

THE EXPERIMENTAL DETERMINATION OF
THE FUNCTION OF OBSIDIAN SCRAPERS
RECOVERED FROM THE FORMATIVE
PERIOD SITE OF LA LAGUNA, TLAXCALA,
MEXICO: A SCANNING ELECTRON
MICROSCOPE APPROACH

by

CARL ANTHONY SMITH

DR. LISA LECOUNT, COMMITTEE CHAIR

DR. MICHAEL MURPHY

DR. KEITH JACOBI

DR. DAVID CARBALLO

A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Arts
in the Department of Anthropology
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2011

Copyright Carl Anthony Smith 2011
ALL RIGHTS RESERVED

ABSTRACT

Small obsidian scrapers recovered at the archaeological site of La Laguna and other sites throughout Central Highland Mexico have been interpreted as tools used to process Mexican agave plants for the production of sap. Ethnographic research conducted by Parsons and Parsons (1990) illustrated a striking similarity between the form and function between the modern iron scrapers utilized by modern populations to scrape agave plants for the production of sap and archaeologically recovered obsidian scrapers. However, these tools are possibly multi-purpose implements and Parsons and Parsons (1990) suggest the use of high-powered microscopic analysis to sort out agave scrapers from tools used to process other materials. Using replica obsidian scrapers, several materials were processed to understand the formation of microscopic use-wear on the edge surfaces of tools used to scrape agave, local Mexican woods, deer bone and deer hide. These tools were analyzed with a scanning electron microscope (SEM) and compared to archaeological tools from La Laguna. Analysis indicated that use-wear formation from each different material was distinguishable from one another based on the development and prevalence of microflaking, polishing, and striations. As a result, likely functions were assigned to archaeological tools based on the unique wear patterns present on their used edges. Results indicate that residents were creating spoon-shaped obsidian scrapers to process maguey for sap, while some scrapers were created as multipurpose implements.

DEDICATION

This thesis is dedicated to everyone who helped me and guided me through the creation of this manuscript, in particular, my mother who stood by me and continually encouraged me throughout the time taken to complete it.

LIST OF ABBREVIATIONS AND SYMBOLS

SEM Scanning Electron Microscope

PALL Proyecto Arqueológico La Laguna

m Meters

BC Before Christian era

AD anno Domini

μ Micrometre

mm Millimeter

ACKNOWLEDGMENTS

I am pleased to have this opportunity to thank the many colleagues, friends, and faculty members who have helped me with this research project. I am most indebted to Dr. David M. Carballo, my original thesis advisor, for not only helping devise this particular approach and research topic, but also for his continued guidance and support. I would also like to thank all of my committee members, Dr. Lisa LeCount, Dr. Keith Jacobi, Dr. Michael Murphy, and Dr. David Carballo for their invaluable input, inspiring questions, and support of both the dissertation and my academic progress. I would like to thank Dr. Lisa LeCount for continuing to assist and advise me in the final stages of my study, especially in regards to writing this manuscript, and Dr. Robert Clouse for his assistance with lithic analysis. I would also like to thank Johnny R. Goodwin and all staff of the Central Analytical Facility for their assistance in collecting data with their scanning electron microscopes. Last, but not least, I wish to thank my friends and colleagues from Tlaxcala, Mexico—especially señor Isaac whose interpretations and expertise regarding maguey scraping and pulque production were invaluable.

This research would not have been possible without the support of my friends and fellow graduate students and of course of my family—especially my mother—who never stopped encouraging me to persist.

CONTENTS

ABSTRACT.....	ii
DEDICATION.....	iii
LIST OF ABBREVIATIONS AND SYMBOLS.....	iv
ACKNOWLEDGMENTS.....	v
LIST OF TABLES.....	viii
LIST OF FIGURES.....	ix
1. INTRODUCTION.....	1
2. GEOGRAPHIC, HISTORIC, AND PREHISTORIC BACKGROUND.....	11
3. SAMPLES AND METHODS.....	35
4. RESULTS OF THE STUDY.....	68
5. DISCUSSION AND CONCLUSION.....	103
REFERENCES.....	119

LIST OF TABLES

3.1	Expected results summarized.....	49
3.2	Variables measured on experimental and archaeological obsidian scrapers	45
4.1	Microwear features on experimental obsidian scrapers.....	69
4.2	Microwear features on archaeological obsidian scrapers	102

LIST OF FIGURES

1.1 Spoon-shaped experimental scraper (left) and archaeological scraper recovered from La Laguna, Mexico (right)	2
1.2 Discoidal experimental scraper (left) and archaeological scraper recovered from La Laguna, Mexico (right)	3
2.1 La Laguna in relation to some modern and ancient cities and sites	13
2.2 3D rendering of La Laguna.....	18
2.3 Site map of La Laguna.....	19
2.4 An average-sized mature maguey.....	26
2.5 A freshly cut maguey and a maguey filled with aguamiel.....	31
2.6 Illustrations of indigenous tools.....	32
3.1 Experimental scraper 1 used to process maguey	52
3.2 Experimental scraper 2 used to process Mexican pine	52
3.3 Experimental scraper 3 used to process deer bone	53
3.4 Experimental scraper 4 used to process deer hide	53
3.5 Experimental scraper 5 used to process maguey	54
3.6 Experimental scraper 6 used to process Capulin	54
3.7 Experimental scraper 7 used to process deer bone	55
3.8 Experimental scraper 8 used to process deer hide	55

3.9	Experimental scraper 9 used as a control.....	56
3.10	Experimental scraper 10 used as a control.....	56
3.11	Archaeological scraper 11- TLX-97 I/6UU/2562.....	57
3.12	Archaeological Scraper 12 - TLX-97 I/11L/871	57
3.13	Archaeological Scraper 13 - TLX-97 I/F.....	58
3.14	Archaeological Scraper 14 - TLX-97 I/F.....	58
3.15	Archaeological Scraper 15 - TLX-97 I/F.....	59
3.16	Archaeological Scraper 16 - TLX-97 I/F.....	59
3.17	Illustration of scraping.....	61
3.18	One of the maguey cores used to test experimental scrapers.....	63
3.19	Another maguey core used to test experimental scrapers	63
3.20	Capulin branch used to test an experimental scraper.....	64
3.21	Mexican pine branch used to test an experimental scraper.....	65
3.22	A deer femur used to test experimental scrapers	66
3.23	Portion of deer hide used to test experimental scrapers.....	66
4.1	Microflaking along dorsal aspect of experimental scraper #1 used to process maguey.....	71
4.2	Attrition and polishing of the edge of the dorsal aspect of experimental scraper #1 used to process maguey.....	71
4.3	Small pits along the edge of the dorsal aspect of experimental scraper #1 used to process maguey	72
4.4	Microflakes along the edge of the dorsal aspect of experimental scraper #2 used to process wood	73
4.5	Edge polishing and beveling along the edge of the dorsal aspect of experimental scraper #2 used to process wood.....	73

4.6 Small striations above flake scar on the edge of the dorsal aspect of experimental scraper #2 used to process wood.....	74
4.7 Utilization damage on the edge of the dorsal aspect of experimental scraper #3 used to process bone.....	75
4.8 Light erosion of flake scars on the edge of the dorsal aspect of experimental scraper #3 used to process bone.....	75
4.9 Striations and grooves on dorsal aspect of experimental scraper #3 used to process bone.....	76
4.10 Small, eroded microflakes and striations on the edge of the dorsal aspect of experimental scraper #5 used to process hide.....	77
4.11 Edge rounding on dorsal aspect of experimental scraper #4 used to process hide.....	77
4.12 Edge rounding on dorsal aspect of experimental scraper #4 used to process hide.....	78
4.13 Microflakes on edge of the dorsal aspect of experimental scraper #5 used to process maguey.....	79
4.14 Microflake erosion on edge of dorsal aspect of experimental scraper #5 used to process maguey.....	79
4.15 Small striations on the dorsal aspect of experimental scraper #5 used to process maguey.....	80
4.16 Microflakes along dorsal aspect of experimental scraper #6 used to process wood.....	81
4.17 Microflakes along dorsal aspect of experimental scraper #6 used to process wood.....	81
4.18 Edge beveling and microflake erosion of dorsal aspect of experimental scraper #6 used to process wood.....	82
4.19 Edge beveling and microflake erosion of dorsal aspect of experimental scraper #6 used to process wood.....	83
4.20 Edge beveling and microflake erosion of dorsal aspect of experimental scraper #6 used to process wood.....	83

4.21 Polish/edge bevel on dorsal aspect of experimental scraper #7 used to process bone.....	84
4.22 Flake track on dorsal aspect of experimental scraper #7 used to process bone.....	84
4.23 Microflaking along dorsal aspect of experimental scraper #8 used to process hide.....	86
4.24 Eroded microflake scars along dorsal aspect of experimental scraper #8 used to process hide.....	86
4.25 Hide polish along dorsal aspect of experimental scraper #8 used to process hide.....	87
4.26 Striations along dorsal aspect of experimental scraper #8 used to process hide.....	87
4.27 Heavily eroded dorsal aspect of archaeological scraper #11.....	89
4.28 Microflaking along dorsal aspect of archaeological scraper #11.....	90
4.29 Pits and depressions along dorsal aspect of archaeological scraper #11.....	90
4.30 Striations and polish along dorsal aspect of archaeological scraper #11.....	91
4.31 Heavily eroded edge along dorsal aspect of archaeological scraper #12.....	92
4.32 Microflakes along dorsal aspect of archaeological scraper #12.....	92
4.33 Striations on ventral aspect of archaeological scraper #12.....	93
4.34 Manufacture and use-wear flaking on the dorsal aspect of archaeological scraper #13.....	94
4.35 Polish along dorsal aspect of archaeological scraper #13.....	94
4.36 Bright edge bevel and pitting on the dorsal aspect of archaeological scraper #14.....	95
4.37 Scalar flakes and striations along dorsal aspect of archaeological scraper #14.....	95

4.38 Wedge-shaped microflakes along dorsal aspect of archaeological scraper #14	96
4.39 Small pits and depressions along dorsal aspect of archaeological scraper #14	97
4.40 Striations along dorsal aspect of archaeological scraper #14	97
4.41 Edge polish and erosion and numerous small pits on dorsal aspect of archaeological scraper #15	98
4.42 Microflaking along dorsal aspect of archaeological scraper #15	99
4.43 Right-angle striations on ventral aspect of archaeological scraper #15	99
4.44 Microflaking along dorsal aspect of archaeological scraper #16	100
4.45 Striations on ventral and dorsal aspect of archaeological scraper #16	101

CHAPTER 1

INTRODUCTION

Archaeologists determine how humans behaved in the past by drawing inferences from the physical remains available in the material record. Stone tools constitute an important component of the material record and can answer an array of important behavioral questions about activities in the past. Based on archaeological context, tool characteristics, and ethnographic analogies, tool use and relationships of tools to other components of an assemblage can be inferred. Experimental studies offer an insightful way to understand how ancient stone tools may have been utilized by their makers. Experimental programs easily lend themselves to the analysis of lithic assemblages but only when attempting to answer specific questions about behavior in the archaeological past. Since lithic materials fracture in predictable ways and there are limited numbers of ways tools can be produced, modern replicas of archaeologically recovered tools can be created and used to reconstruct activities carried out in the past. By using modern replicas of ancient stone tools, archaeologists can replicate use-wear patterns, which are edge fractures caused by alteration of the stone surface through contact with other materials such as wood, plant fibers, bone, and stone. Such use-wear patterns can then be compared both macroscopically and microscopically to those found on archaeologically recovered tools. This replication and experimental study is important for clearly inferring tool-use behavior when faced with possibly multi-purpose implements, such as the small, handheld obsidian scrapers recovered throughout Formative period central Mexico.

For this project, Dr. David Carballo and I replicated several small spoon-shaped and discoidal obsidian scrapers like those found within archaeological sites throughout central Mexico (Figure 1.1 and Figure 1.2). The spoon-shaped scrapers were fashioned to be somewhat elongated in relation to the more round discoidal scrapers. The names spoon-shaped scraper and discoidal scraper are derived from this physical difference in shape. These replica tools were created using traditional knapping techniques on raw obsidian obtained from various Mexican obsidian sources located in the Mexican state of Tlaxcala. The knapping technique we utilized was a freehand percussion technique. We held each piece of raw obsidian with one hand while we struck it with a sandstone hammerstone held with the other hand. Each strike with the hammerstone removes flakes of stone from the raw obsidian that eventually allow it to be formed into a functioning tool.



Figure 1.1: Spoon-shaped experimental scraper (left) and archaeological scraper recovered from La Laguna, Mexico (right).

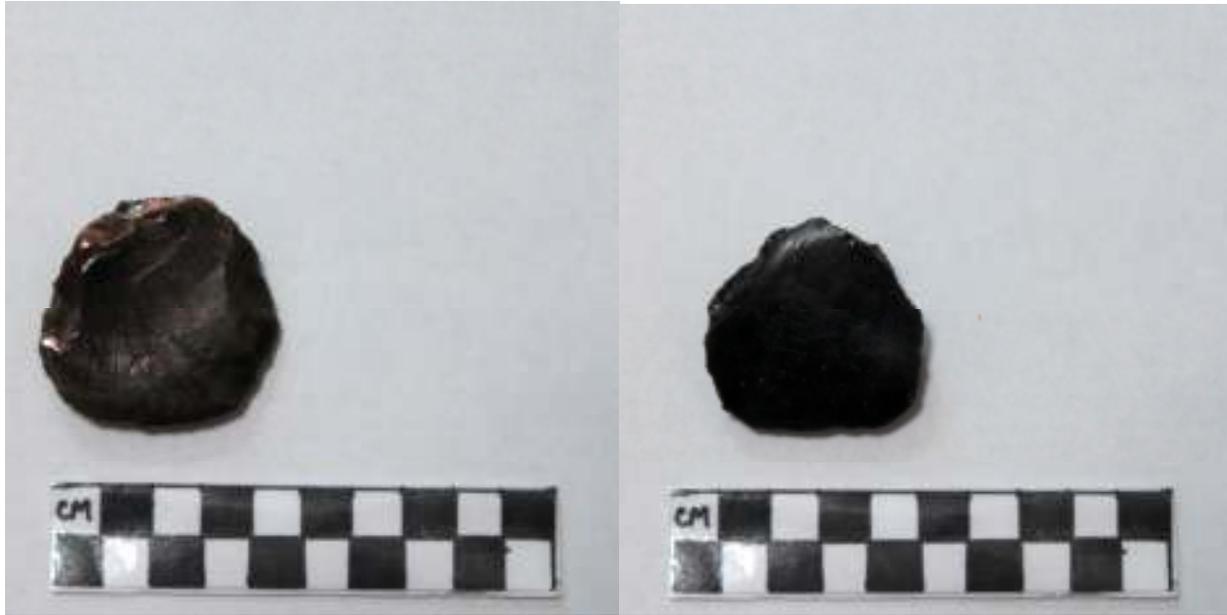


Figure 1.2: Discoidal experimental scraper (left) and archaeological scraper recovered from La Laguna, Mexico (right).

Before experiments on use wear patterns were initiated, the tools were scanned with a scanning electron microscope (SEM) to observe the initial surface and any signs of wear. They were subsequently used to scrape a few different materials that were available to indigenous central highlanders: the Mexican agave—known locally as the *maguey*—the Mexican pine tree, the Capulin tree, and deer bone and hide. Post-use scanning with the SEM documented distinct patterns of use-wear along the used edges of the obsidian scrapers that correspond specifically to each processed material. These findings, when compared to archaeologically recovered scrapers and considered within the greater context of studies performed in central Mexico, support the notion that indigenous peoples were using these small obsidian scrapers to process maguey plants for sap.

The archaeological site of La Laguna, in the state of Tlaxcala, serves as the case study for this research project and its associated questions. My project was conducted under the Proyecto Arqueológico La Laguna, or PALL, directed by Dr. David Carballo (Boston University). The

PALL project seeks to discover what life would have been like in a typical central Mexican town during the late Formative period, roughly 600 BC to AD 150. La Laguna is located on the continental divide in northern Tlaxcala. This area is part of a much greater landscape of towering volcanoes and mountains with a mild climate of wet summers and dry winters. The mountainous geography of the area makes it part of a natural transportation corridor connecting communities from the higher elevation regions of central Mexico to those around the coastal lowlands of the Gulf of Mexico. During the late Formative period, residents of La Laguna differed in socioeconomic status, though not to the degree which characterized later societies and participated in many shared domestic and public rituals (Carballo 2009). As a result, archaeological research at the site attempts to reconstruct how residents of a typical pre-Hispanic community might have lived and articulated themselves within an ever-changing network of trade and exchange with other regions of Mesoamerica (Carballo 2009). Archaeological research at La Laguna is also important because the site lends evidence for development of several trends: the formalization of trade networks, the standardization of at least two deities, and the eventual urbanization of populations into larger cities including Cuicuilco, Teotihuacan, and Cholula. Eventually La Laguna was abandoned when urban civilizations such as Teotihuacan flourished and expanded during the Classic period from AD 100 to 600.

Household archaeology in central Mexico has revealed many interesting developments in domestic craft production and specialization, particularly the importance of domestic spheres of interaction in economic social relations (Carballo 2011; Haines et al. 1997). Further, these households constituted important economic and sociopolitical units (Haines et al. 2004; Hirth 2009). Since these households were specializing in specific goods at specific times they were intimately linked to one another within the context of larger socioeconomic processes.

Essentially, they become important economic and sociopolitical units within the community (Haines et al.2004). Further, it appears that these households were linked together through active manipulation of prestige-enhancing social strategies, such as feasting and cloth production, that were part of domestic ritual practices (Carballo 2011). Just as tracking the distribution of domestically produced and traded goods and other household artifacts is important to reconstructing highland-lowland exchange, understanding the distribution of chipped-stone artifacts—namely those produced from obsidian—offer a new venue through which to explore these exchanges (Carballo 2011; Feinman et al.2005).

Feinman and colleagues (2005) explore the social relations of production and exchange through their household investigations at the site of El Palmillo in Oaxaca. Rather than only focusing on the technological and economic implications of the distribution of shell and chipped-stone tools—including those made of obsidian and greenstone—they use this information to reconstruct social strategies in relation to the quality of raw materials from which tools were created. To achieve this goal, stone and shell artifacts were compared between households near the apex of the site and those near the base of the hill. Higher-status individuals lived further up the hillside and had markedly different artifact assemblages, and, more importantly, higher quality raw stone materials (Feinman et al. 2005). This research raises important questions as to how the quality of tools used within domestic economies may have affected the development of specific use-wear patterns on stone tool artifacts, especially in relation to maguey processing.

In many cases, ancient Mexican households relied on products acquired by processing xerophytic plants, namely the Mexican agave plant, known locally as *maguey* (Haines et al. 2004; see also Parsons and Parsons 1990). This plant was utilized for a variety of purposes including fiber and pulque production, as well as a source of food. Pulque is a lightly fermented

alcoholic beverage produce from the sap of the Mexican agave. Haines and colleagues (2004) found that obsidian stone scrapers constituted a statistically significant portion of the stone-tool assemblages at El Palmillo, and based on this pattern, they suggest that maguey was processed using these tools. At the site of El Palmillo, both maguey production and stone tool production seem to have constituted a large portion of craft specialization among households (Haines et al. 2004). This correlation is also mirrored at the city-state of Otumba (Nichols et al. 2000). Nicholas and colleagues (2000) found a high concentration of spindle whorls—used in maguey fiber production—in association with a high concentration of basalt and obsidian scrapers, likely used for *aguamiel* production. *Aguamiel* is the sap-like substance taken from maguey to produce *pulque*, an activity likely undertaken hand-in-hand with maguey fiber production (Parson and Parsons 1990).

One interpretive problem with chipped obsidian tools, however, is that the possibility that they were general purpose implements useful for a variety of agricultural or domestic functions. While it is widely believed they were used to process maguey to promote sap production, researchers must account for the fact that they have been used to process other materials as well. One possible alternative is that they could have been used to scrape animal bone and hide. Deer were available to ancient highland Mexicans and processing hide into useable materials would have been an important for domestic units specializing in these products; the same is true for possibly removing the remaining tissues from deer bones. Another alternative is that these obsidian scrapers may have been used to remove bark from local woody trees. Wood was used for a variety of activities ranging from the creation of small artifacts to the production of wattle and daub structures abundant throughout the Formative period. My project will account for these alternatives by testing replicated obsidian tools on each material.

It is hypothesized that spoon-shaped obsidian scrapers recovered from archaeological deposits served as the primary means of maguey sap extraction (Carballo 2011; Haines et al. 2004; Parsons and Parsons 1990). After European contact, metal utensils likely replaced the obsidian scrapers for processing maguey plants. This inference is based on a direct historical analogy between the manner in which iron scrapers are used to process maguey leaves today and how ancient scrapers were used in the past, as well as the similarity in form between the two types of scrapers. Parsons and Parsons (1990) present further supporting evidence for the connection between obsidian scrapers and maguey processing based on ethnoarchaeological approaches to stone tool use. They note similarities between modern and ancient maguey processing sites in the Mexican highlands. More importantly, they present first-hand historical accounts that describe obsidian scrapers like those discovered at archaeological sites throughout Mexico being used for maguey processing during the era of Spanish colonial rule (Parsons and Parsons 1990: 280-1). For this analogy to stand up to scientific testing, however, more direct evidence of obsidian scraper use is required. One way to test this idea is to study use-wear patterns that were produced by processing maguey with replicated obsidian scrapers, rather than the processing of other forms of materials such as bone, wood, or animal hide.

Lithic analysis, in conjunction with an experimental archaeological approach, is the most promising route by which to correlate wear patterns present on ancient obsidian tools found at La Laguna and other sites to the processing of specific materials. Parsons and Parsons (1990) suggest that such an approach is important for sorting out which artifacts were parts of the maguey processing toolkit of Central Highland Mexican groups. In general, lithic use-wear analysis relies on basic comparison of the traits of the edge-wear present on stone tools. Use wear analysis requires various tools to view edge wear including microscopes that can increase

the magnification of edges across a range. Particularly scanning electron microscopes offer some of the highest quality magnification available. The scanning electron microscope is generally large and technically complex, requiring the assistance of a technician. Most of the actual commands and controls used to interface with the units, however, are generally intuitive and easy to operate with some practice. The machine bombards surfaces, in this case the edges of replicated and ancient tools, with rays of negatively-charged electrons. To ensure this bombardment is even across the entire surface the object must be coated in a fine metallic film, in this case gold. The visibility of the object is not regulated by laws of light transmission as with stereomicroscopes, so the actual image of the tool remains clear across the surface. As a result, scanning electron microscopy reproduces images at high resolutions and great depth. The SEM analysis of the replicated obsidian scrapers was made possible through the assistance of the Central Analytical Facility of the University of Alabama, in particular Johnny Goodwin who assisted with the operation of the scanning electron microscope. The particular units used were the JEOL-7000 and Phillips XL-30 SEMs located within the Central Analytical Facility on the campus of the University of Alabama at Tuscaloosa.

Many authors have successfully integrated microanalysis, utilizing scanning electron microscopy, and lithic use wear analysis to further define the development of wear patterns from working specific materials (Aoyama 1995; Grace et al.1985; Keeley 1980; Lewenstein 1981; and Tringham 1974). Many of these studies are criticized for the use of a qualitative comparative analysis distinguished by simply stating whether a trait is present or not present. Keeley (1980), however, believes that microanalysis of edge-wear can lead to correct reconstruction of tool use behavior through understanding the ways in which a tool is used on a material and the wear patterns that emerge. Further, Tringham (1974) believes that lithic microanalysis can add to

existing stone-tool analysis by accounting for changes in lithic assemblages and general cultural changes. By understanding, testing, and cataloguing tool use behaviors researchers can track changes over time in raw material selection, production, and use of tools in a given geographic or cultural area. Aoyama (1995) also suggests that lithic microanalysis of materials associated with archaeological contexts can determine the function occupation areas played in the past, such as distinguishing ritual areas and areas used as a council house.

Not all lithic materials exhibit the same physical hardness and homogeneity of crystalline structure; therefore use wear resulting from any given task will differ depending on the type of stone and the type of material being worked. Tringham (1974) utilizes microanalytic techniques to understand the formation of edge-wear damage present on European lithic material, results which can be correlated to specific worked materials. Keeley (1980) goes beyond this study by creating a large-scale experimental program to clearly distinguish between wear patterns produced from working stone tools on different materials like plants, wood, bones, and hides. Like Tringham, Keeley (1980) found that particular actions performed on specific materials will produce certain wear patterns that can be characterized, replicated, and identified. Keeley strengthens these findings by successfully utilizing use wear microanalysis to determine what materials were being worked by stone tools comprising an unknown assemblage (Hayden 1971).

Finally, Suzanne Lewenstein's (1981) study of Mesoamerican obsidian blade function is similar to Keeley's and Tringham's experimental programs. She argues that use-wear accounts for three major points in lithic analysis. First, use wear accounts for associations between the formations of wear patterns to different tool use behaviors on different worked materials. Second, use wear studies generate general propositions for the formation of edge-damage on

stone tools, especially through repeated testing. Lastly, use wear analysis allows researchers to discover the function of tools in a sample.

Lewenstein's research calls for two types of analysis. First, a researcher should undertake field analysis based on general observation at archaeological sites. These observations include observation of the archaeological, environmental, and physical contexts of the artifact, which are important for creating initial determinations of the function of stone tools (Lewenstein 1981). Second, an intensive program of experimentation with replicated tools and subsequent microanalysis of use wear—similar to Keeley's and Tringham's experimental approaches—should follow the initial observations. Both of these approaches will create complimentary results, effectively tying experimental findings to archaeological evidence (Lewenstein 1981).

In the following chapters I introduce and test the relationship between the development of distinct wear patterns on ancient Mexican obsidian scrapers and the materials they processed using an experimental approach developed from the programs of Keeley, Tringham, Lewenstein, and Aoyama. Like their experimental programs, I have chosen to replicate use-wear patterns by processing maguey, two species of woody trees, and deer bone and hide with obsidian scraper replicas to compare the patterns that emerge along the edges of the tools. Chapter Two provides general background and overall context for the investigation by describing the geography, cultures, and trends that define Formative period central Mexico. Chapter Three elaborates upon the samples and methodologies used within my study. Chapter Four details the use-wear patterns revealed from the microanalysis of the replicated obsidian scrapers. Chapter Five provides a discussion of the findings presented in the previous chapter and tie them into the overall historical and cultural context of the investigation.

CHAPTER 2

GEOGRAPHIC, HISTORIC, AND PREHISTORIC BACKGROUND

To more effectively provide evidence that correlates lithic use wear to ancient activities at La Laguna, and elsewhere within highland Mexico, it is first important to provide a general background to the study region and recent investigations. This chapter places my research within its unique geographic, historical, and social context—specifically the central Mexican highlands during the Formative period. First, I briefly introduce the general geography of Mexico as well as the sequence of cultural periods. I then focus on further defining the features of the Formative period in the highlands of Mexico, including some of the findings from previous research at the archaeological site of La Laguna where this research was undertaken. Following this brief history of the area, I present the socio-economic context of domestic economies in central Mexico during the Formative period in the context of households before elaborating upon the role of maguey and the exchange and consumption of chipped obsidian tools. I close this chapter by presenting other possible materials that central Mexicans may have been processing with stone tools.

Few regions in the world can boast such a diverse geography as Mexico's. Most of the country lies 900m above sea level, and passing between each valley marks the beginning of a new ecological zone ranging from arctic summits near towering volcanoes to warm and humid coastal jungles. This diversity of climate and geography is reflected in the diversity of natural and cultivated products within each region. As a result, no region was ever truly self-sufficient, rather was part of an interdependent web of exchange and development in which new

technological and cultural advances spread across the landscape within brief periods of time (Coe and Koontz 2002). Although indigenous peoples were just as diverse in their languages and communities, each developed unique modes of land cultivation and hunting strategies of wild game over the millennia. Wild animals—like the white-tailed deer, ducks, fish, and collared peccary—were abundant during ancient times. The only animals ever to be domesticated in Mexico were the dog and turkey, both exploitable for their meat. The most notable domesticated plants available to ancient Mexicans were maize, beans, and squash, foods which continue to provide a dietary staple today. All of these components situated themselves within unique systems of seasonality in which the scheduling of harvests, hunts, and the culling of domestic herds and flocks tied each area of Mexico together in a larger web of symbiotic development (Flannery 1968).

Broad cultural changes that developed across Mexico are characterized by archaeologists as periods: Early Hunter-Foragers, Archaic, Formative, Classic, Epiclassic, and Postclassic. The Early Hunter-Foragers period is the first occupation of Mexico extending from roughly 200,000 years ago until about 8,000 BC. Although the exact beginning date is under debate, scholars agree that people living in tiny, nomadic bands thriving on large-game hunting were present in Mexico by Late Paleoindian or Clovis times around 11,000 BC (Coe and Koontz 2002:19). The Archaic period (8,000 to 2,000 B.C.) heralded experimentation and the domestication of plant foods crops, especially maize, by ancestral Mexicans. The Formative period (1800 BC and AD 150) is marked by introduction of pottery and village life that are widely recognized as resulting from the domestication of plant foods in the previous period (Coe and Koontz 2002). Following the Formative period, the rise of states like Teotihuacan and Monte Albán marked the Classic period which span the first century AD to AD 700. The subsequent Epiclassic period witnessed

their decline as smaller cities replaced these larger state powers from AD 700 to 1300. By AD 900, many of these smaller cities were replaced by more militaristic Post-classic period states like the Toltecs and later the Aztecs. The mighty Aztec civilization would thrive during this period until the Spanish conquest in AD 1521.

My research focuses on the Formative period because I am interested in cultural developments that set the stage for later state level societies including the formalization of trade networks, the standardization of religious deities, and the urbanization of populations into cities such as Cuicuilco, Teotihuacan, and Cholula. Coe and Koontz define the overall

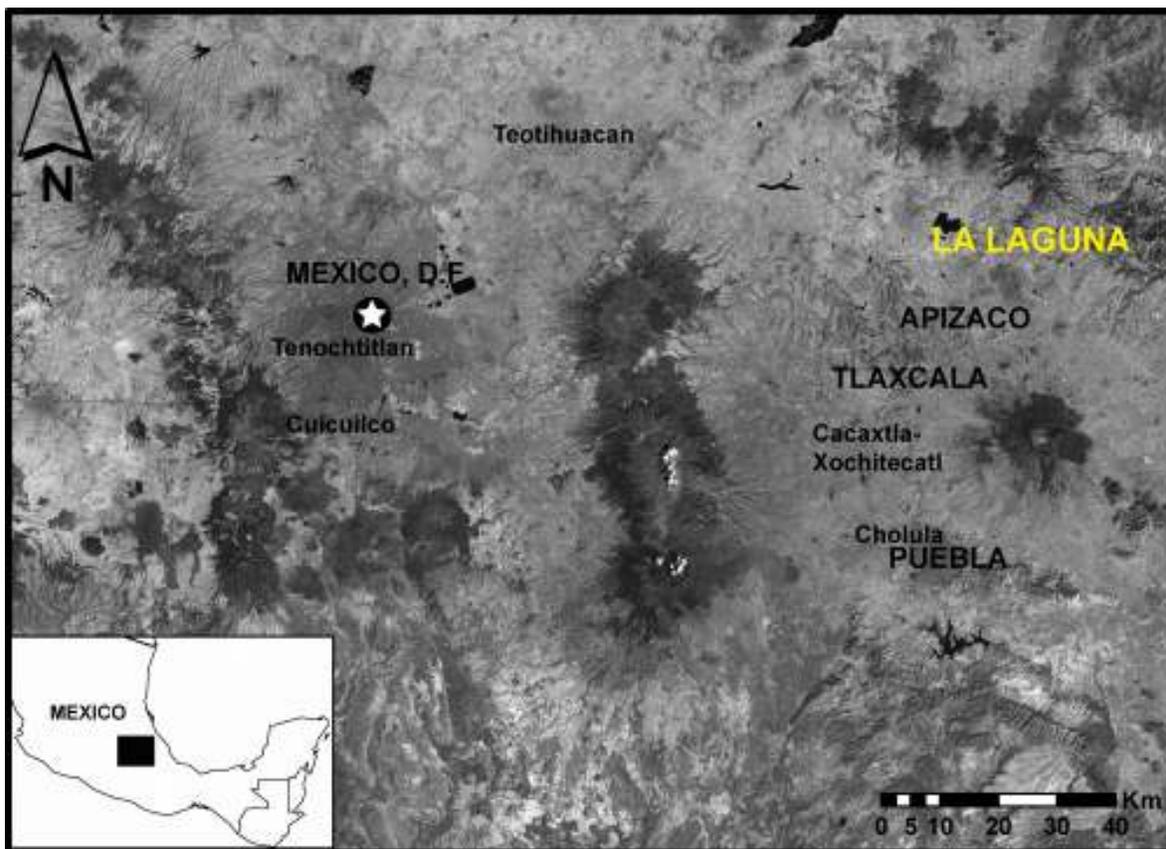


Figure 2.1: La Laguna in relation to some modern and ancient cities and sites (Carballo 2009).

Formative or Preclassic period as "that epoch when farming based on maize, beans, and squash really became effective—effective in the sense that villages, and hamlets had sprung up

everywhere in Mexico" (2002:41). The increased number of villages was due to an increasing population resulting from the domestication and cultivation of plant food crops during the previous Archaic period. This population increase filled central and southern Mexico with small camps and hamlets which likely developed into settled villages within a few generations. However, it must be noted that the domestication process took roughly three millennia. This may be due to a number of factors like the lack of domesticable animals, the cultural environment of Mexico or the nature of the plants themselves (Coe and Koontz 2002:43). Although animal husbandry was absent in Mexico, these developments—along with the development of pottery, weaving, grinding and chipping of stone, and modeling female clay figurine—make it comparable to the Neolithic period of the Old World.

The Formative period is divided into three distinct parts: the Early, from 1800 to 1200 BC; the Middle, from 1200 to 400 BC; and the Late, from 400 BC to AD 150. In Mexico, the most notable advance made by people during the Late Formative was the development of the temple-pyramid complex (Coe and Koontz 2002:53). Earlier temples had been constructed like common perishable homes with perishable thatched roofs, which were erected on low earthen platforms faced with sun-hardened clay. Diagnostic pottery from this period featured bright colors and an increase in the size and length of vessel feet.

The Late Formative period in central Mexico is interesting for comparative perspectives regarding how regional polities develop. This is especially true when considering these polities in relation to proto-urban centers, cities, territorially expansionistic states, and the growth and intensification of the economic and ideological exchanges directly tied to these polities (Carballo 2009). Most large urban or proto-urban centers emerging during the Formative period were located in the southern portions of central Mexico, which was more suited for growing maize

than the north. Some of the more notable of these sites were Cuicuilco, Tlapacoya, Tlalancaleca, and Xochitecatl. These early centers were abandoned by the first century AD as Teotihuacan gained political power and mass-migrations were prompted by volcanic eruptions in the southern Basin of Mexico.

As the number of communities with larger and more elaborate domestic structures increased during the Late Formative, the evidence for both increasing social inequality and elite differentiation also mounts (Carballo 2009). Besides the size of these communities and the elaboration of homes, the artifacts found within these domestic structures points to these increasing social differences. For example, higher quality raw stones and more rare trade goods indicate status differences in people's ability to acquire goods. Inhabitants of larger settlements were more likely organized by individuals with more formalized authority, which was needed to coordinate the construction of public ceremonial precincts. Communities in northern central Mexico, like the modern state of Tlaxcala, were also part of this larger process of elite differentiation.

The Site of La Laguna, Tlaxcala, Mexico in Formative Period Mexico

Geographically, my study centers on the central Mexican altiplano, located between the eastern and western branches of the Sierra Madre mountain range. Specifically, the research area lies east of the Basin of Mexico within the Neovolcanic Axis of the Mexican highlands in the modern state of Tlaxcala. The climate in this area is generally temperate with wet summers and dry winters. This area is part of a natural transportation corridor connecting the higher elevations of central Mexico to the coastal lowlands around the gulf. Farmed for the last 3000

years, it was one of the most densely settled areas in the Americas (Borejsza et al. 2008). Hillsides in the area were particularly at risk of erosion, turning farming into an intensely strategic endeavor.

The archaeological site of La Laguna is located roughly 2600m above sea level in the northeastern part of Tlaxcala, straddling the slopes of three adjacent hills. During the later Formative period when sites like Cuicuilco and Tlapacoya in central Mexico experienced initial urbanization and state formation, La Laguna was one of the largest communities in Tlaxcala (Barba et al. 2009; Carballo and Pluckhahn 2007; Merino Carrion 1989). The archaeological site features a central plaza and several large mounds covering roughly 100 ha. Today, the site is situated on a large agricultural estate, Ganadería La Laguna, which dates back to at least the 18th century. The land, no longer used for cultivation, is reserved for raising cattle used in bullfights.

My thesis research is part of the Proyecto Arqueológico La Laguna and directed by Dr. David Carballo (Boston University). His research aims to discover what the typical life in a central Mexican town would have been like. The first excavations at La Laguna were carried out as part of the University of California, Los Angeles (UCLA), Formative Project, directed by Richard Lesure, and within which Aleksander Borejsza and Carballo served as field directors. The quantity of ceremonial architecture in relation to nearby settlements suggests that the community controlled a modest hinterland during the Formative period, although contemporaneous centers in southern Puebla-Tlaxcala and the Basin of Mexico were larger (Carballo 2007, 2009). Several radiocarbon dates, architectural styles, and most pot sherds date the site to the Late Formative periods (c. 600 to 400 BC) with a second phase of occupation in the Terminal Formative dating from approximately 100 BC to AD 150) (Borejsza 2008; Carballo 2006, 2007). By the time Teotihuacan flourished during the Classic period, La Laguna was

abandoned; although there is some indication that the site was reoccupied much later by isolated homesteads during the Middle and Late Postclassic (AD 1150 to AD 1520). The site tells the story of a pre-Hispanic community whose inhabitants were economically linked to the rest of Mexico through extensive networks of trade and exchange. Although they differed in socioeconomic status they participated in many shared domestic and public rituals. As a result, households constitute an important unit of analysis for understanding ritual practices, status, and developments in economic specialization in relation to larger socioeconomic processes.

The earliest extensive excavations at La Laguna centered on Area F and uncovered a residential platform occupied by a commoner family. Artifacts uncovered at the platform indicate the activities that the occupants were performing. For example, a large pit in front of the house would have served to roast maguey, while stone scrapers nearby would have been used to remove sap and fiber from the leaves. The following year, excavations at Area H revealed elite structures. The size and style of these houses, as well as the presence of imported goods, demonstrated the way in which the family expressed their socioeconomic status. The excavations undertaken at Area H were key to understanding the overall status differences at La Laguna, as in the differences discovered between the residential structure at Area F and that at Area H. In 2008, remote sensing defined several new structures which were subsequently excavated. In Area G, the team focused on revealing a system of retaining walls in the center of a large plaza. This revealed that the ceremonial center had been artificially flattened to allow for the construction of the plaza and ballcourt. Excavations at the ceremonial center at Area G continued in 2009 revealing ritual behavior similar to later Mesoamerican societies such as the Teotihuacanos and Aztecs. The ceremonial center itself consisted of an I-shaped ballcourt to the west, a main temple complex to the east, and a large central plaza. The rest of the structures

consist of several other smaller mounds and platforms that were constructed around the ceremonial core.

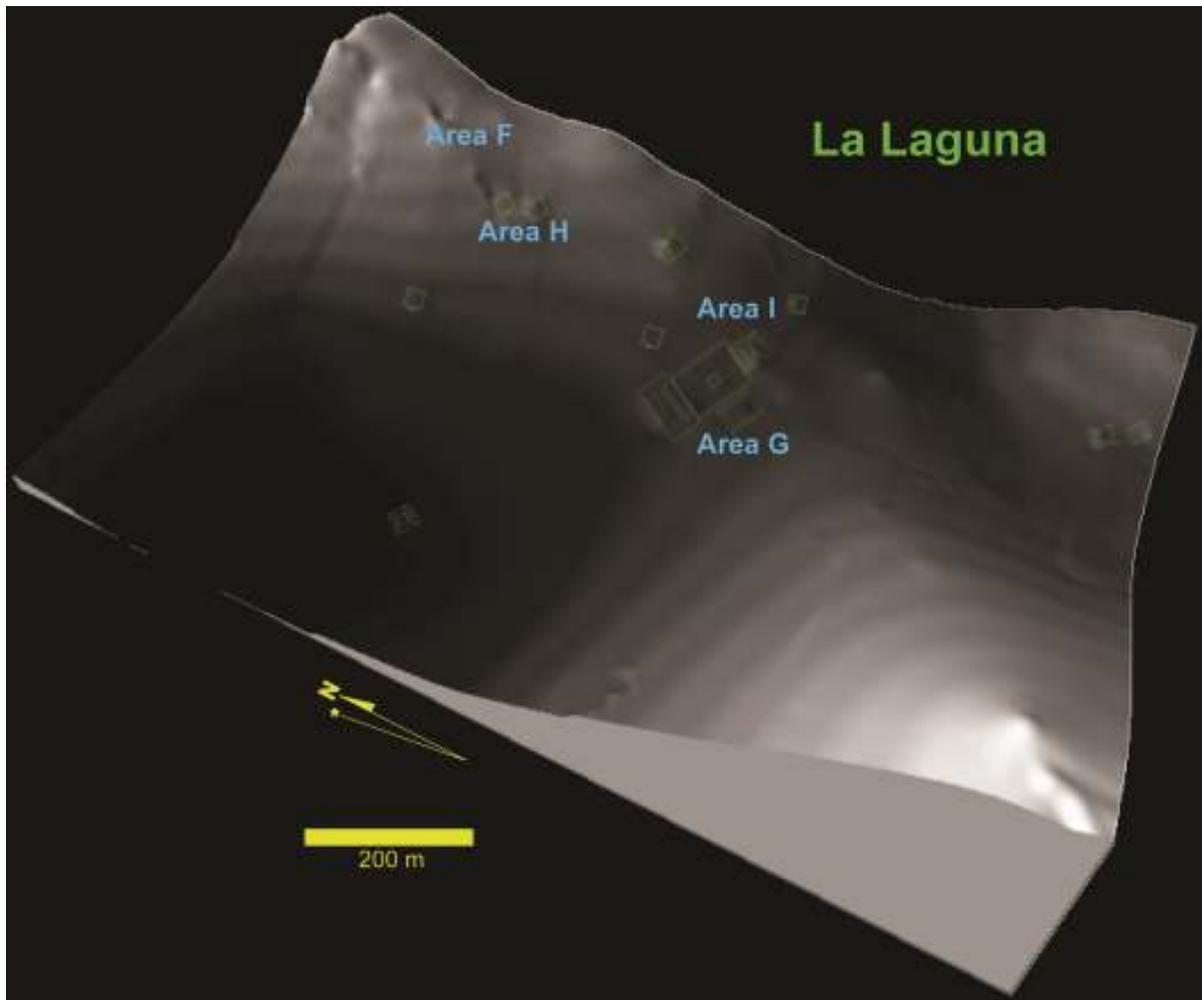


Figure 2.2: 3-D rendering of La Laguna. (Carballo 2009)

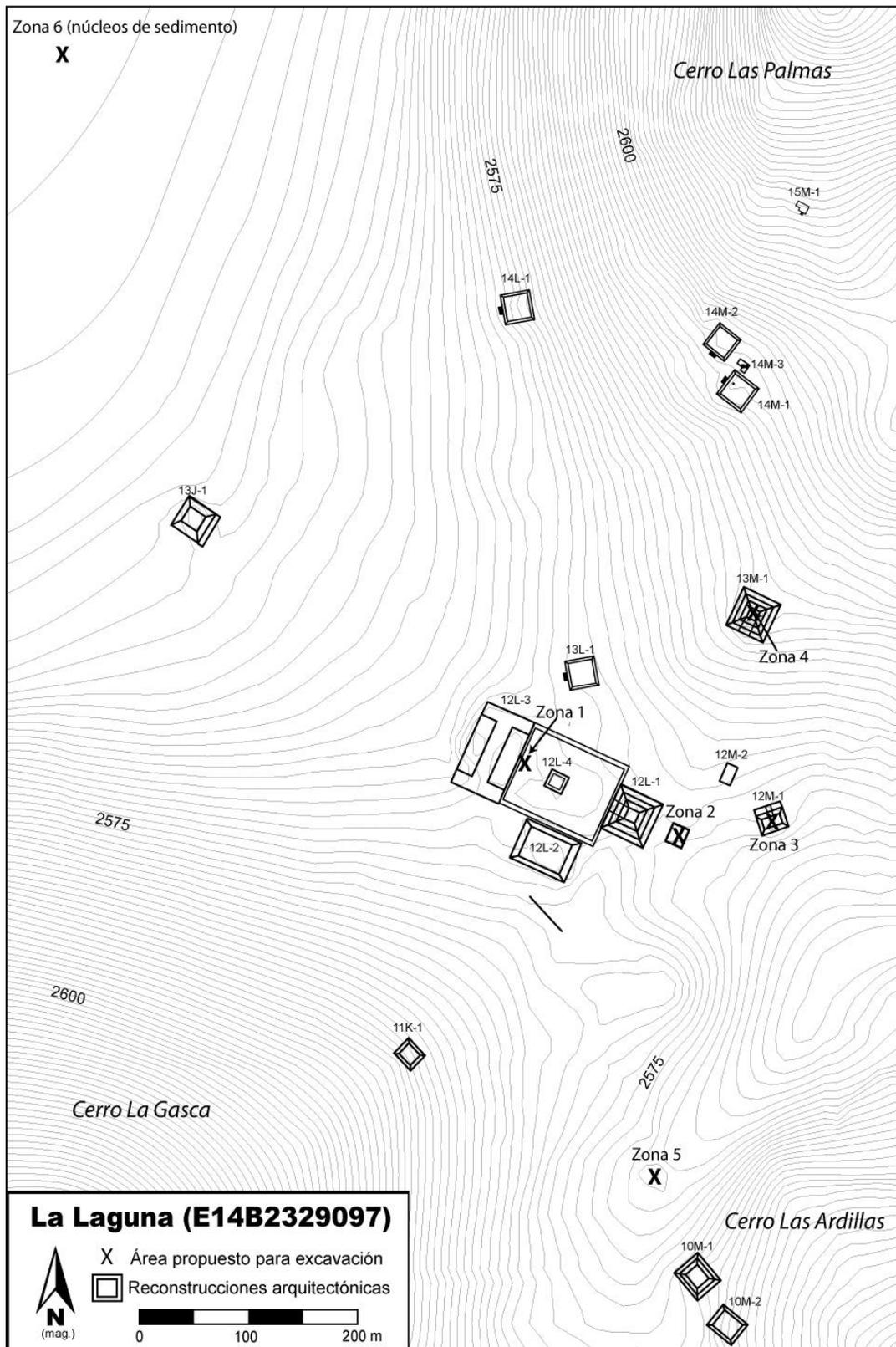


Figure 2.3: Site map of La Laguna (Carballo 2009).

The Classic period central Mexican pantheon has its origins in the domestic contexts of the Middle to Terminal Formative period (c. 600 BC to AD 100). Two styles of effigy vessels, the Old God of Fire and the Storm God, appear at La Laguna and at contemporaneous central Mexican sites. Carballo (2007:53) describes an effigy vessel as a “depiction of an animate being on a container or receptacle.” Based on this definition, effigy vessels were present in central Mexican assemblages as early as 1300 BC. These early vessels were mainly incense burners featuring animals, like opossums. Depictions of an elderly male, identified as the Old God of Fire, began to replace these zoomorphic incense burners around 600 BC in the Puebla-Tlaxcala region. The Storm God also appears at this time mainly on jars designed to hold liquids, incense censer lids, and small ritual masks; the latter two are the only forms found at La Laguna. Carballo (2007) indicates that the contemporaneous and widespread introduction of these two forms of effigy vessels signify heightened religious integration during the Late Formative. This co-occurrence indicates that people were actively manipulating the two deities within domestic contexts across both large and small settlements and across both ends of the socioeconomic spectrum.

The representations of the Old God of Fire at La Laguna depict an anthropomorphic figure with drawn legs and crossed arms, a position that was a symbol of authority in Mesoamerica. For example, Aztecs depicted various male deities, including the Old God (Huehuetotl) and the Lord of Fire (Xiuhtecuhtli) in this fashion (Carballo 2007; Lopez Lujan 1994:171-298, 2001; Matos Moctezuma 1988:85-121; Pasztory 1983:222-227). The Teotihuacano and Aztec versions of the Fire God were similarly conceptualized as an old man and they featured some stylistic similarity to Formative examples—like the addition of ear spools in some cases. The Storm God effigy vessels feature a mustache-like upper lip and a

curling mouth full of sharp teeth (Carballo 2007; Miller and Taube 1993:162, 166; Pasztory 1974:3; von Winning 1976:150). The La Laguna example is similar including an incised upper lip and sharper upper teeth, indicating strong shared conceptualizations of the Storm God in central Mexico during the Late Formative (Carballo 2007).

These widely standardized Formative depictions shaped religious beliefs in ways that both generated change in the form of increasing unification and standardization and perpetuated continuity, especially in relation to rites of exchange and communion (Carballo 2007). Late Formative populations must have been increasingly unified in their conception of proper deities, vessels, and practices for domestic rituals, presumably due to the rise of larger-scale social institutions and increased economic interaction. These trends continued in Classic-period Teotihuacan society and remained central to the Aztec pantheon in the Post-classic period.

Houses are the most conspicuous representations of status differences found in ancient societies because they can express and reproduce dimensions of social relations (Blanton 1994; Carballo 2009). Carballo found that there were three types of house structures that existed throughout the prehispanic central Mexico. These were isolated residences, residences clustered around a patio or walled enclosure, and large agglutinated multifamily compounds (Carballo 2009:476). Due to differences in these types of structures at La Laguna, families appear to have been differentiated based on the size and elaboration of their homes, actively shaping their physical and social surroundings to meet their needs (Carballo 2009). Carballo's excavations of domestic structures in Area F revealed a residential platform approximately 120m² in size which would have supported a small wattle-and-daub structure. Excavations in Area H revealed a larger structure made up of two residential platforms and a smaller annexed platform which may have been used as a kitchen or for storage. The size of Area H compared to Area F indicates that

it was an elite household that was more connected to long-distance exchange based on its artifact assemblage of greenstone, shell, and other exotic materials (Carballo 2009).

Among the excavations, pottery and chipped-stone tools constituted the most abundant artifact classes and dated the structures to the Late Formative period. The stone tools found at La Laguna were primarily made from obsidian, most of which were imported from the Paredón source at least 58km away. These tools were used in both formal and informal cutting, piercing, and scraping activities (Carballo 2006; Carballo et al. 2007; Carballo 2009). In both Areas F and H, smaller “spoon” or “turtle-backed” unifacial obsidian scrapers were discovered (Carballo 2009). However, in Area F, a five-times higher frequency of basaltic/felsic stone tools were discovered suggesting more prominent production of trapezoidal maguey scrapers known as *desfibradores* used for removing fibers from maguey leaves in this area as compared to other parts of the site. These types of tools were especially concentrated near roasting pits at Area F that featured carbonized maguey remains. These associations indicate that inhabitants of Area F were processing maguey for food and fiber, while the small scrapers were used by people in both areas for other tasks such as extracting sap, or *aguamiel*, from maguey plants and / or scraping wood and hides (Carballo 2009). Overall, these processed materials and the associated lithics are attributed to craft production and suggest that diversified household economies had low levels of interdependence in production activities (Carballo 2009). Further, both elite and commoner households engaged in similar domestic craft activities, a pattern which is consistent with diversified economic strategies that buffered against agricultural risk.

Natural transportation corridors made these religious and socioeconomic changes possible. Several major sites in the Basin of Mexico, such as Teotihuacan, Cuicuilco, Tula, Texcoco, and Tenochtitlan, likely took advantage of these corridors during various periods.

Monte Albán and its surrounding area was probably one of the important end destinations that utilized another important corridor south of Puebla-Tlaxcala. Moving east towards the coast, the transportation corridors led expeditions over the Sierra Madre Occidental mountain range towards the Gulf Coast. Likely coastal termination points were somewhere near the archaeological site of El Tajin, sites near the modern city of Veracruz, and near Matacapán. However, there were likely a vast number of places ancient people were going to trade.

These natural corridors allowed for the diffusion of people, goods, and ideas between highland and lowland communities. Further, they sped the rate of cultural exchange and political evolution as competing groups or polities vied for control. Central Mexican groups established interregional contacts between sites located along mountain corridors to facilitate economic and ideological relations during the Formative period (Carballo and Pluckhahn 2007). Carballo and Pluckhahn (2007) state that the exchange of goods and ideas across Mexico would have had profound effects on communities in northern Tlaxcala during the Formative period. By observing the relative costs of using various nearby transportation corridors, their study identified the Tlaxcala Corridor as a major artery of communication and exchange. Almost half of all Formative settlements and ceremonial centers were located within and along it.

Importantly, La Laguna straddles the Tlaxcala Corridor leading from the Basin of Mexico towards the coast. The placement and number of ceremonial structures at La Laguna imply that exchange and ritual were important factors that led to its impressive size during the Formative period (Carballo and Pluckhahn 2007). Since obsidian was procured from several major sources throughout Mexico's history, various chemical analysis techniques exist to locate the specific sources from which raw stone was quarried.

Laser ablation-inductively coupled plasma-mass spectrometry, and neutron activation analysis allow researchers to trace the source systems from which ancient Mexicans were retrieving raw obsidian (see Carballo et al. 2007; Cobean et al. 1991; Boksenbaum et al. 1987). These techniques are a type of chemical fingerprinting which can identify particular chemical concentrations, as well as similarities and differences between artifacts. The ability to locate these sources and attribute artifacts to them is integral for reconstructing Prehispanic trade systems, the development of Formative polities, and procurement activities (Carballo 2007).

According to Carballo and colleagues (2007) the Paredón obsidian source was important for Formative Tlaxcalans, although they were exploiting the Oyameles/Zaragoza, Otumba, and Pachuca sources from the Central and Oriental regions. Over time, Tlaxcalans began to procure raw obsidian from only the Central sources coinciding with the development of regional centers in the area. Data indicate that greater lithic occupational specialization occurred at this time as well as an intensified involvement with the Mesa Central economic sphere (Carballo et al. 2007).

Archaeological research at La Laguna illustrates the importance that households played in the development of complex craft production and exchange networks during the Formative period. Considering the position of these households within society is especially important to understand the diversified and interdependent modes of economic production and competition that began to articulate themselves during the Formative period.

Archaeologists agree that the household of central Mexico was a fundamental unit of production. Domestic economies in the highlands often participated in high-intensity production of craft goods (Carballo 2011; Feinman 1999). Further, households often participated in multicrafting—multiple, sometimes interrelated production activities—to buffer against risk by

incorporating themselves in several economic networks (Carballo 2011; Charlton et al. 1991; Hirth 2006, 2009).

Intensive household production was initially stimulated by economic symbiosis between early sedentary households and communities, and later, by market demand in which commoners turned to crafting as a source of supplementary income (Carballo 2011; Feinman 1999; Feinman and Nicholas 2000, 2004, 2005, 2007; Feinman et al. 2002, 2006; Hirth 1993a, 1993b, 2006, 2009). Economic symbiosis was important to these highland Mexican communities (Carballo 2011; Sanders 1956). The central Mexican highlands offered precious volcanic stones as well as xerophytic plants such as maguey and nopal cacti that were important for creating a range of products. The remarkably adaptable maguey was more evenly distributed throughout the altiplano than obsidian making at least two or more species available to households; therefore ancient Mexican populations were tied together through the symbiotic exchange of these products.

Maguey Sap Production and Stone Tool Use: Past and Present

Smith (1963) indicates that modern maguey plants are frequently used as property markers as well as for the production of sap. Poles and boards can be made from their dried leaves as well. Growing maguey along with other crops may have greatly extended the nutritional base of farmers throughout highland Mexico extending agricultural productivity beyond the normal seed plant season. Further, the plant itself could be used as food during years of low grain yields or processed for fiber during the winter off-season for annual seed crops offering a stable source of raw material for craft productions (Evans 1990; Parsons and Parsons

1990). Ethnographic and historic records confirm the interplanting of maguey and maize in the highlands (Parsons and Parsons 1990). Maguey remains one of the main cultigens able to resist frost and thrive during the winter dry season. However, the rapidly perishable nature of maguey products ensures that more storable seed crops like maize will still be more valuable for long-term subsistence. Besides providing another nutritional component to the prehispanic diet, maguey continues to be important for soil conservation by providing barriers to sheet wash and soil erosion (West 1968; Patrick 1985).



Figure 2.4: An average-sized mature maguey.

The development of urbanized states during the Formative period presented an opportunity for households to specialize in maguey-based products. Evans (1989, 2005) details the household organization of maguey processing at the archaeological site Cihuatecpan, documenting a diversity of maguey products which required coordination to facilitate year-round

tending and processing of the plant. The labor and time intensive nature of maguey production would encourage extended families to reside in joint households similar to the way Aztec maguey specialists were organized by *calpulli*, or supra-household group (Charlton et al. 1991; Nichols 2000) At Cihuatecpan, specialized processing techniques included the production of spinnable fibers that female members of the household would weave together into thread. The segmentation of tasks may have been one factor that contributed to economic partnerships and even gender equality (Evans 2005; Ember 1983).

Intensification in xerophytic plant use, particularly for textile production in the northeastern Basin of Mexico is correlated to population growth during the Postclassic (Nichols et al. 2000; Parsons and Parsons 1990). The fiber made from maguey, known as *ixtle*, was important for making sacks, brushes, sandals, cordage, and cloth (Evans 1990; Parsons and Parsons 1990). Maguey fibers were produced locally since the vast amount of waste it created could not be effectively moved. Specializing in the production of maguey fibers and sap as exchangeable items could have also provided a buffer for families during seasons of poor maize yields (Nichols 2000). However, the products made from maguey are extremely perishable forcing archaeologists to reconstruct their importance through the tools used to exploit them.

Working in Oaxaca, Feinman, Nicholas, and Haines demonstrated the importance of specialized stone-tool knapping and xerophytic plant processing among households at El Palmillo, a Classic period terrace site (Feinman et al. 2006; Haines et al. 2004). Numerous spindle whorls were recovered from the site and differences in the quality of the whorls indicate differences in social status and access to goods (Feinman et al. 2006). Whorls recovered from upper, more elite terraces are smaller and were likely used for spinning much finer maguey fibers or cotton associated with higher-status individuals. According to Haines and colleagues (2004),

maguey fiber production constituted a significant portion of domestic craft activities at El Palmillo.

The chert tools required to process these plants also created a linked craft specialization that reflected differential access to the best raw materials (Feinman et al. 2006; Haines et al. 2004). At El Palmillo, the proportion of better quality stone increases in higher level terraces, as compared to the proportion of better quality stone in lower level terrace assemblages. However, most stone types from local sources are of poor quality. This pattern indicates that elites had access to high-quality, non-local stone. However, non-obsidian *raspadores*, or dome-shaped scrapers, found at El Palmillo are made from low-quality material. The use of low-quality stone for scrapers results in a duller edge, which antithetically, is important for preserving maguey fibers since sharp tools will cut the fibers into smaller fragments when they are extracted from the leaves of the plant with scrapers (Parsons and Parsons 1990). All of these differences in production and consumption appear to have linked households together economically through the exchange of specialized domestic craft production.

Maguey sap, or *aguamiel*, was another important product of maguey processing. In fact, it may have extended the nutritional base of farmers in the arid zones by providing a fresh, nutritious drink where water was scarce (Evans 1990). Parsons and Parsons (1990) suggest that aguamiel production may peak during the dry season. Studies suggest that aguamiel contains important amino acids that are found in limited quantities in maize (Gentry 1982; Ruvalcaba 1983). Fish and colleagues (1986) also note that 100g of cooked maguey flesh contains 347 calories and 4.5g of protein. Even for the modern Otomi, fermented aguamiel products supplied 12 percent of total calories, 6 percent of total protein, 10 percent of total thiamine, 24 percent of

total riboflavin, 23 percent of total niacin, 48 percent of total vitamin C, 8 percent of total calcium, and 20 percent of total iron (Anderson et al. 1946:888).

Once collected sap can either be used as is or allowed to ferment into *pulque*, a mildly alcoholic beverage. According to Aztec mythology, *pulque* was created by Quetzalcoatl and consumption extends to shortly after the creation of the first people (Kicza 1980). *Pulque*, however, only lasts about a week before it attains an unacceptable color, taste, and consistency. As a result, there are some indications that syrup and sugar derived from maguey sap may have been more important than *pulque* during prehispanic times. Loyola (1956:139) found that it took about 16 liters of aguamiel to produce one kilogram of sugar. For syrup, Rangel (1987:82) found that 10 liters of aguamiel were required to produce one liter of syrup.

With the nutritional benefits of maguey sap in mind, it is plausible that prior to the Late Formative period there may have been some household specialization of maguey products. However, because of the how quick aguamiel spoiled, specialization in ancient times would have likely remained at the community level (Parsons and Parsons 1990). On the other hand, more durable syrups, sugars, fibers, and textiles may have formed the basis of household specialization and intercommunity exchange networks. Parsons and Parsons (1990) argue that maguey utilization would have expanded with increasingly hierarchical communities during the Late and Terminal Formative periods. After the collapse of Teotihuacan, a more evenly distributed population in the Valley of Mexico may have further expanded maguey utilization since sap and fiber could have been transported by water to consumers.

Ethnohistorical records written by the Spanish provide most of the information archaeologists know about prehispanic maguey utilization. Used carefully, the wealth of ethnographic and ethnohistoric records can help evaluate and reconstruct social institutions from

the past. Marcus (2000:232) notes, "The ethnohistoric record and ethnographic data are too compelling to ignore, but their use requires discipline and a great deal of common sense."

Marcus's statement is certainly valid for reconstructing maguey production and stone tool use in ancient Mexico. During colonial rule, traditional methods of maguey utilization were transformed in several ways. Sometime after their arrival, the Spanish realized that assuming the distribution and production of local indigenous commodities could prove to be a lucrative endeavor. One result was the systematic cultivation of magueys on large Spanish-owned plantations (Kicza 1980). As pulque sales became more lucrative, traditional modes of subsistence became less important around Mexico City. The introduction of iron also radically altered the tool kit associated with maguey processing. Perhaps, just as powerful, the railroad, introduced in 1873, altered patterns of production, distribution, and consumption by linking distant points across Mexico.

Nonetheless, today, maguey sap production follows a straightforward process that has remained relatively unchanged from prehispanic times (Parsons and Parsons 1990). Therefore, modern techniques can be used as a model to understand ancient production systems. Today, the plant is initially castrated and allowed to sit for a few days. Material left over from castrating the plant's central frond is cleared away with the scraper. After this, a thin film is removed from the interior cavity to initiate sap flow. For two or three days this is repeated, leaving scrapings and sap within the cavity. On the third or fourth day, this waste material is thrown out and the cavity is scraped again. By this time, the cavity wall should have turned a pale yellow color indicating the onset of maximum flow of aguamiel. For two to six months the plant is visited twice daily by a *tlachiquero* to collect sap and continue scraping the cavity.



Figure 2.5: A freshly cut maguey (left) and a maguey filled with fresh aguamiel (right).

The sixteenth century Spanish friar, Fray Toribio Motolinia (1951) provided excellent overviews of maguey utilization—particularly for sap and fiber—within one or two generations of Spanish contact. Motolinia also observed something quite similar to modern sap production techniques:

"After the *metl* or maguey has matured and its stem is full-grown, they cut off its top together with five or six prickles where they are tender. The stem, which is above ground and from which the leaves issue, is as large as a sizeable pitcher. They cut into the stem, making a cavity as large as a good-sized olla. By the time the plant is completely exhausted and the gouging is finished about two months pass, the lapse of time depending on the bulk of the plant; and each day during this time the sap is collected from that cavity into which it drops" (cf. Motolinia 1951:331-34).

The modern maguey scraping tool kit is comprised of four major components. A small iron scraper is used to remove thin portions of the plant tissue from the central cavity. A scraper sharpener is also kept close to ensure the scraper's edge is well honed. A collecting gourd known as an *acocote* is used to remove aguamiel from the maguey's central cavity. Finally, a large container is used to hold aguamiel collected with the *acocote*. Fray Bernardino Sahagun, another sixteenth-century friar, discussed and illustrated several different types of obsidian blades and scrapers, one of which was used to produce sap within the maguey cavity:

"The blade maker produces them from black stone using a pole supported by the feet and hands, and each time a blade is detached from the stone, and of these blades some are for shaving the head, and others for other things; some come from the surface and other are backed, and some have two cutting edges, and others serve to scrape the interior part of the maguey so that liquid issues forth" (Dibble and Anderson 1961, 1964; Sahagun 1969).

Further, Sahagun (1961:179) states that the Otomi "went boring the maguey plant." These descriptions of how the tools themselves were used conform to Motolinia's indications of how the maguey was being utilized around the time of Spanish colonization.

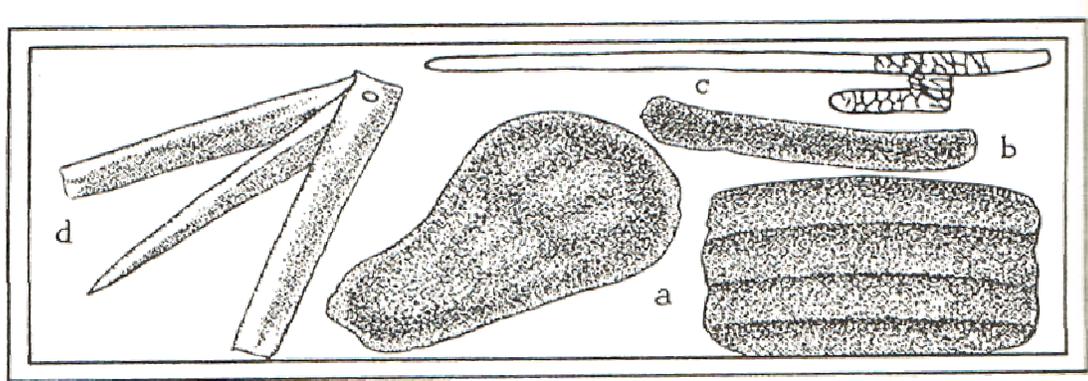


Figure 2.6: Illustrations of indigenous tools (Sahagun 1961).

Significance of the Study

Unfortunately, the archaeological record is mostly uninformative about the importance of aguamiel and pulque in ancient times. Nonetheless, Parsons and Parsons (1990) believe that the use of aguamiel likely extends back as far as the Formative period. This study attempts to document the use of obsidian scrapers for extracting maguey sap during the Formative period at the site of La Laguna.

Many researchers have inferred that the presence of chipped-stone scrapers within archaeological assemblages indicates the extraction sap in highland communities (see Carballo

2009; Haines et al. 2004; Parsons and Parsons 1990). Further, many archaeologists have seen similarities of form and function between modern iron scrapers and archaeological discoidal scrapers that occur in archaeological sites throughout north-central and highland central Mexico. A variety of obsidian, chert, and basalt tools could have served as the prehispanic analogues of modern maguey processing tools. The problem with specifically stating that these small, obsidian scrapers tools were used to process maguey for sap production is that they could have been multipurpose implements useful for a variety of tasks. This possibility is exactly what I seek to test with my research.

One possible alternative for the use of obsidian scrapers is wood scraping. During the Formative period, houses were constructed using wattle-and-daub. This technique would have utilized local woods as well as maguey-fiber ropes to lash together canes and tie them to weight-bearing posts (Flannery and Marcus 2005:31-34). Mexican pine trees, known locally as *ocote*, are still one of the most abundant tree types throughout the country and were one of the most important resources available to highland communities (Ortmann and Carballo 2009; Adriano-Morán and de Tapia 2008; Santley 1979). At the slightly earlier village of Tetel, charcoal evidence indicates that pine trees were abundant in the area and readily utilized (Lesure et al. 2006). The same is true at La Laguna, even though the site was larger and occupied later, where pine was frequently used in the construction of residential and ceremonial structures (Ortmann and Carballo 2009). The *capulin*, a type of cherry tree, was also important to ancient Mexicans and even contributed to their diet. Besides the maguey, *capulin* was one of the most important secondary cultigens available to ancient Mexico (Ortmann and Carballo 2009; Santley 1979). Adriano-Morán and de Tapia (2008) also suggest that these two tree types became important fuels at Teotihuacan during the Classic period.

The processing of animals, especially deer bone and hide, is another possible alternative. Formative period highlanders were exploiting jackrabbits and dogs but deer meat may have been the most important animal protein (Lesure et al. 2006; Santley 1979). Lesure and colleagues (2006) discovered that deer or other unidentified large mammals constituted roughly 40 percent of faunal remains at the archaeological site of Tetel. If this is true, then it is entirely possible that small scrapers may have been used to de-flesh portions of bone. Coe and Koontz (2002:51) also indicate that deer provided not only meat, but hides that probably would have been cleaned of fat by small obsidian scrapers. However, Webster (1986) argues that around 900 to 100 BC, big game hunting constituted less than 80 percent of meat consumed with smaller game becoming more important. This fact may lend support to the notion that obsidian scrapers were being used to extract sap from maguey plants in the central region of Mexico. In any case, sorting out the components of the prehispanic maguey tool kit can best be accomplished through microscopic studies of wear patterns and plant residues on stone tools (Parsons and Parsons 1990). My study seeks to understand the relationship of wear patterns to processed materials in order to discover what these tools were used for, and the following chapter will provide an overview of the techniques and methods I utilized.

CHAPTER 3

SAMPLES AND METHODS

This chapter describes the materials and methods I utilized during the course of my research to evaluate potential components of the maguey processing toolkit. Since my project is experimental in nature, I provide a conceptual overview of ethnographic analogy and experimental archaeology. I also discuss the use-wear approach to lithic analysis that has become a major component of experimental studies dealing with stone tool technologies and I also survey recent use-wear studies that influenced the development of my research program. Lastly, I discuss the specifics of my research including the raw materials and techniques I used to make the replica tools, the dependent and independent variables recorded, cleaning and pre-scan preparation of the experimental tools, scanning electron microscope (SEM) procedures and photomicrography, and the experiments to duplicate use-wear on replicas that match those seen on archaeological tools.

This research utilizes ethnographic analogy to determine the function of ancient tools. I infer that obsidian scrapers recovered at the archaeological site of La Laguna were used to scrape maguey based on the way in which modern, iron implements are used today for the same function. Ascher (1961b) describes the use of analogy in archaeology as inferring non-observable behavior by linking it to observable behavior thought to be relevant. In this sense, analogy provides not only the hypotheses for understanding ancient human behavior but also foundations upon which to base and test them (Charlton 1981).

In the case of my project, both ethnographic and ethnohistoric records provide firm starting points to create analogies. Early Spanish records, like those kept by Motolinia and Sahagun, cited in Chapter 2, offer a glimpse into the lives of indigenous Mexicans around the time of contact. More importantly, they discuss the tools utilized at the time. More recent ethnographic work, like that conducted by Parsons and Parsons (1990), illustrates a direct historical connection between maguey utilization practices of Colonial and modern times. The tool kit associated with maguey scraping has changed due to the introduction of iron as a preferred raw material for the production of scrapers; however, the basic practice of scraping maguey has remained the same. Therefore, the form and function of an ancient tool, specifically an obsidian scraper, is a useful starting point to reconstruct the maguey toolkit of ancient Mexico.

It is believed that ancient Mexicans utilized small obsidian scrapers to process the inner core of maguey to induce sap flow. These tools may have been hafted or handheld. However, the introduction of iron during the Colonial period offered a more effective raw material from which to produce scrapers, thereby rapidly replacing obsidian tools. I believe that these iron scrapers, still used today, represent a modern analogue to the ancient obsidian scrapers crafted by indigenous Mexicans to process maguey or a variety of other materials. To test such a hypothesis, direct experimentation of how tools may have been used in the past is required through the use of an experimental program that compares the development of use-wear on modern replica obsidian scrapers to the use-wear on ancient obsidian scrapers.

Experimental Archaeology

Experimental archaeology provides a way to enhance analogies developed from observations in the ethnographic and ethnohistoric records (Charlton 1981). Regarding experimental approaches, Tringham (1978:169-179) says:

"... observation of and experimentation with archaeological materials cannot be separated from hypothesis building and testing, and as a corollary, that basic research in archaeological materials is as much an integral part of archaeological question answering as the philosophical model building of Binford, Plog, and Clarke. "

The importance and function of experimental approaches in archaeology have long appeared to be generally underestimated or misunderstood (Reynolds 1999; Sarayday and Shimada 1973). Reynolds (1999) believes this may be due to confusion regarding experiment, experience, and education. He defines experience as the process by which people actually do things and learn the nature and application of various archaeological technologies. Education is integral to experience and experiment because the methodology by which an action is performed is central to a concept of education. With this in mind, Reynolds (1999:157) defines an experiment as "a method of establishing a reasoned conclusion, against an initial hypothesis, by a trial or test." Due to this, the experimental process enhances interpretations of the material record by allowing the testing of interpretations. However, to be successful, an archaeological experiment must satisfy several important tenets. First of all, an experimental project must be capable of direct examination and created with an adequate foundation of data. Also, an experiment should be designed so that results may be assessed statistically, creating impartiality on the part of the researcher. Second, an experiment cannot be designed to enhance our understanding of motive or emotion in the past. As a result, the focus of an experiment can and should only be the representation of structure, process, and function.

Several types of experimental approaches exist which deal with various aspects of the archaeological record ranging from the reconstruction of ancient buildings to the testing of new technology to aid in excavation. However, within the context of my project, Reynolds' (1999) category of process and function experiments are most important. This category is similar to what Ascher (1961a) calls an imitative experiment, or those experiments in which matter is used as it is believed to have been used in the past. These types of approaches utilize replicas and reconstructions of implements to test functionality and purpose in an effort to reconstruct behavior. Ascher (1961a) offers five methodological stages with which to accomplish this. First, a limited working hypothesis must be converted into a testable experiment. Second, experimental materials must be selected. Third, the experimenter must operate with objective and effective materials. In other words, these materials used in the experiment must have been available in an aboriginal setting (Ascher 1961a). Fourth, the experimenter must carefully observe the results of the experiment first without reference to the original archaeological and ethnohistoric data, which ensures an unbiased interpretation of the results. Relying on materials available aboriginally, finding corroborating evidence, and performing several alternative experiments are further steps to increase confidence in the experimental inference (Ascher 1961a). Reynolds (1999) indicates that there is a need for more process and function experimenting especially for implements which attract definitive interpretations. However, a range of data beyond the experiment itself must exist to validate experimental findings.

Lithic Use-Wear Studies

For my research, lithic use-wear analysis will be the most important framework to interpret experimental data. During the 1950s, Sergei Semenov (1964) conducted comprehensive use-wear studies influencing the work of later scholars like George Odell (2004) and Larry Keeley (1984). These researchers were concerned with discovering the signatures of various types of wear that formed on the edges of stone tools after they had been used to process different materials like plants, woods, hide, bone, and antler. In 1977, Hayden hosted the first Conference on Lithic Use-Wear to bring use-wear advocates together to prove the accuracy of the technique and attract new practitioners (Odell 2004). Lithic use-wear analysis had suffered from setbacks caused by a failure for use-wear analysis to be readily accepted. However, continued extensive testing resulting not only in overcoming potential problems, but a highly trained group of researchers that employed all possible techniques available to them.

Use wear can be observed using one or more of the following techniques: macroscopic assessment, low-power stereomicroscopes, high-power magnification, and scanning electron microscopy (Odell 2004). Macroscopic assessment is performed with the naked eye, sometimes with the use of a 10X magnification hand lens. This kind of low power technique can be used to observe use-wear from cutting or scraping hard materials with thin edged tools or the presence of gloss or polish on sickles blades used to cut plants (Odell 2004). Most traces, however, are more subtle requiring greater magnification. On the lower end of the magnification scale, low-power techniques use standard stereomicroscopes, also known as dissecting microscopes, available in most biology departments. Stereomicroscopes have a magnification range extending from 10X to 160X and this range is appropriate for viewing and cataloguing use wear traces (Odell 2004).

Odell (2004) notes that low-power approaches are suitable for ascertaining the dominant motion or activity in which a tool was engaged. High-power magnification, on the other hand, is useful for learning what materials (bone, hide, wood, etc.) tools processed. The binocular metallurgical microscope with incident lighting is preferred in this case with magnification extending up to 500X. The only downside to these tools is that these types of microscopes rely on lighting to illuminate the artifact being examined.

The scanning electron microscope (SEM) is the most effective tool for conducting functional studies of stone tools (Odell 2004). These large machines, usually operated with the aid of a skilled technician, have a magnification range of 10X to 500,000X. In the most basic sense, SEM works by imaging a sample surface by scanning it with a high-energy beam of negatively charged electrons. The electrons interact with the atoms in a sample producing signals that contain information about surface topography, composition, and even electrical conductivity. As a result, SEM can reproduce an image at high magnification with excellent resolution and depth; this clarity also extends to photographs of the sample. The main problem with SEM involves limitations of the size of the staging area where the artifact is placed. This small compartment often limits the size of the object that can be viewed. Further, the nature of SEM electron stream requires the application of a very thin metallic coating of a material like gold, palladium, platinum, or tungsten. This ensures that electrons are distributed evenly across the surface of an object keeping them from "charging," or gathering an electrostatic charge in a specific place which distorts the image. Researchers have worked around these issues by creating synthetic replicas, acetate peels, or smaller portions of tools (Odell 2004). However, the issue with object size keeps samples sizes and sample pools small, making SEM analysis

ineffective for studying whole assemblages. However, Odell (2004) states, "The SEM can be very effective in lithic analysis, but only for specific questions requiring small sample sizes."

Tringham and colleagues (1974) believe that microwear studies add a completely new dimension to lithic studies allowing researchers to account for cultural change and variation. They conducted a series of experiments to test the formation of edge damage on stone tools used in various ways, especially to answer questions about lithic assemblages from Neolithic period Central and Eastern Europe. They were specifically interested in testing how a tool was used, the material it processed, angle of the edge of the tool, and how it was held. Besides reconstructing the formation of polishes and striations on stone tools, however, they were interested in tracking another damage pattern called microflaking, the chipping of the edges of a stone tool. To perform the study, they created replicas of Neolithic chalk flint tools and used them to process materials such as bone, wood, and plants. All the materials they chose to process were widely available to European societies living in temperate or Mediterranean environments during the Holocene (Tringham et al. 1974). The tools were used to cut, saw, whittle, groove, scrape, shave, bore, and chop a range of materials to account for the formation of all possible wear and microflake patterns. The researchers also controlled for various environmental phenomenon by subjecting some stone tools to water damage and trampling. In the case of scraping, the researchers found that semicircular or step-scar microflakes detach from the surface opposite of that which directly contacted a worked material. Also a marked difference in wear pattern formation was observed between "soft" and "hard" materials (Tringham et al. 1974). Soft materials included the skin and flesh of various plant and animal species. These materials tended to produce only scalar shaped scars. Hard worked materials, like bone and certain woods, produced step-scars which obliterated scalar scars; these

microflakes were rapidly detached even before 1000 strokes had been completed. Different worked materials and different actions produce qualitatively and quantitatively different microwear patterns along the used edge of a tool (Tringham et al. 1974).

Keeley (1980) experimented with the formation of use wear and its diagnostic abilities in the seminal work *Experimental Determination of Stone Tool Function*. He began by replicating chalk flint tools discovered at Lower Paleolithic period British sites. Replicas of Lower Paleolithic tools were tested on materials widely available to people living in this time period including wood, bone, meat, and hide. The actions used to process these materials were whittling, planing, sawing, cutting, chopping, adzing, scraping, boring, and wedging. Once finished, the experimental tools were analyzed using both low and high power microscopy and compared to archaeological tools to test the diagnostic validity of the experimental program. This procedure ensures that all forms of utilization damage are investigated and recorded. Most of the experiments were performed outside with dirty hands to more accurately represent the possible behaviors and gestures of the distant past (Keeley 1980). Keeley notes that any experimental program should be relevant to the ecology and general conditions of sites from which tools originate, to the materials people were likely processing, and to rock types from which tools were likely made. Keeley believes that only the relevant variables should be noted, and that breaking down independent variables to more specific degrees is not productive. For example, breaking down the action of scraping into particular variables such as the length of the stroke, the angle of the edge to the surface of the worked material, and so forth atomizes actions, which only increases the artificiality of the experiment. This scientism pushes the experimenter away from the prehistoric behavior of the tool user who was not concerned with these specific variables, but only completing a task (Keeley 1980).

Lewenstein (1981) argues that use-wear observed on Mesoamerican blades can allow for the identification of wear patterns corresponding to particular uses and processed materials and the determination of probable function. She replicated obsidian blades based on those recovered from Patarata 52, a Classic period residential area in Veracruz, Mexico. The tools were made using ethnohistorically recorded techniques and used on materials known to be utilized during prehistoric times. Tools were used to scrape, saw, and whittle for a total of 500 to 2250 strikes. Of particular interest for my project, she found that obsidian blades became dull while scraping hide after 325 strokes producing very little polishing and very small microflakes (Lewenstein 1981:180). Even when used for 2000 strokes, wear patterns remained essentially the same. In general, Lewenstein (1981) follows Tringham and colleagues (1974) proposition that the relative hardness of the contact material is highly correlated to microflake size. Also, a correlation between processing non-woody plants and a unique wear pattern featuring striations and possible comet-shaped pits was confirmed (Lewenstein 1981; see also Keeley 1980). Lewenstein (1981) also confirmed that scrapers are distinguishable from cutting tools based on the presence of asymmetrical dorsal/ventral wear resulting from scraping.

What is most interesting about this study, however, is the use of two complimentary phases of study to assign function to archaeological tools. The first phase consists of a non-intensive, preliminary field study. This stage involves ancient sorting tools based on suspected functionality based on tool form, material types, and associations with other artifacts or features. When this is possible, the researcher can interpret lithic assemblages in terms of activity sets, especially when closely grouped tools can be aggregated into functionally specific tool kits (Lewenstein 1981). Differences in the distribution of these tool kits and functional classes of stone tools can indicate changing activities over time at a site. Considered in relation to other

artifact classes such as bones, pollen, and faunal remains, testable behavioral hypotheses can be generated from these initial field observations of tools within their archaeological context. Like her experimental study on obsidian blades, the second stage of this type of research can involve the replication of recovered tools and the use of high-power microscopy to assess the development of use-wear patterns (Lewenstein 1981).

Aoyama (1995) conducted a series of replication experiments with obsidian, chalcedony, and agate tools on various materials to understand Classic Maya lithic use. The worked materials chosen for the study were grasses of the *Gramineae* family, composite plants, wood, bamboo, bottle gourd, cornstalk, chili, squash, avocado, pineapple, papaya, coconut, yucca, meat, hide, bone, antler, *jute* snail, soil and stone. The actions performed with experimental tools included sawing, cutting, grooving, scraping, whittling, chopping, and boring. Each experiment involved different numbers of stroke for each action, although some went up to 5,000 strokes. The wear patterns produced on these replicas were used to determine the function of archaeological specimens taken from Late Classic period assemblages from Copán, an archaeological site in western Honduras. The use wear patterns that developed on the stone tools were assigned types. For obsidian, 11 unique use wear patterns were developed on the experimental samples (Aoyama 1995).

Aoyama (1995) termed these unique wear types as Patterns a, b, c, d, e, f, g, h, i, x, and y. Pattern b developed from the processing of wood and other plants and consisted of a bright and smooth polish, long and thin striations, and many small pits. Pattern d emerged from bone and antler scraping. This wear pattern had a bright, smooth, and flat polish with slightly rounded edges. Further, striations and pits were not as frequently observed as from other wear patterns. Hide working produced Pattern e which appeared as a matted, rough texture with many striations

and pits near the edge of the tool. The other various patterns Aoyama observed were noticeably different and were produced from processing meat, Gramineae, and *jute* snails. When this typology was used to microanalyze the use-wear patterns on the archaeological samples of tools, Aoyama (1995) was able to reconstruct not only tool function, but the possible function of the structures from which they were excavated. For example, the wear patterns on tools excavated from Structure 10L-16 at Copán indicated that both ritualized and specialized production of marine shell ornaments were undertaken at this household. The highly worn tools at Structure 10L-22A, on the other hand, indicated that the structure may have served as a Maya council house where numerous feasts and banquets were prepared. Aoyama (1995) argues that lithic use-wear analysis adds supporting epigraphic and iconographic evidence for the weakening of centralized political authority at Copán.

Expected Use-Wear Patterns from Processing Plant Materials

Keeley (1980) provided generally expected results for use wear patterns left by processing plant materials based on his studies on Neolithic implements from Germany and Syria. According to Keeley, the surface of tools used to process plants should display four key features: 1) a very smooth and highly reflective surface, 2) a fluid appearance, 3) filled-in striations, and 4) comet-shaped pits. Keeley (1980) observed that the comet-shaped pits ran parallel to any striations that appeared. Further, the tails of these pits pointed towards the used edge.

These features were described by Witthoft (1967) as "sickle-" or "corn gloss." Aoyama (1995) discovered similar patterns on non-obsidian (wear Type B) and obsidian stone tools (wear

Pattern b) used to process Gramineae. I infer that a stone tool used to scrape plant material would display these features on the dorsal surface, appearing much like microflakes. The polish, if observed, may appear brighter and more extensive than that of wood polish.

Expected Traces Left by Woodworking

In 54 of 59 woodworking experiments, Keeley (1980) found that a distinctive wood polish was formed on the working edges of experimental stone tools. This polish was not dependent upon whether the wood was fresh or seasoned, nor was it dependent upon the species of wood, specifically whether it was a hard or softwood species. The polish was characterized as very bright and very smooth in texture, commonly gently curved or domed on the peaks of surface features. Further, the polish spread into the valleys between features through continued use of the stone tool. Scraping tools held at a roughly 90 degree angle to the processed material produced a polish on the opposite ridges of stone tools (Keeley 1980). On thin edges, the development of polishing was much less because the friction-affected area is constantly being removed and broken away by continuous scraping action (Keeley 1980). Interestingly, Keeley (1980) noted that extremely thin-edged tools were unlikely to have been very efficient for scraping wood based on this observation. Striations, on the other hand, were not particularly common, although a broad and shallow striation, approximately 15 μm length, appears to be unique to woodworking implements. The formation of microflaking and scarring on edges of wood working tools illustrated no consistent variation unique to this action. Nonetheless, small, deep, and scale-shaped flakes often occur when scraping wood with thin-edged stone tools.

Aoyama's (1995) Pattern b seen on Copan obsidian blades was consistent with Keeley's woodworking pattern. His Pattern b is characterized as bright and very smooth polish, and is similar to what Aoyama (1995) calls a Type B wear pattern found on non-obsidian stone tools, although polishing on obsidian was present to a much greater extent. Further, the surfaces on which Pattern b polishes appeared were relatively flat and somewhat rounded. Any striations observed were thin and long. This pattern was further characterized by pitting across the polish surface.

Expected Traces by Working Bone

Keeley (1980) noted that bone polish formed on tools much more slowly than polish that formed by wood working, even after much use. Bone polish is distinguished from other types of polish by the presence of many tiny pits. Cleaning with an HCl solution is required to reveal these pits which are usually filled in with apatite, a bone mineral (see Keeley 1980 and Vaughan 1985). Notably, bone polish on stone scrapers is much more localized on high points of surface features and does not appear as smooth as wood polish, which often displays a grainy texture. Both Keeley's (1980) and Vaughan's (1985) experimental data displayed these characteristics; however, Vaughan (1985) noted that transverse actions, like scraping, produced numerous comet-tails on the polish surface. This feature may sound similar to the comet-shaped pits found on sickle-gloss polish, but striations, especially deep and narrow striations, are much more common on bone-working implements than woodworking tools, especially on the dorsal side of stone tools. Edge damage on bone working tools is generally much more intense and characterized by larger microflakes. Large shallow scalar, large stepped, and small stepped

microflakes occurred much more commonly on stone tools used to scrape bone than stone tools used to scrape wood. Aoyama (1995) further distinguished the wear patterns that developed from scraping bone and antler with obsidian stone tools. His Pattern d is characterized by bright, smooth, and flat. The margins of the contact surfaces are slightly rounded, and a few thin striations and tiny pits across the polish surface are also found.

Expected Traces by Working Hide

Keeley (1980) observed that scraping fresh hide produced a slow-forming, bright, and greasy polish on stone tools due to the buildup of various natural lubricants from flesh and fat present in animal hides onto the surface of hide working tools. This polish lacked the smoothness of wood polish, as well as the deep micropitting of bone polish. Striations form as diffuse, shallow features at roughly right angles to the tool. Interestingly, Keeley (1980) discovered that continued use would cause these features to curve around the edge. Microflake edge damage was generally minute because small scars and fractures were usually eroded by the formation of hide polish. Keeley (1980) also noted that hide scraping produced a unique rounding effect on chert tool edges.

Working with a fresh hide may change the way in which use-wear develops. Vaughan (1985) argues that working fresh hide caused many of the same characteristics as cutting meat, fat, and tendons on stone tools, but without the effects of bone contact. Any observable polish traces were distributed fairly equally on the contact and opposite surfaces of the stone tool. This is because the most efficient method of defleshing hides is through a slicing or shaving action rather than scraping.

Aoyama (1995) found that obsidian stone tools used on hide presented a matted, rough texture with numerous tiny pits and striations. These features were present near the edge of the tool. Lewenstein (1981) found little edge rounding on obsidian blades used for the same task. Lewenstein (1981) also observed that her replica obsidian blades became dull after about 325 scraping strokes, although each tool was used up to a maximum of 2000 strokes. The wear patterns observed at 325 and 2000 strokes were essentially the same (Lewenstein 1981). However, the fact that these are blades rather than the discoidal scrapers may affect the formation of use-wear on stone tool edges.

Scraped Material	Observable Microwear Features on Flint Tools (Keeley 1980)	Observable Microwear Features on Obsidian Blades (Aoyama 1995)
Plant (Soft)	Smooth and highly reflective polish that is brighter and more extensive than wood polish; filled-in striations; comet-shaped pits.	Pattern B wear: bright and smooth polish; long and thin striations; numerous tiny pits.
Wood (Medium)	Very bright and smooth polish curved around peaks of surface features; striations not common although broad/shallow is unique to wood; no consistent variation of microflaking.	Pattern B wear: bright and smooth polish; long and thin striations; numerous tiny pits.
Bone (Hard)	Slow-forming polish localized on high points; deep and narrow striations to a greater extent than with other materials; numerous tiny pits; much greater edge damage than other materials.	Pattern D wear: bright, smooth, and flat polish with slightly round edges; striations and pits not frequently observed.
Fresh Hide (Soft)	Slow-forming, bright, and greasy polish lacking smoothness of wood polish and deep micropitting of bone polish; if present, striations are diffuse and shallow; minute microflaking; unique edge-rounding effect.	Pattern E wear: matted and rough texture; many striations; pits near tool edge. These appear near the tool's edge.

Table 3.1: Expected results summarized (Keeley 1980; Aoyama 1995).

Expectations in Relation to Use and Material Hardness

For each scraping experiment, the formation and development of almost all polishes, striations, and microflakes are expected to be produced on the surface opposite the one directly in contact with the worked material (Tringham 1974; Lewenstein 1981; Vaughan 1985). This pattern results because scraping is a one-way movement towards the tool user. Scraping causes the surface of the tool to come into contact with the processed material along a small, concentrated area. Therefore, any polishes, striations, and microflakes will be distributed across a much smaller locus than those produced from sawing or cutting which utilize not only both edges of a stone tool, but also a larger surface area. It is also possible that the development of these features on such a small area may cause them to eventually overlap and merge as use continues.

The hardness of the processed material is also expected to alter the way in which use wear develops on the edges of experimental obsidian scrapers. A hard material is considered to be bone, whereas a soft material is meat or green plants. Medium hard materials are exemplified by various species of fresh wood. Further, the hardness of the stone affects use-wear patterns. Obsidian is a brittle volcanic glass. Its surface is more vulnerable than siliceous sedimentary rocks such as chert to force, so striations and other forms of use-wear should form more readily on the surfaces of obsidian tools (Aoyama 1995).

Obsidian Scraper Replication and Experimentation in Mexico

To discover how wear patterns formed on the edges of obsidian scrapers recovered at La Laguna and other highland Mexican sites, I chose to replicate several different forms and sizes of scrapers from locally sourced obsidian. Using locally available materials aids in determining the function of a sample of obsidian scrapers recovered from La Laguna. Carballo and I knapped these scrapers using a free-hand percussion flaking technique. This form of knapping involves holding a core stable with one hand while striking it with a hard (stone) or soft (wood, antler, or bone) hammerstone in the other hand. In this instance, we chose a sandstone hammerstone. In total, ten experimental samples were prepared and numbered: 1 through 4 (larger discoidal scrapers), 5 through 8 (smaller round scrapers), and 9 and 10 (unused scrapers to be used as controls). Several archaeological samples from La Laguna were also selected for use-wear comparison. These samples were numbered 11 through 16, and their proveniences were recorded. Both experimental and archaeological tools were photographed, illustrated, and measured. Images of these scrapers are provided below.



Figure 3.1: Experimental scraper 1 used to process maguey.

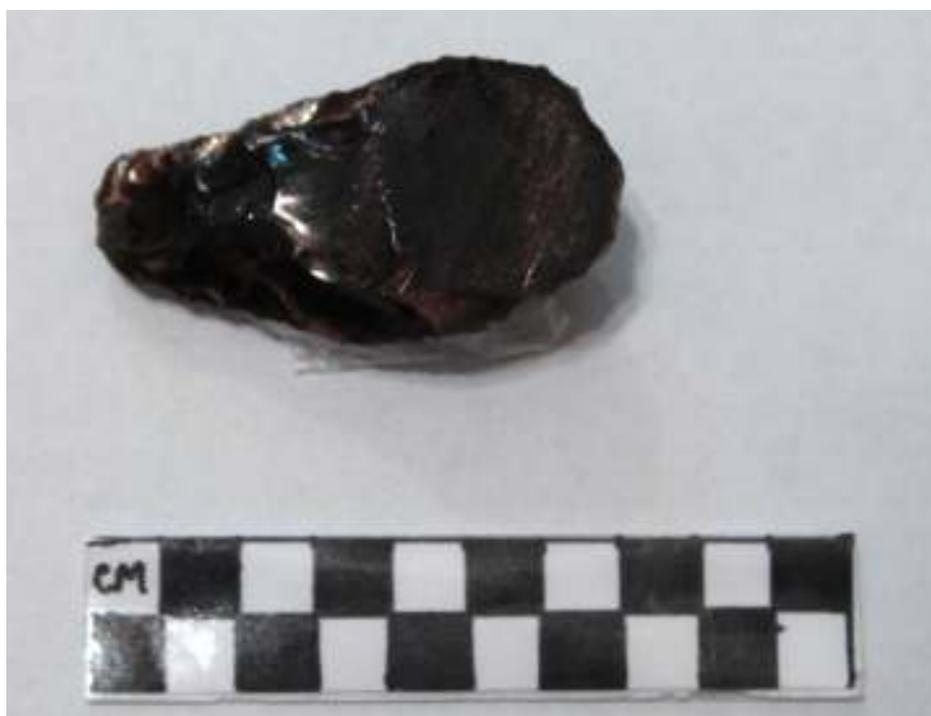


Figure 3.2: Experimental scraper 2 used to process Mexican pine.



Figure 3.3: Experimental scraper 3 used to process deer bone.



Figure 3.4: Experimental scraper 4 used to process deer hide.



Figure 3.5: Experimental scraper 5 used to process maguey.



Figure 3.6: Experimental scraper 6 used to process capulin.



Figure 3.7: Experimental Scraper 7 used to process deer bone.



Figure 3.8: Experimental scraper 8 used to process deer hide.



Figure 3.9: Experimental scraper 9 used as a control.



Figure 3.10: Experimental scraper 10 used as a control.



Figure 3.11: Archaeological Scraper 11 - TLX-97 I/6UU/2562.



Figure 3.12: Archaeological Scraper 12 - TLX-97 I/11L/871.



Figure 3.13: Archaeological Scraper 13 - TLX-97 I/F.



Figure 3.14: Archaeological Scraper 14 - TLX-97 I/F.



Figure 3.15: Archaeological Scraper 15 - TLX-97 I/F.



Figure 3.16: Archaeological Scraper 16 - TLX-97 I/F.

There were several important variables to measure during the course of the investigation. The length, breadth, and thickness, as well as what material each experimental tool processed were recorded as independent variables. Dependent variables recorded include: the type of wear

traces found, the placement of those wear traces on the tool, and the directionality of any linear microwear patterns. These same variables, except for the material processed, were also recorded for archaeological samples.

Sample Number	Type	Length (mm)	Breadth (mm)	Thickness (mm)	Edge Angle (Degrees)	Material Worked	Strokes
1	Experimental	87mm	53mm	15mm	40	Agave	1000
2	Experimental	72mm	36mm	26mm	70	Ocote	1000
3	Experimental	69mm	53mm	26mm	70	Bone	1000
4	Experimental	62mm	38mm	26mm	70	Hide	1000
5	Experimental	57mm	47mm	17mm	30	Agave	1000
6	Experimental	45mm	47mm	13mm	60	Capulin	1000
7	Experimental	33mm	45mm	20mm	70	Bone	1000
8	Experimental	42mm	54mm	20mm	70	Hide	1000
9	Experimental	35mm	51mm	20mm	45	Control	0
10	Experimental	60mm	47mm	21mm	30	Control	0
11	Archaeological TLX-97 I/6UU/2562	47mm	26mm	9mm	40	N/A	N/A
12	Archaeological TLX-97 I/11L/871	43mm	43mm	18mm	64	N/A	N/A
13	Archaeological TLX-97 I/F	35mm	42mm	14mm	40	N/A	N/A
14	Archaeological TLX-97 I/F	37mm	43mm	8mm	50	N/A	N/A
15	Archaeological TLX-97 I/F	57mm	29mm	12mm	50	N/A	N/A
16	Archaeological TLX-97 I/F 1843	34mm	36mm	8mm	10	N/A	N/A

Table 3.2: Variables measured on experimental and archaeological obsidian scrapers.

In terms of microwear, I was specifically looking for the development of polishes, striations, and unique microflaking. Polishes are topographical changes characterized by increasing amounts of smoothing and brightening caused by constant, abrasive action between a stone tool and a processed material during use (Vaughan 1985). Striations are linear abrasions or tiny scratches that appear from use and bear some indication of the direction of a tool's use motion (Vaughan 1985). Striations are defined by their width, depth, and, when applicable, directionality in relation to the axes of the tool. Microflaking is characterized by the formation of scars along an edge resulting from intentional use. These features are formed not only because of the material from which a tool is made and the material being processed, but also because of the tool's edge angle of the tool, contact angle, applied pressure, and deliberate retouching of the tool (Vaughan 1985).

For this experiment, scraping was defined as a motion characterized by pulling tools towards the user with the working edge at a roughly 90 degree angle to the worked material.

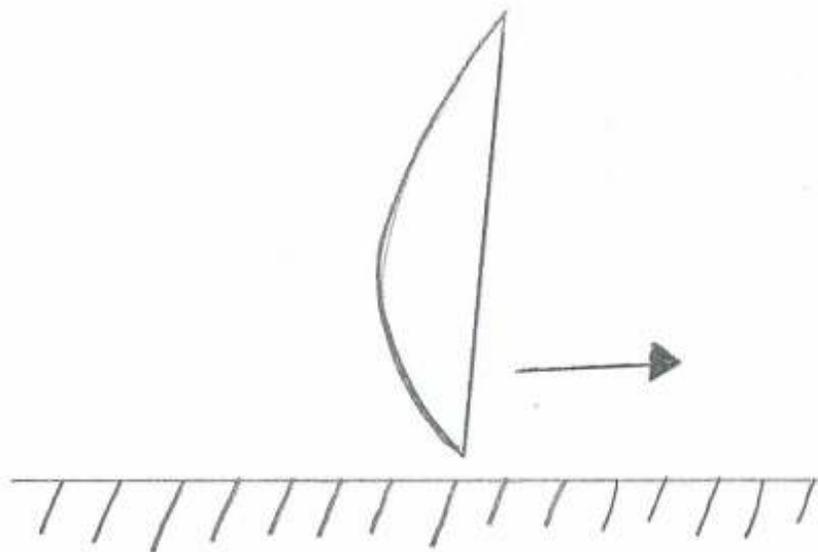


Figure 3.17: Illustration of scraping.

One of each spoon-shaped experimental scraper and one of each discoidal experimental scraper was used to scrape 1,000 strokes on each material (Tringham et al. 1974). I also used bare hands to perform each scrape test. The materials selected for scraping tests were maguey (*Agave* spp.), Mexican pine (*Pinus cembroides*), Capulin (*Prunus salicifolia*), and white-tailed deer (*Odocoileus virginianus*) bone and hide.

Maguey was processed under the direction and assistance of a local *pulque* producer whose expertise was invaluable. Each of the two experimental maguey scrapers were held in my right hand and pulled towards me in a semi-circle around the half-sphere shaped inner core. The length of each scrape was approximately 12 inches. The scraping tests for both kinds of maguey scrapers (small and large) were performed on six individual plants to ensure no single plant was overworked. These tests were performed between 16 June 2010 and 23 June 2010 at Ganadería La Laguna. Overworking causes the plants to toughen too quickly and produce inadequate amounts of *aguamiel*. The actual scraping motion was performed in a circular motion around the inner core of each maguey cavity. This resulted in scrapers that formed concentric circles from the outside of the cavity towards the center. Señor Isaac informed me that it was most effective to scraper the maguey this way rather than to scrape it in a single direction because it resulted in the best flow of sap from the agitated maguey flesh.

It should be noted that gloves may be required for the uninitiated scraper. A skin irritant found on the spines of the plant as well as within the sap produced from the maguey's flesh can cause purpuric agave dermatitis known locally as *geeshee*. The symptoms I experienced were the formation of small red bumps where my hand had directly contacted fresh maguey sap. The rash was similar to other minor allergic reactions and cleared up after a few days of using a topical antihistamine and wearing gloves when scraping the magueys on subsequent days.



Figure 3.18: One of the maguay cores used to test experimental scrapers.



Figure 3.19: Another maguay core used to test experimental scrapers.

The wood scrapers were also used at Ganadería La Laguna on 17 June 2010. The Capulin (Figure 3.20) and pine tree (Figure 2.21) samples chosen for scraping tests were branches measuring no more than 60cm each. These were pulled down from trees around La Laguna. The branches I processed were held steady with my left hand as the experimental wood scrapers were held with my right hand. I then pulled the scrapers towards me down the length of the wood with scrapes of about 10 inches.



Figure 3.20: Capulin branch used to test an experimental scraper.



Figure 3.21: Mexican pine branch used to test an experimental scraper.

Deer bone and hide were procured and processed in Tuscaloosa, Alabama on 30 November 2010. Two femurs, approximately 60cm, were used. I held each femur with my left hand while pulling each experimental scraper down the length of the bone with my right hand. The length of these scrapes was about 8 inches. Fat and skin were left on the selected portion of fresh hide which measured approximately 86cm in width and 40cm in length. To scrape this sample, the hide was held taut as the tool was pulled down, from top to bottom, towards me with my right hand. Each of these scrapes measured approximately 10 inches. Each sample was photographed for records.



Figure 3.22: A deer femur used to test experimental scrapers.



Figure 3.23: Portion of deer hide used to test experimental scrapers.

Before each round of SEM analysis each experimental tool was thoroughly examined with a stereomicroscope to locate used edges and identify the formation of use wear. The archaeological tools were also observed with a stereomicroscope to locate use wear before being viewed with the SEM. Magnifications of 10X to 40X were utilized. Prior to SEM scanning, the experimental and archaeological scrapers were gently hand washed with soap and water, and dried with alcohol and absorbent cotton (see Aoyama 1995; Keeley 1980). The scrapers were then bathed for 10 minutes in a warm, 10 percent HCl solution (see Aoyama 1995; Keeley 1980). The experimental tools were coated in a 200µm layer of gold to improve electrical conductivity within the vacuum chamber prior to the pre-use and post-use SEM analysis. During the post-use SEM analysis of the experimental obsidian scrapers I chose to cut off the used edge of each tool to allow easier mounting and manipulation of the scrapers within the housing chamber of the SEM. As a result, I viewed only the edge rather than the intact tool. The archaeological tools also received a 200µm layer of gold prior to SEM analysis. These tools were viewed intact. The SEM machines used in this study were the JEOL 7000 FE SEM and Phillips XL 30 SEM, located in the Central Analytical Facility (CAF) on the main campus of the University of Alabama, Tuscaloosa. Magnifications of 200X to 1500X were used to view use-wear, whereas magnification of 40X to 100X were primarily used to locate use-wear locations. Technical assistance and guidance was provided by Johnny Goodwin, an instrumentation specialist at CAF. All photomicrographs provided to document use wear traces were taken with the built in imaging hardware of each SEM and recorded digitally to a flash drive. Results of the use-wear experiments are presented in the next chapter.

CHAPTER 4

RESULTS OF THE STUDY

In this chapter I first presented the results from the experimental obsidian scrapers made and used in Mexico to process maguey and other materials. I then presented the results taken from the observed archaeological obsidian scrapers that derive from archaeological excavations at La Laguna. For each experimental tool, I describe what material it processed and any microscopic use-wear features that developed on the tool after use. For each archaeological tool, I describe the use-wear features present on the tools. Comparisons of use wear patterns between replicated and ancient tools and, ultimately, the interpretation of ancient tool use based on this research are discussed in Chapter five.

Use-wear Traces on Experimental Obsidian Scrapers

It is important to introduce a few directional terms that refer to various aspects of the experimental and archaeological obsidian scrapers. To differentiate the front from the back, respectively, the terms ventral aspect and dorsal aspect will be employed. Lateral will refer to any positions further away from the tool's midline. In turn, medial will refer to the positions closer to the tool's midline.

Scanning electron microscopy (SEM) analysis showed each experimental scraper edge to be relatively sharp and well defined before use. This is to say that the margin separating the leading, ventral side of the tool from the dorsal, non-contact side was undamaged and uneroded.

Flake scars on the dorsal aspect were large and well defined, exactly the type expected to form during production of an ancient stone tool. These flakes are defined by the distance between each margin, or edge, and the valley, the area where material has been visibly removed, that lies between these margins. The margins of each flake scar that lie at a higher-elevation than the valleys of each flake scar were also undamaged. No use-wear striations were observable at this point. However, some samples had very large striations created during the manufacturing of the experimental scrapers. The large striations are a result of striking a stone tool with a hammerstone or even accidentally scratching the tool. These large striations can be easily distinguished from use-wear striations by their length and depth--most importantly and they are generally observable with the naked eye, whereas use-wear striations usually are not.

During the scanning electron microscopy, I oriented the used edges of the experimental and archaeological obsidian scrapers towards the imaging apparatus of the machine. This allowed me to view much of the dorsal aspect, or rear, where utilization damage was expected to occur most prominently. I was also able to see portions of the ventral aspect, or front, of each tool. I systematically scanned the entire edge of each tool noting where use-wear features occurred. I photographed and measured any observable polishes, striations, and microflakes with the utilities of the Philips XL-30 SEM.

Below is a description of the use-wear created by each type of processing. Pictures of use wear patterns are courtesy of the Central Analytical Facility of the University of Alabama, Tuscaloosa.

Scraper #1:

Use: Maguey scraping

Observable use-wear features:

Numerous microflakes of approximately 60 μm in length and 20 to 50 μm at their widest points appeared along the dorsal aspect of the scraper's edge (Figure 4.1). The majority of these flakes exhibit wedge-shaped scars that form at approximately right angles to the tool's used edge, although many were either eroded or interrupted by neighboring flakes. Many of the flake scars are heavily eroded after 1000 strokes developing a noticeable polish along the margin separating the ventral and dorsal aspect of the tool edge (Figure 4.2). The polishing does not appear to create a rounded or beveled edge as seen on several of the other tools used on different materials, but is more often observed as an eroded slope extending towards the larger flakes created during the production of the tool. Along the tool's edge, small circular pits form at irregular intervals, however, many appear to be part of larger microflakes (Figure 4.3). The circular pits may have been caused by the constant abrasion of the rough maguey against the somewhat brittle surface of the obsidian scraper. No striations are readily apparent along the dorsal edge.

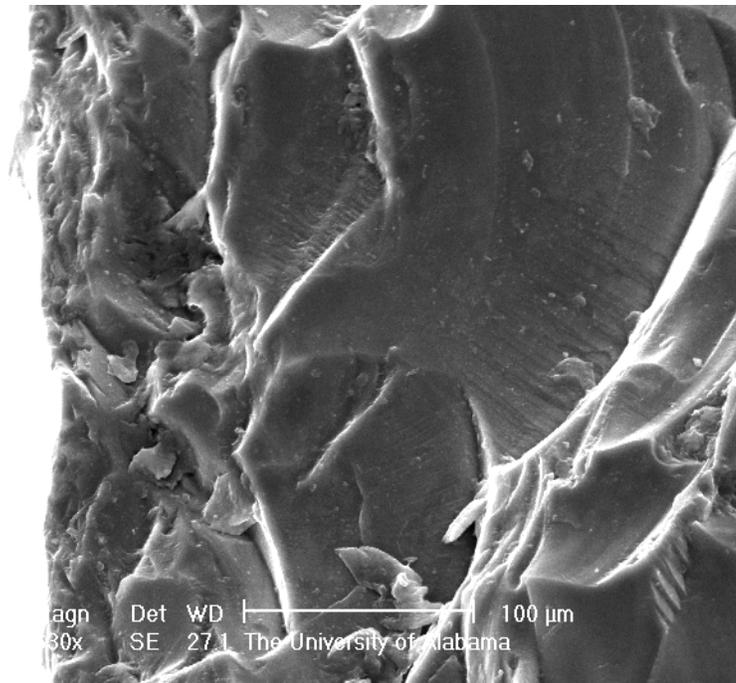


Figure 4.1: Microflaking along dorsal aspect of experimental scraper #1 used to process maguey.

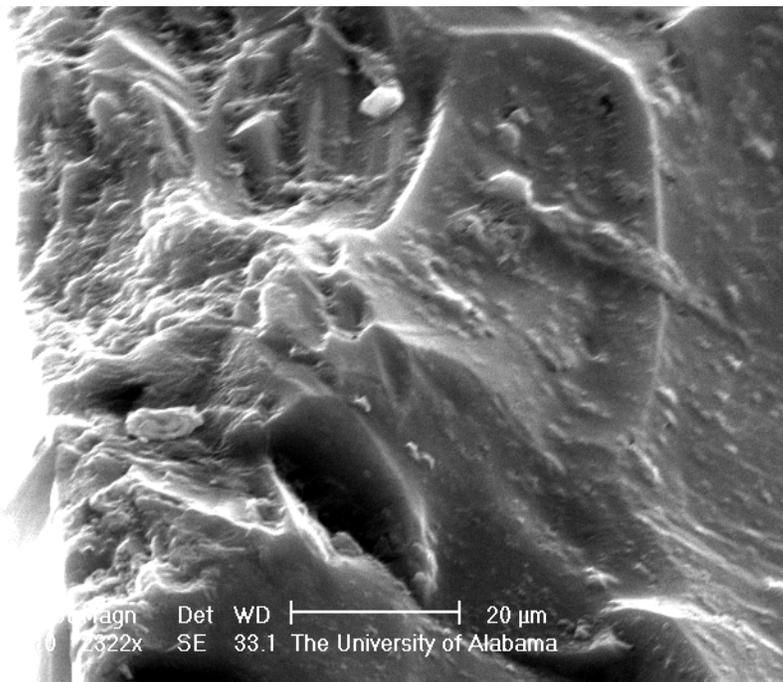


Figure 4.2: Attrition and polishing of the edge of the dorsal aspect of experimental scraper #1 used to process maguey.

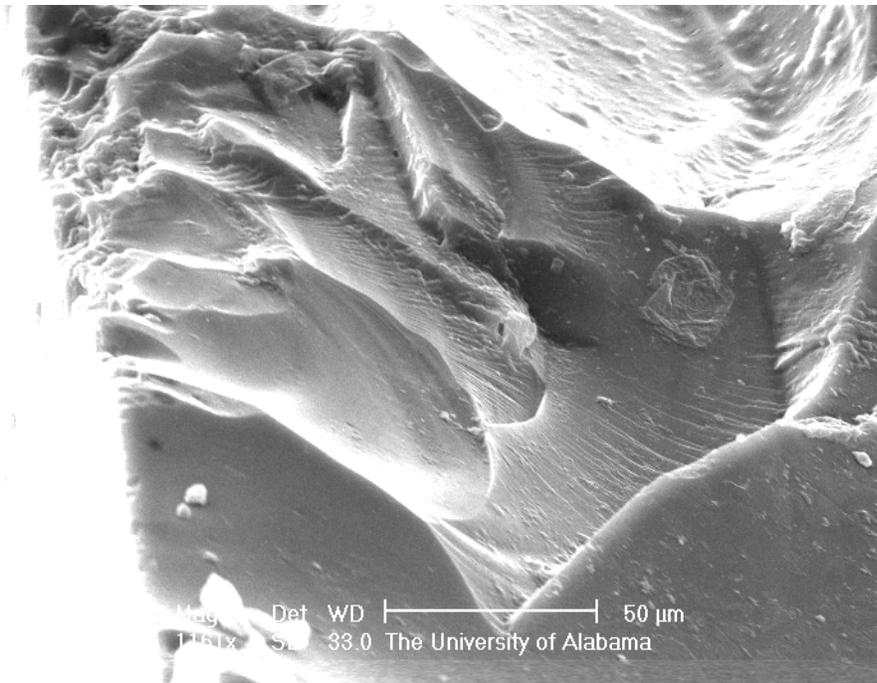


Figure 4.3: Small pits along the edge of the dorsal aspect of experimental scraper #1 used to process maguey.

Scraper #2:

Use: Wood scraping (Mexican Pine)

Observable use-wear features:

Evidence of microflaking exists only along the dorsal, non-contact edge of this particular tool because it was held at a roughly 90 degree angle to the piece of wood that it processed.

Microflakes ranged in size although most are approximately 40 to 100 μm in length (Figure 4.4).

However, the majority of flake scars are heavily eroded resulting in moderate beveling of the tool edge (Figure 4.5). There are areas where flake margins are much less eroded although they are significantly smoother than fresh flakes produced during tool production. This smoothing is gently curved, sometimes with small, localized domes of wearing. These localized areas are called domes because they present themselves as raised undulations across the worn area. Some

striations are present on higher-elevation portions of flake scars. These striations are extremely small (about 10 μm) and are oriented perpendicular to the tool's contact edge.

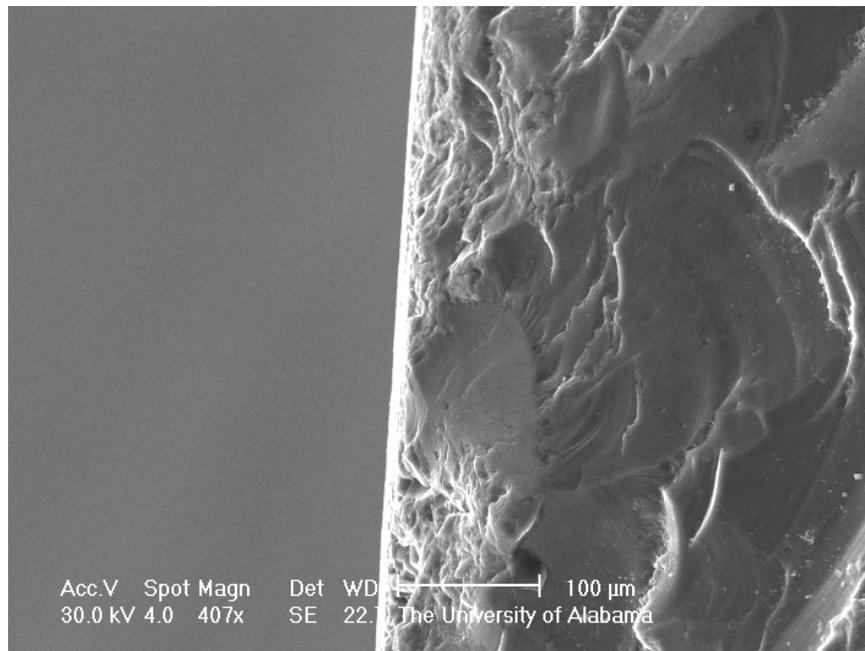


Figure 4.4: Microflakes along the edge of the dorsal aspect of experimental scraper #2 used to process wood.

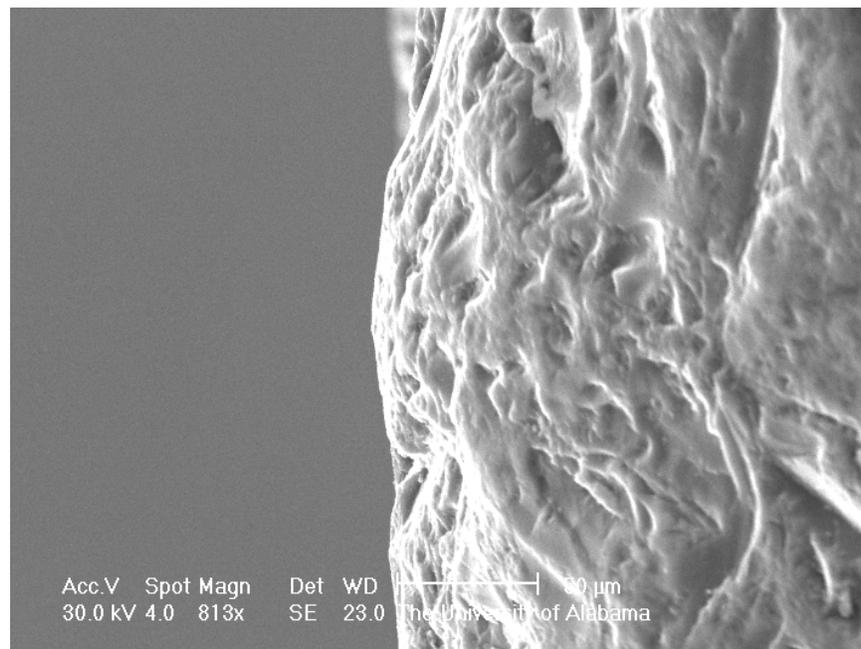


Figure 4.5: Edge polishing and beveling along the edge of the dorsal aspect of experimental scraper #2 used to process wood.

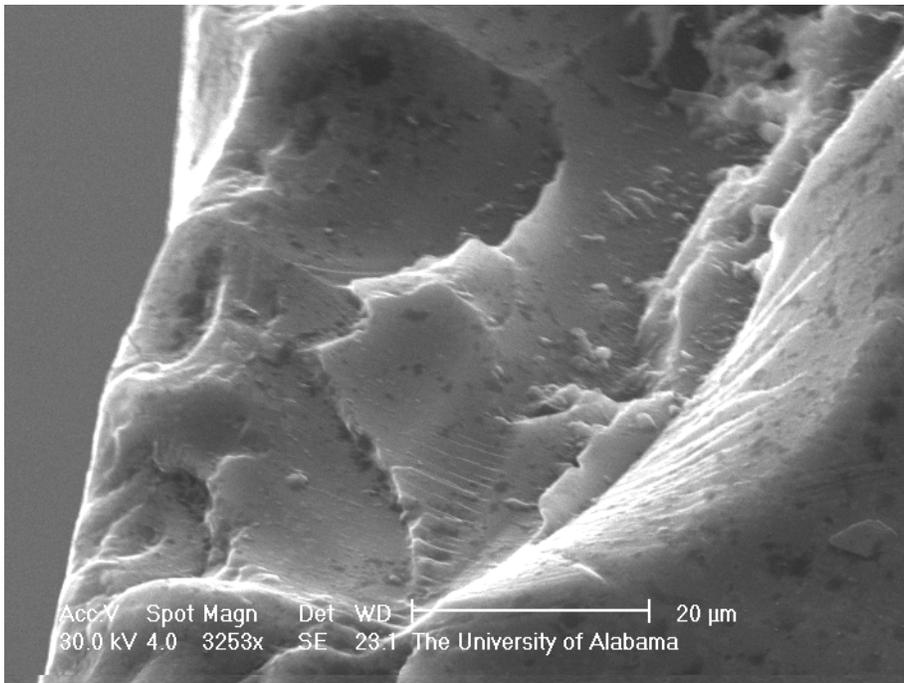


Figure 4.6: Small striations above flake scar on the edge of the dorsal aspect of experimental scraper #2 used to process wood.

Scraper #3:

Use: Deer bone scraping

Observable use-wear features:

The most commonly observed trait on the edge of this experimental bone scraper is the development of relatively intense damage on the edge of the tool (Figure 4.7). Numerous overlapping microflakes developed that are approximately 100 to 200 μ m in length. Polish developed near the tool's edge, which is best characterized as gentle erosion of higher-elevation flake features (Figure 4.8). However, the edge itself remains well-defined due to the constant removal of lithic material from its surface. Numerous striations and grooves are observed posterior to flake scars. Most of these features are approximately 50 μ m in length (Figure 4.9).

Further, while most of these striations are relatively narrow, many terminate in deeper grooves or depressions. All but a few of these striations are oriented at right angles to the edge of the tool.

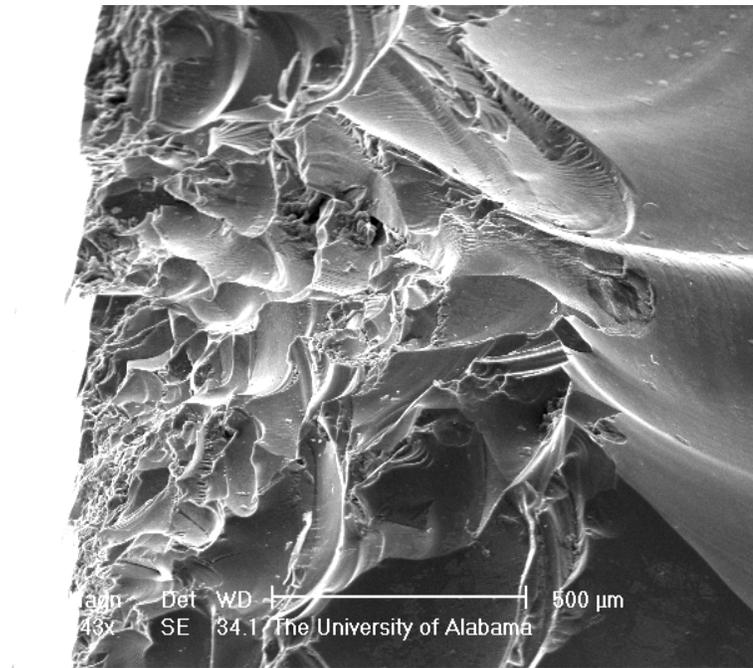


Figure 4.7: Utilization damage on the edge of the dorsal aspect of experimental scraper #3 used to process bone.

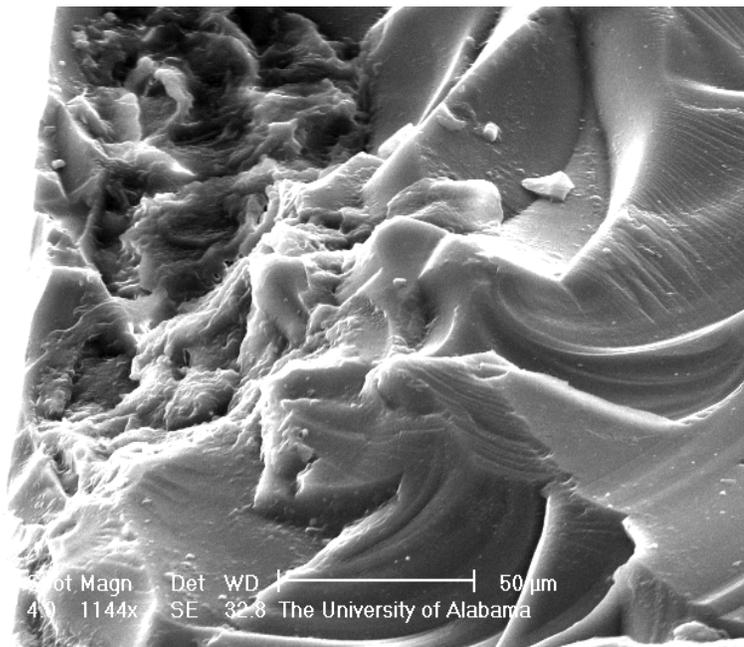


Figure 4.8: Light erosion of flake scars on the edge of the dorsal aspect of experimental scraper #3 used to process bone.

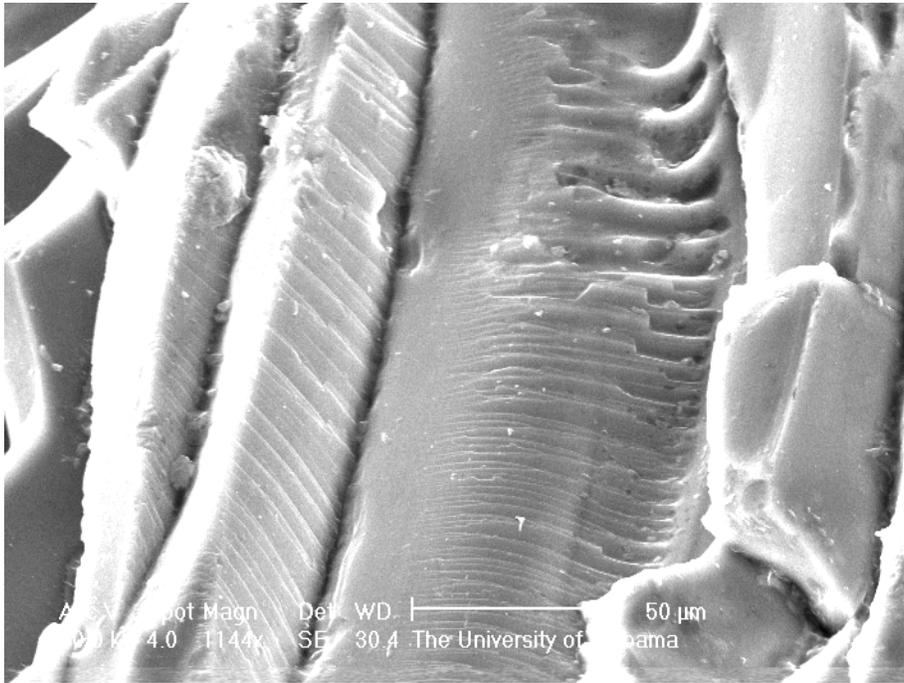


Figure 4.9: Striations and grooves on dorsal aspect of experimental scraper #3 used to process bone.

Scraper #4:

Use: Hide scraping (Deer)

Observable use-wear features:

Very few microflakes can be observed along the edges of this particular experimental scraper. Where they existed, the microflakes are approximately 8 μm in length and 2 μm in width and severely eroded (Figure 4.10). More common than microflakes are small (5 μm) striations that formed almost perpendicular to the edge (Figure 4.10). The most notable feature is the formation of a smooth polish along the edge of the tool resulting in significant rounding and beveling of the margin between the ventral and dorsal aspect (Figure 4.10, 4.11, 4.12).

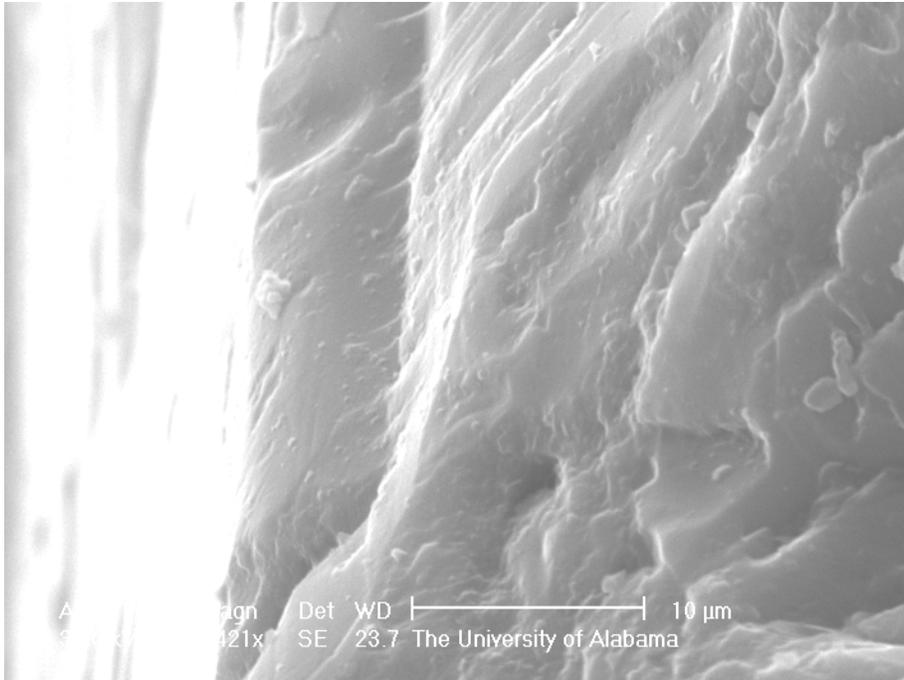


Figure 4.10: Small, eroded microflakes and striations on the edge of the dorsal aspect of experimental scraper #5 used to process hide.

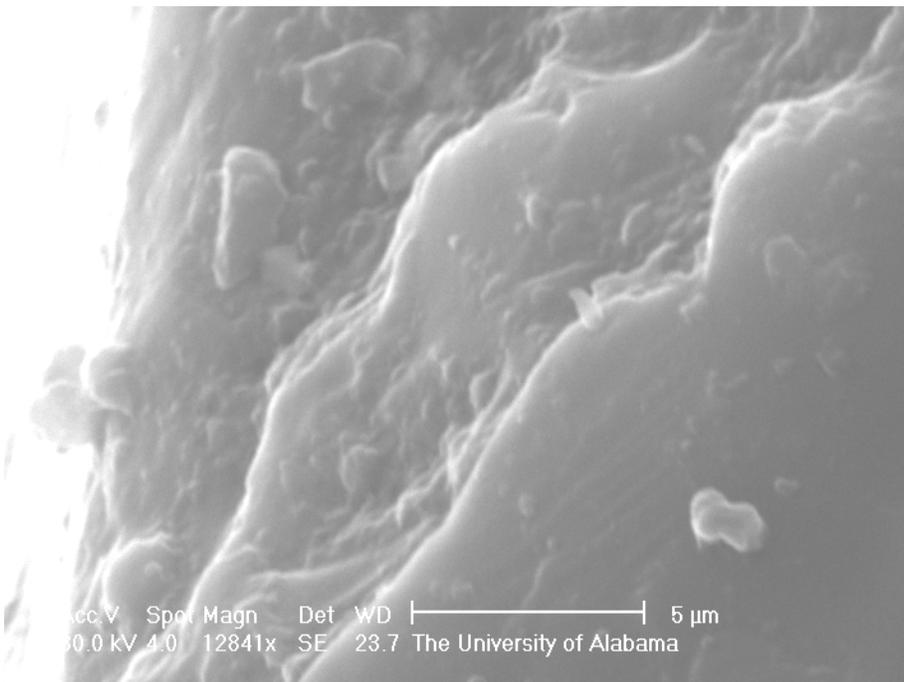


Figure 4.11: Edge rounding on dorsal aspect of experimental scraper #4 used to process hide.

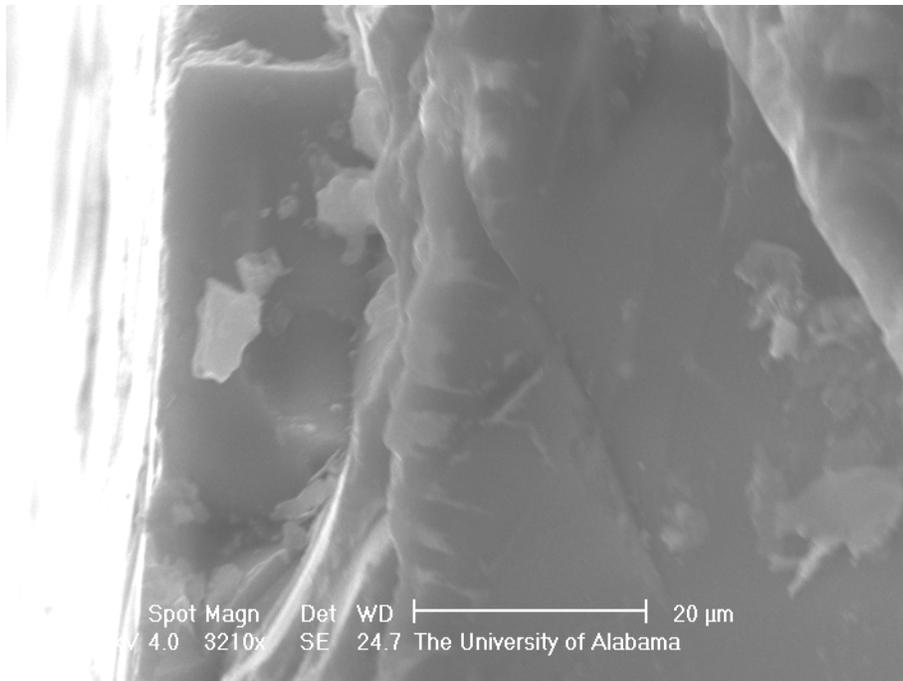


Figure 4.12: Edge rounding on dorsal aspect of experimental scraper #4 used to process hide.

Scraper #5:

Use: Maguey scraping

Observable use-wear features:

This experimental scraper exhibits numerous microflakes along the edge of the tool, most approximately 20 μm in length (Figure 4.13). Further, wedge-shaped flake scars dominate most areas of the tool. Many of these flake scars are heavily eroded or interrupted by other adjacent microflake scars. In terms of polish formation, the edge of the tool was relatively smooth, although the margin itself remains fairly well-defined (Figure 4.14). Some small, rounded pits developed along the edge of the tool. Lastly, some small striations (40 μm) are observed, though they were uncommon (Figure 4.15). These patterns are quite similar to scraper 1 and any differences are likely due to the differences in shape which will change the way the tools themselves perform.

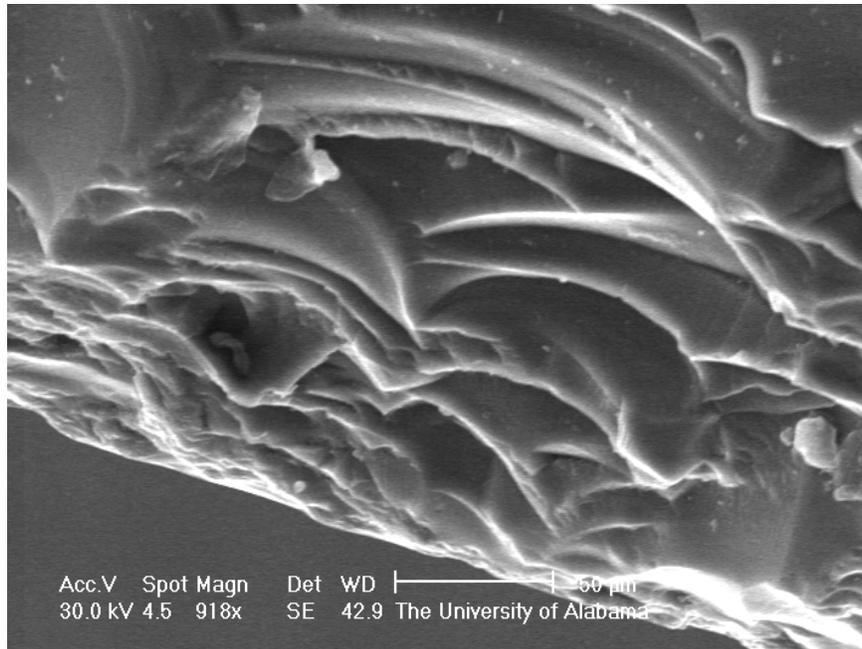


Figure 4.13: Microflakes on edge of the dorsal aspect of experimental scraper #5 used to process maguey.

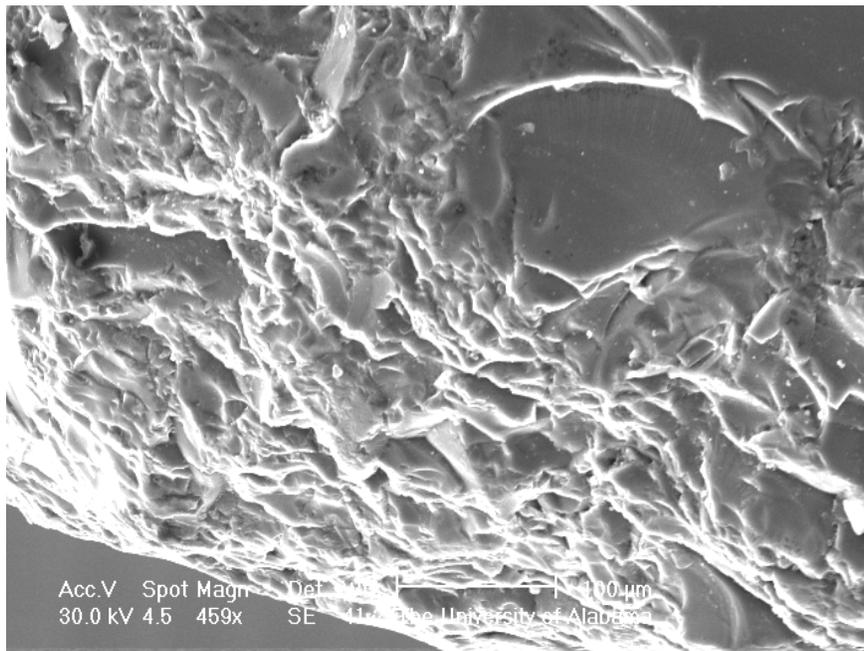


Figure 4.14: Microflake erosion on edge of dorsal aspect of experimental scraper #5 used to process maguey.

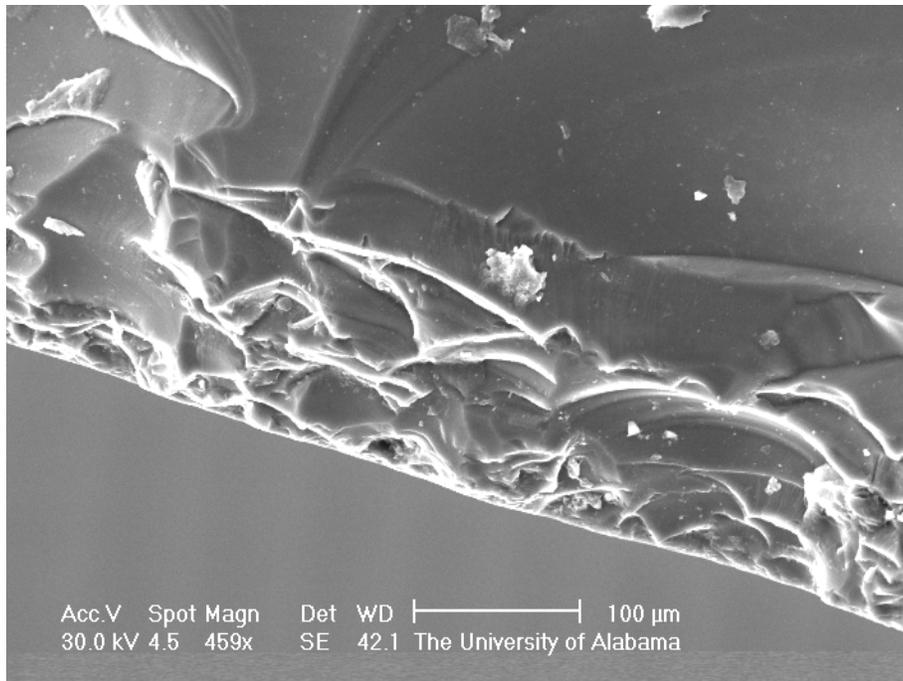


Figure 4.15: Small striations on the dorsal aspect of experimental scraper #5 used to process maguey.

Scraper #6:

Use: Wood scraping (*Capulin*)

Observable use-wear features:

Numerous microflakes (approximately 50 μm) can be observed along the edge of this tool's dorsal aspect (Figure 4.16). Further, the margins between each flake scar are eroded resulting in an undulating polish near the edge of the tool (Figure 4.17). The edge itself is eroded into the proximal portions of the microflakes and moderately beveled (Figure 4.18). Small depressions and pits are observed on the ventral surface no more than 50 μm from the edge of the tool (Figure 4.16).

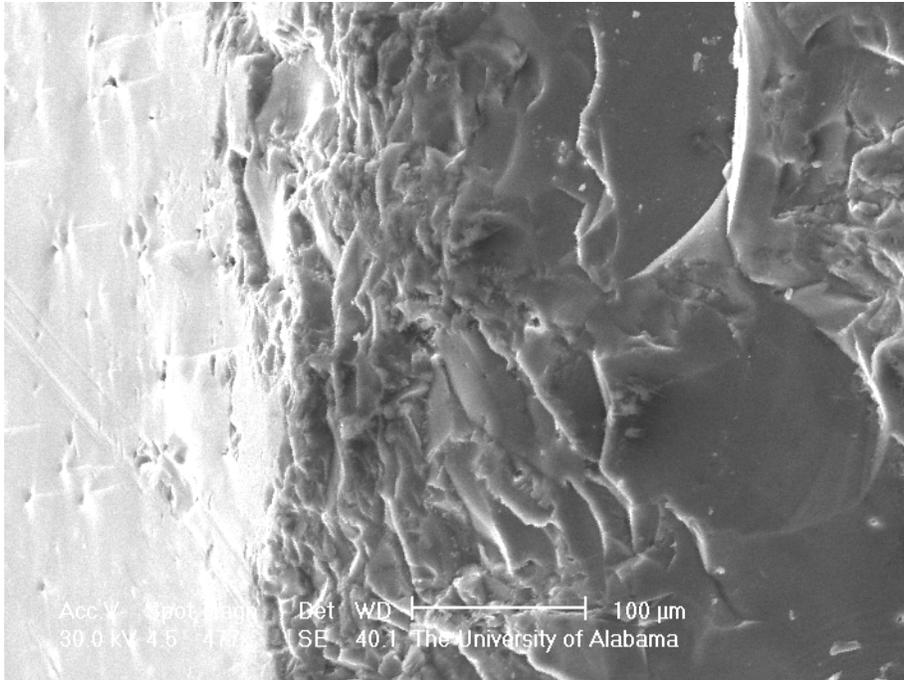


Figure 4.16: Microflakes along dorsal aspect of experimental scraper #6 used to process wood.

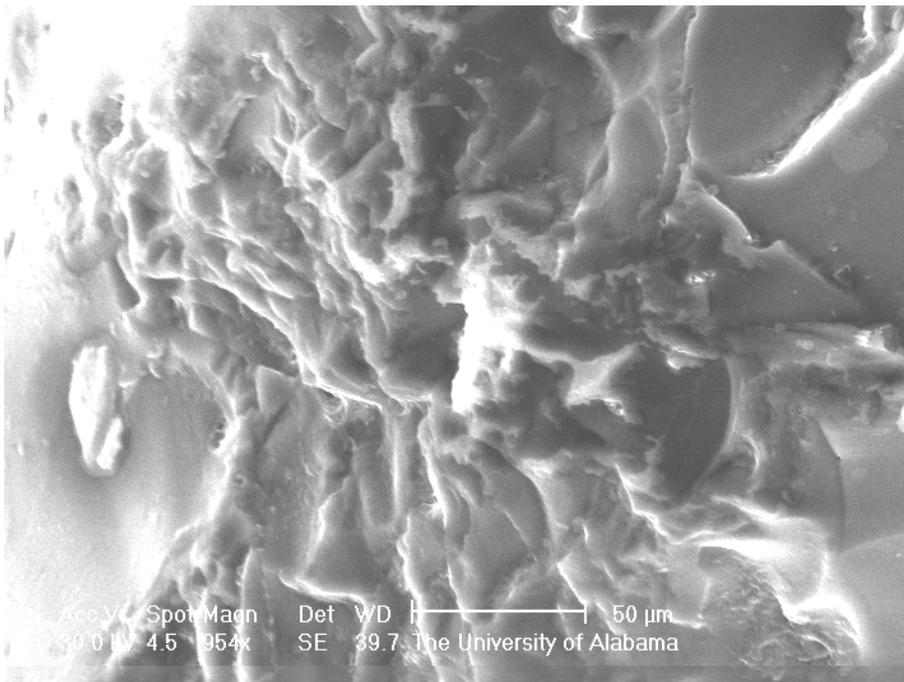


Figure 4.17: Moderately eroded microflakes along dorsal aspect of experimental scraper #6 used to process wood.

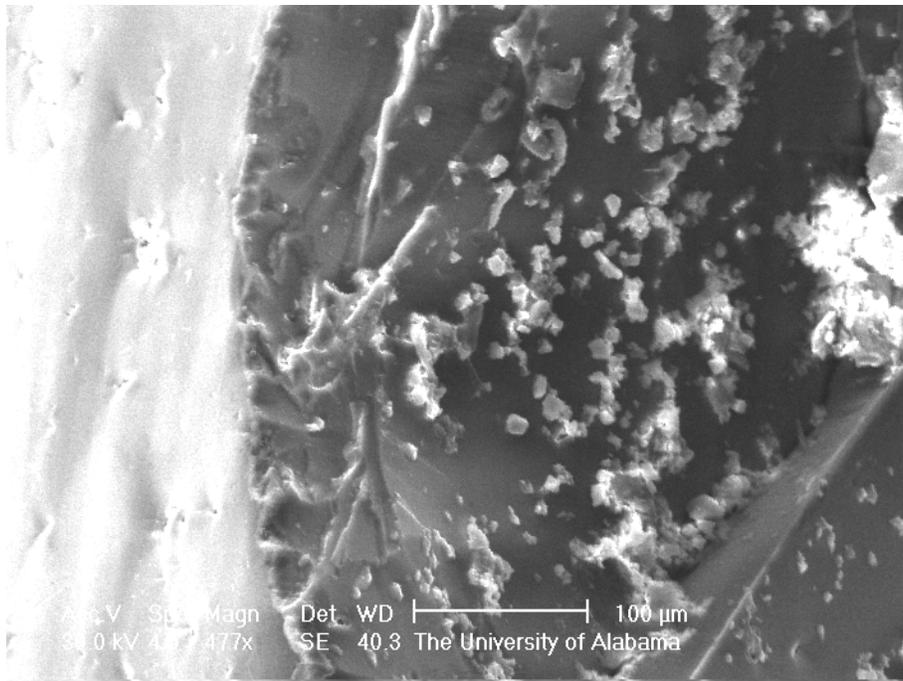


Figure 4.18: Edge beveling and microflake erosion of dorsal aspect of experimental scraper #6 used to process wood.

Scraper #7:

Use: Bone scraping (Deer)

Observable use-wear features:

Near the center of the tool, where most direct contact with bone occurred, there is fairly intense utilization damage. Here overlapping microflake scars can be observed ranging from 50 to 200 μm (Figure 4.19). Interestingly, many larger flakes are themselves damaged by the development of smaller microflakes. In one area in particular, the margin of a larger flake scars displays an 800 μm row of adjacent microflake scars oriented at approximately 90 degrees to the edge of the tool (Figure 4.20). Striations also are readily observable, and some developed into deeper, wider grooves before terminating. Near the edge of the tool, some flakes developed a smooth polish that extends from the ventral aspect to the dorsal aspect; however, this polish

never exceeds 20 μm in length on the dorsal aspect of the scraper (Figure 4.21). Lastly, some areas of the dorsal aspect displays an interesting type of abrasion track oriented at a right angle to the edge of the tool (4.22). This feature is unique enough not to be called a striation; rather I call it a flake track.

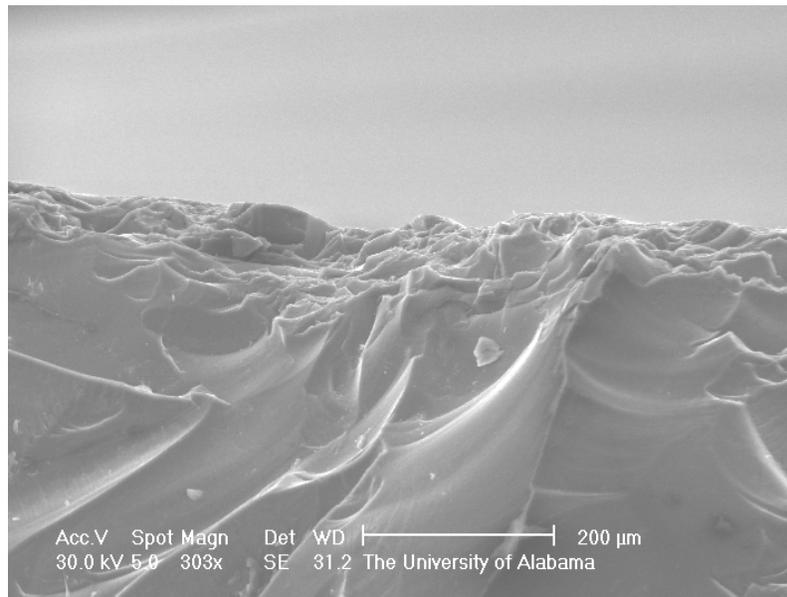


Figure 4.19: Microflakes along dorsal aspect of experimental tool #7 used to process bone.

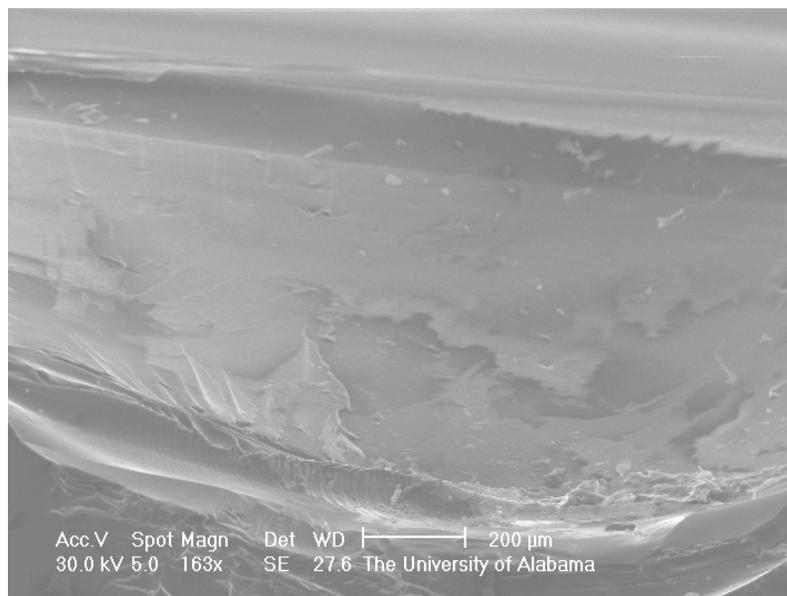


Figure 4.20: Microflaking, striations and grooves within a larger flake scar on dorsal aspect of experimental scraper #7 used to process bone.

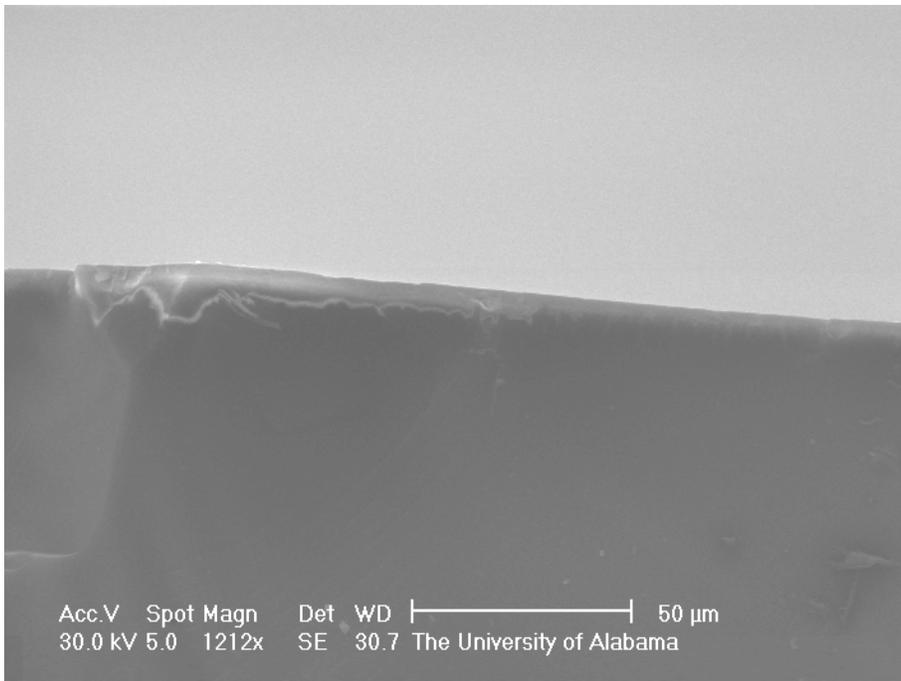


Figure 4.21: Polish/edge bevel on dorsal aspect of experimental scraper #7 used to process bone.

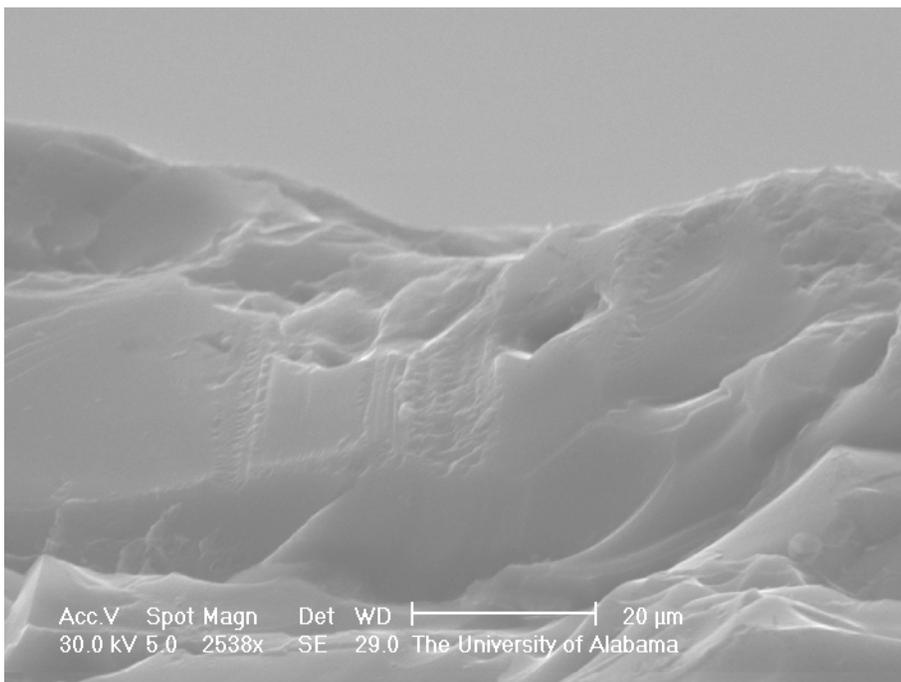


Figure 4.22: Flake track on dorsal aspect of experimental scraper #7 used to process bone.

Scraper #8:

Use: Deer hide scraping

Observable use-wear features:

Interestingly, this tool developed a much greater degree of microflaking than the other experimental deer hide scraper. On this experimental scraper, the microflake scars are approximately 20 μm long and they are located at right angles to the edge (Figure 4.23). Many of these areas may not be as significantly eroded as that seen on similar areas on experimental tool #4. However, areas of flake margin erosion are indeed observable along experimental scraper #8's edge (Figure 4.24). These margins give way to well-developed edge rounding across portions of the contact edge. Further, several areas appear to have succumbed to severe attrition of the dorsal surface. It is possible that continued use would have eroded the entire surface into a gentle slope of polish connecting the rounded edge of the tool to other points on the dorsal aspect. Several high-elevation sites on the dorsal aspect experienced microflaking. These features are fairly eroded and rounded, resulting in a pit-like appearance. An area closer to the edge of the tool that received the most direct contact with the fresh hide displays a well-developed hide polish (Figure 4.25). This sort of polish usually appears bright and greasy and is somewhat less smooth than a wood polish and lacks the intense micropitting associated with bone polish. The most interesting features that developed during the use of this tool were striations of varying lengths. Most of these features are oriented at approximately 90 degrees to the edge of the tool.

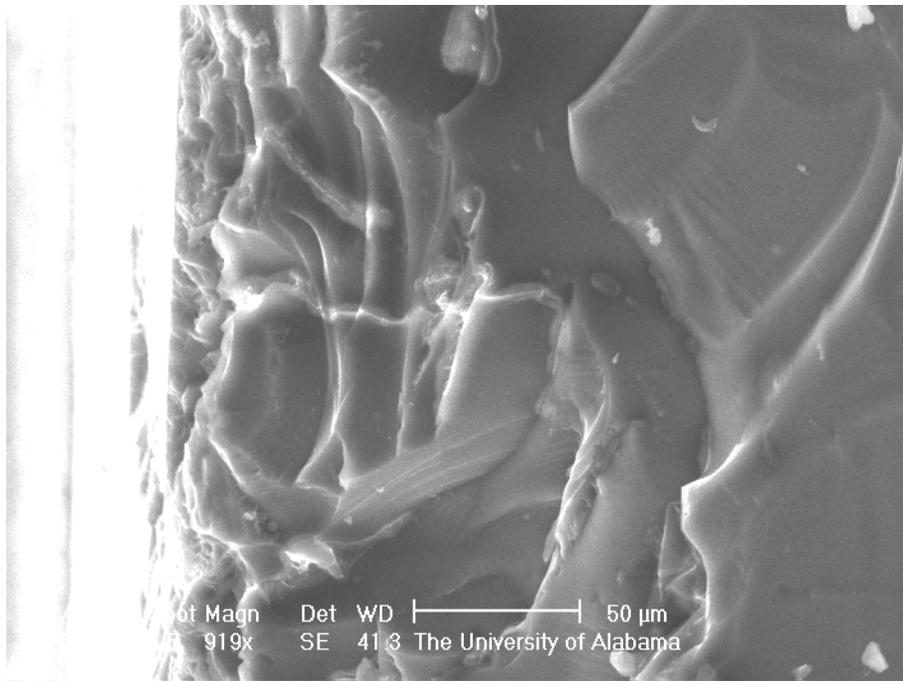


Figure 4.23: Microflaking along dorsal aspect of experimental scraper #8 used to process hide.

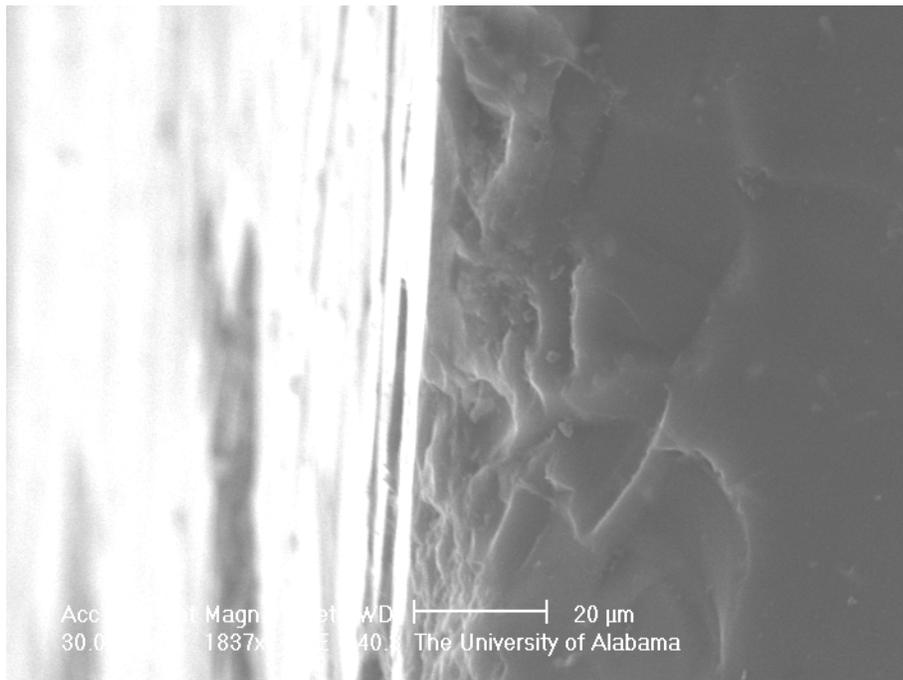


Figure 4.24: Eroded microflake scars along dorsal aspect of experimental scraper #8 used to process hide.

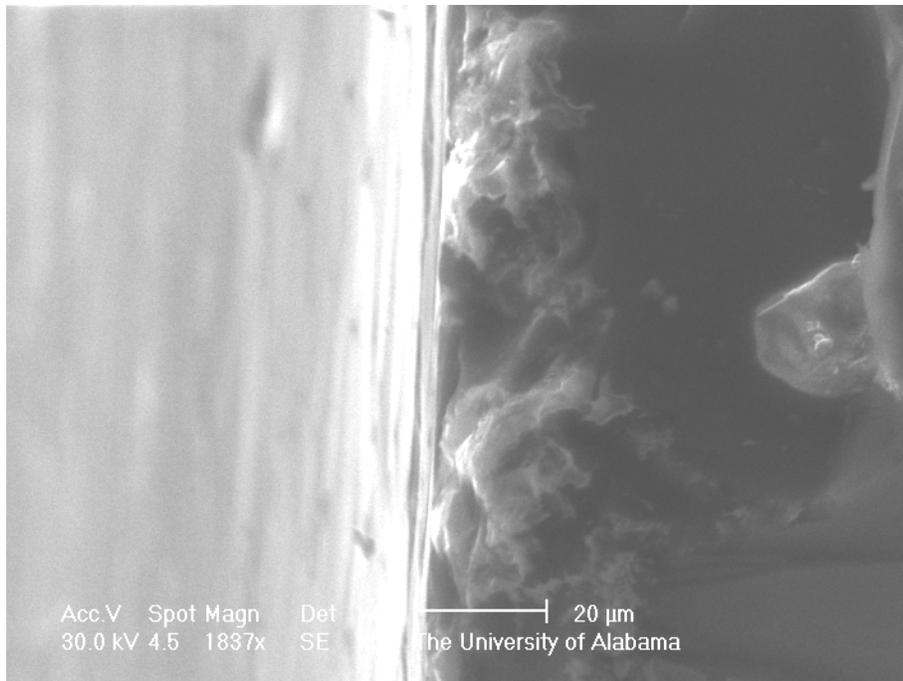


Figure 4.25: Hide polish along dorsal aspect of experimental scraper #8 used to process hide.

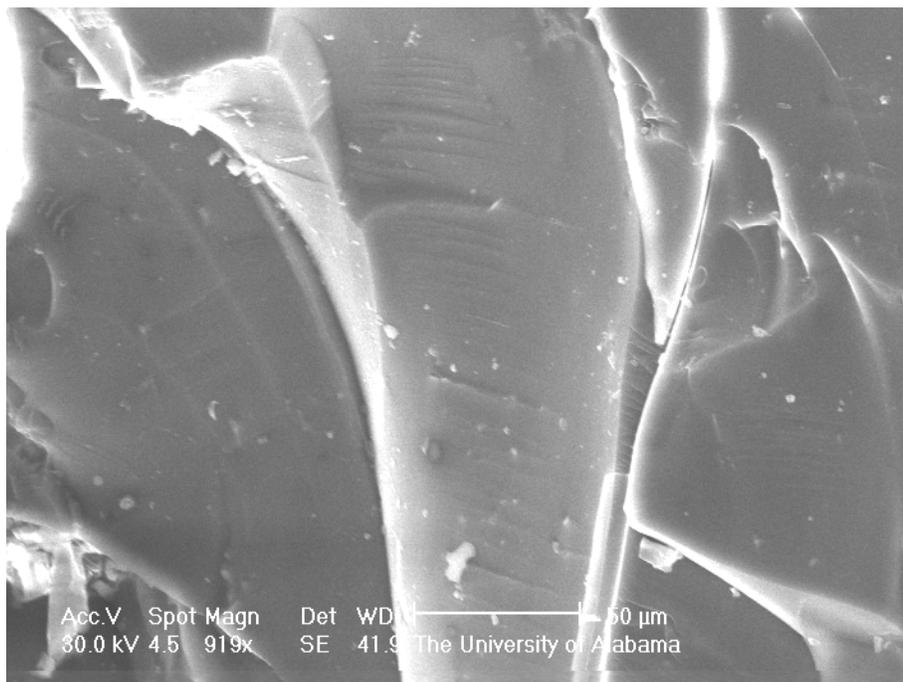


Figure 4.26: Striations along dorsal aspect of experimental scraper #8 used to process hide.

Material	Striations (μm) Max/Min/Mean	Microflakes (μm) Min/Max/Mean	Polish Description	Other
Scraper 1 Maguay	None readily apparent	30 μm /80 μm /60 μm Many wedge-shaped	Distributed along eroded slope on dorsal aspect. Bright, undulating	
Scraper 2 Wood	8 μm /14 μm /10 μm Small, shallow	40 μm /100 μm /60 μm Most of them are highly eroded	Somewhat bright, similar to maguay, localized over domes	Beveling of edge, smooth and somewhat rounded
Scraper 3 Bone	40 μm /80 μm /50 μm Narrow, terminating in deeper grooves and depressions	100 μm /200 μm /80 μm Intense utilization damage with large microflakes	Very little, localized near tool edge.	
Scraper 4 Hide	4 μm /8 μm /5 μm Small, thin	4 μm /10 μm /8 μm Very few, highly eroded	Smooth, dull, somewhat greasy polish	Significant edge rounding
Scraper 5 Maguay	40 μm Uncommon, small	18 μm /40 μm /20 μm Many wedge-shaped	Bright, undulating in some areas	
Scraper 6 Wood	None observed	30 μm /70 μm /50 μm	Bright, smooth.	Some small depressions or pits
Scraper 7 Bone	30 μm /70 μm /50 μm Some become deeper terminating in grooves.	50 μm /200 μm /150 μm Intense damage and overlap of microflake scars	Some polish. 20 μm band near edges that is bright and smooth.	Atypical "abrasion tracks"
Scraper 8 Hide	15 μm /40 μm /20 μm Thin, shallow	10 μm /30 μm /20 μm Less eroded than scraper 4	Dull, somewhat greasy	Some edge rounding.

Table 4.1: Microwear features on experimental obsidian scrapers.

Use-Wear Traces on Archaeological Obsidian Scrapers

Scraper #11 - TLX-97 I/6UU/2562:

Observable use-wear features:

The dorsal aspect of the edge of this archaeological obsidian scraper is heavily eroded (Figure 4.27). Evidence of microflaking oriented at right angles to the edge is observed along the same aspect (Figure 4.28). The flakes are between 30 and 100 μm in length and most are part of a slope that eroded into the tool's edge. The edge itself is somewhat rounded and very smooth. It is covered by irregularly spaced pits and depressions (Figure 4.29). Some very small (30 μm) striations and polishing are observed long the edge (Figure 4.30). Like the flake scars, these are oriented at right angles to the edge. In other areas, what appeared to be striations are simply lines that formed when the microcrystalline structure of the obsidian was damaged during the creation of the tool.

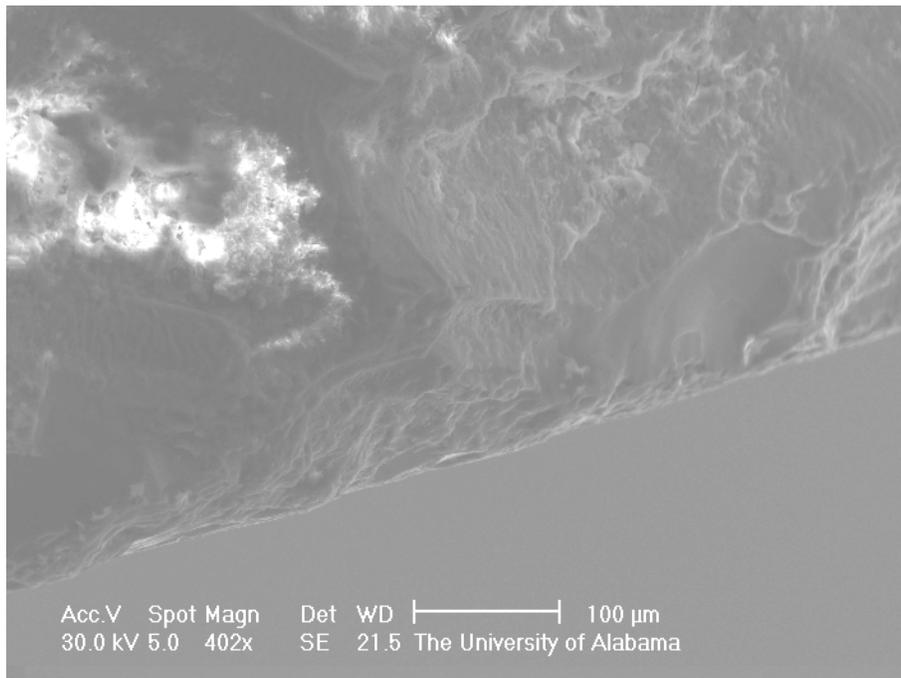


Figure 4.27: Heavily eroded dorsal aspect of archaeological scraper #11.

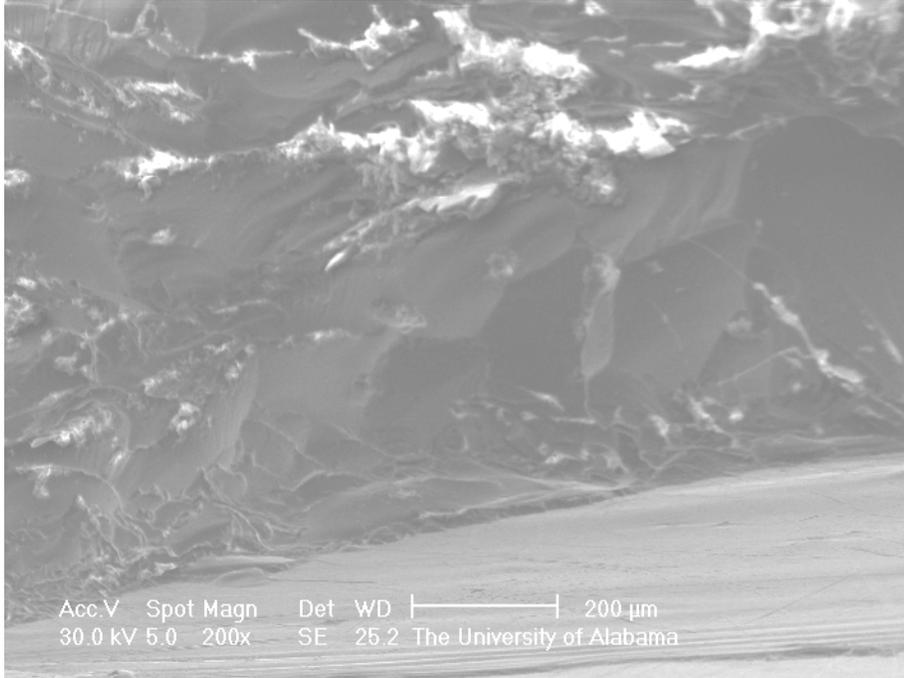


Figure 4.28: Microflaking along dorsal aspect of archaeological scraper #11.

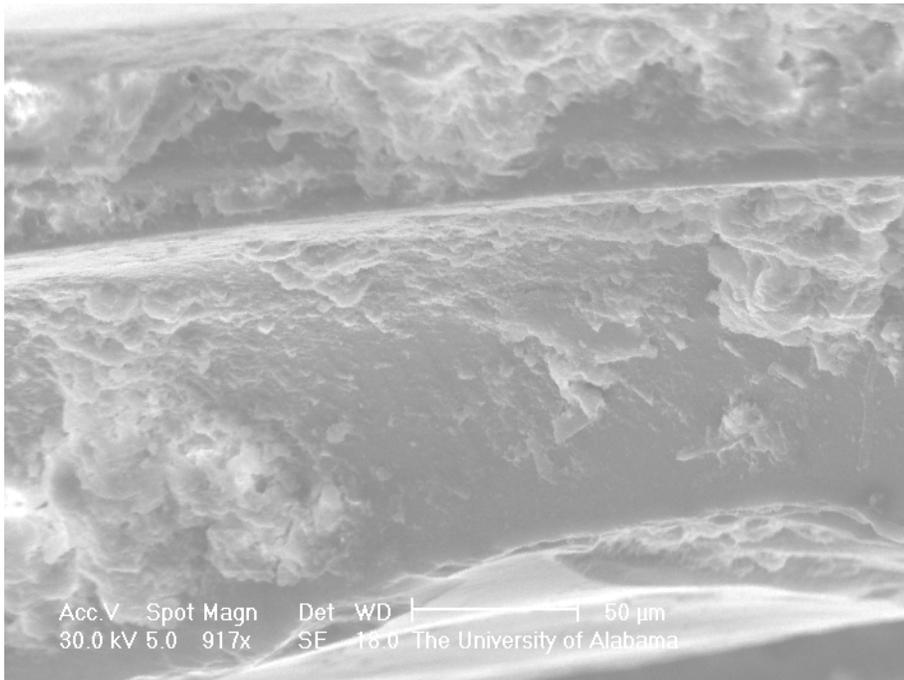


Figure 4.29: Pits and depressions along dorsal aspect of archaeological scraper #11.

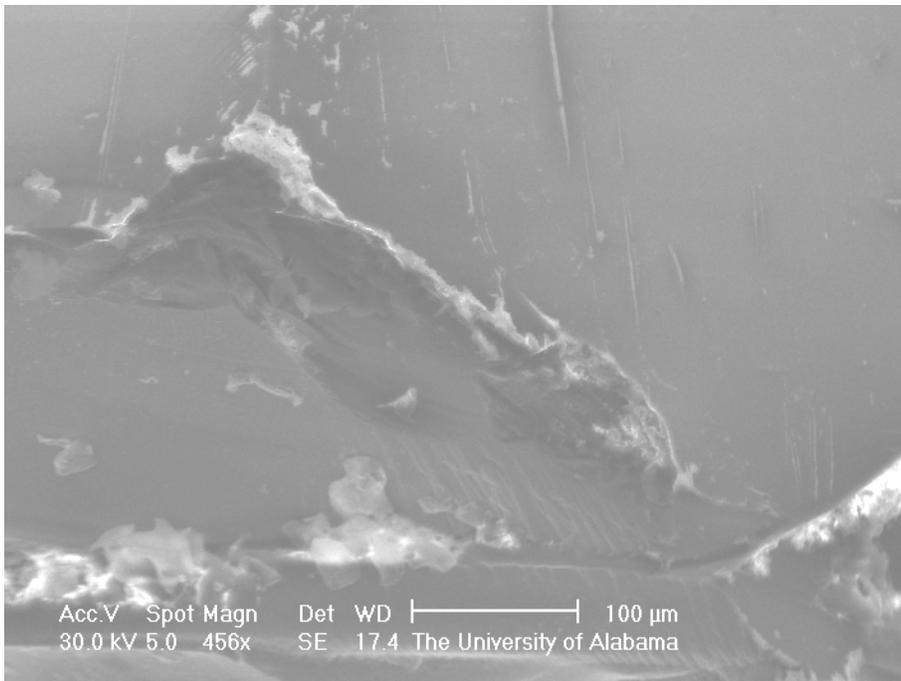


Figure 4.30: Striations and polish along dorsal aspect of archaeological scraper #11.

Scraper #12 - TLX-97 I/11L/871:

Observable use-wear features:

This archaeological scraper displays heavy attrition of the observed edge (Figure 4.31).

Observed microflake scars ranged in size from 20 to 100 μm (Figure 4.32). Both the well-defined flakes and the heavily eroded flakes are oriented at approximately right angles to the edge of the tool. The ventral aspect near the edge of the tool displays numerous striations running at approximately 90 degree angles to the tool's edge (Figure 4.33). However, one area with a well-defined polish displays striations oriented at about 50 to 60 degrees to the edge. This polished area contains many small pits and depressions whose edges are eroded and rounded. The striations on this area are very short (10 μm) and shallow, however.

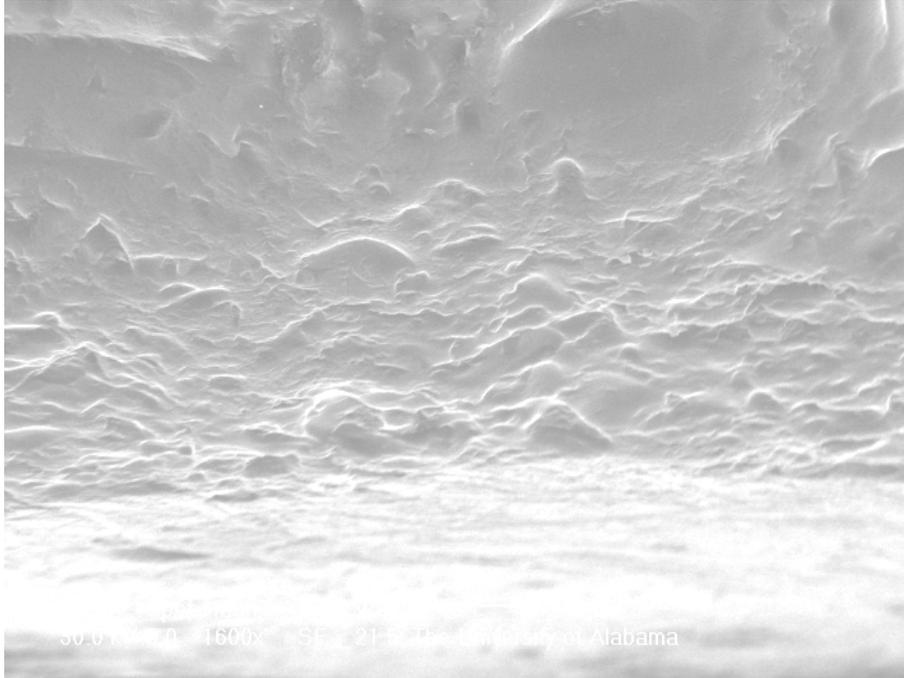


Figure 4.31: Heavily eroded edge along dorsal aspect of archaeological scraper #12.

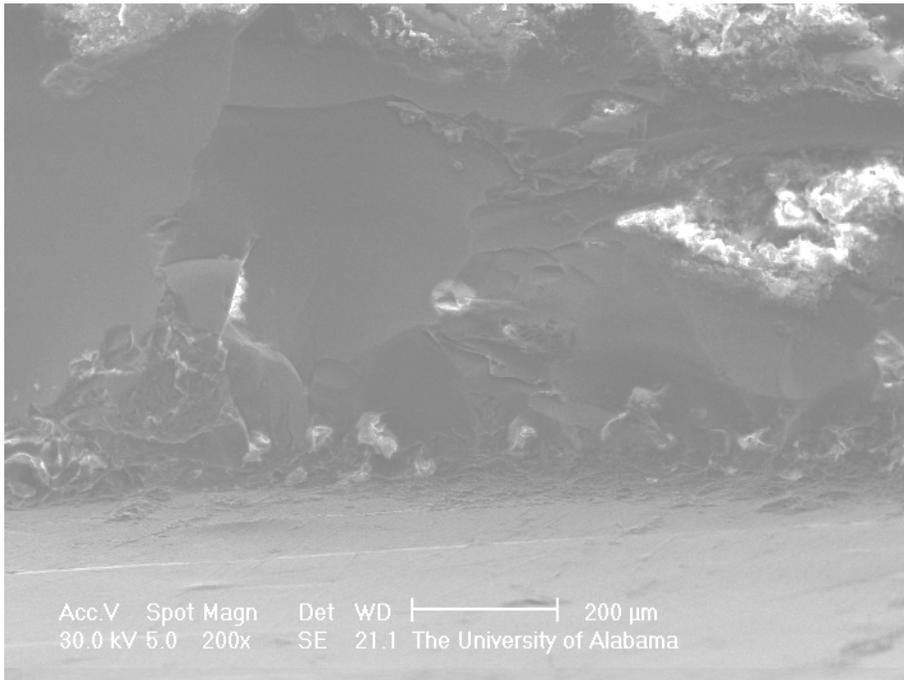


Figure 4.32: Microflakes along dorsal aspect of archaeological scraper #12.

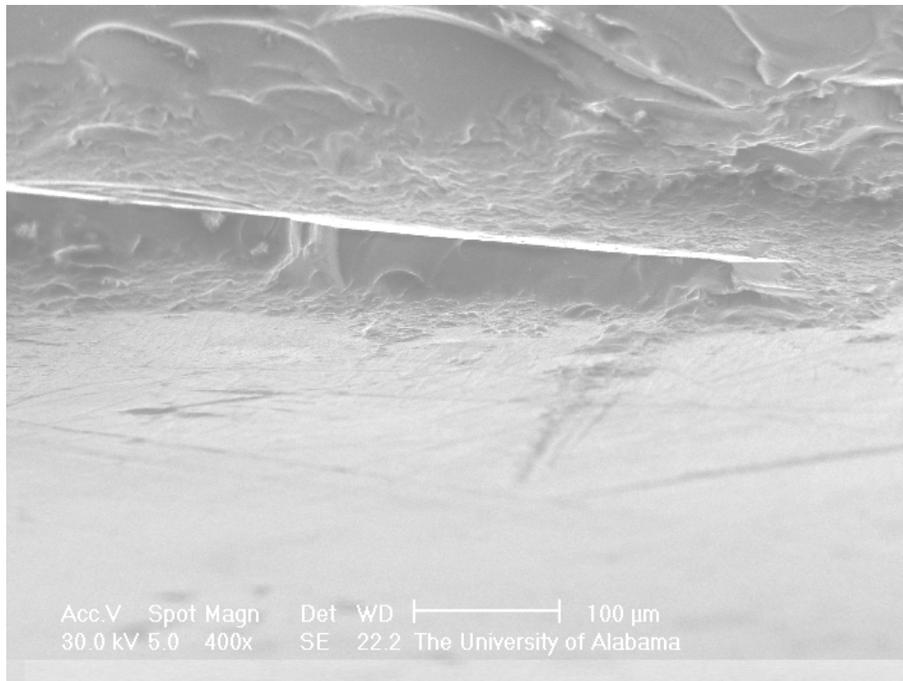


Figure 4.33: Striations on ventral aspect of archaeological scraper #12.

Scraper #13 - TLX-97 I/F:

Observable use-wear features:

Microflakes that formed along the edge of this archaeological scraper are different than the other archaeological scrapers. The edge itself is also not very eroded. On the lateral dorsal edge, the flakes were generally larger (about 200 μm) and probably the eroded remnants created during the manufacturing of the tool (Figure 4.34). There are some smaller flake scars (50 to 100 μm) here as well. On the medial dorsal edge, the tool displays the remains of a relatively bright and rough polish (Figure 4.35). This polish continued developed in other areas as a bright edge bevel (Figure 4.36). Moreover, numerous scalar microflakes of about 10 to 50 μm in length and 5 to 10 μm in width can be observed frequently (Figure 4.37). Striations are also generally observed above these features. Each of these use-wear features is oriented at approximately 90

degree angles to the used edge of the tool. Also, small pits and depressions can be regularly observed along the dorsal aspect above areas where these microflake scars occur (Figure 4.36).

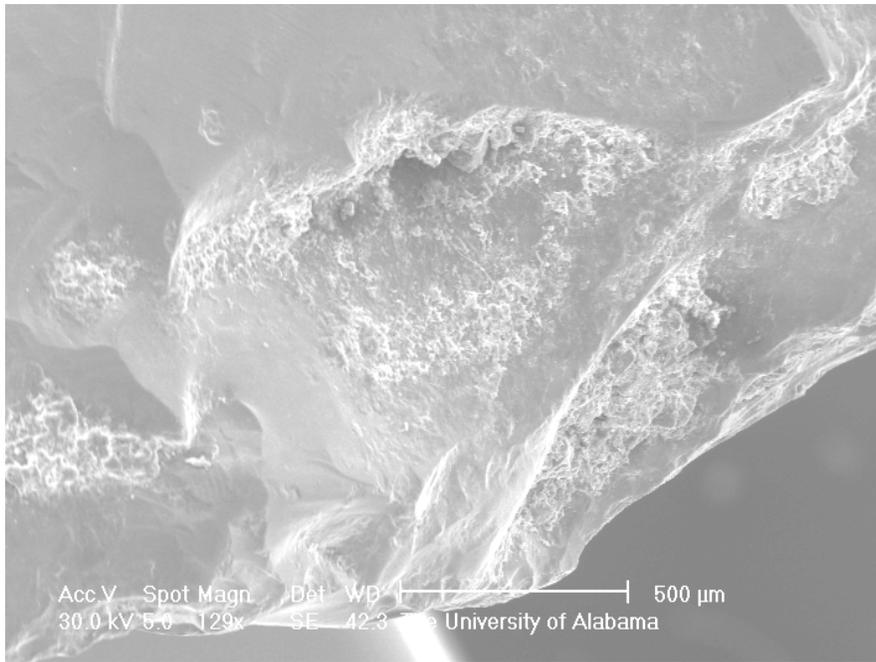


Figure 4.34: Manufacture and use-wear flaking on the dorsal aspect of archaeological scraper #13.

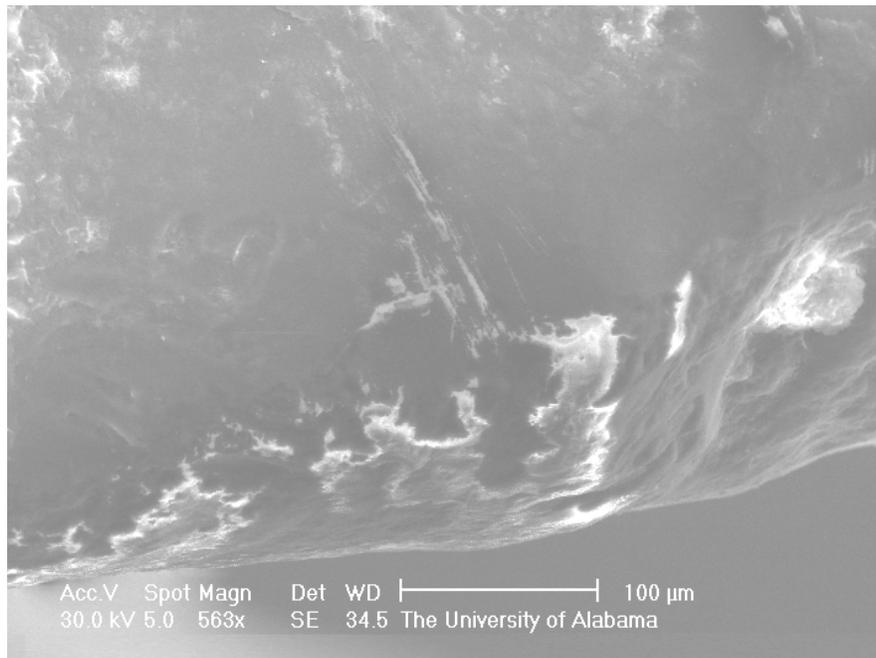


Figure 4.35: Polish along dorsal aspect of archaeological scraper #13.

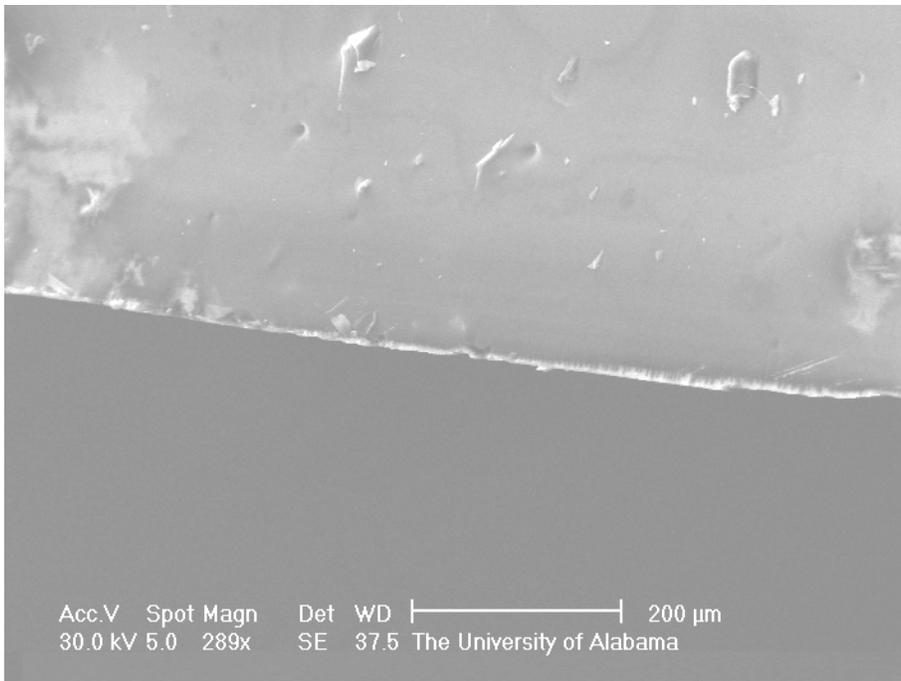


Figure 4.36: Bright edge bevel and pitting on the dorsal aspect of archaeological scraper #14.

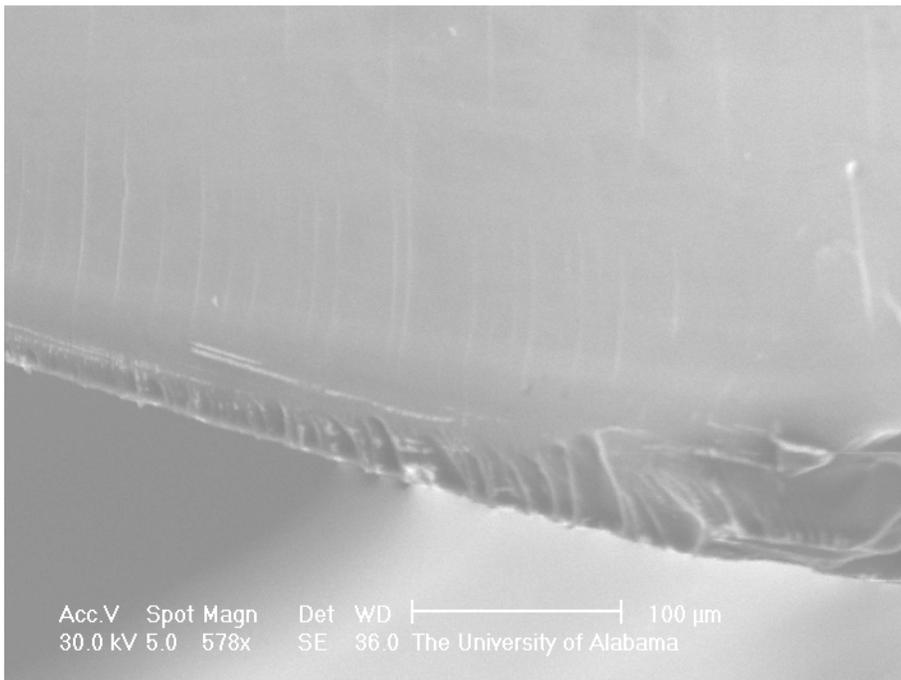


Figure 4.37: Scalar flakes and striations along dorsal aspect of archaeological scraper #14.

Scraper #14 - TLX-97 I/F:

Observable use-wear features:

Use-wear on this archaeological tool is more consistent with the other archaeological samples. Numerous overlapping microflake scars oriented at right angles to the dorsal edge can be observed. Many of these flakes are wedge-shaped and approximately 50 to 100 μm in length and 50 to 100 μm at their widest points (Figure 4.38). On areas where the edge was more heavily eroded, small pits and depressions were observed (Figure 4.39). However, the majority of the edge remains well-defined. Some larger striations that are approximately 200 μm in length can be observed on portions of the dorsal aspect of the tool (Figure 4.40).

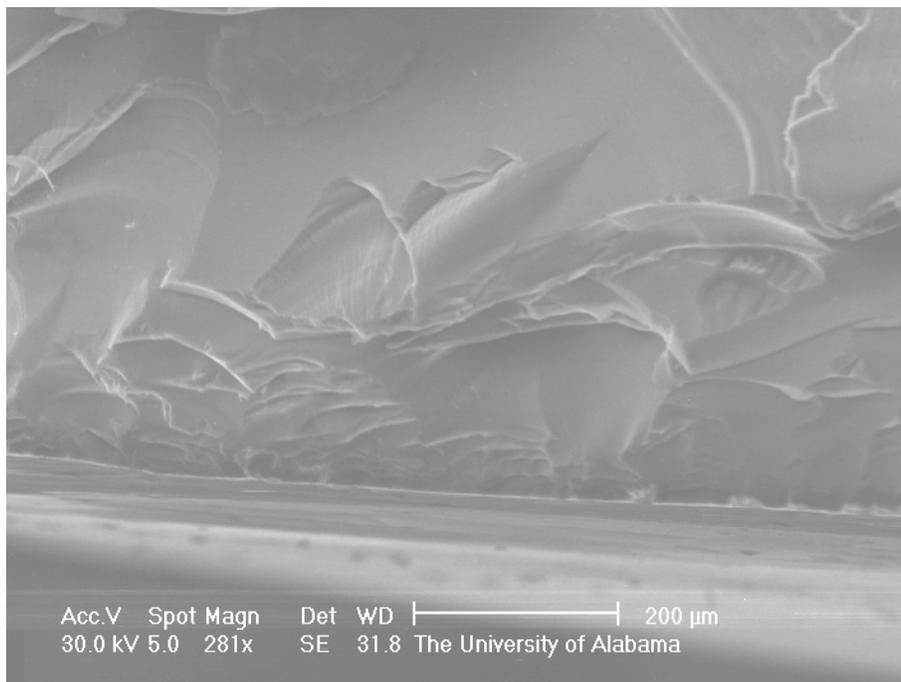


Figure 4.38: Wedge-shaped microflakes along dorsal aspect of archaeological scraper #14.

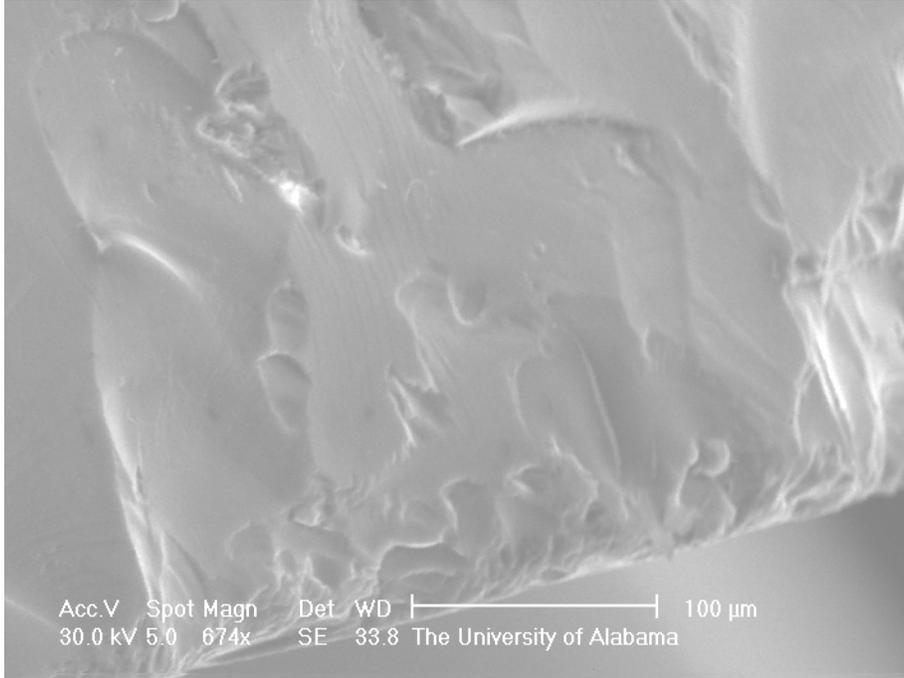


Figure 4.39: Small pits and depressions along dorsal aspect of archaeological scraper #14.

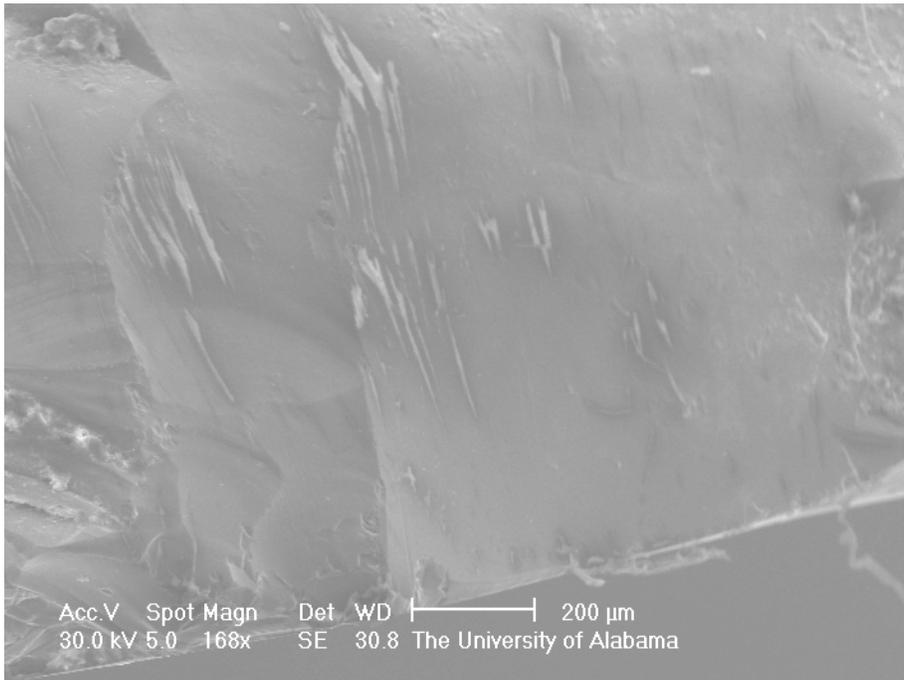


Figure 4.40: Striations along dorsal aspect of archaeological scraper #14.

Scraper #15 - TLX-97 I/F:

Observable use-wear features:

The edge of this archaeological scraper exhibits significant polish and erosion with numerous tiny pits and depressions along the edge (Figure 4.41). However, evidence of microflaking is observed on the dorsal aspect of the scraper's edge (Figure 4.42). Some small areas of bright polish were also observable (Figure 4.42). The majority of these flakes are approximately 50 μm in length and oriented at 90 degree angles to the edge. The observable portion of the ventral edge displays numerous right angle striations that extended to the contact edge of the archaeological scraper (Figure 4.43).

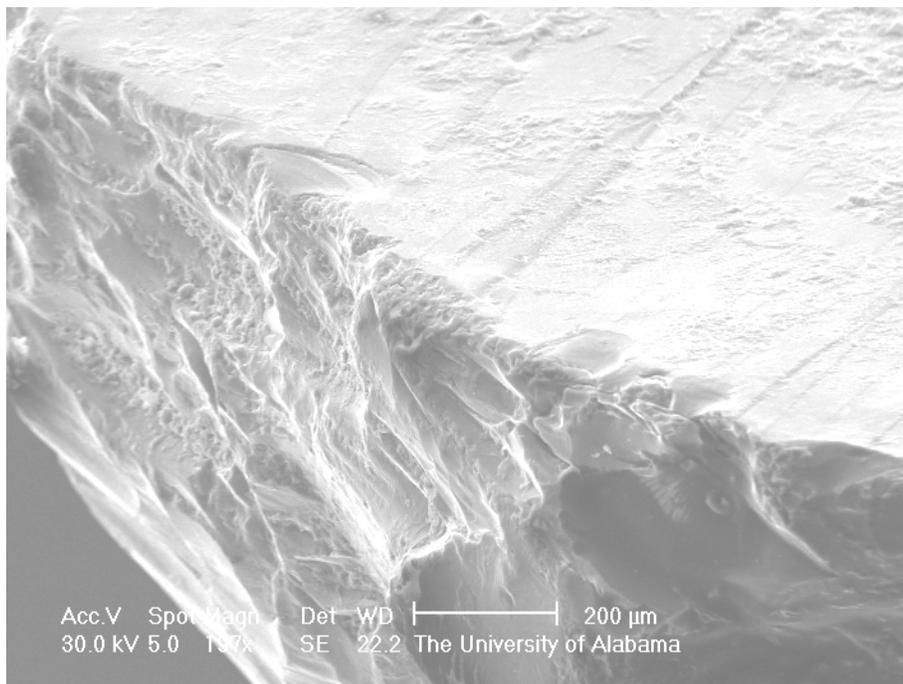


Figure 4.41: Edge polish and erosion and numerous small pits on dorsal aspect of archaeological scraper #15.

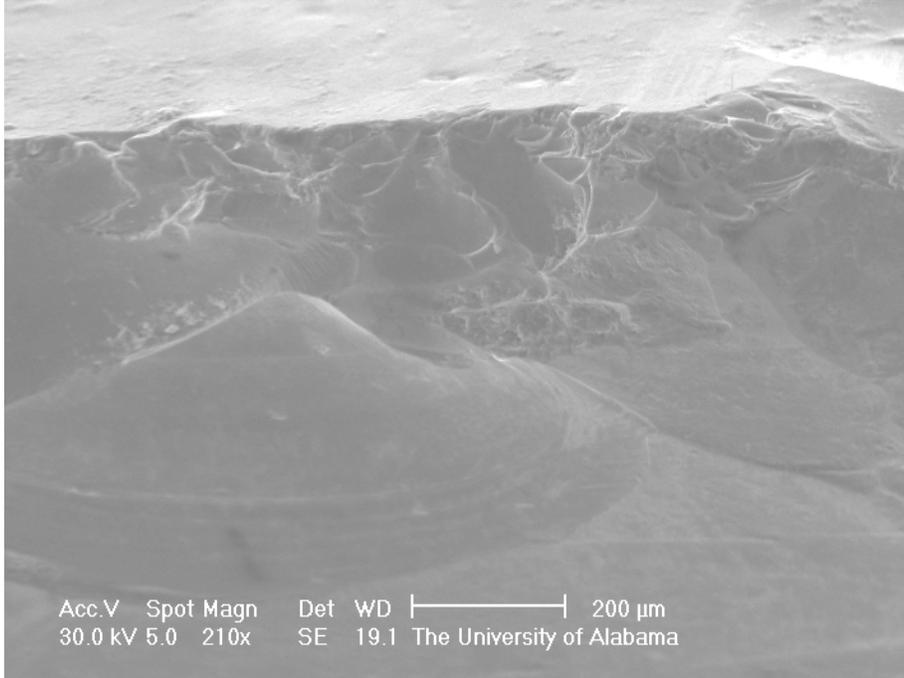


Figure 4.42: Microflaking and polish along dorsal aspect of archaeological scraper #15.

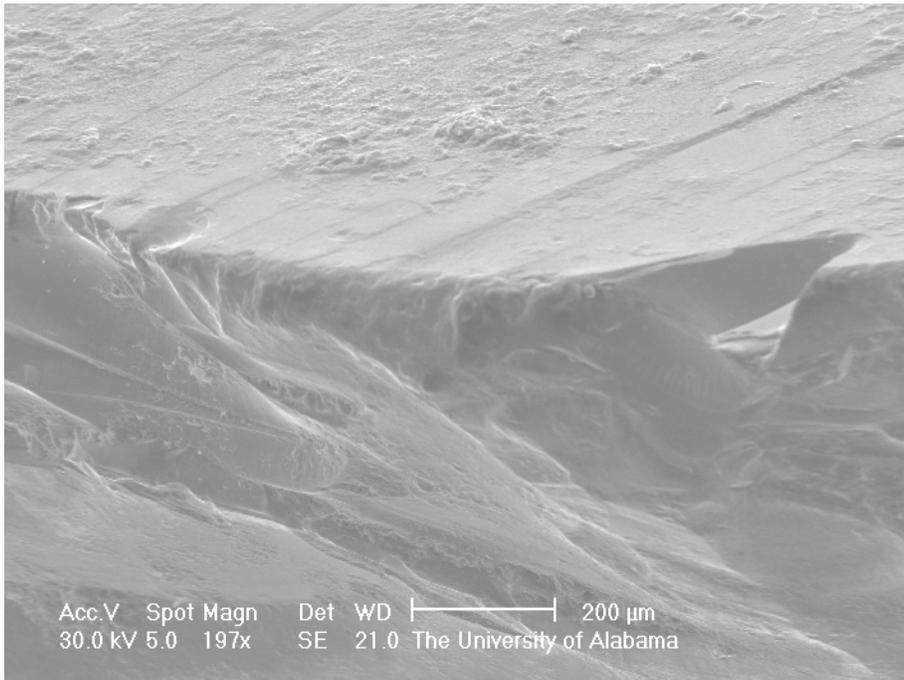


Figure 4.43: Right-angle striations on ventral aspect of archaeological scraper #15.

Scraper #16 - TLX-97 I/F 1843:

Observable use-wear features:

Microflake scars are oriented perpendicular to the edge and observed along the dorsal aspect of this archaeological scraper (Figure 4.44). These flakes ranged in size from about 20 μm to 50 μm in length. In general, these flakes remain well-defined. This is to say that they have not eroded into the edge itself. Since the edge remains mostly uneroded, a well defined polish was difficult to observe. Along a small portion of the tool's edge, striations at right angles extend from the ventral aspect towards the tool edge (Figure 4.45). Other small, narrow, and shallow striations can be observed on various selected portions of the tool's dorsal aspect. The majority of these striations are at approximately right angles to the edge of the tool. They range in size anywhere from 30 μm to 50 μm in length.

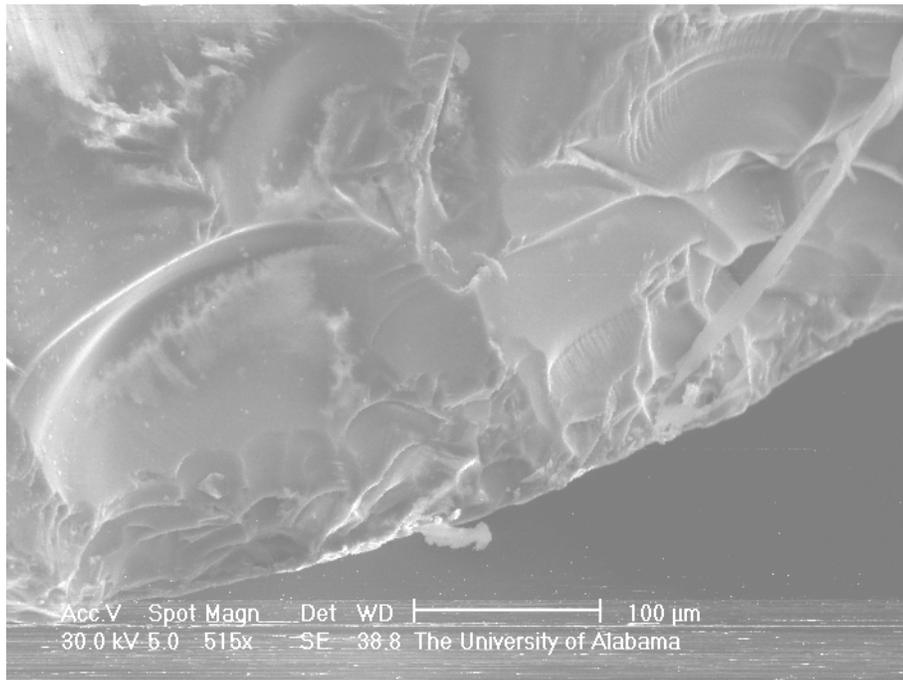


Figure 4.44: Microflaking along dorsal aspect of archaeological scraper #16.

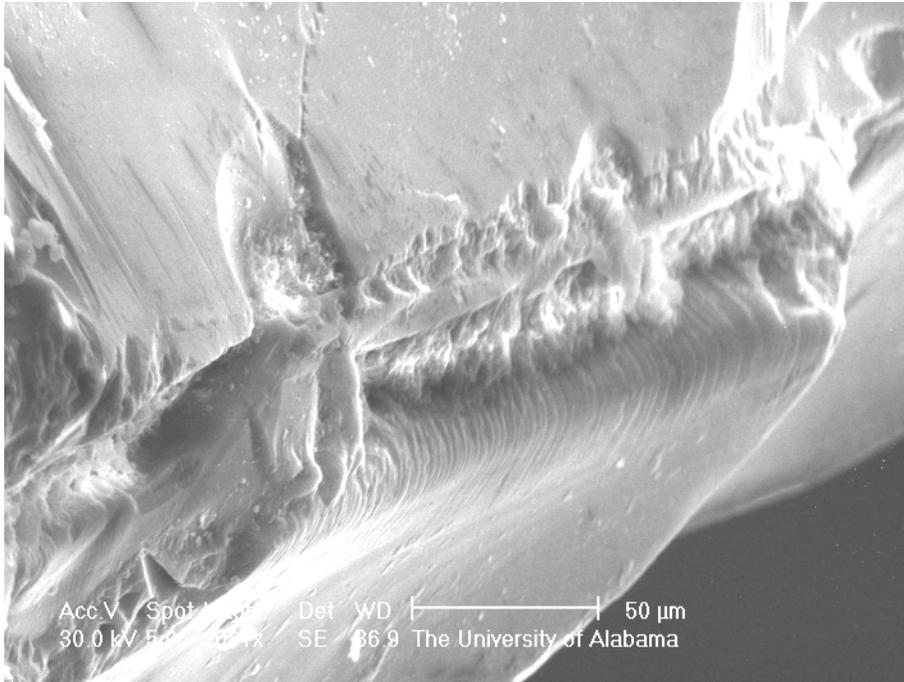


Figure 4.45: Striations on ventral and dorsal aspect of archaeological scraper #16.

Sample	Striations (μm) Max/Min/Mean	Microflakes (μm) Min/Max/Mean	Polish Description	Other
Archaeological 11 - TLX-97 I/6UU/2562	20/40/30 μm Very few.	30/100/70 μm	Very little polish. Somewhat fluid-like.	Some edge rounding/smoothing. Irregularly spaced pits and depressions.
Archaeological 12 - TLX-97 I/11L/871	10/30/20 μm (dorsal). 20/70/45 μm (ventral). More numerous on ventral side.	20/100/60 μm Many are wedge-shaped.	Some polishing. Bright, fluid- like.	Small pits and depressions. Some rounding.
Archaeological 13 - TLX-97 I/F	50/70/60 μm Located above scalar microflakes.	50/100/60 μm (lateral). 10/50/30 μm (medial).	Bright, rough polish on medial area of dorsal edge. Continues as a bright edge bevel.	Small pits and depressions along edge.
Archaeological 14 - TLX-97 I/F	20/200/120 μm Few, fairly high on the dorsal aspect.	50/100/60 μm Many are wedge-shaped.		Small pits and depressions on areas of more erosion.
Archaeological 15- TLX-97 I/F	200 μm or greater. Only present on the ventral side.	40/60/50 μm	Small areas of bright polish.	Numerous small pits.
Archaeological 16 - TLX-97 I/F 1843	30/50/40 μm (ventral). 10/40/25 μm (dorsal).	20/50/40 μm		

Table 4.2: Microwear features on archaeological obsidian scrapers.

CHAPTER 5

DISCUSSION AND CONCLUSION

This chapter provides a discussion of the results of this study and reconstructs tool-use behavior at the archaeological site of La Laguna.

Use-Wear Patterns on Replicated Scrapers

My experimental maguey scraping tools produced some interesting characteristics similar to the patterns observed by Keeley. On scraper 1 and 5, numerous microflakes were produced which were heavily eroded. The degree of microflaking on the dorsal aspect of these tools was most likely caused by the relatively harder nature of maguey in comparison to grasses and other plant materials. However, the tools which Keeley analyzed were more like blades used to cut than implements used for scraping. On scraper 1, small pits were observed along the edge of the tool. While they were not the same as Keeley's "comet-shaped" pits they could be related. The polish observed on these obsidian scrapers was not as distinct as on siliceous sedimentary rocks appearing mostly on the margin between the ventral and dorsal aspect of each scraper. However, some of the higher margins of the flakes present on the dorsal aspect of these scrapers were smooth and highly reflective.

The different shape of each experimental tool likely had some bearing on the way in which use-wear formed, mostly because of the way in which the tool was held during use. The longer spoon-shaped scrapers were much more efficient than the smaller round scrapers because

the hand had more area to grasp the tool. This subsequently allowed the tool to have much greater contact with the maguey's inner surface during use. These experimental obsidian scrapers performed adequately but could not compare to the efficiency of the iron scraper utilized by señor Isaac for several reasons. Not only did his iron scraper have a strong handle, but it also had a sharper, more honed edge which could cut into the maguey. However, in my opinion, an obsidian implement could have likely been used to scrape the flesh of maguey plants since they could keep a much sharper edge than other volcanic stones available to ancient highlanders.

Scrapers 2 and 6 produced microwear traces different from other experimental tools, but consistent with wood working. On both specimens, the flake scars along the dorsal edge of the tool are severely eroded. On scraper 2 this is especially true. Further, the edge of scraper 2 is extremely worn and beveled. The erosion of flake scars appears to create undulating domes of wear on the margins between flakes. Interestingly, scraper 6 had somewhat more apparent flake scars although they too are worn. Furthermore, on scraper 6, many small pits were observed on the ventral surface of the tool near the contact edge. Some striations did develop. Although they were not long as observed by Aoyama, they were extremely thin and shallow. I attribute the minute differences between these two experimental scrapers to the difference in the bark hardness of the Capulin and Mexican pine trees.

Scraper 3 and 7 displayed intense utilization damage similar to that defined by Keeley and Aoyama for bone working. Flake scars were continually formed and overlapped. Unlike the edges of the other experimental scrapers, the edges of tools 3 and 7 remained well defined due to the constant removal of lithic material from the edge. Numerous striations and grooves were observed at right angles to the edge of these scrapers. As with the other scrapers, the angle of

such striations and grooves were useful indicators of motion, indicating that the tool had been used at a roughly 90 degree angle and scraped across materials. The edge of scraper 7 displayed what could be the most well-defined bone polish, which was bright, smooth, and flat in nature. Further, scraper 7 had a unique wear pattern I called a flake track, which is characterized as a small row or line of extremely small microflake scars that form as a linear abrasion. The ones I observed were formed above larger flake scars in close proximity to striations. This feature appeared to be a cross between the development of striations and microflakes. The formation of flake track on this tool may be due to the shape of the scraper. In comparison to scraper 3, scraper 7 is more curved in which resulted in a more localized development of microwear features.

Scraper 4 and 8 were used to scrape fresh hide, and when use wear patterns are compared to the other experimental scrapers, immediate differences are apparent on the edges of these replicated tools. Most notable, the edge of each scraper became so severely worn and smoothed that it created a rounded edge. On scraper 4, numerous small striations were created that curved somewhat towards the distal end. Almost all of these features formed at right angles, illustrating directionality of use. Scraper 4 also demonstrated some polishing on raised edges. Different from bone polish, hide polish is flat and quite dull. Interestingly, scraper 8 developed more microflaking than scraper 4. However, numerous striations did develop. I believe that the different shape of scraper 8 resulted in a much different scraping approach that likely changed the way in which the tool contacted the surface of the fresh hide. As a result, increased amounts of microflaking were observed on this scraper than on scraper 4.

Attributing Use to Archaeological Specimens

The results derived from performing experimental scraping tests with scrapers 1 through 8 provide a framework for attributing possible uses to archaeological specimens recovered at the archaeological site of La Laguna in Tlaxcala, Mexico. To do so, use-wear features must be carefully compared to those on experimental scrapers to reveal similarities in the formation of microwear patterns. Paying close attention to the directionality of these features can reveal the way in which a tool was held and used. The types of microwear features present on the edges of the archaeological tools can reveal what they processed. However, one must consider the fact that these tools have been buried since the Formative Period in central Mexico. As a result, the use-wear features present on their edges may have changed somewhat due to geological processes. However, I believe that the diagnostic features observed on these archaeological obsidian scrapers will resemble the features observed on the experimental obsidian scrapers.

Scraper #11 - Proposed maguey scraper

The dorsal aspect of the edge of this artifact was heavily eroded with right-angle microflakes between 50 and 100 μm in length. I also observed a few striations about 30 μm in length oriented at right angles to the contact edge. The 90 degree orientation of flake scars and striations on the edge of this archaeological tool illustrates that it was used in a longitudinal motion. Since flakes were removed at right angles on the dorsal aspect of the tool, it would have been pulled across material towards the tool user. These characteristics are indicative of scraping. The sizes of the microflakes are consistent with the range of size of the microflakes along the dorsal aspects of experimental scrapers 1 and 5. These flakes are more consistent with

maguery or soft wood processing than with hide or bone processing. Processing bone would have created substantially more edge damage, while hide processing would have produced much less microflaking. The contact edge itself was somewhat rounded and smooth, although not quite in the same way that is consistent with hide scrapers microwear features. The degree of edge rounding on certain parts of the tool edge was much greater than that found on the two experimental maguery scrapers; however, this is likely due to being buried in the ground for such a long period of time, or possibly being used many other tasks than the experimental maguery scrapers. The edge was covered with small irregularly spaced pits and depressions. The presence of small pits and depressions was also consistent with those on the experimental maguery scrapers. On some raised areas of the dorsal aspect of the tool, evidence of polishing was observed. This polish feature was bright and fluid-like.

This tool bears a striking resemblance to the shape of some of my larger experimental spoon-shaped scrapers. Its edge angle is consistent with a few of the experimental scrapers. Although this archaeological specimen is not as wide, it very well could have been hafted and used to execute scraping tasks effectively. Its small size may have actually been more useful for scraping the maguery's central cavity. If hafted, then it would have performed more effectively than my experimental maguery scrapers because it could exert more pressure with each scrape. The small size of the tool may have also meant that it could not have been used to scrape larger pieces of materials, such as hides or trees. These materials would likely have required somewhat wider tools with a more honed edge, allowing the tool to not only scrape but cut material.

I believe that this archaeological sample was likely used to scrape maguery for the production of sap based on these microscopic and microscopic features. The directionality of the microwear features indicates that the tool was used in a scraping motion. The qualities and

dimensions of the microwear features are consistent with maguey features present on scrapers 1 and 5. Taken together these most likely indicate that this archaeological sample was used to scrape the interior of maguey plants.

Scraper #12 - Proposed maguey scraper

The dorsal aspect of this archaeological obsidian scraper was heavily eroded with microflake scars ranging in size between 20 and 100 μm , but these scars were not as numerous as expected from a bone scraper. Erosional features were oriented at right angles to the edge. The sizes of microflakes were similar to scraper 11, as well as experimental scrapers 1 and 5. The ventral aspect of this tool had some striations running at right angles to the contact edge. Like scraper 11, the orientation of flake scars and striations to the edge indicate that this tool was used in a transverse motion like scraping. Like scraper 11, scraper 12 had many small pits and depressions along the dorsal aspect near the contact edge. Most notable, this scraper displayed the presence of wedge-shaped microflakes like those found on experimental scraper 1 and 5. Like scraper 11, the edge of scraper 12 was worn to a much greater degree than the experimental scrapers. Again, however, this is very likely due to extended use of the archaeological tool or its time in the ground since the wear on the edge was not consistent with hide scraping. This tool form resembles the discoidal experimental scrapers numbered 5-8. This archaeological sample's edge angle of 64 degrees is consistent with the experimental scrapers. The large angle would have prevented the tool from being used as a cutting implement. For example, this tool would likely have not been able to cut the fat from hides as efficiently as a tool with a very small, honed edge angle.

I believe this tool was used to scrape the inner core of maguey plants based on these microscopic and macroscopic features. The directionality of the microwear features is indicative of a scraping motion. Also, the edge angle indicates that the tool would have been primarily used for scraping rather than any other activity. Further, the qualities and dimensions of the microwear features fell within the range of the experimental maguey scrapers and even scraper 11. Taken together these facts indicate that this tool was most likely used to scrape the interior of maguey plants.

Scraper #13- Proposed multipurpose scraper

The use-wear on this archaeological scraper was different than that found on the other archaeological samples. Large flakes, likely produced during the manufacture of the scraper, were observed on the lateral portion of the dorsal aspect. Towards the medial aspect of the tool's edge, little microflaking occurred or the microflake scars were too heavily eroded from use or from being buried to be distinguishable. The remains of a distinct polish were observable on the more medial area of the dorsal aspect of this sample. The largest areas of this polish appeared dull and somewhat greasy, which is characteristic of hide polishes. In other areas, it developed into a bright edge bevel whose appearance is more characteristic of plant polishes. Along this bevel area, some small scalar microflakes and long, thin striations were observed. These sorts of microflake scars are more consistent with bone scraping than plant, wood, or hide scraping. However, it is peculiar that there is not more damage across the rest of the archaeological scraper's surface if this were indeed used to scrape bone. These features were oriented at right angles to the contact edge, a pattern that indicates this tool was used in a transverse motion like

scraping. Unique to this specimen were the numerous large pits and depressions above the contact edge on the dorsal aspect.

The form of this tool resembled the experimental disc-shaped scrapers, although it was quite thin and had an edge angle of approximately 40 degrees. The peculiarity and range of microscopic features on this tool's edge make identifying the materials it processed hard to identify. This tool may have served as a small multipurpose scraping tool that was hastily made and quickly discarded. It is also likely that this tool was constantly retouched until it was rendered too small to be reused. This would explain why it has features from several scraping activities.

Scraper #14 - Proposed maguey scraper

This tool was more similar to the other archaeological samples, although the margins of flake scars and the edge remained much better defined. That is to say, they were not heavily eroded. As a result, no feature resembling a polish was observed along most of the tool's edge. Numerous overlapping microflake scars were observed oriented at right angles to the contact edge indicating that this tool was used in a transverse motion indicative of scraping. Many of these scars were wedge-shaped and about 50 to 100 μm in length. On areas where the edge was more heavily eroded, small pits and depressions were observed. Some striations were also observed that appeared to have a bright plant-like polish. Some very small areas along the edge also displayed a bright polish.

Formally, this archaeological specimen resembled the experimental disc-shaped scrapers with an edge angle of about 50 degrees. Lengthwise, the shape of the edge was much more circular than the other archaeological and experimental scrapers. However, the dorsal aspect

curved backwards away from a flatter ventral aspect like all the other tools. This resulted in microflake reduction on the ventral aspect consistent with a scraping motion. Based on these microscopic and macroscopic features, it is likely that this plant was used to process maguey. However, the fact that so many flake features remain well defined may indicate that the tool was discarded before it was worn down as far as archaeological scrapers 11 and 12.

Scraper #15 - Proposed maguey scraper

The edge of this archaeological scraper was heavily eroded with numerous tiny pits and depressions along the edge. These features were similar to scraper 11 as well as the experimental maguey scrapers. Further, like scraper 11 and 12, the margin between the ventral and dorsal aspect of the tool was severely eroded. Numerous, eroded microflakes were observed along the dorsal aspect that were about 50 μm in length and oriented at right angles, much like scraper 11. The directionality of these features indicates that the tool was used in a transverse motion like scraping. The ventral aspect of this sample was important for ascertaining use motion. On this portion of the obsidian scraper, many grooves and striations were observed and were oriented at right angles to the contact edge. Polishing was not observable along most parts of the dorsal aspect of the tool. However, some small areas of bright polish were observed.

Macroscopically, this specimen bears a striking resemblance to archaeological scraper 11. Like that sample, this scraper was long, narrow, and likely hafted. The edge angle was approximately 50 degrees, similar to, although somewhat less, than scraper 11's edge angle. The macroscopic and microscopic features on this archaeological sample lead me to believe that this scraper was utilized to scrape the inner core of maguey plants. I also believe that this is the most diagnostic archaeological sample among the tools I tested because the qualities and dimensions

of its features are the most consistent with the features on the experimental maguey scrapers. By this I mean that the microflakes, the few striations, and the little polish observed were very similar to the ranges of qualities and dimensions of the microwear features on the experimental scrapers. The features were also similar to the archaeological scrapers although the features were more consistent with experimental tools.

Scraper #16 - Proposed bone scraper

Microflake scars were readily observed along the edge of this specimen. These flakes ranged in size from about 20 to 50 μm in length and were oriented at right angles to the contact edge. This directionality indicates that the tool was used in a transverse motion indicative of scraping. Like scraper 14, the margins of these scars and the edge remained well-defined in comparison to the other archaeological samples. As a result, any polishing was unobservable as with scraper 14. The most unique feature on this sample was the appearance of numerous striations. These extend from the ventral aspect towards the tool's contact edge. Other small, narrow, and shallow striations were observed across the tool's dorsal aspect. The majority of these striations were oriented at right angles to the contact edge, ranging in size from 50 to 500 μm in length. The size and number of these striations is characteristic of processing hard material such as bone.

Formally, this scraper resembles the archaeological and experimental disc-shaped scrapers, although its edge angle is an extremely small 10 degrees. Like scraper 13, it is possible that this tool was utilized repeatedly and reduced to its current size. However, unlike scraper 13, it does not have a wide variety of microwear features consistent with various scraping activities. In this case, the last thing the tool may have processed could be bone or some other hard

material. The number and size of striations, as well as the amount of microflake reduction is too great to have been caused by processing hide, wood, or maguey. Therefore, I believe that this tool was used to deflesh meat from bones.

Conclusion

Since maguey byproducts--specifically sap, flesh, and leaves--decay over time, it is necessary to reconstruct ancient maguey processing behaviors and strategies through the artifacts which endure. In this case, observations based on the microwear patterns on small obsidian scrapers offer the best insight into discovering the importance maguey may have played in the small settlement of La Laguna in the Mexican altiplano. These observations can also assist in sorting out components of the tool kits these ancient Mexicans were utilizing during their daily lives.

Based on the comparison of the microwear features on several experimental and archaeological obsidian tools, it appears that residents at La Laguna were taking part in activities related to maguey processing, most likely the production of sap. This assumption is based on the specific microwear features discussed above. However, the archaeological samples also indicate that residents were very likely using some of their obsidian scrapers to process other materials. Nonetheless, because most tools displayed maguey microwear features they appear to have been primarily fashioned for maguey processing. These tools also originated from only two excavation areas around the site. These were excavation areas I and F. This demonstrates that at least two different household groups were undertaking maguey processing rather than only one

group at a single location. This indicates the importance that this plant and its products must have played for the community of La Laguna.

For the archaeological specimens, it seems likely that the spoon-shaped scrapers are much more likely to have been used maguey scrapers, or, at the very least, used primarily on maguey than the discoidal scrapers. Their smaller shape, greater edge angle, and the fact that they were probably hafted would make them much more efficient scrapers than a handheld discoidal scraper. Although neither form of scraper was hafted, during the experimental portion of my study the spoon-shaped experimental scraper used on maguey performed much more effectively and was easier to handle within the maguey cavity than its discoidal counterpart. The extra length on the spoon-shaped scrapers offered a sturdy handhold whereas the discoidal scrapers did not have such a convenience. This was not necessarily true for the other materials I processed. For example, the discoidal scraper was able to make smaller, more accurate scrapes than the somewhat larger spoon-shaped scraper on the woods samples I processed. On hide, the discoidal scrapers with the smallest edge angle appeared to cut away at fat as they were scraped along the material.

The size of the scraper and its edge angle appear to factor into the way it may have been used in the past. As I mentioned previously, the discoidal scrapers with the smallest edge angle performed best when scraping hide. Due to all the fat and some leftover flesh on the hide, the more fine edge related to a smaller edge angle allowed the scraper to cut away at the fat more so than the spoon-shaped scrapers that had a much larger edge angle. The smaller size of the discoidal scrapers also seemed to lend themselves to this activity as well. Had I been more focused on cutting as I scraped, the smaller dimensions of the discoidal scrapers could have allowed me to much more easily reduce the length of my average scrapes to cut at the hide as I

pulled to scraper towards me. This was true for bone as I attempted to deflesh the deer femurs with my experimental scrapers. However, an obsidian blade would have been much more useful than either of the two experimental scrapers. I found the opposite to be true among the experimental obsidian maguey scrapers. The spoon-shaped scraper was able to scrape much more effectively than the maguey scraper because of its larger edge angle and its somewhat larger size. The discoidal scraper's smaller edge angle and smaller size made it feel much less sturdy as the spoon-shaped scraper. I did not note any difference in ease of use based on the size and edge angle of the experimental scrapers used to scrape wood.

The way a tool handles also appears to influence the way it may be used. Although the spoon-shaped scrapers did not always seem to perform the best for every material they processed, the extra lithic material allowed me to have a better grip regardless of what I was scraping. Had the experimental samples been more similar in size to the archaeological samples, hafting it may have increased their effectiveness even more. Modern metallic scrapers have a crescent-shaped blade that is welded onto a metal handle wrapped in cord. This handle allows the user to apply more force from the blade's edge into the maguey's flesh causing the plant to produce more sap. The same could have been true for a hafted scraper used during the late Formative. Flake scars on the dorsal aspect of the archaeological spoon-shaped scrapers appear indicative of hafting. Future research should not only include hafted tools with their samples, but should also look at microwear features left at the site of haft attachment. These will likely appear similar to the microwear traces left by activities that would grind or rub against wood.

More microwear studies on artifacts recovered in central Mexico are warranted to test the results of my study and possibly reveal more information about ancient Mexican archaeology. These studies will serve as an important next step in establishing more conclusive relationships

between obsidian scrapers recovered from archaeological sites around the area and the materials archaeologists believe constituted important components of domestic economies. Being able to determine the function of seemingly multipurpose implements can aid in identifying large-scale trends of maguey utilization across Mexico's history by identifying the actual materials the tools were used to process. Further, this sort of analysis could also be used to identify changes in local and regional economies and trade networks by tracking the changes in maguey utilization based on the consumption of stone tools.

Due to the limitations of analytical time using the SEM, the sample size for this project was relatively small. A much larger sample size of both experimental and archaeological scrapers will yield much more significant results. Further, the ability to observe microwear at various intervals of use would also be important in developing a stronger baseline for the formation of microwear features on obsidian scrapers. For example, tools could be observed at intervals of 200 scrapes for comparison between each stage of microwear formation. Additionally, some experimental tools could be subjected to non-use related activities to produce different types of wear. Some tools could be buried while others could be stepped on or submerged in running water. These actions might be able to replicate some of the features that appear on archaeological samples thereby distinguishing them from use wear.

A larger sample size of archaeological specimens will also illustrate a much broader range of microwear formation and may help to more definitively assign tool use. It may also help alleviate problems with some of the more ambiguous microwear patterns indicative of possible multipurpose tools. An example of these patterns is found on archaeological scraper 13. Furthermore, definitive assignments of tool function could sort out the components of not only the maguey scraping toolkit, but also toolkits associated with other important activities. This is

especially important in places where known archaeological maguey processing sites have been discovered. A larger sample size from various archaeological sites around the Puebla-Tlaxcala region could also indicate how different materials may be processed at different ratios based on the available resources in an area and the trade networks with which they are engaged. Samples compared between sites of different ages and contemporaneous settlements may also indicate changing trends in the materials being processed by these obsidian scrapers over time.

Discovering other types of quantitative analytical methods is also important. Keeley (1980) suggests measuring the reflectivity of surfaces using a light meter with light and dark field illumination. A light meter measures how much light is available during photography. Light and dark field illumination refers to using either illumination (like optical microscopy) or darkness (SEM) while observing something microscopically. Grace and colleagues (1985) suggest using a method of image processing called "grey-level scoring." This method passes a beam of light through a photographic negative of microwear traces to measure the density of each pixel. This relates information about very small differences in tone. These differences classify micropolishes by calculating the difference in polishes from unused flint.

Beyond advances in technology, there is much research left to be done in regards to assigning function to stone tools discovered by archaeologists. Techniques have certainly improved with time and researchers continue to make advances in the field of microwear analysis. The first step towards any definitive conclusions, however, is a refinement of the experimental methodology which can streamline the overall research program. Second, the creation of set analytical techniques to identify and differentiate microwear features will significantly unify various opinions and viewpoints regarding the classification of features. The creation of specialized SEMs or analytical programs catering specifically to the archaeologist

interested in tracking microwear patterns is encouraged. This could significantly shorten the time it takes to observe experimental and archaeological samples within the SEM allowing researchers to look at more samples. Lastly, the development of a strong, wholly objective, and quantitative measurement methodology will alleviate some of the problems associated with the mostly qualitative measurements and comparisons of microwear analysis.

REFERENCES

- Adriano-Morán, Carmen Cristina, Emily McClung de Tapia
2008 Trees and Shrubs: The Use of Wood in Prehispanic Teotihuacan. *Journal of Archaeological Science* 35:2927-2936.
- Anderson, Richmond K., Jose Calvo, Gloria Serrano, and George C. Payne
1946 A Study in the Nutritional Status and Food Habits of Otomi Indians in the Mezquital Valley of Mexico. *American Journal of Public Health and the National Health* 36(8):883-903.
- Ascher, Robert
1961a Experimental Archaeology. *American Anthropologist, New Series* 63(4):793-816.
1961b Analogy in Archaeological Interpretation. *Southwestern Journal of Anthropology* 17(4):317-325.
- Aoyama, Kazuo
1995 Microwear Analysis in the Southeast Maya Lowlands: Two Case Studies at Copan, Honduras. *Latin American Antiquity* 6(2):129-144.
- Barba, Luis, Jorge Blancas, Agustín Ortiz, and David Carballo
2009 Geophysical Prospection and Aerial Photography in La Laguna, Tlaxcala, Mexico. *ArchaeoSciences* 33:17-20.
- Boksenbaum, William Martin, Paul Tolstoy, Garman Harbottle, Jerome Kimberlin, and Mary Neivens
1987 Obsidian Industries and Cultural Evolution in the Basin of Mexico before 500 B.C. *Journal of Field Archaeology* 14(1):65-75.
- Borejsza, Aleksander, Isabel Rodríguez López, Charles D. Frederick, and Mark D. Bateman
2008 Agricultural Slope Management and Soil Erosion at La Laguna, Tlaxcala, Mexico. *Journal of Archaeological Science* 35:1854-1866.
- Bourke, John G.
1894 Distillation by Early American Indians. *American Anthropologist* 7(3):297-299.
- Carballo, David M.
2007a Effigy Vessels, Religious Integration, and the Origins of the Central Mexican Pantheon. *Ancient Mesoamerica* 18:53-67.

- 2007b Formative and Classic Period Obsidian Procurement in Central Mexico: A Compositional Study Using Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry. *Latin American Antiquity* 18(1):27-43.
- 2009 Household and Status in Formative Central Mexico: Domestic Structures, Assemblages, and Practices at La Laguna, Tlaxcala. *Latin American Antiquity* 20(3):473-501
- 2011 Advances in the Household Archaeology of Highland Mesoamerica. *Journal of Archaeological Research* 19:133-189.
- Carballo, David M., and Thomas Pluckhahn
 2007 Transportation Corridors and Political Evolution in Highland Mesoamerica: Settlement Analyses Incorporating GIS for Northern Tlaxcala, Mexico. *Journal of Anthropological Archaeology* 26:607-629.
- Charlton, Thomas H.
 1981 Archaeology, Ethnohistory, and Ethnology: Interpretive Interfaces. *Advances in Archaeological Method and Theory* 4:129-176.
- Charlton, Thomas H., Deborah L. Nichols, Cynthia Otis Charlton
 1991 Aztec Craft Production and Specialization: Archaeological Evidence from the City-State of Otumba, Mexico. *World Archaeology* 23(1):98-114.
- Cobean, Robert H., James R. Vogt, Michael D. Glascock, Terrance L. Stocker
 1991 High-Precision Trace-Element Characterization of Major Mesoamerican Obsidian Sources and Further Analyses of Artifacts from San Lorenzo Tenochtitlan, Mexico. *Latin American Antiquity* 2(1):69-91.
- Crist, Raymond E.
 1939 The Pulque Industry. *Economic Geography* 15(2):189-194.
- Ember, Carol R.
 1983 The Relative Decline in Women's Contribution to Agriculture with Intensification. *American Anthropologist* 2:285-304.
- Evans, Susan T.
 1989 House and Household in the Aztec World: The Village of Cihuatecpan. In *Households and Communities: Proceedings of the Twenty-first Annual Conference of the Archaeological Association of the University of Calgary*, edited by S. Maceachem, D. J., Archaer, and R. D. Garvin, pp. 430-440. Archaeological Association of University of Calgary, Calgary.
- Evans, Susan T.
 1990 The Productivity of Maguey Terrace Agriculture in Central Mexico during the Aztec Period. *Latin American Antiquity* 1(2):117-132.

Evans, Susan T.

2005 Men, Women, and Maguey: The Household Division of Labor Among Aztec Farmers. In *Settlement, Subsistence, and Social Complexity: Essays Honoring the Legacy of Jeffrey R. Parsons*, edited by R. E. Blanton, pp. 198-228. University of California Cotsen Institute of Archaeology, Los Angeles.

Feinman, Gary M.

1999 Rethinking Our Assumptions: Economic Specialization at the Household Scale in Ancient Ejutla, Oaxaca, Mexico. In *Pottery and People: Dynamic Interactions*, edited by J.M. Skibo, and G.M. Feinman, pp. 81-98. University of Utah Press, Salt Lake City.

Feinman, Gary M. and Linda M. Nicholas

2000 High-intensity Household-scale Production in Ancient Mesoamerica: A Perspective from Ejutla, Oaxaca. In *Cultural Evolution: Contemporary Viewpoints*, edited by G.M. Feinman and L. Manzanilla, pp. 119-142. Kluwer Academic/Plenum Publishers, New York.

Feinman, Gary M. and Linda M. Nicholas

2004 Unraveling the Prehispanic Highland Mesoamerican Economy: Production, Exchange, and Consumption in the Classic Period Valley of Oaxaca. In *Archaeological Perspectives on Political Economies*, edited by G.M. Feinman and L.M. Nicholas, pp. 167-188. University of Utah Press, Salt Lake City.

Feinman, Gary M. and Linda M. Nicholas

2005 More Than Alluvial Land and Water: The Late Pre-Hispanic Emergence of Eastern Tlacolula, Oaxaca, Mexico. In *Settlement, Subsistence, and Social Complexity: Essays Honoring the Legacy of Jeffrey R. Parsons*, edited by R.E. Blanton, pp. 229-259. University of California Cotsen Institute of Archaeology, Los Angeles.

Feinman, Gary M. and Linda M. Nicholas

2007 Craft Production in Classic Period Oaxaca: Implications for Monte Alban's Political Economy. In *Craft Production in Complex Societies: Multicraft and Producer Perspectives*, edited by I. Shimada, pp. 97-119. University of Utah Press, Salt Lake City.

Feinman, Gary M.; Linda M. Nicholas; Helen R. Haines

2002 Houses on a Hill: Classic Period Domestic Life at El Palmillo, valley of Oaxaca, Mexico. In *Seeking a Richer Harvest: The Archaeology of Subsistence Intensification, Innovation, and Change*, edited by T.L. Thurston and C.T. Fisher, pp. 23-61. Springer, New York.

Feinman, Gary M.; Linda M. Nicholas; Helen R. Haines

2006 Socioeconomic Inequality and the Consumption of Chipped Stone at El Palmillo, Oaxaca, Mexico. *Society for American Archaeology* 17(2):151-175.

Flannery, Kent V.

1968 Archaeological Systems Theory and Early Mesoamerica. In *Anthropological Archaeology in the Americas*, edited by B. J. Meggers, pp. 67-87. Anthropological Society of Washington, Washington.

Flannery, Kent V. and Joyce Marcus

2005 *Excavations at San José Mogote I: The Household Archaeology*. Museum of Anthropology, University of Michigan, Ann Arbor.

Fish, Suzanne K., Paul R. Fish, Charles Miksicek, and John Madsen

1986 Prehistoric Agave Cultivation in Southern Arizona. *Desert Plants* 7(2):107-12, 100.

Gentry, Howard S.

1982 *Agaves of Continental North America*. University of Arizona Press, Tucson.

Grace, R.; I.D.G. Graham.; M.H. Newcomer.

1985 The Quantification of Microwear Polishes. *World Archaeology* 17(1):112-120.

Haines, Helen R., Gary M. Feinman, and Linda M. Nicholas

2004 Household Economic Specialization and Social Differentiation: The Stone Tool Assemblage at El Palmillo, Oaxaca. *Ancient Mesoamerica* 15:251-266.

Hirth, Kenneth G.

1993a The Household as an Analytical Unity: Problems in Method and Theory. In *Prehispanic Domestic Units in Western Mesoamerica: Studies of the Household, Compound, and Residence*, edited by Robert S. Santley and Kenneth G. Hirth, pp.21-36. CRC Press, Boca Raton, Florida.

1993b Identifying Rank and Socioeconomic Status in Domestic Contexts: An Example from Central Mexico. In *Prehispanic Domestic Units in Western Mesoamerica: Studies of the Household, Compound, and Residence*, edited by Robert S. Santley and Kenneth G. Hirth, pp. 121-146. CRC Press, Boca Raton, Florida.

Hirth, Kenneth G.

2006 *Obsidian Craft Production in Ancient Central Mexico*. University of Utah Press, Salt Lake City

Hirth Kenneth G.

2009 Craft Production, Household Diversification, and Domestic Economy in Prehispanic Mesoamerica. In *Housework: Specialization, Risk, and Domestic Craft Production in Mesoamerica, Archaeological Papers No 19*, edited by K.G Hirth, pp. 13-32. American Anthropological Association, Washington, D. C.

Hayden, Brian

1979 *Lithic Use-Wear Analysis*. Academic Press Inc, New York.

- Keeley, Lawrence H.
1980 *Experimental Determination of Stone Tool Uses*. University of Chicago Press, Chicago.
- Kicza, John E.
1980 The Pulque Trade of Late Colonial Mexico City. *The Americas* 37(2):193-221.
- Lesure, Richard G., Aleksander Borejsza, Jennifer Carballo, Charles Frederick, Virginia Popper, and Thomas Wake
2006 Chronology, Subsistence and the Earliest Formative of Central Tlaxcala, Mexico. *Latin American Antiquity* 17(4):474-492.
- Lewenstein, Suzanne M.
1981 Mesoamerican Obsidian Blades: An Experimental Approach to Function. *Journal of Field Archaeology* 8(2):175-188.
- López Luján, Leonardo
1989 *La Recuperación Mexica del Pasado Teotihuacano*. Instituto Nacional de Antropología e Historia, Mexico City
- Loyola Montemayor, E.
1956 *La Industria del Pulque*. Imp. Miguel Leon Sanchez, Mexico City.
- Marcus, Joyce
2000 Toward an Archaeology of Communities. In *The Archaeology of Communities: A New World Perspective*, edited by M.A. Canuto and J. Yaeger, pp. 231-242. Routledge, New York.
- Matos Moctezuma, Eduardo
1988 *The Great Temple of the Aztecs: Treasures of Tenochtitlan*. Thames and Hudson, London.
- Merino Carrión, Beatriz Leonor
1989 *La Cultural Tlaxco*. Serie Arqueológico, Colección Científica 174. Instituto Nacional de Antropología e Historia, Mexico City
- Miller, Mary, and Karl Taube
1993 *The Gods and Symbols of Ancient Mexico and the Maya: An Illustrated Dictionary of Mesoamerican Religion*. Thames and Hudson, London.
- Motolinia, Fray Toribio
1951 *Motolinia's History of the Indians of New Spain*, translated by F. Speck. Academy of American Franciscan History, Washington, D. C.
- Nichols, Deborah L.
1987 Risk and Agricultural Intensification during the Formative Period in the northern Basin of Mexico. *American Anthropologist, New Series* 89(3):596-616.

- Nichols, Deborah L., Mary Jane McLaughlin, and Maura Benton
 2000 Production Intensification and Regional Specialization: Maguey Fibers and Textiles in the Aztec city-state of Otumba. *Ancient Mesoamerica* 11:267-291.
- O'Dell, George H.
 2004 *Lithic Analysis*. New York: Plenum Publishers.
- Ortmann, Nicole and David Carballo
 2009 Análisis Arqueobotánico. In *Informe Técnico al Instituto Nacional De Anthropología e Historia*. Presentado ante el Instituto Nacional de Antropología e Historia, Mexico City.
- Parsons, Jeffrey R.
 1974 The Development of a Prehistoric Complex Society: A Regional Perspective from the Valley of Mexico. *Journal of Field Archaeology* 1(1/2):81-108.
- Parsons, Jeffrey R., and Mary H. Parsons
 1990 *Maguey Utilization in Highland Central Mexico: An Archaeological Ethnography*. The University of Michigan Museum of Anthropology, Michigan.
- Pasztory, Esther
 1974 *The Iconography of the Teotihuacan Tlaloc*. Studies in Precolumbian Art and Archaeology, No. 15, Dumbarton Oaks, Trustees for Harvard University, Washington D.C.
- Patrick, L.
 1985 Agave and Zea in Highland Central Mexico: The Ecology and History of the Metepantli. In *Prehistoric Intensive Agriculture in Tropics*. I. Farrington, ed. Pp. 539-547. B.A.R. International Series No. 232, Oxford.
- Rangel, Samuel
 1987 *Ethnobotánica de los Agaves del Valley del Mezquital*. Tesis para obtener el Título de Biología. Univ. Nac. Aut. de México, Mexico City.
- Reynolds, Peter J.
 1999 The Nature of Experiment in Archaeology. In *Experiment and Design in Archaeology*, edited John M. Coles and A. F. Harding, pp. 156-162. Oxbow Books.
- Ruvalcaba, Jesús
 1983 *El Maguey Manso: Historia y Presente de Epazoyucán, Hgo.* Universidad Autónoma Chapingo, Depto. de Industrias Agrícolas, Colección Cuadernos Universitarios, Serie Ciencias Sociales, No. 4., Texcoco, México.
- de Sahagún, Fray Bernardino
 1961 Florentine Codex: General History of the Things of New Spain. In *Book 10, The People*, translated by C. Dibble and A. Anderson. Monographs of the School of American Research and the Museum of New Mexico, Santa Fe

de Sahagún, Fray Bernardino

1963 Florentine Codex: General History of the Things of New Spain. In *Book 11, Earthly Things*, translated by C. Dibble and A. Anderson. Monographs of the School of American Research and the Museum of New Mexico, Santa Fe.

de Sahagún, Fray Bernardino

1969 *Historia General de las Cosas de Nueva España*, translated by A. M. Garibay. Editorial Porrúa, S.A, Mexico City.

Sanders, William T.

1956 The Central Mexican Symbiotic Region: A Study in Prehistoric Settlement Patterns. In *Prehistoric Settlement Patterns in the New World*, edited by G. R. Willey, pp 115-127. Viking Fund Publications in Anthropology, New York.

Santley, Robert S., and Eric K. Rose

1979 Diet, Nutrition and Population Dynamics in the Basin of Mexico. *World Archaeology* 11(2):185-207.

Saraydar, Stephen C., Izumi Shimada

1973 Experimental Archaeology: A New Outlook. *American Antiquity* 38(3):344-350.

Smith Jr., C. Earle

1963 Something Old, Something, New: Farm Practices near Tehuacán, Mexico. *Economic Botany* 17(3):200-210.

Tringham, Ruth; Cooper, Glenn; Odell, George; Voytek, Barbara; Whitman, Anne

1974 Experimentation in the Formation of Edge Damage: A New Approach to Lithic Analysis. *Journal of Field Archaeology* 1(1/2):171-196.

von Winning, Hasso

1976 Late and Terminal Preclassic: The Emergence of Teotihuacán. In *Origins of Religious Art and Iconography in Preclassic Mesoamerica*, edited by H.B. Nicholson, pp. 143-156. University of California, Los Angeles, Latin American Center Publications, Ethnic Arts Council of Los Angeles, Los Angeles.

Webster, Gary S.

1986 Optimization Theory and Pre-Columbian Hunting in the Tehuacan Valley. *Human Ecology* 14(4):415-435.

West, Robert C.

1968 *Population Densities and Agricultural Practices in Pre-Columbian Mexico, with Emphasis on Semi-Terracing*. Pp. 361-69. Verhandlungen des XXXVIII Internationalen Amerikanistenkongresses, Band II, Munich.