ungava Bay, Quebec, Canada (NMNH 089999)

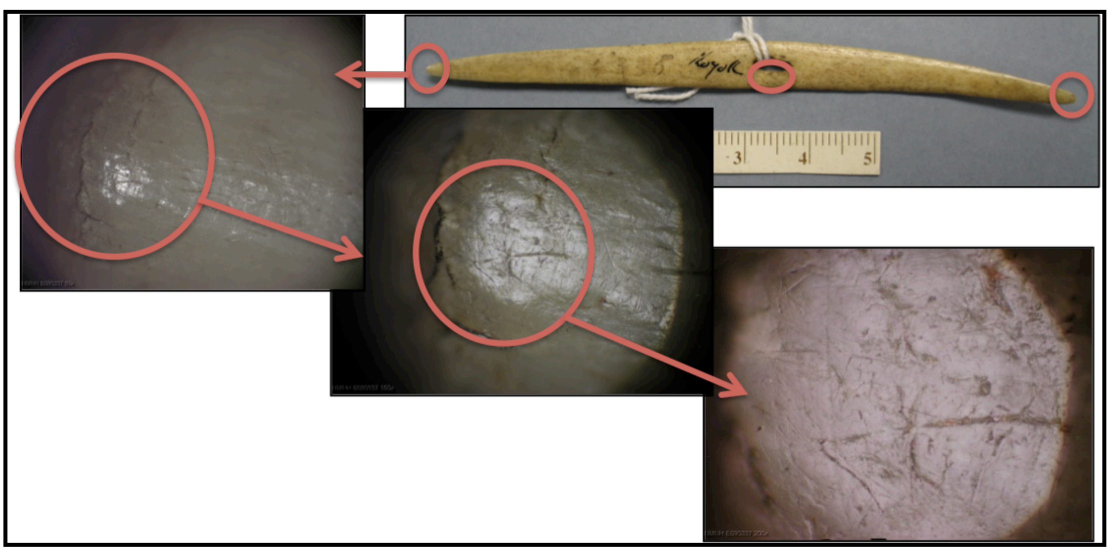


Figure 9.9. Snowshoe needle with use wear on the tip, Eskimo, Bering Strait, Alaska (NMNH E044335)

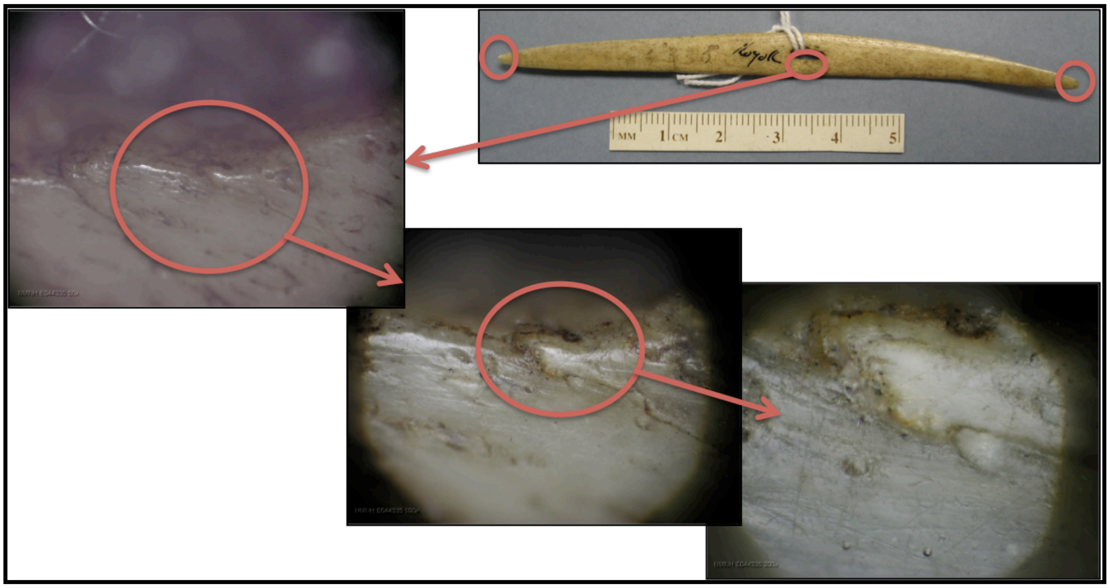


Figure 9.10. Snowshoe needle with use wear on the perforation, Eskimo, Bering Strait, Alaska (NMNH E044335)

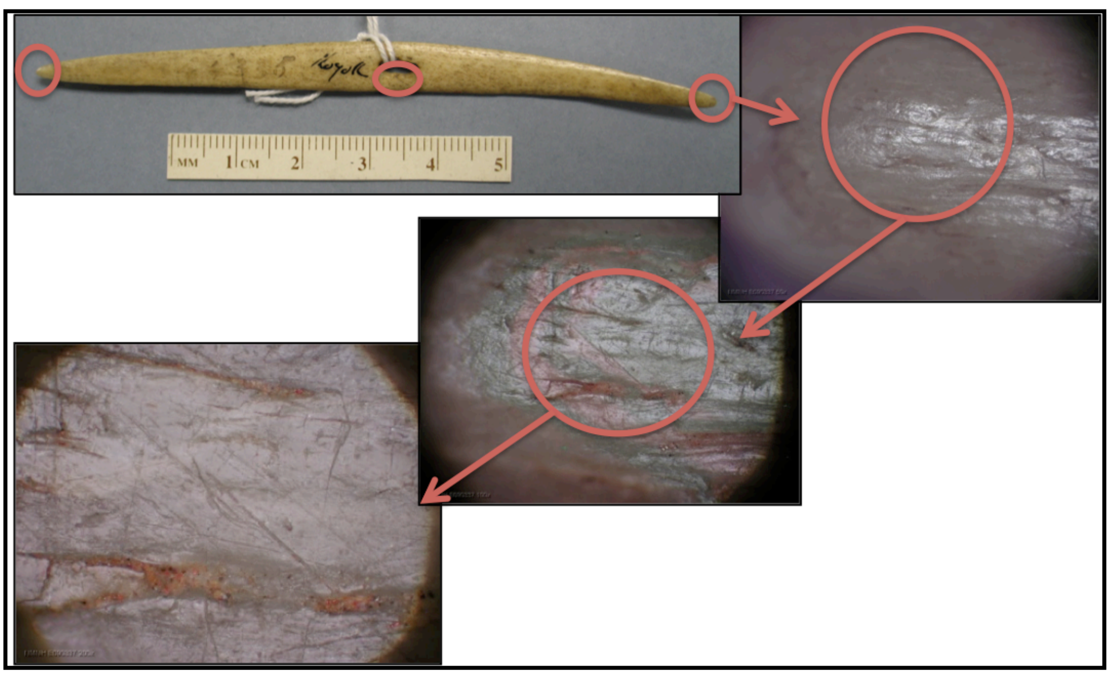


Figure 9.11. Snowshoe needle with use wear on the perforation, Eskimo, Bering Strait, Alaska (NMNH E044335)

9.1.3. Tribological assessment

The snowshoe needles studied microscopically for this study display wear patterns consistent with the tribologically derived predictions for wear from animal fibers (Table 9.1)

Table 9.1: Tribologically Predicted Use Wear Attributes of Ethnographic Snowshoe Needles

Attribute	***Polish***	***Attrition***	***Striations Present***	***Striation Organization***	***Striation Size***	***Micro-topographic Edge-rounding***	***Pitting***
***Animal** Fibers: Predicted State*	Invasive	Rounded	Not present	Disorderly, irregular	Varied	Substantial rounding or volume loss	Frequent
Count	12	11	3	8	4	14	10
***Plant** fibers: Predicted state*	Non-invasive	Flat or planar		Regular, patterned	Similar	Limited rounding or micro-deformation	
Count	3	4		4	8	1	
State Not Predicted for Either			Present	None	None		Few or none
Count			12	3	3		5

The only attribute with patterning inconsistent with the tribological predictions for wear from animal fibers is the variation in striation sizes. This deviation from the model's predictions is also found overall in the ethnographic assemblage, suggesting that this prediction is not met, generally. The patterns are also overall fairly similar among snowshoe needles. In an archaeological case, the coincidence of similar morphology

and shared wear patterns would suggest similar functions, which is indeed the case for these artifacts. As demonstrated in Table 9.1, most of the predictions for wear on bone surfaces from animals fibers generated with the tribological model are met in the sample of snowshoe needles.

9.2. Case Study II: Use Wear Patterning

Another way of demonstrating whether ethnographic collections can contribute to the construction of use wear analysis standards is to examine the patterns of wear found on tools and use that as a filter to select tool groups. If ethnographic materials can be analyzed through tribological principles to create standards for use wear analysis by activity, then patterns in wear attributes should also be able to be used to identify use groups.

For the second case study, the artifacts that met all four of the tribologically derived use wear patterns for plant fiber contact on worked bone surfaces were isolated. These attributes are:

- Non-invasive polish
- Flat or planar micro-attrition

- Striations of similar size and organization
- Limited micro-topographic edge-rounding

Of the collection, only six artifacts met these criteria: one Pomo basketry awl, two Micronesian mat needles, two Winnebago mat needles, and one Chippewa mat needle. No artifacts used on animal fibers from either ethnographic or experimental collections met these criteria, so the wear pattern predictions developed through tribological principles for plant fibers against bone do select for only tools that were used against plant materials. The artifacts come from different regions and reflect both basketry and mat-making and different morphologies.

The Winnebago mat needles (NMNH E005205 [study number E-212] & E005206 [study number E-213]) were collected on the Winnebago reservation in Nebraska in 1867. They are made in the same way and have a shared morphology. They are made from a smoothed rib with a rounded point at one end and a central perforation (Figure 9.12). E-212 has straight, smooth edges while on the squared end of E-213 one side of the tool has a scalloped edge. E-213 displays macrowear in the form of a smoothed and rounded perforation (Figure 9.13, 10x). Macrowear on both needles also includes fine scratches and a surface luster (as visible on E-212 in Figures 9.14 and 9.15). However, macroscopically, neither needle displays marked evidence of use. In fact, prior to microscopic analysis it was not clear whether E-212 had been used or whether the scratches on the surface were remnants of the manufacture process. Microscopic use

wear is planar with a non-invasive polish and extremely dense striations arranged parallel to and crossing the long axis of the tool (Figure 9.16: tip of E-213 at 50x, 100x, 200x).

Figure 9.12. Chippewa mat needles (from top, NMNH E005205, E005206, E360144 [2])

Figure 9.13. Macroscopically (10x) visible smoothing of perforation on mat needle, Chippewa (NMNH E005206)

Figure 9.14. Macroscopically visible intercrossing striations on superior face of mat needle, Chippewa (NMNH E005205)

Figure 9.15. Macroscopically visible intercrossing striations on inferior face of mat needle; notice also the remnants of spongy bone, Chippewa (NMNH E005205)

Figure 9.16. Chippewa mat needle with use wear on the tip (NMNH E005206)

The Pomo basketry awl (NMNH E203589 [study number E-241]) was collected in 1899 in California. Although described as a fibula in the museum's database, the tool is made from an ulna sharpened into a point with the proximal end left unmodified (Figure 9.17). Scraping and chattermarks from manufacture are visible on the surface. The tip is smoothed and rounded from use and striations perpendicular to the axis of the tool are macroscopically visible along the mesial portion of the artifact. Use wear along the shaft of the awl has a light, patchy non-invasive polish with crossing striations. Striations are of a similar size, although their orientation is more varied than that seen in the mat needles (Figure 9.17). This striation distribution is probably due to a combination of straight insertions, rotation in place, and extraction.

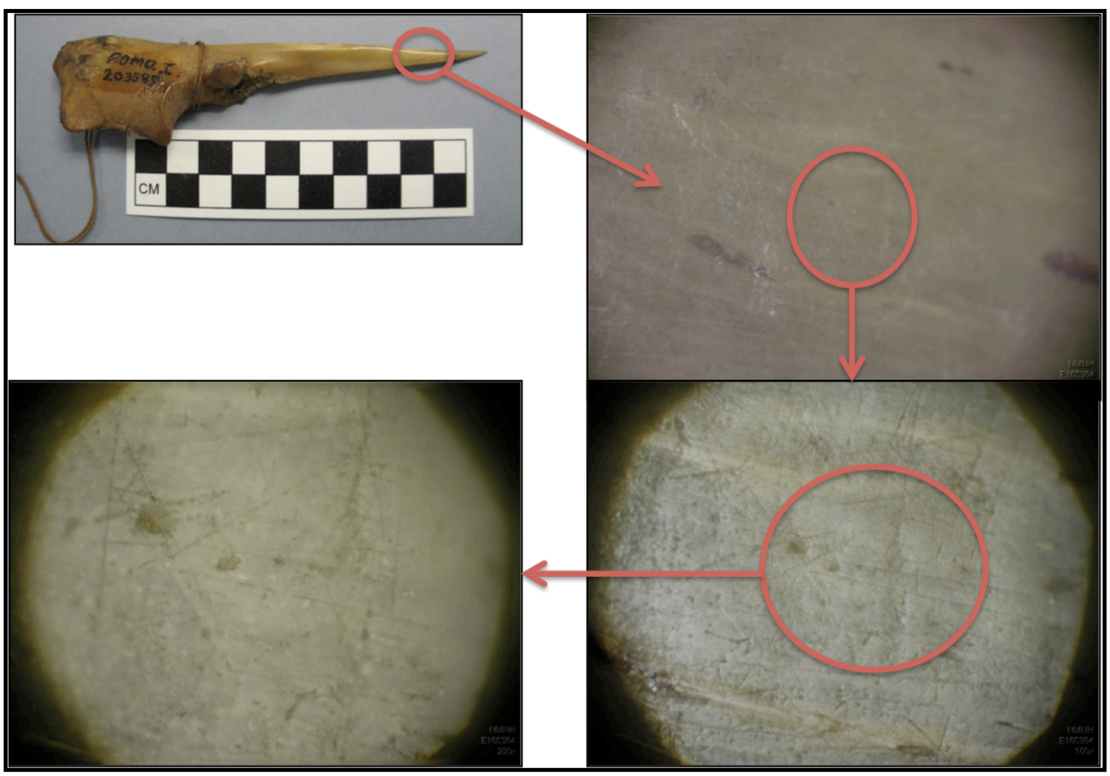


Figure 9.17. Pomo basketry awl (NMNH E203589)

The Chippewa mat needle (NMNH E278140 [study number E-256]) was collected on the White Earth Reservation in Minnesota in 1913 and is part of the Densmore collection. Another needle and a mat accompany this specimen (Figure 9.18). The needle was produced on a split rib with a pointed end and a squared off end. The perforation is located about 1/3 of the length from the squared end and the needle is broken across the perforation. Although the surface is consolidated, wear patterns can be discerned. Macroscopically, the surface is smoothed and a few striations run parallel to the tool's axis along the entire length of the tool, distributed more densely at the tip. Microscopic wear consists of a heavy, bright, smooth, non-invasive polish. The microtopography is extremely flat with moderately dense striations running transverse to the long axis of the tool (Figure 9.19). These striations likely result from the angle and direction of insertion of the needle.

Figure 9.18. Chippewa mat with two needles (NMNH E278140)

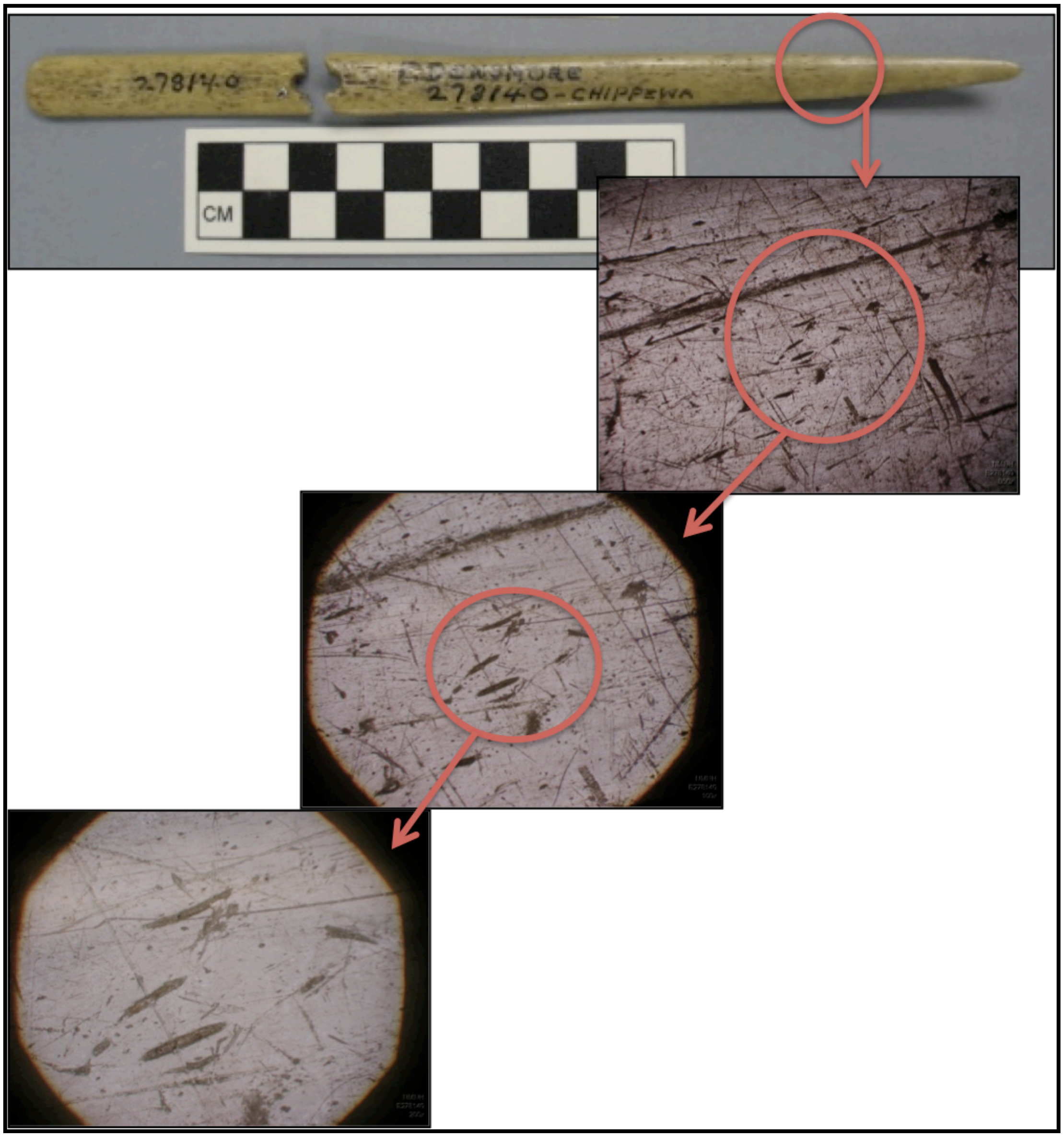


Figure 9.19. Chippewa mat needle with use wear on the fact near the tip (NMNH E278140)

The two mat needles from Micronesia (NMNH E415130 [study number E-266] and E415131 [study number E-267]) were collected in Micronesia in the Chuuk State on the Puluwat Atoll in 1972. They are identified as needles or "etifarr". The needles are made on split ribs, pointed at both ends, and with two perforations at the center of the tool

(Figure 9.20, Figure 9.21 [E-266]). E-266 displays limited macroscopic wear and it was not possible to clearly determine the degree of use prior to microscopic examination. One of the perforations has smoothed edges and there are limited striations subparallel to the tool's axis on the rounded (exterior bone surface) face. E-267 displays stronger macroscopic evidence of use. The surface has extensive striations. On the rounded (exterior bone surface) face, numerous, dense striations run parallel to the axis. At the tip striations are also distributed perpendicular or diagonal to the axis. On the border, striations cross diagonally in both directions. Microscopic wear consists of a light, non-invasive, flat polish. There are few striations, but those present are oriented transversal to the long axis of the tool and intercrossing each other (Figure 9.22). Once again, striations are probably the result of the angle of contact of the tool.

Figure 9.20. Micronesian mat needles (NMNH E415130 & E415131)

Figure 9.21. Micronesian mat needle with macrosopic striations (NMNH E415131)

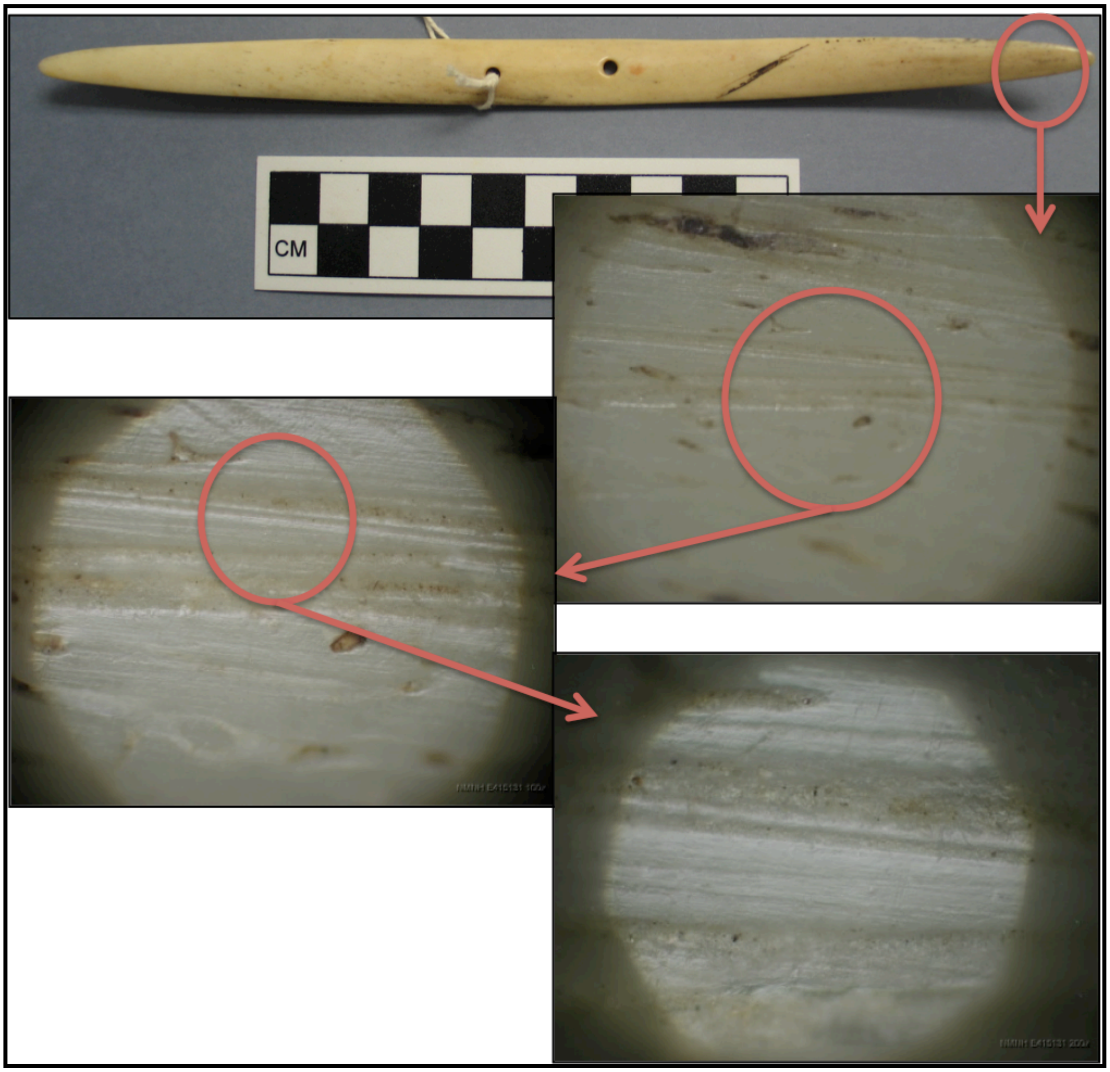


Figure 9.22. Micronesian mat needle with use wear (NMNH E415131)

9.2.1. Summary

The artifacts with microscopic use wear patterns meeting the predictions for plant fiber wear were all used against plant materials. Morphologically, they vary. It is useful to

bear in mind that the morphological range of ethnographic tools securely associated with working only plant fibers is somewhat limited. The mat needles share some morphological characteristics, including their general size and being made from a split rib, and are recognizable as a distinct tool form. The basketry awl bears no similarity to the mat needles and is morphologically more similar to other awls for hide working, weaving, or other purposes. For example, no sewing needles in this sample were used exclusively on plant fibers. Only microscopic use wear can identify this tool as a basketry awl. Macroscopically, their wear patterns are quite distinct; levels of polish, kinds and organization of striations, and rounding vary among the specimens.

9.3. Case Study III: A Single Artifact with Two Contact Surfaces

The final case study takes the case of a single artifact with two contact surfaces, one used on plant fibers and the other used against animal fibers. The artifact in question, NMNH E127873, has a long Quinault matting needle made from a minimally modified bird bone and a mat made with the needle collected from the Quinault Reservation in 1887 by Charles Willoughby, in what was at the time the Washington Territory. The needle was used to sew reeds into a mat with a plant fiber cord. However, rather than thread the plant fiber cordage through the eye of the needle, a more durable sinew cord is threaded through the eye and then twisted with the plant fiber to connect the two kinds of cordage.

On the perforation, use wear typical of animal fibers is present: microtopography is rounded with a thick, rounded, invasive polish. There are no notable striations. On the tip, wear from plant fibers is present: smooth, glossy, non-invasive polish covers a microtopographically flat surface. Striations are moderately dense on the tip, with an organized, crossing distribution. Thus, on a single artifact made of a single bone, wear on the two ends is completely distinct, due solely to the use contact materials used on the two ends. Microscopically, the two working surfaces do not even appear to be from the same artifact, demonstrating the importance of examining different sample areas on the same artifact and setting the scale of use wear analysis at the working surface, rather than the artifact as a unit.

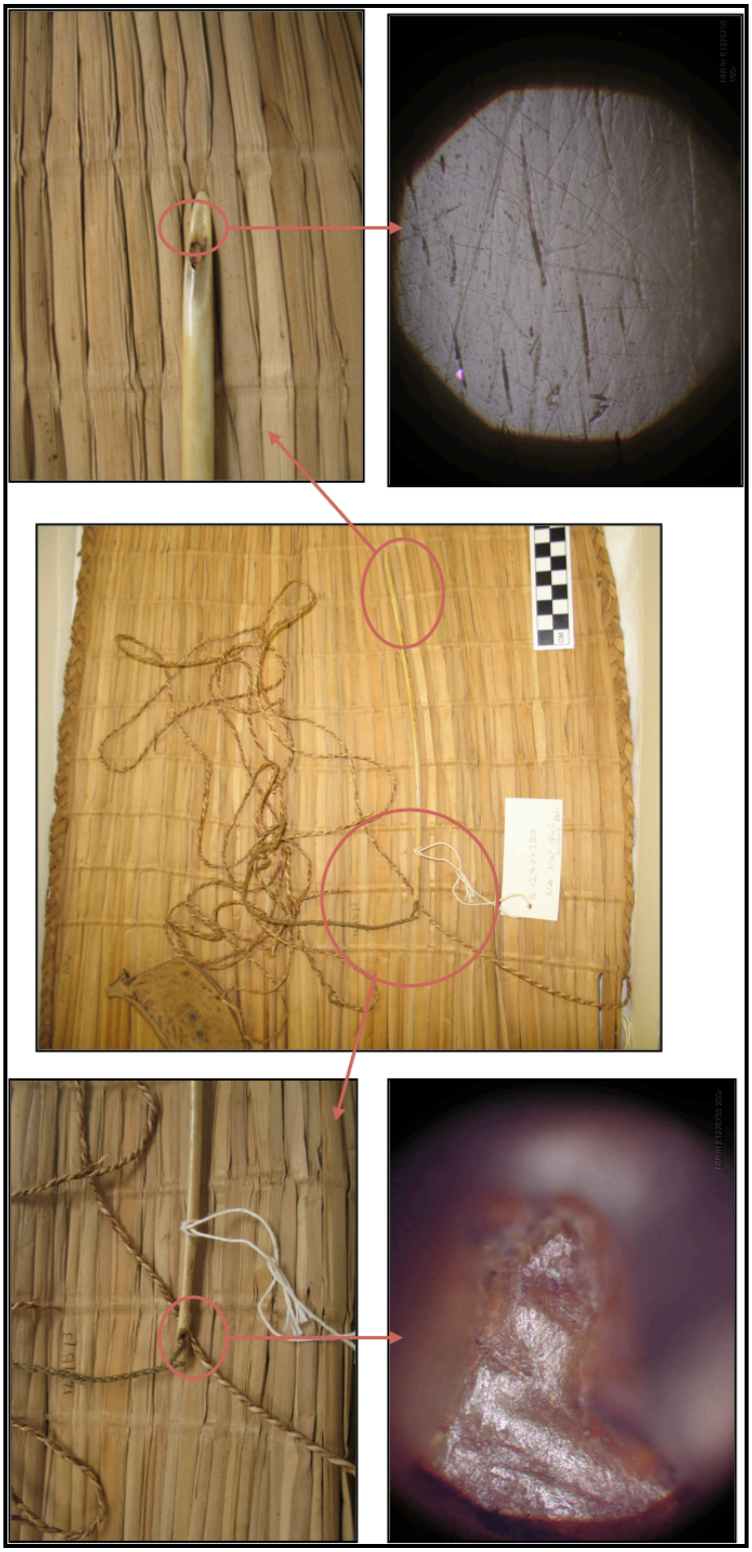


Figure 9.23. Quinault mat and needle with wear from sinew on the eye and wear from plant elements on the tip (NMNH E127873)

9.4. Linking ethnographic object studies with the goals of archaeological research

It has been shown that tool forms with no analogue in the archaeological record can yield wear patterns useful for creating analytical standards for archaeological analysis and that wear patterns can indicate the similar uses of dissimilar tools. Because these artifact forms are not known archaeologically, the relevant question is whether the constellation of wear traits they share are also found archaeologically. If so, then an inference regarding the function of archaeological tools with the same wear patterns can be made.

These contrasting case studies show the utility of ethnographic artifacts and tribological principles to construct standards for archaeological comparison and show two different means by which comparisons can be made. The cases are complementary, in presenting two of the ways that archaeological collections can be sorted: by morphological variation or by variation in attrition patterns. Here, I have shown that in some ethnographic cases morphological patterns reflect activities while in other cases, wear patterns can reveal activity patterns.

There are no morphological analogies in the Late Upper Paleolithic to snowshoe needles or mat needles and artifacts with the morphology of the basketry awl can serve many

functions. This means that object-level or behavioral-level analogies cannot be easily drawn between ethnographic and archaeological artifacts. However, similar wear patterns do exist in the archaeological collections, allowing us to suggest that similar material interactions produced the use wear on archaeological artifacts.

The use wear patterns documented on the snowshoe needles, as well as other ethnographic and experimental tools used on animal fibers, provide the standards that allow the identification of some archaeological artifacts as tools used on animal materials. For example, the *sagaie* from Entrefoces, A-57 (Figure 9.23), displays the microtopographic edge-rounding and rounded, invasive polish characteristic of use wear from animal fibers, like that seen in E-230, a snowshoe needle (Figure 9.24).

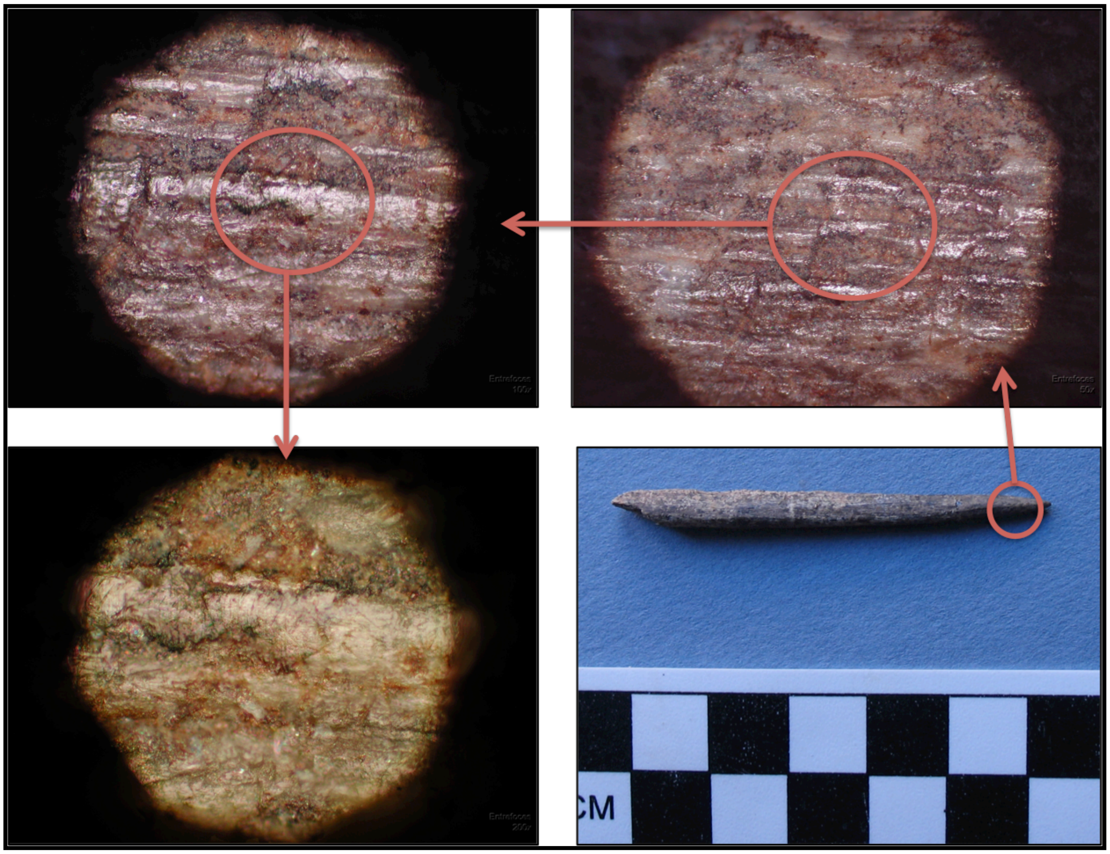


Figure 9.24. Sagaie from Entrefoces with use wear from animal fibers (A-57)

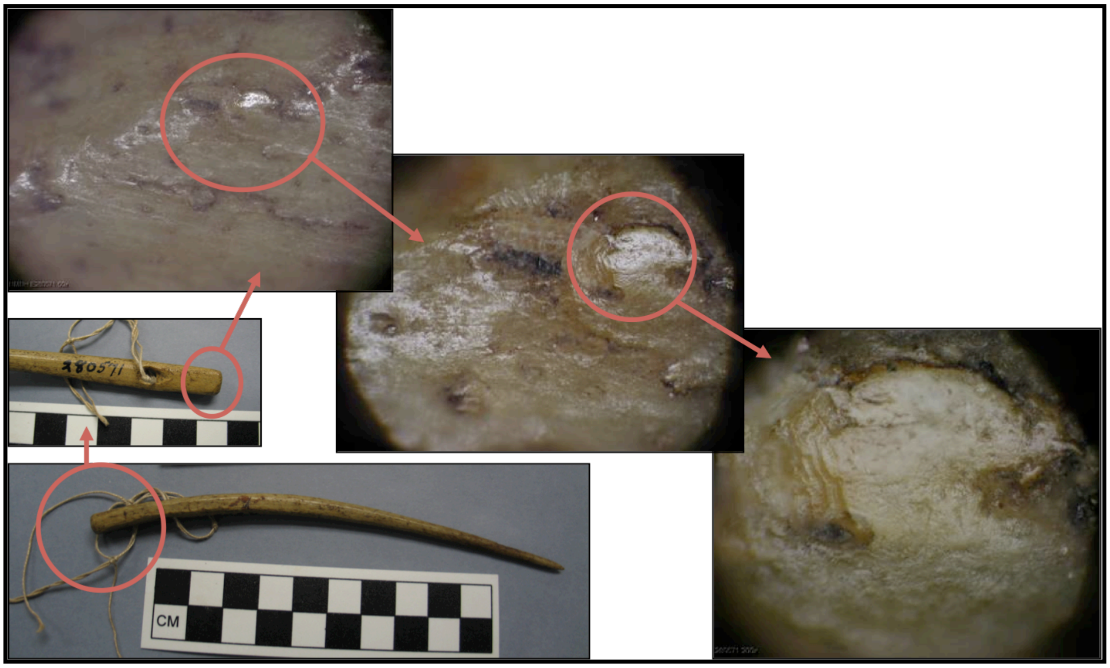


Figure 9.25. Fish stringer with use wear, Siberia (NMNH 280571)

Likewise, the use wear pattern used to select artifacts from the ethnographic collection can also be applied to the archaeological artifacts. This sample contains five artifacts of varied morphology, including needle eye A-346 from El Juyo (Figure 9.26), displaying the non-invasive polish, flat microtopography and crossing striations also identified on mat needle E-256 (Figure 9.27).

Figure 9.26. Needle from El Jujo with use wear indicative of plant fiber contact (9Q3 #4)

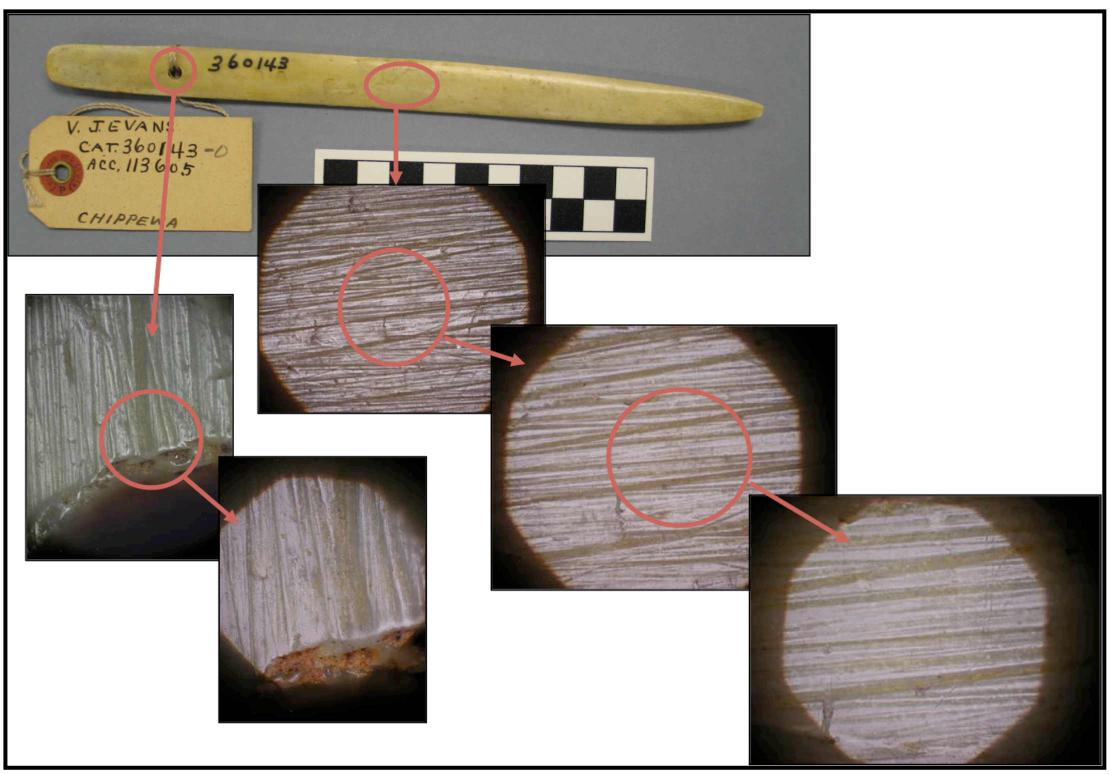


Figure 9.27. Chippewa mat needle with use wear from plant fiber contact (NMNH 360143)

9.5. Conclusions

In both of the above examples, behavioral or task-level interpretations cannot be made solely on use wear patterns. Instead, use wear standards indicate the materials that were likely worked with the archaeological artifacts. An interpretation of activities carried out with the artifacts requires a consideration of tool morphology and should be made by considering the assemblage of artifacts at a site as a unit. This kind of analysis falls beyond the limits of this project, where the emphasis is instead on developing standards at the scale of the working surface as a first step.

This chapter provided a detailed example of two ways that ethnographic collections can contribute to the construction of analytical standards for the analysis of use wear on archaeological artifacts. In the following Chapter 10 (Archaeological Analysis), these standards will be applied to artifacts from Late Upper Paleolithic sites in Northern Spain.

Chapter 10. Archaeological Analysis

The archaeological component of the case studies in this dissertation derives from Late Upper Paleolithic levels of archaeological sites in Northern Spain. A primary concern in designing the research described here was developing ways to identify the use of bone tools during the Upper Paleolithic on plant and animal fiber industries, as we know little about these activities during this time period. Identifying the different ways that bone tools were used, especially in the production of fiber industries, is crucial to understanding the social and economic organization of Late Upper Paleolithic people.

Because of the prevalence of large game bones at Late Upper Paleolithic sites, many with cutmarks that indicate both butchery and hide removal, the assumption that Late Upper Paleolithic people made and used hides and leathers is generally uncontroversial, despite very few studies aimed directly at understanding the details of hide preparation and use. Although we often envision Paleolithic people dressed exclusively in furs and hides as they produce stone and bone instruments, there is extensive evidence that the extraction of plant fibers and the manufacture of textiles and basketry were also possible. Bone and lithic technologies from the Late Upper Paleolithic are extremely complex and sophisticated; the production of perishable technologies was undoubtedly also highly developed. Climatic shifts at the end of the Pleistocene resulted in the availability of new plant fiber sources. This period is also known for a dramatic increase in the number and variability of osseous tool forms, the function of many of which

remains unknown. Of particular interest is the appearance of the eyed bone needle around 20,000 years B.P., which appears much earlier in Eastern Europe and at the same time and in the same places as the earliest evidence for woven textiles (Adovasio, et al. 2001; Adovasio, et al. 1996; O. Soffer, et al. 2000; Stordeur 1990; Stordeur-Yedid 1979).

The previous chapters have demonstrated that use wear analysis of osseous industry from contemporary and historic contexts can provide evidence of the manipulation of plant and animal fibers, primarily in the manufacture of perishable technologies. These chapters have also shown that the use of bone artifacts for the production of plant and animal perishable objects was common, even in the recent past. Although there are always many factors – cultural, social, economic, personal, habitual, temporal, historically contingent – that affect the choices made in the selection of tools and gestures in a production sequence (Lemonnier 1992), it has been suggested that the material qualities of bone uniquely suit it for selection as the raw material for sewing needles, basketry awls, hide scrapers and smoothers, and other tools associated with the production of perishable technologies. Thus, while the analysis of worked bone assemblages cannot provide complete information on the fiber industries of the past, it does constitute a productive avenue through which the role of perishable goods can be approached.

In this chapter, I provide basic background on the archaeology of the Late Upper Paleolithic, with a focus on Northern Spain, in order to situate the archaeological

analyses that will follow. I then present the analysis of artifacts from three small Late Upper Paleolithic sites in Northern Spain: Entrefoces, El Perro, and El Juyo. The sample size from each site is small, so no statistical analyses have been conducted, but I will provide a narrative description of the use wear signatures on artifacts from the two smaller sites and an analysis of use wear patterns for El Juyo, followed by the analysis of these attrition patterns using the tribological model developed earlier in the dissertation. I discuss the significance of the wear patterns identified within their cultural and archaeological context. I conclude with some new directions for further research.

10.1. Upper Paleolithic Chronology

The Upper Paleolithic of Western Europe is typically divided into four primary phases: the Aurignacian, Gravettian, Solutrean and Magdalenian. Variations or definitions of these terms are many and vary dramatically from region to region. However they are still broadly recognizable schema for subdividing the period at the end of Pleistocene in Europe (Table 10.1).

<table>
<tr><th colspan="5">Table 10.1: Upper Paleolithic Chronology with Important Changes in Osseous and Perishable Technologies</th></tr>
<tr><th>Temporal Phase</th><th colspan="2">Dates in Spain (^{14}C uncal)</th><th>Climatic Events</th><th>Osseous and Perishable Industries</th></tr>
<tr><td>Aurignacian</td><td colspan="2">40,000-27,000</td><td>End of Oxygen Isotope Stage (OIS) 3</td><td>Needle appears in Eastern Europe; sagaies appear throughout Europe; twisted, dyed flax from Georgia; textile impressions in Eastern Europe</td></tr>
<tr><td>Gravettian</td><td colspan="2">27,000-20,000</td><td>Beginning of OIS 2</td><td></td></tr>
<tr><td>Solutrean</td><td colspan="2">20,000-17,000</td><td>Last Glacial Maximum</td><td>Needles in Western Europe; earliest known preserved cordage at Ohalo II, Israel</td></tr>
<tr><td rowspan="2">Magdalenian</td><td>Early</td><td>17,000-13,000</td><td>Tardiglacial, Dryas I (15,000-14,500)</td><td>Cast of cordage from Lascaux</td></tr>
<tr><td>Late</td><td>13,000-11,000</td><td>Significant warming and fluctuations until Dryas III (11,000-10,000)</td><td>Round cross-section harpoons, continued diversity in sagaies, other osseous tools</td></tr>
<tr><td>Azilian</td><td colspan="2">11,000-9,000</td><td>Pleistocene-Holocene transition</td><td>Flat cross-section harpoons replace most other osseous artifacts, except awls</td></tr>
</table>

The Upper Paleolithic comprises the cultural historical period that comes at the end of the Pleistocene, or last Ice Age, in Europe, after the appearance of anatomically modern humans and before the transition to the Holocene and the concomitant cultural changes that took place in the Mesolithic and Neolithic. Temporally, it dates to roughly 40,000-10,000 years ago and is separated into a number of stages, which cannot be viewed as

true cultural entities, given the extremely broad temporal and geographic ranges described by these terms. These categories are better thought of as chrono-cultural complexes. The study carried out for this dissertation focuses on the Late Upper Paleolithic, especially the Magdalenian and Azilian periods, about 18,000-10,000 years ago. This period follows the Last Glacial Maximum. Anatomically modern humans are the only human species remaining in Europe by this period.

During the Upper Paleolithic, human groups that lived in Europe shared some broad similarities across the continent, although regional variation was always present and grew over time. The inhabitants of Western Europe during the end of the Pleistocene were hunter-gatherers with a fairly mobile lifestyle. There are few architectural structures known from this period and no identified long-term, year-round settlements. Although diets varied among groups, there are no domesticated plant species known from this time period and the only animal possibly domesticated was the dog (Musil 2000). Technologically, the lithic and osseous industries of the Upper Paleolithic are varied and are often quite elaborate. The only ceramic technology identified in Europe at this time comes from the innovative Moravian Gravettian sites – which will be discussed in greater detail later – and these are figurines rather than vessels. In many areas, the Upper Paleolithic is known for the complexity and diversity of symbolic artifacts. However, the archaeological record is fairly sparse, given the 30,000 years it represents, and there are still many unanswered questions about Upper Paleolithic lifeways, technologies, and cultural behavior. Currently, the kinds of structures or living arrangements the people of the European Upper Paleolithic had, what forms of

perishable technologies they created, how they organized seasonal production and mobility over the course of a year, or the exact nature of their social structures are all unknown.

10.1.1. The Early Upper Paleolithic of Northern Spain

In northern Spain the human and hominid record of the Pleistocene is rich, including Acheulian sites known in the area from Irikaitz (Guipúzcoa) and La Verde (Cantabria). Important Mousterian sites are Valdegoba, El Pendo, Morín, Sidrón, La Viña, Llonín, and Amalda. Late Mousterian dates range from about 41,000-36,000 years ago. Lithic and subsistence evidence suggest continuity between Mousterian and early Aurignacian in northern Spain. About 12 sites in northern Spain contain assemblages that can be attributed to the Aurignacian and these levels are mostly poor with few antler artifacts and pierced teeth are the only symbolic material commonly found, along with an abundance of “Mousterian” material within these levels (Straus 1992).

There is a very limited Gravettian record in northern Spain with known site density lower than that of France and an overall increased emphasis on stone rather than bone tools and microliths. The period was characterized by an unstable, fluid environment and some sites show concentrated hunting, especially in montane areas where an emphasis on caprids as prey has been noted. Engravings have been dated to this period

by overlying dated sediments but as of yet, no paintings and very few Early Upper Paleolithic examples of mobile representation or personal adornment are known from northern Spain. During the Last Glacial Maximum, human and large animal populations from throughout Europe appear to have concentrated in refugia in Italy and Iberia. This period is characterized by innovation in technology and practices, including various lithic points, eyed needles, and *sagaies* with mounted bladelets. New practices included expanded diet breadth, increased use of specialized hunting sites, exploitation of aquatic resources, and increased symbolic behavior. There is evidence for new modes of social organization in the form of site clustering and regionalization of artifact styles. Exchange of raw materials and finished goods is also indicated (Bicho, et al. 2007).

10.2. The Late Upper Paleolithic

10.2.1. The Solutrean

Because the Solutrean is the period in which the conditions for an expansion in fiber technology in Western Europe may have been set up, I will briefly outline the developments in osseous technology and general culture history during this period, to set the stage for research done on Magdalenian and Azilian sites. Significant changes in the production of perishable technologies may have taken place during the Solutrean. At this time eyed needles, nets, and woven and dyed fabrics are all present in Eastern

Europe (Adovasio, et al. 2001). The Solutrean was a time of extreme technological innovation in Western Europe and among the new artifacts types that appear at that time is the eyed bone needle. In the Last Glacial Maximum, cold increased significantly in northern Europe leaving few edible plants and animals, although summer vegetation may have been rich. Subsequently, northwestern Europe was abandoned and the number of sites in southwestern Europe increases. During the period of peak cold, 20,000-18,000 B.P., the Alps, Pyrenees, and much of northern Europe were glaciated, leaving only a very small passage between the refugia of Italy and Iberia. This period is known as the Solutrean in southern France and Iberia. Settlement in Spain was concentrated on the coast. Strategic locations with natural shelters facing south and access to valleys that channeled the movement of herbivores across the landscape were favored. Sites were also selected based on access to water, which probably also provided trees for fuel (Straus 1991, 2000).

Overall in Iberia the number of sites is about the same for the Gravettian and Solutrean, but the Solutrean represents a much smaller time period, from 21,000-18,000 B.P., thus suggesting that populations were greater during the latter period. As human, animal and plant populations retreated to smaller southern spaces, stresses in the form of subsistence pressure and the need for negotiation of social relations and boundaries as new groups came into contact may have been present. Subsistence in the period is characterized by specialization of hunting techniques for big game and diversification in the addition of small game and aquatic resources. During the Solutrean and the transition to the Magdalenian, experimentation and innovation were high, resulting in

the replacement of lithic bifacial points by composite tools of mounted backed bladelets and in many new forms of osseous artifacts (Straus, et al. 2002).

Straus (2000) suggests that the Solutrean is best viewed as a response to the peak of the Last Glacial Maximum, in which populations retreated to refugia in southwestern Europe. He argues that lithic point styles and other aspects of material culture are best understood as ways of moderating both subsistence and social stresses associated with climatic deterioration and localized population pressure.

Although most currently known sites are located with access to both the coast and mountain zones, it is likely that we are missing many small, open-air logistical sites. As a result, the population density estimates may be low for the Solutrean. This period appears to represent the beginning of logistically organized settlement and specialized sites. Throughout the Solutrean, subsistence is intensified through new techniques and technologies. These techniques include the use of natural topography such as valleys and snow banks to aid hunting. Additionally, many resources are added to the diet, including difficult to hunt animals such as the ibex, and low-return resources such as shellfish (Straus 1991). Developments in art and artifact styles may indicate the role of artifacts in negotiating relationships between diverse cultural groups through display and exchange (Schwendler 2004; Straus 1982).

Heather Stettler (1998, 2000) examined Upper Paleolithic organic assemblages from a number of sites in northern Spain and found evidence among these artifacts that the

Solutrean is a transitional period representing significant changes in human behavior. She identified major differences in assemblages that distinguish the Early Upper Paleolithic material culture from that of the Late Upper Paleolithic. The Solutrean, however, does not fit in either group consistently. It could be grouped with either the Early or Late Upper Paleolithic, depending on the variable or artifact examined. Stettler notes differences in needle morphology, species selected for perforated teeth, form of tooth perforations, and the degree, intensity, frequency, innovation and degree of association of design elements. These trends are seen as indications of a major shift in human behavior during the Solutrean, resulting in a highly innovative, expressive, communicative Late Upper Paleolithic set of behaviors.

10.2.2. The Magdalenian

The Magdalenian is the fourth, and final, stage in the traditional four-stage chronology for the Upper Paleolithic. After the Last Glacial Maximum, with increasing warmth, gradual, patchy recolonization of the northern portion of Europe took place. In Spain, people also moved inland into Cantabria and up the sides of the Pyrenees (Cazals and Bon 2007; Rissetto 2010; Utrilla Miranda 1981). The Magdalenian followed the Solutrean and preceded the Azilian (see Table 10.1). Both of these periods are defined primarily on the basis of climatic factors in addition to variation in material culture. As discussed previously, the Solutrean took place during the Last Glacial Maximum, which

was characterized by cold and dry conditions. The Azilian and Mesolithic take place in the subsequent Holocene, the latest temperate interglacial phase, in which we currently find ourselves. Thus, the Magdalenian can first be defined as the period between these two climatic phases. The Magdalenian is that time between the Last Glacial Maximum and the Holocene in which the overall trend was one of warming and increasing humidity, although the occupants of the period were more likely to have noted the extreme variability of this period. Some of the more extreme fluctuations were in fact at a time scale that would have been easily incorporated in the cultural memory of Magdalenian people, as changes took place over a few generations.

The Magdalenian has been the object of a vast amount of archaeological research on a wide range of topics. The period is particularly known for the rupestral and mobile art that is found throughout the Upper Paleolithic but finds its most impressive and widespread expression during this later period. As the period in which the grandest and most impressive painted caves were elaborated, the Magdalenian has long called attention to itself as a subject of archaeological investigation, particularly in the excavation of large caves and in the creation of typologies of cave paintings and related imagery on bone and other media. The material culture of the Magdalenian is, in general, vast. Caves with tens of centimeters, if not meters, of dense archaeological levels are not uncommon. The lithic material from the phase, while not as flashy as the Solutrean points and other lithic artifacts from the Last Glacial Maximum, is numerous and well-studied. In general the lithics are characterized by micro-blade technologies, likely mounted in osseous shafts, and burins, scrapers, and other small lithic artifact

forms. Utilized flakes are also common (Baldeón 1985; Cazals 2000a, b; Gassiot Ballbè 2002; Symens 1986).

10.2.2.1. The Magdalenian in Northern Spain

The broad sequences of the Upper Paleolithic were originally defined in France and then its use has extended to other regions of Europe. There are difficulties in applying this chronological system in other regions, especially for the Magdalenian of Northern Spain, as noted by a number of researchers over the years (Corchón Rodríguez 1994, 1999; Freeman, et al. 1988; González Morales 2005; González Sáinz and Utrilla Miranda 2005; Mussi 2001; Straus 2005). Early in the development of the discipline, researchers such as the Abbe Breuil and Hugh Obermaier in Cantabria, and other key figures such as V.G. Childe, were deeply influenced by the concept of diffusion and migration as the primary means by which changes in material culture occurred. This tendency, coupled with the early and prolific work of many French prehistorians ranging from the essentially amateur to the completely professional, resulted in a *modus operandi* centered on the search for origins of innovation and means by which these innovations spread. While it is undeniable that there are certain key features that are widespread and can be used to define the Magdalenian on a broad geographical scale, in fact, there is also a high degree of regional variability. One aspect of that variability is critical to this research, namely, the appearance of the eyed needle at different times in different places.

However, this is only one tiny example of the overall pattern of localized variability, innovation, and tradition. Here, I will focus on the Magdalenian in Northern Spain.

The transition from the Solutrean to the Magdalenian was gradual in northern Spain. The Magdalenian here was a period in which populations decreased, as some groups returned to areas farther north as glaciers and cold conditions receded. Unlike the challenges that faced Magdalenian peoples moving out of southern European refugia into more northern zones, and faced a recolonization period, for the Magdalenians of Iberia, the challenges of recolonization do not frame the cultural innovations of the Magdalenian. While the climate and ecology changed, the physical and geological landscape stayed the same for the populations that did not venture out of Iberia, but rather spread through newly depopulated areas.

The Magdalenian of northern Spain was characterized by overall climatic amelioration, with continued instability. An overall diversification of lithics and a shift in emphasis to low-investment tools, along with increased and diversified symbolic expression is apparent at this time. There is an increase in site density in the lowlands and along river valleys, accompanied by a return to uplands and more northern areas, as well as an increasing diversification of site types. Cave painting flourished in this period; some large painted sites are found at the center of clusters of living sites. Geometric signs and hunted animals are common in the repertoire of these paintings; other animals and anthropomorphs also occur but with less frequency. Mobile art and objects of personal adornment are also common. Communication throughout much of Western Europe

may have been aided by shared conceptual themes and depiction styles, even as the import of lithic material and other items from outside northern Spain decreased (Straus 2005).

A number of studies have helped define the general outlines of Magdalenian lifeways in Northern Spain and neighboring regions. Nathalie Cazals (Cazals 2000) examined lithic materials from the majority of the sites presented here. Cazals (2000) shows that functional analyses indicate that many Early Magdalenian lithic tools, particularly informal or expedient ones, were used for multiple functions or have forms that do not correspond to a single function. She concludes that specialized sites probably did not exist. Instead, sites with an extreme predominance of a certain faunal species probably reflect environmental issues, rather than prey selection. However, the production of osseous tools along with the cutting of soft materials that she identifies from lithic use wear is not inconsistent with the use of the site for concentrated hunting of one species. Nonetheless, Cazals notes importantly that wear analyses often reveal a much larger range of functions than studies focused on identifying morphological types, a fact that is more marked in studies of minimally worked industries such as that of the lithic assemblages of the Early Magdalenian of Cantabria. She discusses the lithic assemblages of Rascaño and Erralla and shows that there is a large degree of variation that is masked by simple morphological analysis because informal tools or minimally retouched pieces constitute an important fraction of the lithic assemblage and are functionally diverse despite their typological uniformity.

A number of site types can be identified for the Magdalenian. One of the better-known studies of Magdalenian social organization in northern Spain is that by Margaret Conkey (1980). Although Conkey's analysis was criticized for the compression of 50cm of stratigraphy as a single depositional episode, it does show the potential importance of bone and antler as expressive media during the Late Upper Paleolithic. Conkey (1980) argued that while the dominant model for hunter-gatherer ecology has long been a generalized aggregation-dispersal model, it is often the case that these two site types are determined to be present a priori and then archaeological evidence is fitted to the model. Aggregation-dispersal organization has been identified in ethnographic populations in a number of environments and seems to be related to variation in resource availability over the year. However, when considering social reasons for aggregation, a significant amount of variation is revealed. Conkey argued that alternating aggregation-dispersal modes may not be of great antiquity as a pattern of human or hominid organization.

From the ethnographic record, Conkey identifies certain features of aggregation. Labor per individual is not decreased, and may increase. Resource quantity and diversity may increase. Ritual serves to stabilize an inherently unstable organization. She notes that if social mechanisms are necessary to aggregation, then aggregation-dispersal patterns could not have evolved before the social mechanisms that supported and enforced it did.

Conkey used the Magdalenian of northern Spain as a case study for her argument. In the Late Upper Paleolithic, most sites identified as aggregation sites are caves too small to house 100+ people, but since these cave sites are the location of the vast majority of excavation, analyses of settlement and social organization have focused on these sites. Conkey identified certain variables that might be used to discern aggregation sites from other Late Upper Paleolithic occupations, including: settlement duration, spatial extent, number and social roles of individuals, activities or context, and reuse. Conkey notes that many of the indicators of aggregation will vary by type of aggregation, but may also vary between groups even for the same aggregation type. Site maintenance may be of use in identifying duration of aggregation. If Altamira was an aggregation site for the "harvest season," as suggested by Freeman, then archaeological markers of large groups should be evident. These archaeological signatures might include repeated seasonal occupation, maintained internal site organization, along with a greater range of activities than can be identified at other, smaller, coeval sites.

Because of the age and limited extent of excavation at Altamira, it is nearly impossible to identify very many specific activities. However, it is necessary to demonstrate the relative diversity of artifacts and tasks at the site to establish its role as an aggregation location by Conkey's criteria. Faunal remains indicate a seasonal occupation of the site, but seasonal occupation is not always associated with aggregation. Despite the limited extent of excavation at the site and the grouping of stratigraphic levels, diversity in fauna and artifact assemblages appear high. Given their social and symbolic importance, Conkey chose osseous artifacts as the object of her analysis of stylistic

diversity at Altamira. There are 58 engraved bone and antler objects at Altamira, some of which are formal tools while others are otherwise unmodified bone and antler. Engravings were analyzed at a number of scales: the most fundamental is design element (line, curve, etc), which may be organized by structural principles (continuous, interrupted, closing, etc). Thirty of fifty-eight artifacts at Altamira show a structural principle and nearly all of the structural principles identified in the Magdalenian overall are found at Altamira.

Conkey's statistical analysis (Conkey 1980; Kintigh 1984)indicated that design elements were more variable at Altamira and certain designs were unique to the site. Structural principles were more variable but there were no principles unique to the site. This may indicate that structural principles were shared throughout the region while differentiation took place at the scale of design element. Diversity in design elements at Cueto de la Mina suggests that it may be another location of aggregation. Design elements found there but lacking at Altamira are all unique to Cueto de la Mina.

In another attempt to identify aspects of the aggregation-dispersal mode of mobility in the Late Upper Paleolithic of northern Spain, Straus (1987) cataloged several major clusters of symbolic sites in Cantabria and argued that they correlate with habitation clusters. Areas that are lacking in caves whose predominate use was the creation of cave art are typically also lacking in habitation sites. The sites are distributed through the region in clusters that are marked at the center or the boundaries by major “sanctuaries” which may have played a number of roles in the Upper Paleolithic,

including marking territories, communicating identity or other information and facilitating aggregations for the purpose of exchange or to facilitate seasonal large-group subsistence techniques. The clusters each have major sites, generally major "sanctuaries" and numerous small and medium-sized sites. Clusters are separated from each other by "buffer zones" which are generally many kilometers in size and devoid of either habitation sites or evidence of symbolic behavior. The major clusters of Late Upper Paleolithic sites in northern Spain are those of Nalon, Rio Sella, Posada, Rio Nansa, central Santander, and Ramales.

Summary: The Magdalenian in Spain was a time of significant change, likely related both to environmental and social shifts. Population decreased while new sites in the mountain zones were established. Magdalenian material culture is rich, with lithic and osseous tools important components in most sites. During this period, there may have been substantial changes in the ways that groups related to each other on the landscape, although the social dimensions of Magdalenian life are not clear.

10.2.3. The Azilian

The Azilian follows the Magdalenian but precedes the true Mesolithic in Northern Spain. Azilian sites can technically be defined by the presence of harpoons with flat cross-sections and fall around 11,000-10,500 B.P.   The other classic marker of the Azilian,

painted cobbles, is rare in Azilian sites in Northern Spain. Most Azilian sites overlie Magdalenian deposits and the subsistence patterns are similar. Lithic technology is also fairly similar to Magdalenian levels, although with a simplified lithic repertoire and an emphasis on microliths. The Azilian is interesting from the perspective of osseous artifacts, as the diversity of bone tools drops dramatically during this period. Harpoons and simple awls are the most common kinds of osseous artifacts. Even more curious, considering their role in the manufacture of fiber technologies, bone needles disappear entirely (Adán Álvarez, et al. 2001; Fernández-Treguerres Velasco 1980, 2006).

10.2.4. Climate and ecology in the Late Upper Paleolithic

The environment in which human groups live is the stage on which all their activities play out, and as such, provides a number of possibilities and constraints for innovation. This is not to say that the environment determines the curve of human trajectories, but rather, that the inescapable fact is that the resources immediately available to a group are those that are likely to play a primary role in their daily lives.

One general argument made to support the assumption of the primacy of leathers and hides in the Late Upper Paleolithic is based on the harsh, cold climate and fluctuating environment of the last Ice Age (Gilligan 2010; Owen 2005). The basic argument is as follows: temperatures in the Ice Age were lower and more variable, while humidity was

higher. The environment was harsh, but conducive to big game hunting, as large game are not affected by these climate swings, and biotic communities arose that contained a mix of flora and fauna not currently seen in the more stratified ecozones of today's globe.

Populations were highly mobile, in order to take advantage of these resources, and relied on symbolic means to negotiate interactions between and within groups on the landscape. These characterizations of the social and environmental context of the Late Pleistocene are then extended into assumptions about the material culture of people of this time, which includes the idea that hides and leathers were the only kind of soft materials used for the manufacture of clothing and other artifacts. For example, Ian Gilligan (2007, 2010) argues that the production of tailored clothing allowed anatomically modern humans an advantage over Neandertals during the coldest temperatures in the Solutrean during the cold snap of the Last Glacial Maximum. He suggests that woven clothing may have appeared soon after in Eastern Europe as temperatures warmed, because clothing had taken on social meaning during the period when it was physically necessary to ensure survival, but the warmest furs and hides were no longer essential for conserving body heat. Gilligan does not consider the effect of seasonal shifts in weather on the production and use of fur or woven clothing.

There are two problems with these characterizations: 1) they are not entirely correct, but are gross oversimplifications of a long and socially and climatically complex period

and 2) the assumptions about the impact of environmental change on material culture do not result from this environmental description.

Regarding the simplistic environmental reconstructions, while the end of the Pleistocene was certainly cooler and wetter, in general, than current conditions, this characterization minimizes the amount of variation on the scale of years and generations – the scales at which people make objects and choices about those objects.

In addition, Owen (1994) argues that misconceptions about the climate during the Upper Paleolithic have led researchers to imagine a barren landscape, devoid of usable plants, but that in reality fibrous plants were widely available. The evidence of plant diversity for the Late Upper Paleolithic is primarily palynological. Although the pollen profile at a site is not a direct indication either relative abundance of plants on the landscape or of the human exploitation of plant resources, the presence of pollen does indicate the availability of these plants for human use. The plants identified through pollen analysis can then be assessed for utility in the production of perishable materials, based on ethnographic and historical manufacture and use records. The mere presence of usable plants, however, does not establish their use – this must be determined through other means.

As a base condition, however, pollen from Late Upper Paleolithic sites in Northern Spain indicate that fiber-yielding plants were present in the environment (Boyer-Klein 1981; Boyer-Klein and Leroi-Gourhan 1985; Carrión García, et al. 2000; Carrion, et al. 2000;

Leroi-Gourhan 1986; Owen 1999; Tyldesley and Bahn 1983). Examples include grasses (*Graminaea*), sedges (*Cyperaceae*), cattails (*Typha latifolia*), birch (*Betula spp.*), nettle (*Urtica spp.*), juniper (*Juniperus spp.*) and willow (*Salix spp.*), all of which could have been used for the production of basketry or woven fabrics.

Ethnographic reports on groups that live in harsh climates, such as the North American Arctic (which is colder and drier than much of the Western European Upper Paleolithic), indicate that plant materials are widely exploited. Ethnographic data also indicates that plant materials form an important component of the material culture even of groups in harsh, cold environments such as the North American Arctic and Subarctic. The bark and bast of many trees can be used for the production of basketry and cordage, which can be woven into other forms. Bark and tree root objects often decay quickly, but have been recovered from Late Mesolithic and Early Neolithic sites in Denmark (Berghe, et al. 2009; Hald 1942, 1950). Cordage can also be produced from flowering plants notably including nettle (*Urtica spp.*), milkweed (*Asclepias spp.*), flax (*Linum lewisii*), hemp (*Cannabis sativa*) and kelp (*Nereocystis luetkeana*). Many varieties of rushes, coarse grasses, and silk grass have also been used to make baskets, mats, bags and nets. Eskimo groups, despite the harsh environment they lived in, relied on fibrous plants for a variety of purposes, including the production of mats, baskets, cordage netting, ropes, and ornaments. A variety of grasses were also used as padding and insulation in shoes. Aleuts made exceptionally fine baskets, mats and rope from dune grass (*Elymus arenarius mollis*) (Damas 1984; Moerman 1998; Osgood 1970). Archaeological materials from the Great Basin include basketry as old as 11,000 years made with the following

raw materials: tule (*Scirpus spp.*), cattail (*Typha latifola*), sagebrush (*Artemisia tridentata*), true rush (*Juncus spp*.), willow (*Salix spp.),* cane (*Phragmites spp.*), Indian hemp (*Apocynum spp.*), milkweed (*Asclepias speciosa*), cedar (*Juniperus osteosperma*), cliff rose (*Cowania mexicana*), white sage (*Eurotia lanata*), and squaw bush (*Rhus trilobata*) (Owen 2005; Strong 1969). Thus, both plant based technologies of great age known archaeologically and ethnographic exploitation of plants even in cold climates suggest that plants almost certainly played an important role in the material culture of Upper Paleolithic Spain.

10.3. Bone Tools in the Late Upper Paleolithic of Spain:

Osseous materials are one of the major sources of raw material for the construction of artifacts in the Upper Paleolithic and were worked into a range of forms. Some of the common artifact forms, including harpoons, hunting points, and eyed needles have relatively well-defined functions, while others, such as spatulate forms, incised rods, and fine points are less well understood. Here I present the analysis of worked bone and antler artifacts from three Late Upper Paleolithic sites from north-central Spain, La Peña del Perro, El Abrigo de Entrefoces and La Cueva del Juyo (Figure 10.1).

Figure 10.1. Location of Entrefoces, El Juyo and El Perro in Northern Spain

As has been noted, there is a significant knowledge gap in our understanding of Late Upper Paleolithic cultures that revolves around raw materials that were likely to have affected many aspects of social and economic life. This is due both to the lack of awareness of the potential of many recovery and sampling techniques as well as the assumption that there is nothing to be found, so why look for it? This attitude is reflected by the differences in approaches to Upper Paleolithic sediments as opposed to those of Neolithic sites, where it is more commonly expected that seeds, grains, tiny macro-botanical fragments, basketry, textiles, hides, and imprints or casts of perishable

materials might be located through extremely careful excavation techniques. These finds, when they do appear, often make for big news, justifying them in the face of the first barrier, economic considerations.

However, because most archaeologists assume that there was no little use of plants either as key dietary elements or as raw materials in the Upper Paleolithic, the investment of floating large portions of the sediment, sampling for pollens and phytoliths, chemical analyses to identify organic remains, and cautious washing and processing strategies are not generally employed. Excavation best practices would include very careful digging, flotation, water screening, and recovery protocols aimed at all classes of organic remains. Two major obstacles prevent this type of maximized recovery. The first, and widely recognized, barrier is the economics of fieldwork, both in terms of money and time. Full recovery is often assumed to be costly and laborious, and at times the output does not seem to justify the increase in energy and resources invested into the recovery of a small percentage of finds. However, many simple changes in recovery methods can dramatically increase the likelihood of recovering small, fragile or unusual archaeological remains (Freeman, et al. 1998; Nagaoka 2005). There are, of course, exceptions to this rule, which have often produced impressive finds. For example, Freeman and Echegaray found that flotation of sediment from El Juyo allowed them to not only recover vast amounts of macro-botanical, insects and tiny lithics, but also produced minute fragments from the osseous industry, including an impressive collection of 48 needle eyes that probably would not have been recovered otherwise.

10.4. Analysis of Archaeological Collections

The original scope of this project was quite broad in terms of the archaeological collections to be studied. The number of Late Upper Paleolithic sites in Northern Spain is large and many have significant collections of bone and antler tools. However, logistical difficulties reduced the number of accessible collections and the possibility for microscopic study of all specimens. Poor preservation of osseous artifacts at some sites, such as Altamira, rendered further microscopic study useless as wear patterns were obliterated or flaked off (Figure 10.2). Because the archaeological section of this study was preliminary and explorative and designed to test the utility of the comparative standards developed for the assessment of different kinds of wear from soft materials, the final sample was intentionally limited. Finally, in light of the extraordinary nature of the El Juyo collections, these were selected as the focus of the archaeological study. Small collections from the sites of Entrefoces and El Perro were also studied, providing a social and economic contrast to the people and activities that created the deposits at El Juyo. Later research will expand on these findings and attempt to make comparisons between sites and across regions, as this study is by no means meant to be interpreted as a representative sample of the osseous artifacts of the Late Upper Paleolithic of Northern Spain.

Figure 10.2. Needle from Altamira with complete morphology but no preservation of the original surface

Cave deposits from Upper Paleolithic contexts tend to be complex palimpsests that compress hundreds or thousands of years of deposition. Identifying individual events or activity areas is rarely possible with the excavation techniques commonly employed. Distinguishing such events requires fine-scaled recovery methods and careful attention to taphonomy, provenience and site layout. Because of the enormous amount of work entailed in excavating, mapping and analyzing a site for activity areas or fine-grained chronological distinctions, few excavations focus on this kind of data. However, given my interest in identifying the use of plant fibers for artifact construction, I grouped artifacts by site rather than any finer chronological or intrasite provenience distinctions. This allows me to focus on the goal of grouping artifacts by use material, rather than examining the patterns of bone tool production or use more specifically at the site level. This approach is appropriate to the available information on the Late Upper Paleolithic in Northern Spain and to the questions of interest.

10.4.1 Spanish Late Upper Paleolithic worked bone studies

The worked bone collections from Late Upper Paleolithic Northern Spain are large, often well preserved, and impressive, so they have received extensive attention, especially in terms of their typological significance for chronology building and their possible roles in symbolic communication. Common artifacts include antler *sagaies*, antler harpoons, formal and informal bone awls, engraved bone, perforated teeth, antler and bone nuclei and blanks, shell tools and collected shells, antler and bone rods or batons (*varillas*), and other objects (Adán Álvarez 1997; Álvarez Fernández 2006; Barandiarán Maestu 1967, 1994; Corchón Rodríguez 1986). Barandiarán's worked bone typology for the region includes five families of artifacts (*apuntados* [pointed], *aplanados* [flat], *dentados* [toothed, serrated or hooked], *perforados* [perforated], *varios* [miscellaneous]), 30 artifact groups and 81 artifact types, many of which have several sub-types (see Appendix II). It was not logistically feasible to microscopically study the entirety of the worked bone assemblage from any site. However, nearly all of the sites studied have published osseous artifact inventories and typological analyses (Barandiarán 1985; Barandiarán Maestu 1981; Cabrera Valdés 1991; Delgado Peña 1990, 1991; González Morales 1986; Morales and Moreno 1988).

Several classes of osseous artifacts were identified as having the greatest potential to inform on the questions posed in this study. These are the same forms that were used

to create the experimental and ethnographic samples. They can be placed in five groups:

- needles
- awls, bodkins, pins
- spatulate tools and smoothers
- rods, batons, *varillas*
- *sagaies* and fine antler points (*puntas finas*)

A sixth class, mesial fragments, may represent complete artifacts from any of these categories. Although mesial fragments are usually grouped into one of the above classes based on size and raw material, in my analysis I opted to isolate these objects in order to avoid making both functional and morphological assumptions based solely on object diameter and raw material.

10.4.1.1. Needles

Eyed bone needles are a common artifact found at most Late Upper Paleolithic sites in Northern Spain. They can be defined primarily by a longitudinal form and the presence of both a perforation or eye and one or two pointed ends (Figure 10.3). Although not

technically part of the definition of a needle, most needles in the Late Upper Paleolithic are quite small. In practice small mesial fragments on long bone tools found at Late Upper Paleolithic sites are usually identified as needle fragments if the diameter is under ~5mm.

Figure 10.3. Complete, broken needle, El Juyo (10M6 85)

The definitive work on Upper Paleolithic needles is that of Danielle Stordeur-Yedid (1979), who undertook a large-scale study on the form, manufacture, and to a lesser extent, use of bone needles in the Late Upper Paleolithic of France. Her careful examination of all bone needles known at that time allowed her to reconstruct a generalized manufacture process and a morphological typology to group different kinds of needles and to show that needles appear in the Franco-Cantabrian region during the Solutrean. McComb (1989) also identified both needles and needle blanks in the Upper Paleolithic collections from Britain and Belgium, none of which are demonstrably older than the Late Solutrean. Although she does not clearly state her criteria for recognizing a "needle blank," she does note that about half of them were removed from the cortical

section of bone or antler with the groove and splinter technique, which results in an approximately triangular cross-section, while the other half were made from sawed strips of bird bone, which have a rectangular or oval cross-section and may still have interior veins visible on one side of the blank or needle. Bird bone needles are not common in Late Upper Paleolithic Northern Spain.

At sites from the Late Upper Paleolithic in Northern Spain, needle production is generally begun with the extraction of a blank, or long, narrow segment, typically by the groove and splinter technique. The proximal end is then sawed off transversely and the blank is abraded into shape, including the creation of the tip. The perforation of the needle to produce the eye is often begun with scraping on one or both sides to thin the area to be pierced. On some unfinished blanks, a small incision marking the location of the eye can be seen. Needle eyes in McComb's sample range from 0.4-0.1 cm long and 0.4-0.1 cm wide while Stordeur-Yedid's sample ranges 1.4-0.6 mm and most are approximately circular. Bilateral drilling, resulting in a biconical shape, is the most common method for actual perforation, after which the interior of the eye may be smoothed. Any small, robust projection can be used to make the eye, including sharp flakes (McComb 1989). Most needles are highly polished, which can be achieved with finely edged lithics and serves to consolidate the surface, which strengthens the artifact. This often obliterates all or most manufacturing traces. Some needles are curved, which may have been the original shape or a taphonomic factor. There is some evidence of the reworking of broken needles including abrupt tip angles and evidence of smoothing over breaks. Reperforated eyes are not uncommon. McComb (1989) identified use

wear on only one needle in the form of localized polish. Several are broken at the eye, which may have been a result of use, and several are polished at the tip, but this may have been due to manufacture rather than use.

10.4.1.2. Awls, Bodkins, Pins

This class is the most diverse and the most poorly defined in terms of both morphology and proposed function. There are no clear morphological definitions of these kinds of artifacts, aside from the presence of one pointed end. These tools range in both size and manufacture technique from tiny splinters of bone that have been sharpened (Figures 10.4-10.9) to split and pointed long bones, most commonly metapodials and ulnae. Some artifacts have been made from fully extracted bone blanks that do no retain any anatomical features, while others are only modified at the working zone. It is likely that the long and pointy objects that fall into this class encompass numerous functions. Some are likely to be single-purpose tools while others are likely to be multi-functional. The variation in size is also greater than the other artifact groups discussed here.

Figure 10.4. Pointed bone artifact, El Juyo (10M 156 #254)

Figure 10.5 Pointed bone artifact, El Juyo 10N 9 #838)

Figure 10.6 Pointed bone artifact, El Jujo (12P 7, Niv 4)

Figure 10.7 Pointed bone artifact, El Juyo (9O 175 #61)

Figure 10.8 Pointed bone artifact, El Juyo (10 N1 #3949)

Figure 10.9 Pointed bone artifact, El Juyo (10R 160 #1995)

Those artifacts that are identifiable to the element were not available for study, as they were curated with the faunal collections. Thus, awls from split ulnae or metapodials, while common at Late Upper Paleolithic sites, were not included in this sample. Generally, they may be made on the long bones of any of the commonly identified species at Late Upper Paleolithic sites, including ibex, red deer, or roe deer.

McComb (1989) defines pins as narrow cylinders of bone or ivory which are pointed at one end and have a bulb or swelling at the other end. Of the three needles in her study, one is perforated but McComb says that its size “precludes this piece from being a needle” (McComb 1989:113). From their form, McComb suggests that they were used to pin clothing or hair and she finds the suggestion of de Heinzelin (1973) that the perforated pin was designed to hold decorations such as flowers or feathers convincing.

10.4.1.3. Spatulate tools, smoothers

Spatulate tools or smoothers (Fr: *lissoirs*), are quite common in the French Late Upper Paleolithic but are somewhat less common in the Late Upper Paleolithic of Northern Spain. *Lissoirs* and spatulas constitute a poorly defined category that has variously been assigned a range of morphological definitions and proposed functions (Figures 10.10-10.11).

Figure 10.10. Spatulate tool tip (El Juyo 10Q 880)

Figure 10.11. Spatulate tool tip (El Juyo 951478#362)

Although defining the class is difficult, due the variation in form and attributed function, generally, the identification of the *lissoir* or smoother relies on the presence of an active zone used for polishing which is narrow, somewhat shiny, and where polish from the working of soft materials is the primary use wear present (Averbouh and Buisson 1996, 2003). These tools are often made from full or split ribs from medium and large-sized herbivores, although other forms are also known. The production of blanks consists of roughing out a rectangular shape from the rib. For the common *lissoirs*, first the head of the rib is cut or snapped off. Then, in some cases the borders were grooved so that the two sides could be split, while in other cases a groove was made down the face of the rib to delimit a finer blank. The distal end was shaped by scraping or abrasion against sandstone. McComb (1989) described a group of tools she names "bone segments with polish" that also fits in with general spatulate tools. This group is composed of rib

sections, generally curved, with polish (*lissoirs*) and may be related to "spatulas". Polish is found on several of these artifacts on the ends or lower surface of the bone. Aurélia Peltier (1986) identifies this polish as resulting from hide scraping, although some of her results were inconclusive due to the poor preservation of the artifacts. McComb states that trying to identify the source of polish is not possible. None of the examples studied were made from antler, although antler spatulate tools are found at some Upper Paleolithic sites in Spain.

10.4.1.4. Rods, batons, varillas

The rods, batons, wands, and *varillas*, are elongated, narrow tools that do not have a pointed end, thus distinguishing them from awls and other long, pointy tools (Figure 10.12). They range from fragments a few centimeters long to around 15 cm. Small fragments may be difficult to identify as either a *varilla* or *sagaie* section, as they are differentiated from *sagaies* based on the presence of a beveled end on the *sagaie*. The purpose of these tools is unknown, although the names assigned to them – wand, baton – indicate that many researchers assume that their function is primarily symbolic or communicative. Soffer (2004), however, has suggested that the shape and size of these tools indicates that they could serve as weaving battens.

Figure 10.12. Varillas from Entrefoces (A-52, A-62, A-63)

10.4.1.5. Sagaies, antler points

Long, pointy antler forms are generally all identified as hunting points (Fr. and common English usage *sagaie*; Sp. *azagaya*). These points vary in diameter and length, ranging up to 1.5cm in diameter and as long as 10cm in length, although occasionally longer ones appear (Figures 10.13-10.17). *Sagaies* are often decorated. Some *sagaies* are made from bone. Knecht (1997) suggests that the following common characteristics of all osseous points are related to hafting techniques: textured surfaces (either cancellous bone or scored areas), notched or incised lateral edges, rounded forms with distinct flattened areas.

Figure 10.13. Sagaie, superior face, El Juyo (11Q #6200)

Figure 10.14. Sagaie, inferior face, El Juyo (11Q #6200)

Figure 10.15. Large, decorated bone sagaie or varilla, El Juyo (8O #374)

Figure 10.16. Sagaie, no bevel, El Juyo (9R #79)

Figure 10.17. Decorated sagaie, El Juyo (8N #517)

A common kind of bone or antler artifact in the Late Upper Paleolithic of Northern Spain is the *punta fina*, or gracile point, that is distinguished by its small diameter, often under 10mm (Figures 10.18-10.19). While some of these may be hunting points, it is likely that not all served this function.

Figure 10.18. Small decorated sagaie or punta fina, El Juyo (8O #363)

Figure 10.19. Small sagaie or punta funa, El Juyo (9Q #573)

One of the original proposals of this study concerned the identification of these delicate artifacts as projectile hunting points. Although mechanical properties clearly to not drive every choice made by people within a production sequence, especially in a case such as the choice between bone and antler as a raw material, physical characteristics may have some influence. Particularly in the Late Upper Paleolithic of Northern Spain, unmodified antler is rarely recovered from the archaeological record, but unmodified bone is abundant. It is not unreasonable to suggest that raw material selection may have been driven, in part, by the curation of antler for specific kinds of uses. Additionally, certain kinds of tools, like *sagaies*, are *nearly always* made from antler in the Late Upper Paleolithic, indicating strong selection for a material in this case. Thus, I suggest that the production of *puntas finas* from antler is not chance, but a deliberate choice that may reflect something about the task carried out with these tools.

10.4.2. Sample Selection

Use wear analysis is always complicated by the small sample size that can be analyzed in detail and by a range of factors that limit the availability of objects with attrition signatures (see LeMoine 1997). The artifacts to be studied microscopically were selected from the site-level assemblage based on morphology, condition, and other logistical constraints. Based on ethnographic evidence and performance requirements, those forms that might have been implicated in the production of artifacts from animal or plant fibers were identified. This sampling strategy served a number of purposes. Primarily, it limited the number of artifacts to be studied microscopically to a manageable number. It also limited the scope of the analysis to surface wear patterns based on the defined research goal. Finally, making comparisons across a more limited range of artifact forms facilitates use wear analysis by placing some constraints on the likely ways in which artifacts were used.

Sampling is subject not only to the vagaries of research logistics, but also to a number of factors that affect either all archaeological collections, or are particular to the nature of worked bone and antler. Foremost, taphonomy and excavation and survey design contribute to the make-up of collections that are available for study. Bone is an organic material with a mineral component and is subject to some deterioration under most burial conditions. The basic environment of the karstic caves of Northern Spain is

conducive to the preservation of the mineral component of bone, while more acidic environments are more likely to preserve the collagen component of bone. It has been noted that worked, and especially polished, bone can be more resistant to decay (Johnson 1994), although it is not clear whether this is due to the compaction of the exterior surface from working, which hinders the absorption of water, or to some other factor. In some cases, however, despite preservation of the tool's overall morphology, wear patterns are not visible, due to deterioration of the outermost artifact surface.

Small sample sizes are a difficulty encountered with both ethnographic and archaeological collections. The number of tools from any one area is small in most ethnographic collections, so variation within populations is difficult to assess. Archaeological excavations rarely yield large osseous collections either, due to a variety of taphonomic and methodological factors. Thus, statistical analysis and analyses of site or regional patterning can be difficult. Here, I present the collection studied from these sites, including macroscopic and microscopic analysis.

10.4.3. Entrefoces

El Abrigo de Entrefoces is located on the side of a narrow pass in the region of La Foz de Morcín, Asturias, along the Río Riosa. Excavations at the site took place from 1980-1989 and revealed a sequence of Magdalenian levels, from Early Magdalenian through the

beginning of the Late Magdalenian (approximately 15,000-12,000 years ago). One carbon date from the Early Magdalenian in Level B returned a range of 14,690 ± 200, uncalibrated (Benéitez González and Calleja Fernández 2002; González Morales 1990a). Faunal remains from the site largely consist of caprid and bovid remains typical for the Magdalenian of this area. The lithic industry is predominantly quartz, although retouched tools were preferentially made on chert.

10.4.3.1. Use wear analysis

Twelve artifacts were selected for analysis from the Entrefoces collection. Once again, the sampling strategy was affected by logistical constraints on the artifacts available for study as the Museo de Oviedo was undergoing large-scale renovation, and was then narrowed down to those artifacts with morphological characteristics expected of tools of fiber industry manufacture. Three antler rods (*varillas*), two broken eyed needles – both conserving the base of the perforation, three mesial sections, one worked rib or spatulate tool, and three partial or fragmentary *sagaies* were analyzed.

A-54 is a large, eyed bone needle, recovered from disturbed sediment. The surface is heavily consolidated and wear is not clearly present. The eye does not display evidence of wear, although the surface is largely obscured. Mesial surfaces do not display use wear.

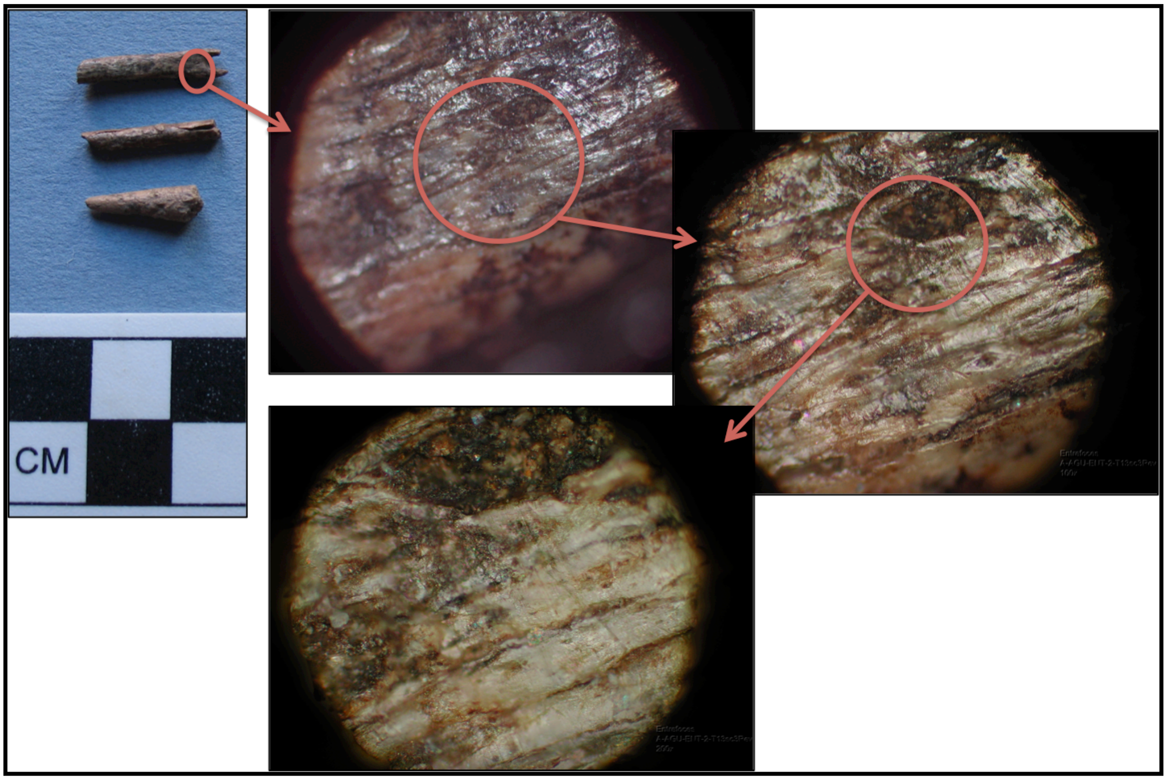


Figure 10.20. Needle without use wear, Entrefoces (A-54)

A-57 is a small, undecorated antler point and use patterns clearly indicate its function as some sort of awl used in a rotating motion with numerous short, transversal striations visible crossing high points of the surface, however the use material is difficult to identify. The polish is non-invasive but shows significant rounding. The general rounding of all surfaces, including striations suggests that the use material was hide or leather, and that the point was used with a rotating motion.

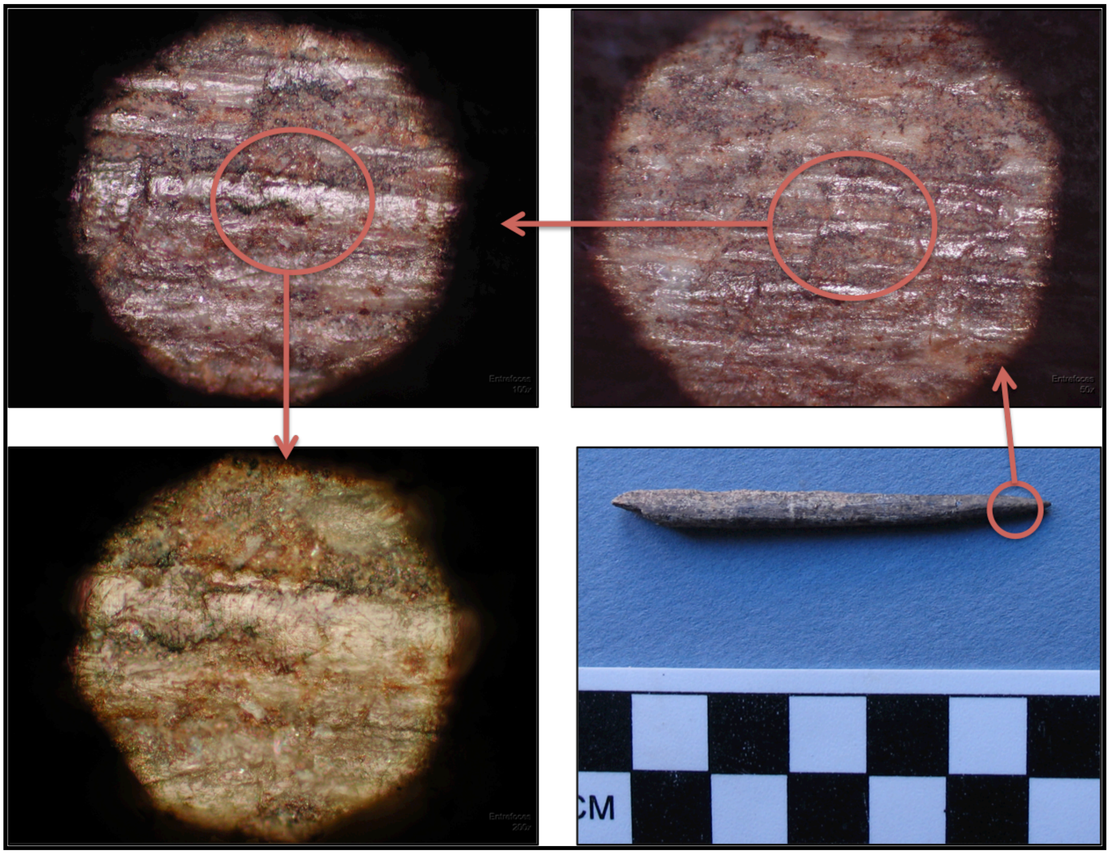


Figure 10.21. Sagaie with use wear, Entrefoces (A-57)

A-58 is a worked antler fragment that may be partially perforated. The poorly preserved and consolidated surface shows no clear indications of use, so it is unclear if this is a piece being reworked by perforation, or if it was broken or lost mid-way through manufacture. The surface appears finished and is highly smoothed with evidence of manufacture obliterated.

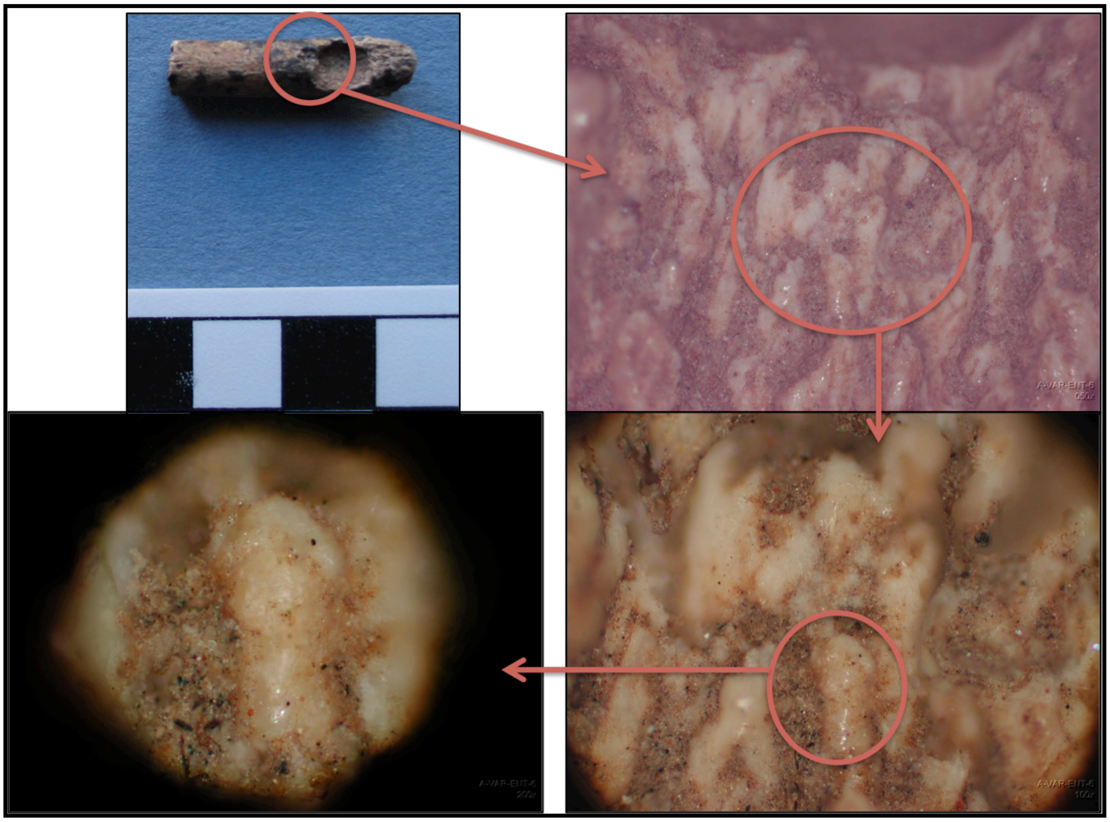


Figure 10.22. Partially perforated artifact from Entrefoces (A-58)

A-59 is a mesial fragment of a flattened oval cross-section point or awl. The smoothed, rounded edges of all surface features indicate that this piece was probably in contact with hide or leather. The strong presence of ochre in all low points of the surface suggests that the leather material, rather than being worked with the tool, may have been leather with an ochre slurry used to polish the surface. However, ochre is not present on all areas of the artifact, so this tool may have been used in conjunction with ochre or this may due to depositional history, as ochre beds are not uncommon at Late Upper Paleolithic sites in Northern Spain.

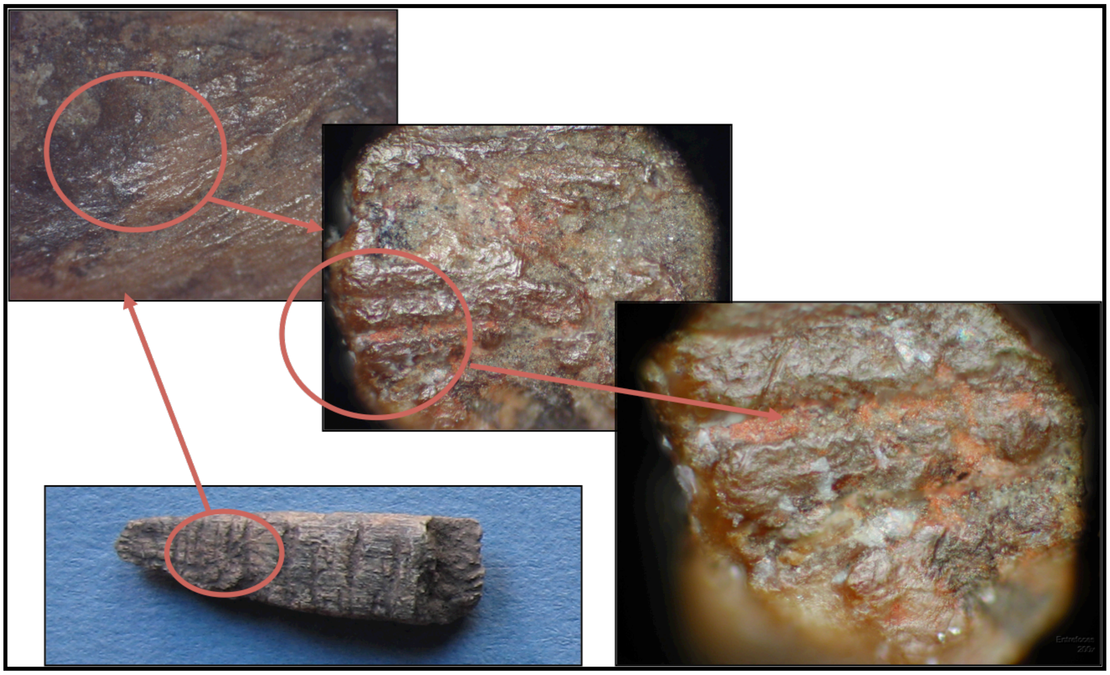


Figure 10.23. Sagaie incised bevel with use wear and ochre residue, Entrefoces (A-59)

A-60 is a split rib in very poor condition. The thick layer of opaque consolidant renders microscopic analysis impossible and it is not even fully clear that the piece is worked bone, although the shape suggests modification.

Figure 10.24. Split rib, Entrefoces (A-60)

A-61 is a split and smoothed rib, formed into a spatulate tool with a squared off, flattened end. Wear is smooth, bright and pitted with frequent, dense, patterned intercrossing striations. The wear pattern is likely due to use on hide, although use of plant materials may also produce this wear pattern. Edges are fairly rounded, although polish is not invasive. Small, grouped, regular striations cross, slightly diagonal to the perpendicular axis of the tool. A small green (synthetic?) fiber clings to the surface on the border and consolidant may be obscuring some surface patterns. Damage from excavation, visible on the surface in some places, has gouged away some of the original surface.

Figure 10.25. Rod with use wear, Entrefoces (A-61)

A-62 is an incised antler varilla or rod. There are three similar varillas from Entrefoces, which present wear that may be indicative of use with plant fibers. The function of

these rods is unknown and their general shape is not suggestive of any particular mode of use. This wear looks very similar to experimental wear from weaving nettle fibers (Figure 10.18, see also Figure 7.6) and indicates substantial use on a soft material. The shape of this specimen would be conducive towards its use in weaving and the incisions may be related to its use in this capacity or may be decorative.

Figure 10.26. Varilla with use wear, Entrefoces (A-62)

A-63 is another antler *varilla* or *sagaie*, with a single, large bevel at one end, broken across the opposite end. The upper surface (opposite the bevel, by convention) is decorated with numerous, regular incisions perpendicular to the axis of the tool. The upper surface of the object displays smooth, planar, well-developed polish with small, bunched striations parallel to the axis. Wear patterns indicate contact with a soft material, but it is difficult to determine the nature of the contact material. If this is a hunting point, wear could possibly result from handling and hafting, although this is not strongly supported by the data.

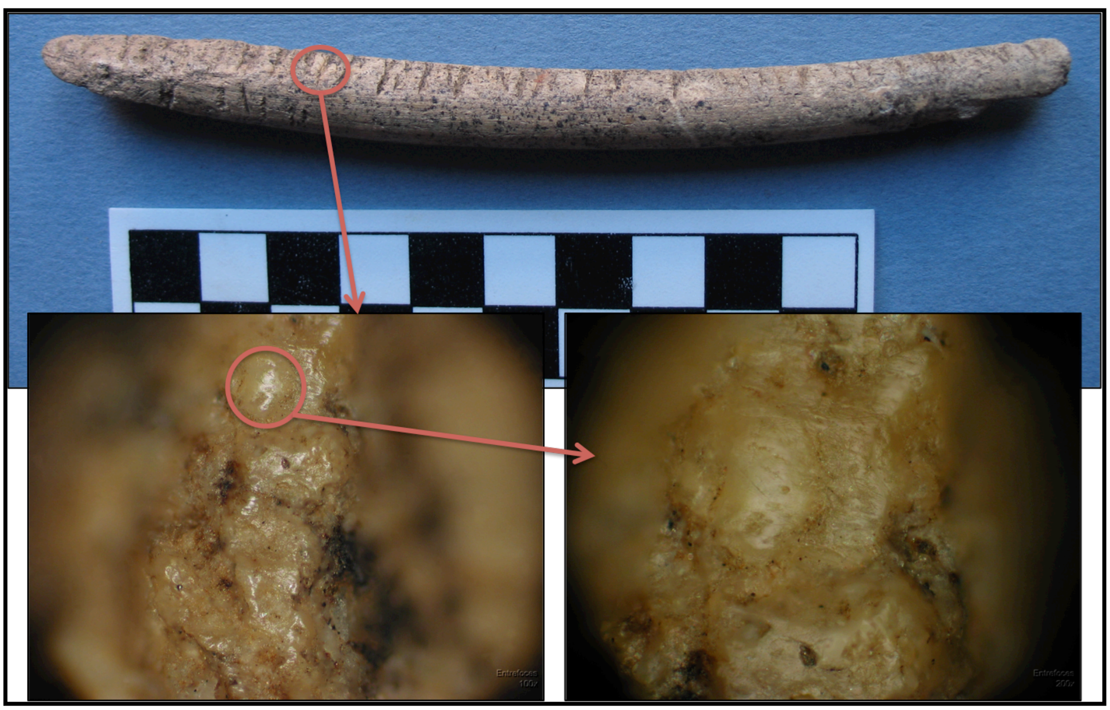


Figure 10.27. Varilla wth use wear, Entrefoces (A-63)

A-64 is a small, decorated antler point or *sagaie*. The piece is in poor condition and has been consolidated, so wears are somewhat obscured. Strong attrition and rounding indicate fairly intensive use, likely on animal hide. Wear is most clearly defined on the bevel, where pitting and longitudinal striations, along with marked loss of volume are evident, indicating that this was the area of the artifact with the most contact with a soft material. Likewise, the tip shows compression and rounding, with some irregular scratches and pits, reflecting pressure but no dominant direction or angle of use. The rest of the surface shows some rounding and polish, but no other distinctive attrition, suggesting minimal contact with other surfaces aside from handling.

Figure 10.28. Decorated sagaie with use wear, Entrefoces (A-64)

10.4.3.2. Summary and Conclusions: Use Wear at Entrefoces

The collection from Entrefoces is notable for the high number of antler rods or *varillas* with perpendicular incisions, which comprise fully one quarter of the analyzed sample. The function of these objects, which are fairly common in the Late Upper Paleolithic of

Northern Spain, is unknown and ethnographic analogies have not provided researchers with many clear directions for further work. The analysis of use wear on antler is more difficult than on bone, as the worked surface is more porous and patterns of attrition can be difficult to identify. However, there are indications that at least some of these artifacts were used against plant fibers.

The Entrefoces collection is varied, both morphologically and functionally. Generally, preservation of osseous artifacts at the site is good and use wear can be documented on many of the tools. Similar to the lithic and faunal evidence, bone and antler tools at Entrefoces indicate a range of subsistence and economic activities took place at the site. Eight of the twelve specimens analyzed have identifiable use wear, although the origin of that wear is strongly suggested by diagnostic attrition patterns in only six of those cases. Wear on some of the *sagaies* may be due to their use as hunting implements, although a more comprehensive study of impact fractures would strengthen this interpretation (Letourneux and Pétillon 2008; Pétillon 2005, 2006). Additionally, the numerous incised antler rods at the site may be implicated in the manipulation of plant fibers. Although the kinds of fiber-based industries made and used in the Magdalenian are currently unknown, artifacts such as those at Entrefoces may provide evidence for the exploitation of a broad range of fiber sources during the end of the Upper Paleolithic.

10.4.4. El Perro

La Peña del Perro (El Perro) is a small set of rock shelters on the Cantabrian coast, located near the present-day town of Santoña and close to the Bay of Santoña and the nearby marshes at the mouth of the Río Asón. The site was occupied from the Late Magdalenian (approximately 12,500-12,000 years ago) through the Azilian (around 12,000-11,2000 years ago) and Mesolithic and contains Azilian and Mesolithic shell middens, along with representative lithic, bone, and faunal deposits from each of these periods (González Morales 1990b; González Morales and Díaz Casado 1992; González Sáinz and Utrilla Miranda 2005; Morales and Moreno 1988). Although both looting and use of the rock shelters for penning livestock resulted in some stratigraphic disturbance, a good deal of the deposits were found to be intact and excavations were carried out in five field seasons from 1985 through 1990, under the direction of Manuel Ramon González Morales. Level 1 was dated to the Mesolithic and will be excluded from this discussion. The lithic industry at the site is typical for the Late Magdalenian and Azilian of the Cantabrian region, with an emphasis on locally acquired raw materials and a tendency toward microblade technologies, especially those forms with simple and abrupt retouched edges. Several stone points were also recovered. Both terrestrial fauna and marine shells are abundant at the site. The shell middens document the transition from rocky tide zone species in the Azilian to estuary species in the Mesolithic. Non-figurative linear engravings were also found on the cave walls and are likely to be

Upper Paleolithic in origin, as similar engravings are common in Upper Paleolithic sites in the Cantabrian region (González Morales 1990b).

The osseous industry included several temporally diagnostic pieces, including an Azilian perforated unilateral harpoon from Level 2a and a number of decorated *sagaies*. Also recovered from Level 2a were a straight bipoint *anzuelo* or gorget, a sharpened bone splinter, the possible end section of an engraved *sagaie*, and a rib fragment with transversal cutmarks. Level 2b, also pertaining to the Azilian, contained a smaller flattened perforated harpoon, 2 puntas de base recortada, two mesial antler point fragments, and two bone points or awls made on bone splinters. Level 2c, dating to the Late Magdalenian, had a single eyed needle and three decorated and one undecorated *sagaie* fragments. Finally, in Level 3, which contained very few cultural remains and could not be assigned to a chrono-cultural unit, a single small *sagaie* fragment was recovered.

10.4.4.1 Use wear analysis

Three artifacts from El Perro were studied microscopically for traces of wear from animal or plant fibers, along with a fourth specimen, that has been reported as a needle fragment, but upon microscopic analysis turned out to be unmodified microfauna. The artifacts were selected based on their availability for study at the time, as the Museo de Santander was being rebuilt in a new location and collections were in storage, as well as

the possibility that these items were used for processing or manipulating fibers, based on morphological characteristics. One complete eyed needle, one mesial fragment, and one point (*punzón*) were selected for analysis.

A-208 is a complete eyed bone needle recovered from Final Magdalenian levels at El Perro. Although the surface is heavily affected by post-depositional scratching, the smooth, pitted polish may be due to use against animal hide. The polish is highly invasive throughout the area of use, suggesting contact against a fiber derived from an animal source. Numerous crossing striations seem to be taphonomic, although it is difficult to eliminate the possibility that some are due to use.

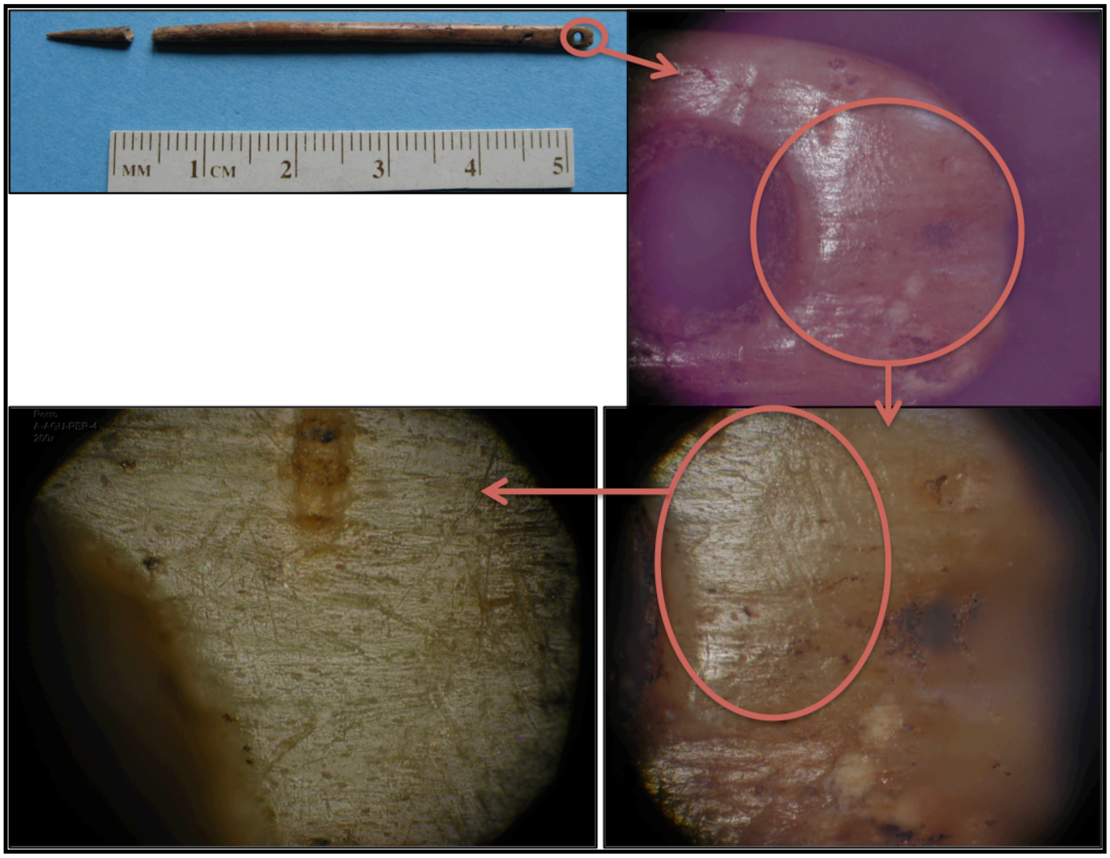


Figure 10.29. Needle from El Perro (A-208)

A-209 is a small mesial fragment of worked bone, likely a needle given its size. The surface is so finely smoothed and polished that no use wear is notable. The piece was probably not used.

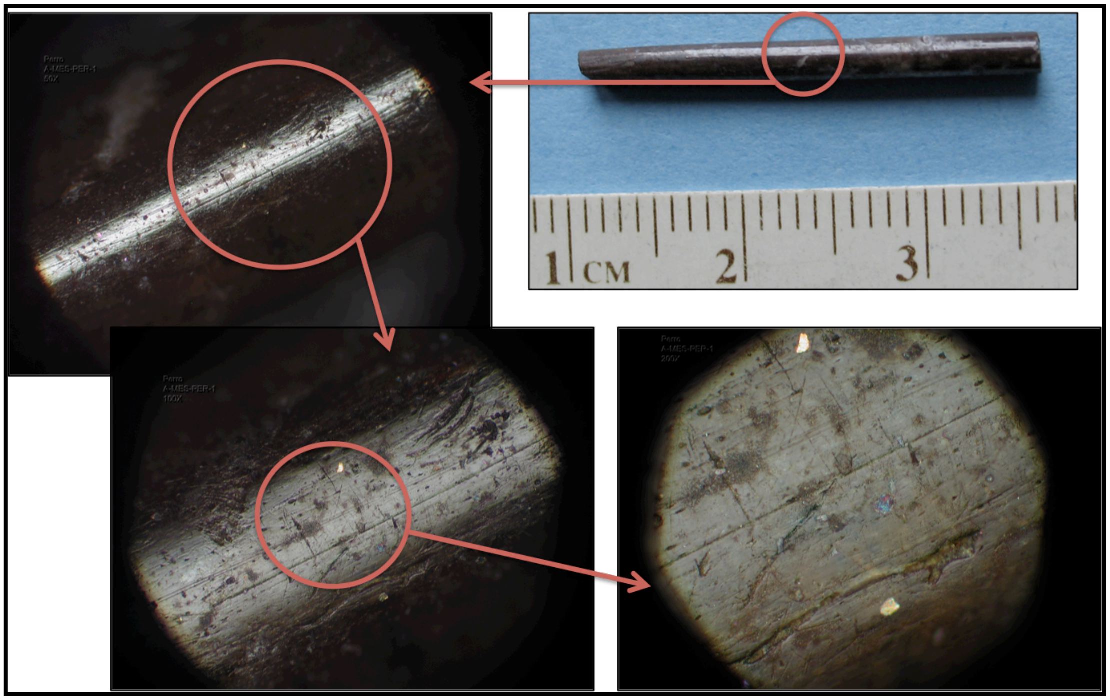


Figure 10.30. Mesial fragment with no notable use wear, El Perro (A-209)

A-210 is a sharpened bone splinter with points on both ends that may have been a multi-purpose tool. Wear typical of both animal and plant materials is present, as indicated by invasive polishes and microtopographic volume loss distributed patchily around the sharper tip, along with areas of noninvasive polish and planar attrition. However, wear against hides predominates. Consolidant brushed onto the surface has obscured wear in several places and can be confused with use polish.

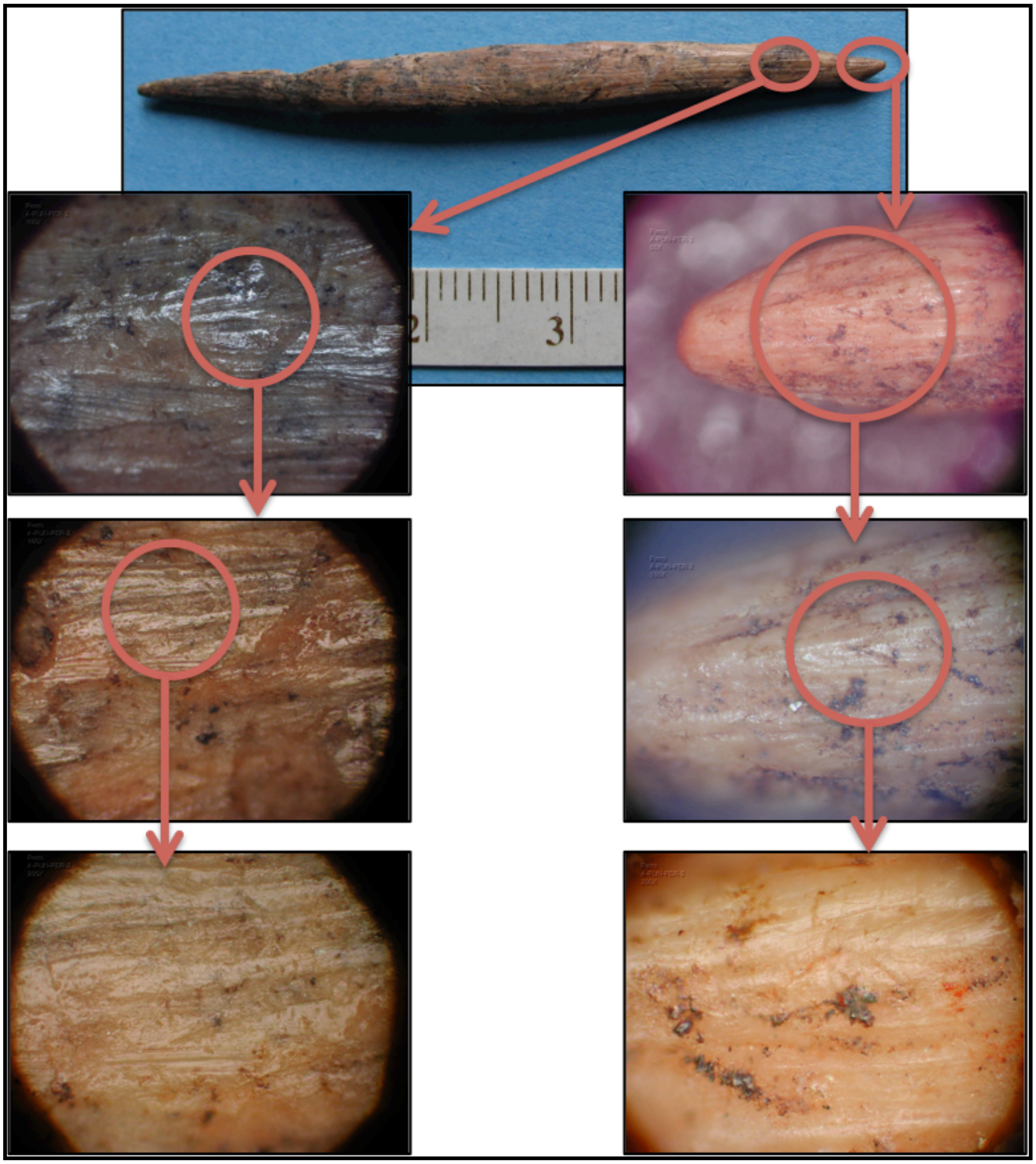


Figure 10.31. Pointed bone artifact with use wear, El Perro (A-210)

A-211 is a microfaunal long bone mistakenly identified as worked bone (see Figure 5.15).

10.4.4.2. Summary and Conclusions: Use Wear at El Perro

The artifacts and wear patterns from El Perro suggest that they were involved in minimal maintenance or repair activities as the primary fiber-based tasks at the site. Of three artifacts studied, two have identifiable wear, primarily from animal-derived sources. A fourth artifact that has been identified as a needle fragment is actually microfauna. Given that the site is a shell midden with limited evidence of longer stays or diverse economic and subsistence activities, it is unsurprising to find little evidence for the manufacture of perishable technologies. The use of the eyed needle on hides and leathers is likely for repair of clothing, bags or nets, as construction of leather clothing or other structures is generally done without the aid of a needle and would not be a likely activity at a coastal shell-collecting site lacking a large faunal assemblage.

10.4.5. El Juyo

The third site from which artifacts were selected for macroscopic and microscopic analysis was La Cueva del Juyo (El Juyo). The site is large and holds an important place in the archaeology of Late Upper Paleolithic northern Spain because of its large artifact collections and possible social significance in the Late Upper Paleolithic of the region. The site has yielded a substantial collection of osseous artifacts, along with other kinds of archaeological remains. The site is found within a large cave located about 8 km from

present-day Santander in the hills leading up from the coast of the Mar Cantábrico inland. There are several galleries, but Late Upper Paleolithic deposits were recovered primarily from the two larger galleries, where the Late Upper Paleolithic entryway is also found. Geometric or non-figurative engraving and numerous smudges apparently from torches are found more widely dispersed in the cave system, although these cannot be attributed a date with any security and Virgilio Fernández Acebo (1985) suggests that they may be substantially younger than the Late Upper Paleolithic site. The Late Upper Paleolithic entryway was blocked off in antiquity by roof-fall and the cave was not opened for excavation until the first field season in 1955. This contributed to the excellent preservation of stratigraphy and archaeological features in the site.

The faunal assemblage at El Juyo is dominated by elk (*Cervus elaphus*) with the second most common animal being the wild horse. A difference in hunting strategy seems to be apparent between these two species, with horse being taken as young, large adults, while the elk taken include juveniles and younger and older adults, of a range of sizes, indicating that elk males and females were probably both hunted at El Juyo. El Juyo appears to have been occupied year-round (Klein and Cruz Uribe 1985). Due to its proximity to the exterior, the interior of El Juyo contains tree roots and substantial communities of rodents, which may have affected the condition of the collections. Additionally, the cave is quite damp, with occasional standing water in the excavated levels. These factors have contributed to variable preservation and condition of faunal remains and worked bone at the site. Pollen analysis at El Juyo suggests that during the occupation of the site the climate was fairly stable, humid, and temperate. A mixed oak

forest predominates in the pollen, however the faunal assemblage suggests colder temperatures and a more open landscape. Plant materials that could have been used to make baskets and fabrics were present in the Late Upper Paleolithic environment around El Juyo.

El Juyo has also been noted for its unusual dimensions, assemblages, and, the possible presence of a structure in the site. Freeman and González Echegaray (1995) describe the discovery of earthen features that were apparently made with some type of "buckets" in which earth of varying textures and colors was packed. The containers were then inverted in piles where the basic shape of the original container was (presumable intentionally) preserved. There are no known containers from the Late Upper Paleolithic that could have served such a function, but this may suggest basketry, as baskets would be a likely container if they were being produced at this time. Baskets are light and maintain their shape. If ceramic containers were used at this time one would expect ceramic sherds to preserve, while baskets would not. Baskets are generally made from plant-based materials. Within these structures large concentrations of bone and antler tools were found in pits. (Freeman and Echegaray 1981; González Echegaray and Freeman 1981). Pits at the base of Mound 1 contained a variety of materials but included needles that seem to have been inserted vertically into the other materials, rather than be tossed in haphazardly. Needles are found in nearly all of the "ritual" pits at the site; at least 55 eyed needles have been recovered from these contexts, along with others from other portions of the cave.

10.4.5.1. Osseous industry at El Juyo

The worked bone collections from El Juyo are large and diverse. Worked bone identified by Barandiarán (1985) range from flaked or other minimally modified bone to perforated teeth and shells to *sagaies*, needles, and *varillas*. There appears to be an unusually large number of needles, *puntas finas*, and *sagaies* for the size of the excavation. Flotation allowed the recovery of a large and morphologically varied set of needle eyes (Figure 10.23). However, many of the El Juyo pieces are in a highly fragmentary state, making comparison to other sites, especially those excavated earlier when many artifact fragments were not curated, difficult.

Figure 10.32. Needle fragments from El Juyo (#91385, 79, 83324, 94308, 94281, 83193, 83302, 83212, 92103, 94184, 83162, 83392, 89097, 91158, 90106, 91351, 92063, 92181)

10.4.5.2. Use wear analysis

Because of the size of the collections, rather than presenting a narrative description of the El Juyo use wear patterns by individual artifact, I will discuss the assemblage as a whole. The morphology of many of the artifacts has already been presented in the text (seeFigure 5.12; Figure 5.13; Figure 9.26; Figure 10.3; Figure 10.4; Figure 10.5; Figure 10.6; Figure 10.8; Figure 10.9; Figure 10.10; Figure 10.11; Figure 10.13; Figure 10.15; Figure 10.16; Figure 10.17; Figure 10.18; Figure 10.19) Ninety-four surfaces displayed

use wear. Of these, 25 had use wear patterns that suggested the worked material. The remaining surfaces had more ambiguous patterns of wear.

Seventeen artifacts displayed wear patterns consistent with use on animal fibers: ten needles, six points, and one mesial fragment. All had rounded polish and nearly all displayed invasive polish and substantial edge rounding. Striations varied significantly within this sample. Unlike cases reported in publications, few of these specimens have significant pitting. However, this result is consistent with ethnographic patterns of animal use wear.

Eight artifacts were identified as displaying use wear indicative of contact with plant fibers. Five needles, one point and two mesial fragments had non-invasive polish, with either limited edge rounding or planar polish. Most of these specimens also had striations that were of similar sizes and displayed patterned orientation. These artifacts suggest that plant fibers were worked at El Juyo.

10.4.5.3. Summary and Conclusions: Use wear at El Juyo

The collection analyzed from El Juyo is notable for the large number of needles and needle fragments (56). Of these, fifteen displayed wear patterns that suggested a worked fiber class. Needles were used on both plant and animal materials at El Juyo. Likewise, mesial fragments and points were both used to work a range of materials.

Thus, even in archaeological assemblages from the same site, morphology does not indicate artifact function.

10.4.6. Summary of the use wear evidence for fiber industries at the sites of Entrefoces, El Perro, and El Juyo

The collections analyzed here are very small and represent only a fraction of worked bone and antler and sites that have small osseous artifact assemblages even considered in their entirety. However, even such a small sample provides evidence for a wide range of activities and reveals some of the "invisible" tasks completed at these sites. Evidence for both manufacture and repair has been identified, as well as both animal and plant fiber signatures, although animal fiber sources predominate. None of the attributions are completely secure, but the high variability indicates that continued study of these collections, with attention to the kinds of fibers represented among the contact materials, is warranted.

The use of the tribologically derived model allows collections to be sorted by the predictions for plant and animal fiber wear. As was shown, many archaeological artifacts have patterns consistent with the predictions for diagnostic differences between fiber classes. In larger collections, statistical tests could be used to sort

artifacts by tribological predictions. Here, however, the sample is sufficiently large and varied to demonstrate the utility of tribology to organize the analysis of wear patterns.

10.5. Conclusions

The analysis of bone tools from the sites of Entrefoces, El Perro, and El Juyo provides information on a number of aspects of Late Upper Paleolithic socioeconomic features at these sites. It indicates that Late Upper Paleolithic people were involved in the manufacture and/or maintenance of perishable artifacts at the sites studied. Despite the small collections, numerous activities and worked materials appear to be represented. The interpretation of these collections in a broader sense is complicated by the limitations of the sample. Due to the deep time depth of these sites, we have very little information about the broader patterns in subsistence, mobility, and social organization of these peoples. However, further archaeological research can situate these sites within a broader social and economic context. The study of use wear on bone tools forms a productive aspect of this study, informing on both the exploitation of bone as a raw material and on the less visible activities that accompanied the more archaeologically visible tasks of hunting, shellfish procurement, food preparation and lithic and bone tool production.

Chapter 11. Conclusions and Future Directions

Because of the age of the archaeological deposits from the Upper Paleolithic, they are primarily comprised of stone, and in some cases, bone, giving us an impoverished view of the range, complexity, and make-up of the material culture from this period. The artifacts that we do have from the Upper Paleolithic are complex and diverse, across material classes. They show that Upper Paleolithic people responded to subsistence and economic challenges with a range of different technologies. We also know that the symbolic record of this period is rich and varied. Finally, it is well known and documented that perishable materials constitute up to 90% of the material culture of living peoples, even in industrialized societies, and even among hunter-gatherers in Arctic areas where plant life is limited. Soft organic materials are also abundant in the few archaeological sites with extraordinary preservation (Croes 1997; Lee and DeVore 1968).

Thus, there is little reason to doubt that perishable technologies were made and used in the Upper Paleolithic. We should assume that they were. However, despite numerous authors noting that perishables were likely to have been produced in the Upper Paleolithic (Adovasio, et al. 2001; Adovasio, et al. 1996; Bahn 1985; Castro Curel 1984, 1990; Hurcombe 2008b; Kehoe 1990, 1999; Owen 1993, 2005; Soffer, et al. 2000; Soffer 2004; Soffer and Adovasio 2004; Soffer, et al. 2000; Tyldesley and Bahn 1983), there has been little systematic effort to explore the subject, aside from research at the Moravian

Gravettian sites where imprints of 30,000 year old textiles have been identified (Grigor'ev 1993; O. Soffer, et al. 2000).

The original questions driving this study relate to the production of perishable technologies in the Late Upper Paleolithic of Northern Spain and to the likely creators of these objects: women, elders, and children. The goal was to identify evidence of the production of fiber technologies and thus shed light on Late Upper Paleolithic life beyond flint-knapping and large game hunting. The simplest approach, given the current state of our extremely limited knowledge of Late Upper Paleolithic perishable technology, was to focus on evidence for the use of plant and animal fibers. Bone tools are common in the archaeological record of Late Upper Paleolithic Northern Spain and many other parts of the world where other fragile organic technologies are more rarely preserved and are commonly used to produce fiber technologies in ethnographic and historic contexts. This study aimed to capitalize on the link between bone tools and the production of animal and plant derived soft materials. That link has proven robust among indigenous peoples of North and South America, as well as in some other areas of the world. Ethnographic research indicates that many bone tools are used by women in the production of perishable goods.

Thus, osseous implements can not only provide information on the production of organic artifacts, but also on the labor of members of society who are often underrepresented in archaeological reconstructions. This study, like others before it, has shown that bone use wear patterns can provide information on the fiber industries that

decay with time and thus cannot be recovered from the archaeological record. While this aspect of bone use wear analysis has been demonstrated for other time periods and locations where the use of both plant and animal fiber sources are known through other means, this dissertation has shown that bone tools may provide a starting point for uncovering technologies whose very presence is not clearly documented through other means.

A multi-scalar, broad-reaching methodology was developed to address bone use wear. In order to understand contact between bone and fiber, isolated insomuch as is possible, from cultural contexts, three kinds of collections were used: experimental, ethnographic, and archaeological. Ethnographic artifact sample selection was based on contact material only, rather than on posited cultural similarity of the manufacturer´s and Late Upper Paleolithic populations. Tribology, rooted in mechanical engineering, was employed to create a predictive model for the results of contact between worked bone surfaces and fibers. Both of these aspects of the research require the unit of analysis be set at the working surface, rather than the artifact.

11.1. Results by Fiber Class

Throughout this dissertation I have discussed the research and results by kind of worked bone collection. In total, I analyzed over 300 artifacts for microwear patterns. Here, I summarize the results from all three collections by fiber class. This allows a better assessment of the wear that results from contact between worked bone and plant or animal fibers.

11.1.1. Wear from Animal Fiber on Worked Bone

The tribological predictions for wear from animal fibers on worked bone derived from the cellular structure of animal fibers and the organization of fibers in worked materials, especially hides. Animal hides are composed of matted, disorderly fibers that often contain many inclusions and are frequently worked with both abrasive and lubricant substances.

All three collections reflect some of these traits strongly. Macroscopically, animal fiber wear can sometimes be identified as a smooth sheen. Rounded polish and significant edge rounding are both common in surfaces worked with animal fibers. Qualitatively, animal polish is also often highly continuous on a surface. Invasive polishes are not uncommon. Striation patterns vary substantially. Although striation size may or may

not vary on surfaces worked with animal fibers, it rarely varies on those worked with plant fibers, so varied striation size suggests animal wear.

11.1.2. Wear from Plant Fiber on Worked Bone

The tribological predictions for wear from plant fibers on worked bone derived from the rigid cell walls of plant fiber cells and from the ways that plant fibers are typically organized when worked into artifacts. Namely, plant fibers are generally bundled or twisted in facilitate their manipulation.

Wear patterns from plant fiber were more variable than those noted for animal-derived wear. In particular, edge rounding and striation organization vary substantially within the sample of surfaces worked against plant materials. Planar and non-invasive polish are more reliable indicators of plant wear. Although not diagnostic, striations that are highly patterned in orientation are more common on surfaces worked with plant fibers. Macroscopically, plant wear is often indicated by large striations. However, many tools show no macroscopic signs of use.

11.2. Conclusions: Wear from Plant and Animal Fibers on Bone Tools

The results of this analysis have both methodological and archaeological implications. The construction of tribologically based comparative standards from experimental and ethnographic sources and their subsequent application to archaeological collections here demonstrate that plant and animal fibers leave distinctive wear patterns on worked bone surfaces. Although use wear analysis is challenging and can be complicated by taphonomic alterations that obscure attrition patterns, tribology allows variation to be sorted more easily and allows the development of powerful predictive models.

It is also clear that no single variable can indicate the worked material. Wear attributes must be assessed as an overall pattern on a working surface. Different variables probably indicate different kinds of wearing mechanisms and will vary independently of each other.

Importantly, the archaeological case studies demonstrate the utility of use wear on bone tools to help understand the subsistence and economic practices at Late Upper Paleolithic sites. More interestingly, wear patterns suggest the manipulation of plant fibers at these sites, indicating a previously unrecognized class of material culture from this area and time period. Further investigation may clarify the importance and nature of plant fiber artifact production in Late Upper Paleolithic contexts in Northern Spain and other geographical areas.

11.3. Perishable Industries in the Late Upper Paleolithic of Western Europe

Both through bone use wear analysis and an assessment of other evidence for the kinds of perishable technologies produced in the Late Upper Paleolithic in Northern Spain, this study establishes that there are unambiguous indications that the exploitation of plant-derived fibers may have begun in Western Europe much earlier than is generally accepted, closer to the time period in which evidence for plant fiber technology is much more prevalent in Eastern Europe. There is no clear evidence in either Eastern or Western Europe to indicate whether perishable industries from plant materials are a new technology, although Adovasio and colleagues argue that the diversity of the Moravian specimens suggests an established industry (Adovasio, et al. 2001). The material from Dzudzuana Cave also indicates the prevalence of diverse kinds of perishable artifacts in the Upper Paleolithic (Kvavadze, et al. 2009). Notably, the first appearance of animal-based soft materials is also unknown but generally assumed to be much earlier.

Further research into both plant and animal fiber industries may provide insight into early societies and technological adaptation to different environments. Gilligan (2007, 2010), for example, considers the role of clothing to be pivotal in the disappearance of the Neandertals and the movement of anatomically modern humans into Eurasia. Our understanding of the development of Mesolithic adaptations would also most certainly

be affected by a better knowledge of the use of perishable technologies such as nets, traps, snares and baskets prior to the Holocene. Future research on bone tools could contribute to both of these large-scale archaeological lacunae.

The implications of these results also affect our picture of the organization of labor by age and gender in the Late Upper Paleolithic. Perishable technologies probably fell outside the purview of young and middle-aged men and a more explicit consideration of this labor enhances and complexifies our view of Late Upper Paleolithic communities by indicating some of the activities carried out by other members of the population. Fore fronting the production of perishable technologies helps rebuild our image of the Late Upper Paleolithic with a population that includes men and women of all ages, from children through elders.

11.4. Future Research

This study is largely methodological and is focused on developing an approach to the systematic study of the use wear signatures of different fibers on bone. None of the samples studied can be taken as representative of the use of bone tools within the context from which they were derived. However, as the methodology has proven useful for pursuing the study of wear from perishable materials, there are several areas of

future research that would strengthen the ethnographic and archaeological analysis to permit more robust conclusions about the use of organic technologies in the past.

11.4.1. Taphonomy

Robust, site-specific taphonomic studies are absolutely crucial to archaeological use wear analysis. This can consist of simply making a microscopic surface analysis of a sample of unmodified bone from the same provenience as the osseous artifacts. Although I set out with the intention of studying unmodified samples, I cannot vouch for the utility of this approach, as it was logistically impossible in the cases of the sites I studied, as worked bone was curated separately from unmodified fauna. As noted many times, the logistical separation of faunal analysts from bone tools specialists compromises both studies, while coordinated research results in better outcomes for both faunal and osseous industry assemblages (Crabtree and Campana 2010; David 2010; Olsen 2007; West 2001). Use wear patterns on archaeological artifacts are often unlike those found in experimental collections; much of this effect is undoubtedly due to the effects of taphonomic agents. Further directions in bone tool research will continue to explore the taphonomic effects that work on osseous artifacts.

11.4.2. Tribology

This dissertation research has shown that tribology has the potential to aid in the study of archaeological use wear. Although tribology is not new in the discipline of bone use wear analysis, a more detailed tribological model can provide greater insight into the accumulation and form of wear. There are many ways in which the application of tribology can be enhanced and broadened.

Use wear patterns are complex. Bone is a soft material that develops wear relatively quickly, although wear may develop more slowly under some conditions (Choyke and Duffy 2011). There are numerous ways that bone tools can be shaped and finished, with some techniques producing a much smoother or more even surface than others. Differentiating between materials worked with bone and materials used to work bone can also be challenging. The gestures used in the manufacture of perishable technologies can vary substantially with different traditions, habits, and skill levels. Archaeological assemblages display even more complex surfaces, as discard conditions and post-depositional taphonomic agents contribute to surface or volume attrition. Thus, understanding the many different factors that have contributed to the appearance of an artifact surface is a challenge.

The preceding analyses illustrate the utility of a tribological model to help understand the complex signatures of archaeological bone use wear. Although not a panacea for use wear analysis, tribological modeling can allow us to understand the kinds of

materials that came into contact with a bone surface, including taphonomic effects. Tribological modeling may also provide direction for further experimentation when new contact materials are suggested by the wear patterns on archaeological implements.

Further research in this area would address a much broader range of materials from a tribological standpoint. Most of the necessary information is available to us, in the form of research in materials science for other purposes, especially in industry. As noted earlier, most pertinent research is aimed at the reduction of wear in a mechanical setting, but the observations on friction and attrition can be incorporated into an archaeological model of use wear accumulation. Although the differences between soft and hard contact materials on bone tools are well documented through experimentation, placing these observations within a tribological context could enhance the interpretive power of these data. Additionally, a tribological model for wear has the advantage of helping predict wear from different kinds of materials and so may assist in understanding worn surfaces resulting from work on novel materials not yet incorporated into our experimental programs.

11.4.3. Experimentation

The experimental portion of this dissertation is the most limited section. As noted in Chapter 7 (Experimental Program), there are many other experiments that are lacking in

order to more fully pursue the study of archaeological use wear patterns. The clearest gap is in the procurement, preparation, and working of barks and bark fibers. For the experimental results to be of use outside of the Late Upper Paleolithic, experiments on materials from plant and animal domesticates, especially wool, flax, and hemp, are also lacking.

A second area that deserves more directed attention in order to supplement the tribological model is the effect of pressure, speed, and angle of contact on the accumulation of wear on tools. This could be considered both with archaeological experiments and through an examination of studies carried out by mechanical engineers.

11.4.4. Ethnographic Collections Research

One of the most valuable contributions of this study to the field of worked bone studies is the emphasis on the systematic microscopic study of ethnographic artifacts. Although many researchers have turned to the literature produced through the last century of ethnographic research to suggest uses of unusual tools, provide inspiration for experiments, and contextualize artifacts from sites with direct historical continuity to the ethnographically documented populations, there have been few systematic studies of museum collections of ethnographic material culture. Close studies of ethnographic

literature and research into historically related populations have clear value to archaeological studies. However, a large-scale, artifact-based, cross-cultural study provides different information to archaeologists, especially when there are no living groups with cultural links to the archaeological population under study.

This study has produced an important data set for understanding archaeological use wear patterns, but there are many ways this sample could be enhanced and expanded. The ethnographic sample created in this study was strongly skewed toward North America, and in particular, the northern third of the continent. This is partly because of the large and diverse osseous technologies of indigenous peoples of the Arctic and the renowned hide-working of native groups from the Plains. However, the production of perishable technologies involves bone tools in many other contexts and it would be extremely useful to include a much broader geographical representation in the sample. A greater geographical spread would also undoubtedly introduce a broader spectrum of raw materials, especially plants, which tend to vary more from region to region than do animal populations.

Another approach would be to consider ethnographic material in a more holistic way than in my previous study. Here, I started with morphological types in a single raw material: bone. I worked from morphological types and museum names to identify use wear patterns on tool surfaces diagnostic of the manufacture of basketry, mats, hides, or other perishable artifacts. Another approach would be to identify the material correlates of the production of fiber technologies by beginning with activities and

working towards both morphological and wear patterns. By looking at all objects associated with plant cordage, mat and basketry production, including tools and end products, it can be better determined if objects were used in the ways suggested by labels and archives.

Comparisons between the ethnographic and experimental collections suggest that the duration of use may be a more influential factor on attrition patterns than I had originally imagined. Although duration of use was documented in all experimental cases and objects were documented at different points during their uselife in most cases, a better understanding of the role of duration of use is necessary. Unfortunately, ethnographic objects almost never have accompanying information that indicates the duration of use, so experiments may provide the best avenue for addressing this question. Ethnographic fieldwork focused on identifying the uses of bone tools in living contexts and resulting attrition patterns on implements would also be helpful. Bone tools continue to be used in many isolated cases, including bone objects used in contemporary crafts such as book making and the use of bone awls in many locations.

11.5. Conclusions

Bone tool use wear provides a powerful line of evidence for investigating economic and social aspects of production in prehistoric societies. Osseous artifacts are nearly

ubiquitous and serve many purposes. The production of perishable goods is one of the most common uses of bone tools, so the methodology presented here can help amplify our understanding of the range of material culture represented in the Late Upper Paleolithic, and more broadly in a range of archaeological contexts.

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APPENDIX I: Photo Credits

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Chapter 2

- Figure 2.1 Needle from Altamira that preserves the original morphology but has no original surface remaining (Altamira CE03960); Courtesy of the Museo de Altamira

Chapter 4

- Figure 4.1 Cross-section of Seri bone awl made on a metapodial, showing the dense, outer cortical portion and the inner spongy section (NMAI 112161); Courtesy of the National Museum of the American Indian, Smithsonian Institution
- Figure 4.12. Cross section of flax, showing bast bundles (white); public domain
- Figure 4.13. Prepared raffia fiber; ©Sage Ross, licensed under the Creative Commons Attribution-Share Alike, 3.0
- Figure 4.14. Kapok seed with fiber; ©J.M. Garg, licensed under the GNU Free Documentation License, Version 1.2
- Figure 4.15. Worked and painted hide from Knife River Historic Site; ©Chris Light, licensed under the GNU Free Documentation License, Version 1.2
- Figure 4.16. Needle with wool, Hopi Pueblo (NMNH E166613); Catalogue No. E166613, Department of Anthropology, Smithsonian Institution

Chapter 5

Chapter 6

Chapter 8

- Figure 8.2 Eskimo net mesh gauges, Alaska, CapePrince of Wales (NMAI 226999 & 226976); Courtesy of the National Museum of the American Indian, Smithsonian Institution
- Figure 8.3 Net needles of varied origin (Burke 2158, 1.2E1335, 2732, 2779, 1746, 1682, 2350, 1308, 2747, 1313, 2743); Courtesy of the Burke Museum of Natural History and Culture, Catalog Numbers 2158, 1.2E1335, 2732, 2779, 1746, 1682, 2350, 1308, 2747, 1313, 2743
- Figure 8.5. Net mesher, Eskimo Nuwukmiut, Point Barrow, Alaska (NMAI 047003); Courtesy of the National Museum of the American Indian, Smithsonian Institution
- Figure 8.6. Eskimo awls, Northwest Alaska (AMNH Anthropology 60/1717 and 60/1718); Courtesy of the Division of Anthropology, American Museum of Natural History
- Figure 8.7. Needle, Eskimo Nuwukmiut, Point Barrow (NMAI 048457); Courtesy of the National Museum of the American Indian, Smithsonian Institution
- Figure 8.8. Awl and sinew twisters, Eskimo, Northwest Territories, Canada (NMNH E001321); Catalogue No. E001321, Department of Anthropology, Smithsonian Institution
- Figure 8.9. Needle case with two bone needles (NMAI 021807); Courtesy of the National Museum of the American Indian, Smithsonian Institution
- Figure 8.10. Hopi Pueblo, basketry awls (NMAI 090624); Courtesy of the National Museum of the American Indian, Smithsonian Institution
- Figure 8.11. Zuni Pueblo, weaving awl, (NMNH E234480); Catalogue No. E234480, Department of Anthropology, Smithsonian Institution
- Figure 8.12. Basketry awls, Seri, Sonoma, Mexico (Burke3-12314-12318); Courtesy of the Burke Museum of Natural History and Culture, Catalog Numbers 3-12314, 3-12315, 3-12316, 3-12317, 3-12318
- Figure 8.13 Awl, Winnebago (AMNH Anthropology 50.1/2236); Courtesy of the Division of Anthropology, American Museum of Natural History

Chapter 9

Chapter 10

APPENDIX II: Barandiarán Worked Bone Typology

The typology developed by Ignacio Maestu Barandiarán (1967: Lamina 33) is used throughout Spain to classify bone tools and objects of adornment. Here I present a translation of the typology.

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
POINTED	I	Points or *azagayas*	1	Point with a rounded base	1.1	Smooth, thin body
					1.2	Longitudinally grooved body
					1.3	With projecting nodes
					1.4	Curved
					1.5	Short and wide
			2	Point with a polygonal base		
			3	Point with a shortened base		
			4	Point with a single beveled base	4.1	Circular cross-section
					4.2	Triangular cross-section
					4.3	Square or polygonal cross-section

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					4.4	Single bevel of more than 1/3 the length of the tool; circular cross-section
					4.5	Single bevel of more than 1/3 the length of the tool; triangular cross-section
					4.6	Single bevel of more than 1/3 the length of the tool; Squire or polygonal cross-section
					4.7	Keeled (carinated); circular cross-section
					4.8	Keeled (carinated); triangular or square cross-section
					4.9	Double-sloped bevel; circular cross-section
					4.10	Double-sloped bevel; triangular or square cross-section
					4.11	Truncated bevel; circular cross-section

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					4.12	Truncated bevel; triangular cross-section
					4.13	Truncated bevel; square or polygonal cross-section
					4.14	Beveled end; circular cross-section
					4.15	Beveled end; square or triangular cross-section
					4.16	Concave bevel; circular cross-section
					4.17	Concave bevel; triangular cross-section
					4.18	Concave bevel; square or polygonal cross-section
			5	Punta with a double-beveled base	5.1	Circular cross-section
					5.2	Triangular, square, or polygonal cross-section
					5.3	Truncated double-bevel; circular cross-section

Family	**Group Code**	**Group**	**1º Type Code**	**Primary Type**	**2º Type Code**	**Secondary Type**
					5.4	Truncated double-bevel; square cross-section
					5.5	Double-bevel with two slopes; circular cross-section
					5.6	Double-bevel with two slopes; square cross-section
					5.7	Inverse bevels
			6	Split-base points	6.1	
					6.2	Intermediate piece
					6.3	Rib with split base
			7	Forked-based point		
			8	Lozenge-shaped point		
			9	Bi-point	9.1	Smooth; circular cross-section
					9.2	Smooth; triangular cross-section
					9.3	Smooth; square or polygonal cross-section
					9.4	With deep longitudinal grooving
					9.5	With longitudinal grooves

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					9.6	With protruding nodules
					9.7	Curved; circular cross-section
					9.8	Curved; triangular, square or polygonal cross-section
					9.9	Curved; flattened cross-section; lateral protrusions
					9.10	Straight with lateral protrusions
			10	Bi-point; centrally flattened	10.1	Straight; circular cross-section
					10.2	Straight; triangular, square, polygonal cross-section
					10.3	Curved; circular cross-section
					10.4	Curved; triangular, square, polygonal cross-section
	II	Pins	11	Gracile bi-point (*punta fina*)		
	III	Fishhook	12	Gracile point with double edge	12.1	=
					12.2	With central “strangulation”
	IV	Large points	13	Large point	13.1	Circular cross-section

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					13.2	Triangular cross-section
					13.3	Square or polygonal cross-section
			14	Grooved large point	14.1	Circular cross-section
					14.2	Triangular cross-section
					14.3	Square or polygonal cross-section
	V	Points with handles	15	Gracile point with bulging base		
			16	Point with bulging base		
			17	Large point with bulging base		
	VI	Pointed artifacts	18	Point on unmodified bone end	18.1	"Perforator"
					18.2	"Burin"
			19	"Arrow point"		
			20	Splinter with prepared base	20.1	Point
					20.2	"Mandibular dagger"
			21	Sharpened splinter		
			22	Splinter worked on all edges by percussion		

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
	VII	Flattened points	23	Flat point with rounded base	23.1	Straight
					23.2	Curved
			24	Flat bi-point	24.1	Straight, smooth
					24.2	Straight, with perpendicular marks near the base
			25	Flat point with a beveled base	25.1	Straight
					25.2	Curved
	VIII	*Varillas* (Rods)	26	*Varilla* with rounded or pointed base	26.1	Planoconvex cross-section
					26.2	Rectangular or flattened cross-section
			27	*Varilla* with oblique single beveled base	27.1	Planoconvex cross-section
					27.2	Rectangular or flattened cross-section
			28	*Varilla* with oblique double beveled base	28.1	Planoconvex cross-section
					28.2	Rectangular or flattened cross-section
			29	*Varilla* with beveled base	29.1	Planoconvex cross-section
					29.2	Rectangular or flattened cross-section
			30	Decorated *varilla*	30.1	Protruding decoration

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					30.2	Rectilinear decoration
					30.3	Curvilinear decoration
					30.4	Figurative decoration
FLAT	IX	Spatulate	31	"Spatula"	31.1	Rounded base
					31.2	Beveled base
					31.3	Strangled base
					31.4	"Fish tail" base
			32	"Pallet"	32.1	Smooth
					32.2	Decorated
			33	"Spoon"		
	X	Blades	34	Blade or bladelet	34.1	Smooth
					34.2	Strangled base
					34.3	Curved
					34.4	Made on a tooth root or horn core
	XI	Polishers	35	"Compressor-chisel-polisher"		
			36	"Burnishers"		
	XII	Wedges	37	"Chisel-wedge"		
	XIII	Retouchers	38	"Retouchers-compressor"	38.1	On wide splinter
					38.2	On long *varilla*
					38.3	On round, thick blank

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
	XIV	Grinding stone	39	Grinding stone	39.1	Mortar
					39.2	Pestle
					39.3	Grinding stone
SERRATED OR BARBED	XV	Propulsor	40	"Propulsor"	40.1	Beveled, rounded or pointed base
					40.2	Perforated base
	XVI	Hooks	41	*Varilla* with a single barb on the end		
	XVII	Harpoons	42	*Varilla* with bulbs	42.1	=
					42.2	Inverted barbs
					42.3	Forked base
			43	Cylindrical harpoon with uniserial barbs	43.1	Smooth base
					43.2	With a node on the base
					43.3	With double nodes on the base
					43.4	Forked base
			44	Cylindrical harpoon with biserial barbs	44.1	Smooth base
					44.2	With a node on the base
					44.3	With double nodes on the base
					44.4.	Forked base
			45	Cylindrical harpoon with a perforated base	45.1	With lateral perforation
					45.2	With central perforation

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
			46	Flat harpoon, no perforation	46.1	With uniserial barbs
					46.2	With biserial barbs
			47	Flat harpoon with circular perforation	47.1	With uniserial barbs
					47.2	With biserial barbs
			48	Flat harpoon with elongated perforation	48.1	With uniserial barbs
					48.2	With biserial barbs
	XVIII	Tridents	49	Split piece	49.1	Simple
					49.2	Complex
					49.3	As a "trident"
	XIX	Barbed artifacts	50	Denticulated splinter		
			51	Splinter worked into a zigzag		
PERFORATED	XX	Batons	52	Perforated baton		
			53	Baton with multiple perforations	53.1	In the form of a "T"
					53.2	Elongated
			54	Perforated point		
	XXI	Needles	55	"Needles"	55.1	Pointed end
					55.2	Rounded or truncated end

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					55.3	Central perforation
	XXII	Bull roarer	56	Lozenge-shaped plaquette with perforated end		
	XXIII	Flat pendants	57	Lozenge-shaped plaquette with grooved end		
			58	Plaquette with perforated end	58.1	Straight borders
					58.2	Serrated borders
			59	Perforated "*azagaya*" base		
			60	Cylindrical artifact	60.1	Perforated end
					60.2	Incised border on one end
			61	Perforated splinter		
			62	Plaquette with perforations on both ends		
	XXIV	Truncated profile	63	Truncated profile		
	XXV	Discs	64	Flat disc or rondelle	64.1	Not perforated
					64.2	Central perforation
					64.3	Off-centered perforation

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					64.4	Multiple perforations
	XXVI	"Pendants"	65	"Tooth pendant"	65.1	Perforated, smooth
					65.2	Perforated, engraved on borders
					65.3	Perforated, engraved on crown
					65.4	Perforated, figurative engravings
					65.5	Incision or grooved on root
					65.6	Incision or grooved on root, engraved
			66	"Shell pendant"	66.1	Perforation on the dorsal face or the hinge
					66.2	Perforation on the ventral face or the external border
					66.3	Multiple perforations
					66.4	Incisions near the base
			67	Vertebra or perforated small bone		
			68	"Bead"	68.1	Perforated sphere

Family	Group Code	Group	1º Type Code	Primary Type	2º Type Code	Secondary Type
					68.2	Perforated hemisphere
					68.3	Cylindrical
			69	"Pearl" with central strangulation		
			70	"Pearl" replica of a natural form	70.1	Tooth or shell
					70.2	Human or animal form
					70.3	Fruit or vegetal form
			71	Truncated cylinder	71.1	Narrow, long
					71.2	Thick, tall
					71.3	Short, fine
			72	Perforated phalange	72.1	Central perforation
					72.2	Transversal perforation
					72.3	Longitudinal perforation
	XXVII	"Whistles"	73	Perforated bone tube	73.1	Single perforation
					73.2	Multiple perforations
MISCELLANEOUS	XXVIII	"Accessories"	74	"Handle"	74.1	Simple
					74.2	Double
			75	Cylinder with perforation or central strangulation	75.1	"Spool"
					75.2	"Bag-handless"
			76	"Case"		

Family	**Group Code**	**Group**	**1º Type Code**	**Primary Type**	**2º Type Code**	**Secondary Type**
			77	"Lid"		
	XXIX	"Ritual objects"	78	"Diadem"		
			79	"Skull cup"		
	XXX	"Works of art"	80	Engraved fragments	80.1	Decorative motifs
					80.2	Figurative motifs
			81	Reliefs	81.1	Full
					81.2	On a barbed artifact
					81.3	On a splinter
		Miscellaneous	82	Miscellaneous		

APPENDIX III: Datasheets

Data Form

AGUJAS, ETC.

Site data

Name:

Location:

Chronology:

Artifact excavation lab number:

Excavation provenience:

Artifact museum catalog number:

Museum provenience:

Study number:

Photos: IMG_; IMG_;

Descriptive data

Typological grouping:

- Barandiarán:
- Stordeur-Yedid: prox: mesial: distal:

- cross-section: mesial: perforation: point:
-

Metric data:

- length:
- max width:
- max thickness:
- width at perforation:
- perforation: length: width: distance from end:

Other information:

- state: blank, partially formed, finished/complete, finished/broken
- portion of piece:
- shape of perforation:
- position of perforation:
- decoration:
- condition:
- conservation history:

Technological data

Raw material:

Blank production:

Shaping/Forming:

Perforation Production:

Finishing:

Object state: Finished tool/ Tool in Production/Debris:

Macroscopic functional data

Summary:

Polish/Luster:

- perforated (1º) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Striations:

- perforated (1º) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Chipping, fractures, etc:

- perforated (1º) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Micro: Study number:
Macro done: Date:

Data Form

AZAGAYAS, SAGAIES, PUNTAS FINAS W/ BEVELS, ETC.

Site data

Name:

Location:

Chronology:

Artifact excavation lab number:

Excavation provenience:

Artifact museum catalog number:

Museum provenience:

Notes:

Study number:

Photos:

Micro: Study number:
Macro done: Date:

Descriptive data

Typological grouping:

- Barandiarán:
- Stordeur-Yedid: prox: mesial: distal:
- cross-section: mesial: point:
- point morphology:

Metric data:

- length:
- max width:
- max thickness:

Other information:

- state: blank, partially formed, finished/complete, finished/broken
- portion of piece:
- decoration:
- condition:
- conservation history:

Technological data

Raw material:

Blank production:

Shaping/Forming:

Finishing:

Micro: Study number:
Macro done: Date:

Object type: Finished tool/ Tool in Production/Debris/formal tool/Expedient tool:

Macroscopic functional data

Summary:

Polish/Luster:

- lateral borders:
- face:
- pointed end:
- beveled/rounded end:

Striations:

- lateral borders:
- face:
- pointed end:
- beveled/rounded end:

Chipping, fractures, etc:

- lateral borders:
- face:
- pointed end:
- beveled/rounded end:

Micro:
Macro done:

Data Form

LISSOIRS, ESPÁTULAS, ETC.

Site data

Name:

Location:

Chronology:

Artifact excavation lab number:

Excavation provenience:

Artifact museum catalog number:

Museum provenience:

Study number:

Photos:

Descriptive data

Typological grouping:

- Barandiarán:
- Averbouh & Buisson:

Metric data:

- length:

Micro:
Macro done:

- max width:
- max thickness:
- max width of fully worked portion:
- max thickness of fully worked portion:

Other information:

- state: blank, partially formed, finished/complete, finished/broken
- portion of piece:
- presence of perforation:
    - if so, length, width, distance from closest end
- decoration:
- condition:
- conservation history:

Technological data

Raw material:

- element if IDable:
- portion of element:

Blank production:

Shaping/Forming:

Finishing:

Formal tool/Expedient tool/Tool in Production/Debris:

Micro:
Macro done:

Macroscopic functional data

Polish/Luster:

- rounded (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Striations:

- rounded (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Chipping, fractures, etc:

- rounded (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Micro: Study number:
Macro done: Date:

Data Form

MESIAL FRAGMENTS

Site data

Name:

Location:

Chronology:

Artifact excavation lab number:

Excavation provenience:

Artifact museum catalog number:

Museum provenience:

Notes:

Study number:

Photos:

Descriptive data

Typological grouping: fragment

- Barandiarán:
- Stordeur-Yedid: prox: mesial: distal:
- cross-section: mesial: oval

Micro: Study number:
Macro done: Date:

Metric data:

- length:
- max width:
- max thickness:

Other information:

- state:
- portion of piece:
- decoration:
- condition:
- conservation history:

Technological data

Raw material:

Blank production:

Shaping/Forming:

Finishing:

Object type:

Macroscopic functional data

Micro: Study number:
Macro done: Date:

Summary:

Polish/Luster:

- lateral borders:
- face:

Striations:

- lateral borders:
- face:

Chipping, fractures, etc:

- lateral borders:
- face:
- ends:

Micro: Study number:
Macro done: Date:

Data Form

POINTS, TIPS, PUNTA FINAS, PINS, BODKINS, ETC.

Site data

Name:

Location:

Chronology:

Artifact excavation lab number:

Excavation provenience:

Artifact museum catalog number:

Museum provenience:

Study number:

Photos:

Descriptive data

Typological grouping:

- Barandiarán:
- Stordeur-Yedid: prox: mesial: distal:
- cross-section: mesial: point:
- point morphology:

Metric data:

- length:
- max width:

Micro: Study number:
Macro done: Date:

- max thickness:

Other information:

- state: blank, partially formed, finished/complete, finished/broken
- portion of piece:
- decoration:
- condition:
- conservation history:

Technological data

Raw material:

Blank production:

Shaping/Forming:

Finishing:

Object type: Formal tool/Expedient tool/Tool in Production/Debris

Macroscopic functional data

Summary:

Micro: Study number:
Macro done: Date:

Polish/Luster:

- lateral borders:
- face:
- pointed end:

Striations:

- lateral borders:
- face:
- pointed end:

Chipping, fractures, etc:

- lateral borders:
- face:
- pointed end:
- fracture:

Micro: Study number:
Macro done: Date:

Data Form

PUNZONES, AWLS, PUNTAS FINAS W/O BEVEL, ETC.

Site data

Name:

Location:

Chronology:

Artifact excavation lab number:

Excavation provenience:

Artifact museum catalog number:

Museum provenience:

Study number:

Photos:

Descriptive data

Typological grouping:

- Barandiarán:
- point morphology:

Metric data:

- length:
- max width:

Micro: Study number:
Macro done: Date:

- max thickness:
- max width of fully worked portion:
- max thickness of fully worked portion:

Other information:

- state: blank, partially formed, finished/complete, finished/broken
- worked portion: fully worked, articular end present; non-articular end present
- portion of piece:
- presence of perforation:
  - if so, length, width, distance from closest end
- decoration:
- condition:
- conservation history:

Technological data

Raw material: bone

- element if IDable:
- portion of element:

Blank production:

Shaping/Forming:

Finishing:

Object type: Formal tool/Expedient tool/Tool in Production/Debris

Micro: Study number:
Macro done: Date:

Macroscopic functional data

Summary:

Polish/Luster:

- pointed (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Striations:

- pointed (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Chipping, fractures, etc:

- pointed (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end: recent

Micro: Study number:
Macro done: Date:

Data Form

VARIOS : FRAGMENTOS, NUCLEOS, HUESO TRABAJADO, ETC.

Site data

Name:

Location:

Chronology:

Artifact excavation lab number:

Excavation provenience:

Artifact museum catalog number:

Museum provenience:

Study number:

Photos:

Descriptive data

Brief description:

Typological grouping:

- Barandiarán:
- other, if appropriate:

Micro: Study number:
Macro done: Date:

Metric data:

- length:
- max width:
- max thickness:
- max width of fully worked portion:
- max thickness of fully worked portion:

Other information:

- state: blank, debris, partially formed, finished/complete, finished/broken, unknown
- portion of piece:
- presence of perforation:
  - if so, length, width, distance from closest end
- decoration:
- condition:
- conservation history:

Technological data

Raw material:

- element if IDable:
- portion of element:

Blank production:

Shaping/Forming:

Finishing:

Object type: Formal tool/Expedient tool/Tool in Production/Debris:

Micro: Study number:
Macro done: Date:

Macroscopic functional data

Polish/Luster:

- rounded (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Striations:

- rounded (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Chipping, fractures, etc:

- rounded (1º) end:
- lateral borders:
- upper face:
- lower face:
- 2º end:

Study number:
Date:

Data Form

FUNCTIONAL ANALYSIS : MACROWEAR

MACROWEAR

Low level magnification; binocular loupe

Crushing and compression

- Location:
- Description:
  - separation of fibers

Use flakes

- Location:
- Distribution:
- Description:
  - types: *chips* (small), *flakes* (med), *fracture* (large)
  - base:
  - shape/form:

Edge-rounding

- Location:
- Distribution:
- Description:
  - on surface: curved, flat
  - on ends or borders: rounded, flat, faceted

***Arrachements*, incisions, *entailles*, fissures, cracks**

- +/-
- Location:
- Distribution:
- Description:

Data Form

FUNCTIONAL ANALYSIS : MICROWEAR

Higher magnification with microscope; 100-200x

Location of sampling:

Polishes or surface alterations

- summary:
- 100x:
  - distribution:
  - connectedness:
  - limit, form of borders:
  - invasiveness/intrusion:
- 200x:
  - microtopography:
  - degree of surface erosion:
  - cross-section or profile:
  - texture:
  - brightness: very bright, bright, moderately bright, matte

Stria

- summary:
- 50-100x
  - distribution:
  - location:
  - frequency:
  - density:
  - organization between e/o:
- 100-200x
  - measurements: l, w, d
- 200x
  - edge of stria: lustrous or not
  - cross-section of stria: U, V
  - base: visible or not; rough/smooth
  - form: long/short; wide/narrow; deep/shallow
  - grouped/indiv

Pitting

- summary:
- 100x
  - location:
  - distribution:
  - orientation/placement:
- 200x
  - morphology: circular, subcircular, irregular, elongated
  - size: large, medium, small
  - edge
  - base

Photos:

- 50x:
- 100x:
- 200x:

Data Form

EXPERIMENTAL PIECES

Descriptive data

Object group:

Brief description:

- cross-section: mesial: perforation: point:
- point morphology:
- shape of perforation:
- position of perforation:
-

Metric data:

- length:
- max width:
- max thickness:
- width at perforation:
- perforation: length: width: distance from end:

Technological data

Raw material:

Blank production:

Shaping/Forming:

Perforation Production:

Finishing:

Use

- Goal:
- Position:
- Movement:
- Material:
- Material form:
- Time:

Notes:

Macroscopic functional data

Summary:

Polish/Luster:

- perforated (1º) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Striations:

- perforated (1º) end:
- perforation:
- lateral borders:
- face:
- pointed end:

Chipping, fractures, etc:

- perforated (1º) end:
- perforation:
- lateral borders:
- face:
- pointed end:

APPENDIX IV: Analytic and Descriptive Terms for Artifact Analysis

Macroscopic Condition

Consolidation: refers to the treatment of artifacts post-excavation in order to stabilize them and protect them. Consolidation is not always necessary and is best carried out by a trained conservator. Contemporary best practice mandates that consolidants be reversible (Johnson 1994), however practices have changed substantially over time. Early consolidation techniques, or sub-standard products such as super-glue, can be detrimental to use wear analysis by obscuring the surface. In some cases thick layers of consolidant appear as a thick, glossy, plastic-like coating on the artifact surface and effectively prevent microscopic study. In other cases, however, consolidant that is skillfully applied with a light hand poses no barrier to the successful analysis of surface attrition patterns.

Chattermarks: A series of short, parallel lines found along a bone surface that are a result of the skidding of a lithic edge against the bone.

Cross-section: The categories for cross-section from the database are:

CrossSections	
CrossSectionShort	**CrossSectionDesc**
Circ	Circular, symmetrical
Subcirc	Subcircular, asymmestrical
Quad	Quadrangular
IrrQuad	Irregular, roughly quadrangluar
Tri	Triangular
Oval	Oval
FlOv	Ovular, flattened centrally
Flat	Essentially flat, thin
Semi	Semi-circle; Plano-convex; one side flat, rest curved
Kidney	Concave on one plane, convex on the opposite
Irreg	Irregular
Anot	Anotomical profile conserved
Other	Other cross-section; see notes

Analytic terms for Use Wear Analysis

Polish*:* refers to the reflective smooth appearance seen on some artifacts or artifact surfaces. Polish can be macroscopic or microscopic, with each having different qualities and measured attributes, and likely resulting from different processes. Macroscopic

polish appears as a smooth, reflective surface or sheen. French researchers prefer to use the term "*lustre*" or *luster*, as a preferable descriptive term, rather than *polish*, which references a causative action. This is probably a better term, but as the use of *polish* is widespread in the English and Spanish (*pulido*) literature, I have adopted the term here as well.

The attributes that I have used to characterize macroscopic polish are:

- *Smooth*: smooth polish is homogenous and has a regular topography to the naked eye. It could follow the contours of the bone or tool or be found in a location of volume loss, but is internally similar

- *Irregular*: irregular polish refers to an area that is polished throughout but the brightness or texture of the polish varies

- *Bright*: bright polish is glossy and highly reflective

- *Matte*: matte polish does not display high reflectivity but is marked by smoothness or a sheen unlike the surface of unmodified bone

- *Continuous*: continuous polish contains few or no unpolished sections

- *Patchy*: patchy polish is distributed noncontinuously, or in patches, that are visible on the artifact surface

The attributes that I use to characterize microscopic polish are:

- *Invasiveness*: the microtopography of worked bone surfaces is rarely perfectly flat, due to the natural makeup of bone, manufacture techniques, and irregularities introduced through handling, storage and use. Polish may be found on both the high and low points of the microtopographic surface and along the sides of grooves or striations, which would constitute a highly invasive polish. On the other hand, a polish found only on the high points of microtopographic relief would be described as noninvasive. This is clearing a sliding scale, rather than discrete attribute states. In my database I characterized polish invasiveness on a 5-point scale: completely invasive (all points are covered with polish); *trame-uni* (French term for a covering, highly invasive polish

- *Attrition form*: microscopic attrition refers to the modification of the microtopography of the worked surface through use, handling and storage. While the shape of the original surface cannot be known with surety retrospectively, it is generally clear how use has affected the surface shape by comparing worn and unworn areas as well as the correspondence between microrelief and other indications of wear, such as polish. Attrition ranges from rounded, in which the borders of striations and high points are rounded and curved, to planar, in which attrition has resulted in a flat plane where topography was more varied before. This variable can be difficult to assess and it is important that the level of magnification be kept constant when comparing attrition form.

Striations: scratches or grooves on the artifact surface. They may result from the removal or displacement of material.

The distribution of striations in the microscopic analysis refers to their location on the object. The orientation refers to the directionality of striations vis-à-vis the axis of the tool. Organization refers to the relationship of striations to each other within a single zone. For example, striations could be distributed at the tip, oriented diagonally (transverse to the long axis of the tool), and intercrossed (striations run diagonally in different directions, crossing each other but at a roughly similar angle).

Volume loss: surface attrition that alters the shape of the surface. Volume loss occurs on both macroscopic and microscopic scales and is frequently linked to the hardness of the contact material. I have used the term *volume loss* to refer to macroscopic and microscopic alteration of the tool form, but *microtopography* refers only to microscopic level modifications of the surface. Microtopography refers to the appearance of the surface under magnification. Some of the topography of a bone surface is due to natural contours and features of the bone itself. In describing microtopography, an attempt is made to describe those features of the bone surface that are due to use-related attrition and are not natural features or a result of manufacture. Volume loss in the tribological model is grouped into:

- *Rounded*: microtopographic surfaces are rounded or domed and have few sharp edges
- *Planar:* microtopographic surfaces are flat and appear sheared off

APPENDIX V: Tribological Results

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-241	Vegetal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-241	Vegetal	non-invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	frequent	Yes
E-241	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-212	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes
E-212	Vegetal	non-invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	frequent	Yes
E-212	Vegetal	invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	few or none	Yes
E-213	Vegetal	non-invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	frequent	Yes
E-213	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-213	Vegetal	invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes
E-213	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-234	Vegetal	invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-234	Vegetal	non-invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-242	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-242	Vegetal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-242	Vegetal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-246	Vegetal	non-invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-246	Vegetal	invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes
E-247	Vegetal	non-invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-247	Vegetal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes
E-239	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-239	Vegetal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-239	Vegetal	invasive	flat or planar	regular, patterned	vary	substantial rounding or volume loss	frequent	Yes
E-239	Vegetal	invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes
E-239	Vegetal	invasive	rounded	regular, patterned	vary	substantial rounding or volume loss	frequent	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-239	Vegetal	non-invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-239	Vegetal	non-invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-255	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-255	Vegetal	non-invasive	rounded	disorderly, irregular	`	substantial rounding or volume loss	few or none	Yes
E-255	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-255	Vegetal	non-invasive	flat or planar	regular, patterned	vary	substantial rounding or volume loss	frequent	Yes
E-256	Vegetal	non-invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	few or none	Yes
E-256	Vegetal	invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-256	Vegetal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-256	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-258	Vegetal	non-invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-258	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-258	Vegetal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes
E-259	Vegetal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-259	Vegetal	non-invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-259	Vegetal	non-invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-307	Vegetal	non-invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-307	Vegetal	non-invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-307	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-307	Vegetal	non-invasive	flat or planar	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-307	Vegetal	non-invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-261	Vegetal	non-invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-261	Vegetal	non-invasive	flat or planar	NA	NA	substantial rounding or volume loss	few or none	No
E-262	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-262	Vegetal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-262	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-262	Vegetal	non-invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-262	Vegetal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-266	Vegetal	non-invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	frequent	Yes
E-266	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-266	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-266	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-267	Vegetal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes
E-267	Vegetal	non-invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	few or none	Yes
E-267	Vegetal	invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-221	Animal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes
E-221	Animal	non-invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-222	Animal	non-invasive	rounded	NA	NA	limited rounding or deformation	few or none	No
E-222	Animal	non-invasive	rounded	regular, patterned	similar	limited rounding or deformation	few or none	Yes
E-222	Animal	non-invasive	rounded	regular, patterned	vary	substantial rounding or volume loss	few or none	Yes
E-226	Animal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes
E-226	Animal	invasive	rounded	regular, patterned	vary	substantial rounding or volume loss	few or none	Yes
E-227	Animal	non-invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-227	Animal	invasive	rounded	regular, patterned	similar	limited rounding or deformation	few or none	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-228	Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-228	Animal	non-invasive	flat or planar	NA	NA	substantial rounding or volume loss	frequent	No
E-228	Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	few or none	No
E-230	Animal	non-invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	few or none	Yes
E-230	Animal	non-invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-230	Animal	invasive	rounded	regular, patterned	similar	limited rounding or deformation	few or none	Yes
E-230	Animal	non-invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes
E-311	Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	few or none	No

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-231	Animal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-231	Animal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes
E-231	Animal	invasive	rounded	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes
E-231	Animal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-231	Animal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-231	Animal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-232	Animal	invasive	rounded	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
E-232	Animal	invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-232	Animal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-232	Animal	non-invasive	flat or planar	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-257	Animal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
E-257	Animal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
E-257	Animal	non-invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
E-257	Animal	non-invasive	flat or planar	NA	NA	limited rounding or deformation	frequent	No
E-257	Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
E-257	Animal	invasive	flat or planar	NA	NA	substantial rounding or volume loss	frequent	No

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
E-234	Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	few or none	No
A-208	Arch--Unk	invasive	flat or planar			limited rounding or deformation	frequent	No
A-211	Arch--Unk	non-invasive	flat or planar	NA	NA	limited rounding or deformation	frequent	No
A-210	Arch--Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	few or none	No
A-210	Arch--Unk	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
A-62	Arch--Unk	non-invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
A-52	Arch--Unk	non-invasive	flat or planar	NA	NA	limited rounding or deformation	few or none	No
A-52	Arch--Unk	non-invasive	rounded	NA	NA	limited rounding or deformation	frequent	No
A-58	Arch --Fish	non-invasive	rounded	NA	NA	limited rounding or deformation	few or none	No
A-62	Arch--Unk	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
A-62	Arch--Veg	non-invasive	flat or planar	regular, patterned	similar	limited rounding or deformation	frequent	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
A-59	Arch--Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	few or none	No
A-56	Arch--Unk	non-invasive	flat or planar	NA	NA	limited rounding or deformation	frequent	No
A-57	Arch--Veg	non-invasive	rounded	regular, patterned	similar	limited rounding or deformation	few or none	Yes
A-57	Arch--Animal	non-invasive	rounded	disorderly, irregular	vary	limited rounding or deformation	few or none	Yes
A-209	Arch--Veg	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	few or none	Yes
A-55	Arch--Unk	non-invasive	rounded	disorderly, irregular	vary	limited rounding or deformation	frequent	Yes
A-61	Arch--Animal	non-invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
A-61	Arch--Animal	non-invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
A-61	Arch--Animal	non-invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
A-61	Arch--Unk	invasive	flat or planar	regular, patterned	vary	limited rounding or deformation	few or none	Yes

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
A-63	Arch--Unk	invasive	flat or planar	NA	NA	limited rounding or deformation	frequent	No
A-63	Arch--Unk	non-invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
A-64	Arch--Animal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
A-208	Arch--Unk	invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
A-208	Arch--Unk	invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
A-208	Arch--Animal	invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	few or none	Yes
A-208	Arch--Unk	invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	frequent	Yes
A-209	Arch--Veg	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	few or none	Yes
A-209	Arch--Veg	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	few or none	Yes
A-210	Arch--Animal	non-invasive	rounded			substantial rounding or volume loss	frequent	No

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
X-1	Animal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
X-1	Animal	invasive	rounded	disorderly, irregular	vary	limited rounding or deformation	few or none	Yes
X-2	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	few or none	No
X-2	Vegetal	non-invasive	rounded	disorderly, irregular	similar	limited rounding or deformation	few or none	Yes
X-3	Vegetal	invasive	rounded	NA	NA	substantial rounding or volume loss	few or none	No
X-5	Animal	invasive	rounded	NA	NA	limited rounding or deformation	frequent	No
X-7	Animal	non-invasive	flat or planar	NA	NA	limited rounding or deformation	few or none	No
X-16	Animal	invasive	rounded	regular, patterned	vary	substantial rounding or volume loss	few or none	Yes
X-17	Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
X-17	Animal	invasive	rounded	regular, patterned	similar	substantial rounding or volume loss	frequent	Yes
X-19	Animal	invasive	rounded	NA	NA	substantial rounding or volume loss	frequent	No
X-24	Vegetal	invasive	rounded	NA	NA	limited rounding or deformation	few or none	No
X-25	Vegetal	invasive	flat or planar	regular, patterned	similar	substantial rounding or volume loss	few or none	Yes
X-26	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	substantial rounding or volume loss	frequent	Yes
X-28	Vegetal	non-invasive	flat or planar	disorderly, irregular	vary	limited rounding or deformation	few or none	Yes
X-28	Vegetal	non-invasive	flat or planar	disorderly, irregular	similar	limited rounding or deformation	few or none	Yes
X-30	Vegetal	non-invasive	rounded	disorderly, irregular	similar	limited rounding or deformation	few or none	Yes
X-32	Animal	invasive	rounded	disorderly, irregular	vary	substantial rounding or volume loss	frequent	Yes
X-52	Vegetal	non-invasive	flat or planar	NA	NA	limited rounding or deformation	few or none	No

StudyID	Use Material Group	Polish	Attrition	Striation Organization	Striation Size	Edge Rounding	Pitting	Striations Present
X-52	Vegetal	non-invasive	rounded	NA	NA	limited rounding or deformation	frequent	No