

Exploring Handaxe Function at Shishan Marsh – 1:
Combining Qualitative and Quantitative Approaches Using the Edge
Damage Distribution Method

by

John K. Murray

B.A., Stony Brook University, 2014

Graduate Certificate, Johns Hopkins University, 2015

Graduate Certificate, University of Victoria, 2017

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Supervisory Committee

Dr. April Nowell, Supervisor
Department of Anthropology

Dr. Yin-Man Lam, Member
Department of Anthropology

Daniel Stueber, Outside Member
Primitive Skills Practitioner

ABSTRACT

Handaxes are some of the longest lasting and most iconic stone tools throughout human evolution. Appearing in the early Pleistocene, these bifacially flaked tools persisted around one and a half million years and span across all of the Old World, from Africa to eastern Asia. Despite their ubiquitous nature, relatively little is known about their function. Handaxes are often speculated to be multi-functional tools which were selected for due to their large cutting edge; however, only a handful of use-wear studies have attempted to elucidate their use in the archaeological record. The lack of experimental use-wear studies surrounding handaxe function is due to preservation issues and the fact that manufacturing and curating handaxes compounds the ambiguity of microwear signatures. The methodology undertaken in this research provides a pathway to overcoming these obstacles through experimental archaeology in conjunction with low powered microscopy, image-based GIS, and statistical hypothesis testing. In particular, this thesis investigates handaxe function at an assemblage scale ($n = 56$) in a late Lower Paleolithic to Middle Paleolithic archaeological site called Shishan Marsh – 1 (SM-1) in al-Azraq, Jordan. Experimental handaxes ($n = 22$) were replicated and used in various activities such as butchery, plant processing, woodworking, shellfish processing, and digging. The results of this research corroborates the idea of handaxes being used as multifunctional tools. These results have implications for handaxe function, hominin tool use in a desert refugia, and provides a new pathway to investigate inter-site variability in handaxe use.

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Chapter 1: Introduction

Research Statement

The Levant (Jordan, Syria, Israel, and Lebanon) is one of the most important regions when considering the evolution and dispersal of the hominin lineage because it lies at the cross-roads of Africa, western Asia, and Europe. During dispersal events out of Africa, hominins would have needed access to vital resources for survival, especially in times of harsh climatic conditions. Shishan Marsh-1 (SM-1), a Late Lower and Middle Paleolithic archaeological site in Azraq, northeast Jordan, presents an exceptional opportunity for exploring the relationship between hominins, technology, and the environment during dispersal events because of its unique ecological context – a desert refugium (Ames and Cordova 2015; Ames et al. 2014; Cordova et al. 2013; Stewart and Stringer 2012). Considering stone tools are one of the primary ways hominins interacted with and modified their environment, uncovering how they were used in specific contexts can help shed light on hominin behavioral variability and adaptive strategies in response to climatic variability.

Functional studies in archaeology provide insights into stone tool use through a combination of microscopy, experimental archaeology, and residue analysis (Marrieros et al. 2015). By using replicated stone tools in modern contexts, archaeologists can document how certain activities damage the edge and apply this knowledge to what is found in the prehistoric assemblage based on principles of uniformitarianism and Middle Range Theory (Binford 1977, 1983). Currently, protein residue results using Crossover Immunoelectrophoresis (CIEP) show that the SM-1 hominins had a broad ecological niche and exploited a wide range of fauna at the oasis including rhinoceros, horse, duck (Nowell et al. 2016) and Asian elephant. These hominins were equipped with a Late Acheulean toolkit that primarily consisted of handaxes, but also included Levallois points, blades, and other retouched flake tools.

The Acheulean industry is present in the archaeological record for almost 1.5 million years. Handaxes are the most iconic stone tool type in the Acheulean toolkit and are found all over the Old

World, but despite their ubiquitous nature, there is very little known about how and why they were used. Researchers have proposed handaxes functioned as utilized cores (Shea 2007), Paleolithic throwing weapons (O'Brien 1981; Samson 2006), and Paleolithic "Swiss Army Knives" that were able to serve many functions (Keeley 1980; Keeley and Toth 1981; Posnansky 1959; Schick and Toth 1994). Experimental work has shown that they are capable of butchery, woodworking, and various other tasks (Claud 2008; Keeley 1980; Mitchell 1995), but only a handful of studies have investigated handaxe function through use-wear analysis (Binneman and Beaumont 1992; Claud 2008, 2015; Claud et al. 2015; Ollé et al. 2014; Lambert-Law de Lauriston 2015; Solodenka et al. 2015; Viallet 2016a, b). The lack of studies analyzing handaxes for use-wear is typically due to their state of preservation (Viallet 2016b) and the fact that they are intensively flaked which compounds the ambiguity surrounding use-wear signatures. Generally, use-wear analyses consist of low powered (Kamminga 1982; Odell 1981; Tringham et al. 1974) and high powered microscopy (Fullagar 1991; Hardy 1994; Juel Jensen 1988; Keeley and Toth 1981; Marrieros et al. 2015; Rots et al. 2016). More recently, researchers have argued for a quantitative approach to use-wear and the application of new technology has helped facilitate this (Evans and Donahue 2008; Evans and Macdonald 2011; Macdonald 2014; Stemp et al. 2015), but these approaches are still in their infancy.

In order to address some of the issues surrounding use-wear analysis, the methodological approach this research takes is a combination of qualitative and quantitative use-wear analyses. I will use low powered microscopy to document edge damage on a subsample of handaxes found within the archaeological layers at SM-1 to gather preliminary information on hardness of contact material. In order to quantitatively assess handaxe use, I will adopt the methodology created by Dr. Benjamin Schoville (2010) in which I will investigate the distribution and frequency of edge damage within the SM-1 at an assemblage scale (Schoville and Brown 2010; Schoville et al. 2016; Wilkins and Schoville 2016). By analyzing these handaxes at a larger scale than the individual tool, I can uncover patterns of use that

might not be present on individual tools (Wilkins and Schoville 2016), while simultaneously accounting for user-error and equifinality within the edge damage. Additionally, this method is a good starting point because it can help inform and complement future analysis on individual handaxes.

Research Goals and Questions

There are multiple goals of this research. The first is to assess the edge damage distribution methodology on an intensely flaked tool type – *can specific activities be distinguished from one another at an assemblage scale?* Additionally, this research will investigate the influence of grip on the distribution of edge damage. The overarching research question of this thesis is: *how were SM-1 hominins using handaxes?* Rather than focusing on specific materials they were used on, although I will provide some insight into this, I plan to explore the activities (e.g., butchery, chopping, and cutting) that handaxes were used for. In order to investigate this question, numerous sub-questions need to be considered. The combination of these sub-questions will help inform my interpretation. These sub questions are:

Q1) Is there a significant difference in edge damage distribution between activity groups (i.e., are they distinguishable from one another)?
Q2) What is the overall distribution of edge damage in the experimental dataset?
Q3) Does grip influence edge damage distribution?
Q4) What is the overall distribution of edge damage at SM-1?
Q5) Does the edge damage distribution at SM-1 differ from a random distribution?
Q6) Does handaxe use change over time?

Q7) Do the experimental distributions reflect SM-1 handaxe use?

Q8) Do the experimental distributions reflect SM-1 handaxe use within layers?

Thesis Outline

Experimental use-wear analysis is one of the primary ways to investigate function in lithic technology and has a long and somewhat tumultuous history. Chapter 2 outlines the various approaches and technologies that have been used since Semenov's (1964) seminal work including a discussion about the counterparts to use-wear, such as residue analysis, to provide a brief background on complementary methods. Moreover, I explore the importance of scale and blind testing within use-wear methodology.

In order to interpret the results of archaeological analyses, it is paramount to situate the archeological assemblage in a broader geographic and temporal context. Chapter 3 provides background information surrounding the Acheulean industry and identifies the gap in the archaeological literature that gave rise to this research. In particular, there is an in-depth discussion about the Movius Line and previous functional studies on handaxes. Afterwards, I contextualize the archaeological layers at SM-1 to other Acheulean archaeological sites in the Levant by providing descriptions of the paleoenvironment and lithic assemblage at each major locality. These sites include Gesher Benot Ya'cov, 'Ubeidiya, Tabun, and Latamne. The chapter ends on a discussion of SM-1 in relation to other sites within the Greater Azraq Oasis Area such as Lion's Spring, C-Spring, and 'Ain Soda, with an emphasis on faunal remains and lithic technology.

Chapter 4 begins with an outline of the 2015 field season where all of the chert was gathered for the handaxe replications. I move on to discuss the replications and provide a quantitative comparison of the experimental dataset to the archaeological assemblage. Next, I explain the pre-experimental

procedure and summarize the experimental protocol. Afterwards, I describe the methodology adopted from Schoville and colleagues (Schoville 2010; Schoville et al. 2016; Wilkins and Schoville 2016), which includes a combination of image-based GIS, Microsoft Excel, and RStudio. Considering Schoville has altered the workflow and graphical output of the methodology slightly over the years, my method is an amalgamation of the various approaches. Lastly, I provide descriptions of the statistical analyses used to analyze the data and explain some confounding factors that may have influenced my results.

Chapter 5 provides the results of the analyses from Chapter 4. The first half of the chapter describes the use-wear found on the experimental handaxes from each activity and a small sub-sample of artifacts. Although I am not attempting to assign edge damage to use on specific contact materials, a preliminary description of the use-wear can provide insight into the hardness of the materials being worked. Afterwards, I use hypothesis testing to answer individual sub-questions and provide the results of the statistical analyses required to answer these questions. I end on some observations of these results.

Lastly, Chapter 6 starts with a discussion of functional studies with an emphasis on a humanistic approach to experimental archaeology. I provide an argument stressing the importance of the experience in these activities and discuss how we generate new archaeological questions and potentially bolster our interpretations. Following this, I discuss the issues surrounding interpreting prehistory through experimental studies and the need for researchers to be conservative and wary of their interpretations. Next, I explore the preliminary observations about handaxe function at SM-1 by combining the results of my analysis with what we already know about the adaptive strategies of the SM-1 hominins. In the end, I describe confounding factors that may have affected my results and briefly recount my conclusions.

Chapter 2: Investigating Function in Lithic Technology

History of Use-wear Analysis in Lithic Technology

A primary goal in paleoanthropology is to understand hominin behavior. One way to accomplish this is through the study of lithic technology. Stone tools are some of the best evidence for hominin behavior because of their high preservation potential. Archaeologists are able to reconstruct a vast amount of information about our ancestors' behavior from an array of approaches within lithic analysis (e.g., typology, technology, reduction sequences, raw material sourcing). Major questions researchers attempt to answer through lithic technology include how and why stone tools were used within certain environmental contexts. In modern times, it is easy to observe how the environment affects the manufacture, use, and disposal of tools but this is much more difficult when interpreting the past.

There are four primary ways of investigating stone tool function: ethnographic comparison and analogy, experimental archaeology, residue analysis, and microwear analysis (Kimball et al. 1995). Ethnographic analogy relies on documentation of cultural tool uses for specific typologies. The combination of the latter three analyses have become essential in modern use-wear studies. Microwear and residue studies require microscopic analysis of the stone tool surface (Grace 1989; Hayden 1979; Kamminga 1982; Keeley 1980; Semenov 1964; Tringham et al. 1974; Vaughan 1985) and typically involve experimental datasets for comparison. This chapter will outline the history of use-wear studies in archaeology and explain the background to the use-wear approaches this research utilizes.

Low-Powered Approach

Since Sergei Semenov's seminal work in 1964, use-wear analysis has played an important role in investigating hominin tool use. Semenov (1964) was one of the first to explore tool function through experimental archaeology and microscopy, referring to it as "traceology". Early research involving use-wear analysis emphasized the low-powered method (Kamminga 1982; Odell 1981; Tringham et al.

1974), sometimes known as the “Tringham approach” because of Tringham et al.’s (1974) systematic study on the formation of edge damage from tool use. Low powered analysis is typically conducted using a stereoscope with magnifications between 25x and 100x. A stereoscope is a binocular microscope with two objective lenses that create a three dimensional image by merging the two separate images (left eye and right eye) into one, three dimensional view. Generally, low-powered use-wear studies focus on analyzing macroscopic edge damage such as microflaking and rounding (Grace 1996, 209). Microflaking is one of the many terms used for the scars on the edge of a flake or tool. These scars can be produced from both intentional use and non-use mechanisms such as trampling, accidental damage, or natural processes (Vaughan 1985, 11). Rounding is a term used to describe the flattening of a sharp edge. This can occur due to intentional use of the working edge or from other non-use factors, such as soil movement or rolling in water. Additionally, it is important to take into consideration the material being worked and the raw material of the stone tool. These factors, along with duration of use and intensity of use, can influence the relative degree of rounding.

Another part of low-powered use-wear analysis is the classification of the microfractures or microflaking (Grace 1996, 209). The classification varies between researchers but in essence is a specific description of individual microflaking scars. Vaughan (1985, 20) distinguishes between two classification approaches: one being an attribute classification and the second being a typological classification. The attribute analysis consists of describing the pattern of microflaking by noting the area of use, distribution along the edge, and proximal and distal cross-sections, whereas a typological classification such as that of Keeley and Newcomer (1977) describes microflaking at the smallest scale: the individual scar (Vaughan 1985, 20). Descriptions of individual scars are based on the morphology of the scar (Keeley 1980).

High Powered Approach

In 1980, Lawrence Keeley published his PhD dissertation, *Experimental Determination of Stone Tool Uses: a Microwear Analysis*, which utilized high powered microscopy to investigate use-wear. Due to his contribution, a high powered approach to microwear analysis is sometimes called the “Keeley approach”. The high powered approach has been adopted by many researchers and is one of the standard approaches in use-wear analysis (Fullagar 1991; Hardy 2004; Juel Jensen 1988; Keeley and Toth 1981; Marrieros et al. 2015; Rots et al. 2016). High powered microwear analysis differs from low powered in three major ways. First, rather than using a stereoscopic microscope, high powered microwear is conducted with compound microscopes such as a metallurgical microscope. These microscopes differ from stereoscopes in that they provide one optical path that is divided at the eyepiece to provide each eye with the same, two dimensional image; they are capable of reaching magnifications up to and sometimes greater than 1000x. For use-wear, high powered approaches typically use magnifications between 200-400x. Secondly, compound microscopes reflect light at a 90° angle to the surface and requires the objective lens to be much closer to the object. Unlike stereoscopes, as the magnification increases on a compound microscope the light intensity also increases which is important when looking for microwear (Keeley 1980). Third, high powered use-wear focuses on attempting to identify and classify polishes and striations formed from various types of materials such as hide, wood, bone, and antler (Keeley and Newcomer 1977; Marreiros et al. 2015; Vaughan 1985). Polishes, or micropolishes, are areas on the edge or edge surface of stone tools that appear bright when observed under a compound microscope. Since its conception, high powered studies have attempted to distinguish materials based off of distinct polishes while also trying to quantify the polish through computer-aided processing (Keeley 1974; Grace et al. 1985; Vaughan 1985). Striations are microscopic indentations or linear “scratches” that are found along the edges of stone tools. These are important because they can be indicative of tool motion. One of the major

shortcomings of the high powered approach is time it requires. The high powered approach can only analyze small parts of an edge at one time which makes analyzing a large sample size very difficult.

Scanning Electron Microscope (SEM)

The use of Scanning Electron Microscopy (SEM) was originally adopted by use-wear analysts to investigate the formation of micropolish, but has become another primary high powered approach to document stone tool surfaces. Meeks and colleagues (1982) and Unger-Hamilton (1984) utilized SEM to investigate micropolishes formed by plant materials. Another major use of an SEM was by Anderson (1980) to study polish formation and show that phytoliths stick to the polished surfaces. Anderson's (1980) work was a primary agent for the development of the silica gel model for polish formation. The silica gel model argues that the presence of micropolish is formed of silica gel through hydration of the stone surface (Grace 1989, 211). An alternative theory surrounding the formation of micropolish is the abrasion model. Proponents of the abrasion model argue that polish is formed from abrasive material wearing down the stone surface. A recent study by Monnier and colleagues (2012) attempted to use SEM to improve residue identification with some success. One downside to SEM is that it may require the item being scanned to be coated in gold which can make it expensive to analyze large samples.

Quantification of Use-wear

With the development of new technologies over the past two decades, use-wear analysis has seen a push towards quantifying use-wear signatures. Early studies attempted to do so using image-processing techniques for discerning micropolishes produced by different worked material (González-Urquijo and Ibáñez-Estévez 2003; Grace 1989; Grace et al. 1985; Newcomer et al. 1986). Grace and colleagues (1985) analyzed photographic images at 200x with a sampling area of 50 x 50 microns¹ and

¹ A micron is 1×10^{-6} or one millionth of a meter

focused on two surface texture features: CON and angular second moment (ASM). CON is the measure of the high scores along the diagonal whereas ASM is a measurement of homogeneity of the image (Grace et al. 1985, 114). Grace and others (1985; Grace 1989) argue that the results of the image analysis show that polishes are sometimes indistinguishable, particularly wood and antler. This has been shown to be the case in various blind test results (for an overview, see Evans 2014) and microwear studies. The methodology and conclusions produced by the authors (Grace et al. 1985; Grace 1989) were met with multiple criticisms (Bamforth 1988; Hurcombe 1988; Moss 1987). In response to these critiques, Grace and colleagues (Newcomer et al. 1988) rebutted the claims against them and defended the methodology of Grace's image analysis. However, over twenty years of research and new methods of quantification have shown that polishes are actually distinguishable from one another (González-Urquijo and Ibáñez-Estévez 2003; Kimball et al. 1995; Stemp and Stemp 2001) and the methodology of the image analysis used by Grace (Grace et al. 1985; Grace 1989) was flawed. More recently, Vergès and Morales (2014) used image-based techniques to create better documentation of SEM use-wear photographs, which aims to reduce expenses and potentially limit or prevent researchers from having to go back to the observation stage when asked for supplementary materials. The authors use a giga pixel image concept that is composed of at *least* one billion pixels.

Another attempt to quantify use-wear with imagery was a multi-faceted approach using imagery, Geographic Information Systems (GIS), and statistics. This method was created and applied by Bird and colleagues (2007). Rather than focusing on quantifying micropolishes, the authors attempted to measure and assess macroscopic "edge damage" distribution; therefore, rather than using high powered microscopy, this approach can be done with the naked eye or a simple stereoscope. This is significant because the method can be done during fieldwork. An early example of looking at edge damage distributions was by Shea (1993) in his analysis of impact fractures in Levantine Mousterian points. Bird and others (2007, 773) differentiate edge damage into two types: Type 1 being damaged as

retouch that displayed appropriate size, regularity, and contiguous removals, whereas Type 2 represents use-wear or taphonomic processes due to the irregularity in shape and size. The artifacts were divided by shape, raw material, and size. For the analysis, the researchers used 31 artifacts, particularly convergent flakes made of quartzite (Bird et al. 2007, 774). In order to digitize the artifacts, they were placed on a 5x5 mm grid to aid in rectification with the center of mass at (0, 0). Once digitized, the authors used ArcView GIS 3.3 to create polygons of the artifacts and edge damage scars with different colors associated with different edge damage. Additionally, a line was drawn underneath the artifact to designate the platform. To analyze the data, the authors used Image Tool and Rockworks to create rose diagrams and ran circular statistics tests (Kuiper's Test and Rayleigh's Uniformity Test) using the program called Oriana (Bird et al. 2007, 775). Kuiper's Test compares the distribution of the data to a desired distribution with a null hypothesis that the data is randomly distributed and the Rayleigh's Uniformity Test analyzes the preferred direction of the distributions. The authors note that a statistically significant result is one where the use-wear is not distributed uniformly and shows an unspecified preferred direction (775).

The methodology created by Bird et al. (2007) was expanded a few years later by Benjamin Schoville during his doctoral research at the Arizona State University and has been consistently refined over the past few years (Schoville 2010, 2014; Schoville and Brown 2010; Schoville et al. 2016; Wilkins et al. 2012; Wilkins and Schoville 2016). Focusing on lithic points at Pinnacle Point 13B in South Africa, Schoville (2010) explores the frequency and distribution of edge damage on convergent flakes and provides the description of the original methodology and the background for the future papers associated with his work. Some major differences between Schoville's methodology and that of Bird are the use of an experimental dataset (Schoville and Brown 2010; Schoville et al. 2016; Wilkins and Schoville 2016), the increased attention to taphonomic processes (Schoville 2014), and the visual representation of the statistical results. Additionally, Schoville explains that this methodology can be

done without expertise in use-wear analysis, which is a major benefit for new use-wear researchers (Schoville and Brown 2010). For this reason I felt that this methodology was a good starting point for this research. The methodology can be done without expert knowledge because the use-wear signatures being identified are supposed to represent “potential edge damage” or PED. The distribution of the damage is the indicator of use rather than the actual scars themselves. These interpretations are based on previous experimental work that have demonstrated that certain activities create edge damage with different distributions (Keeley 1980; Schoville 2010; Tringham et al. 1974). The edge damage frequency and distribution method has been criticized by Rots and Plisson (2014) for lacking multiple lines of evidence on individual tools to determine function. Additionally, they argue that Wilkins et al. (2012) have an “overoptimistic” interpretation of the evidence with various misinterpretations of the use-wear signatures (see Wilkins et al. 2015 for the response). Despite these criticisms, the methodology has a significant place in use-wear studies and can provide statistical insights into function at an assemblage scale.

Surface Metrology

Over the past decade, the quantification of use-wear has been aided by studies utilizing surface metrology. Surface metrology is the measurement and characterization of an object’s microtopography, usually with the aid of scanning or laser microscopy. With more researchers applying technology from other disciplines, more sophisticated ways to quantify and represent use-wear are becoming available. The major forms of surface metrology in use-wear studies are outlined below.

Laser Profilometry

Laser profilometry is another way researchers have attempted to quantify use-wear on stone tools. Stemp and Stemp (2001) were the first researchers to attempt to use a laser profilometer for the quantification of use-wear. In 2003, Stemp and Stemp documented various stages of polish formation

on experimental stone tools using this technology. This approach utilizes mathematic descriptions and a laser profilometer. A laser profilometer uses an optical focus technique with a height sensor to measure a surface's microtopography or texture based off of the confocal principle (Stemp et al. 2009). Stemp and colleagues (2009, 370) explains that the profilometer raises and lowers the objective to find the maximum intensity and generates a profile as it makes measurements across the surface. After the measurements are taken by the laser profilometer, the authors used fractal geometry – specifically a length-scale fractal analysis – to quantify the surface microtopography on various scales (Stemp et al. 2009).

Interferometry

The interferometer microscope was used by Anderson and others (2006) to study microwear signatures on the flint blades of threshing sledges. The authors used a vertical-scanning interferometer to obtain a section of light showing the surface topography of the stone tool. The reference arm of the tool scans the surface at varying heights, similar to some of the other methods mentioned in this chapter. Each position of observation corresponds to an image of a certain intensity of light which is then converted by an algorithm in the normal height Z (Anderson et al. 2006, 1565). This information is then displayed three dimensionally.

Atomic Force Microscopy

Atomic Force Microscopy was first applied to use-wear studies by Kimball and colleagues (1995). An Atomic Force Microscope (AFM) uses the atomic forces between two materials to digitally map a 3D surface with a resolution of 1 nanometer (Kimball et al. 1995, 10). The AFM requires the sample to be moved through piezoelectric ceramics which physically expands or contracts the material when voltage is applied. The voltages are then monitored and the digital map of the surface or microtopography is created. The maps can then be analyzed for grain size, height profiles, and surface roughness. Surface

roughness can be effective in portraying use-wear. The authors used high powered microscopy to identify microwear prior to using the AFM (10). Similarly, Faulks et al. (2011) use a combination of high powered microscopy and AFM to investigate microwear traces on Middle Paleolithic Mousterian tools from Weasel Cave, Russia.

Laser-Scanning Confocal Microscopy (LSCM)

The use of laser-scanning confocal microscopy was pioneered by Adrian Evans and Randolph Donahue in 2008. Their paper does an excellent job of explaining the principle behind the technique. The authors used an Olympus LEXT 3100 laser scanning confocal microscope (LSCM), which is typically utilized for metrology. The microscope creates an image through reflected light from a discrete focal plane (Evans and Donahue 2008, 2225). The position of each point recorded by the laser is then processed into a three dimensional representation. Evans and Donahue (2008) describe the LSCM as a tool that combines the traits of surface metrology, atomic force microscopy, laser profilometry, with the high magnification and depth of field offered by an SEM. Interestingly, the LEXT model the authors used for this study has the capability to scan the surface and edges of the tool at 200x, which allows for a traditional use-wear analysis to be conducted prior to the LSCM. More recently, Stemp et al. (2015) use LSCM to quantify experimental obsidian blades used to recreate Mayan bloodletting activities. With all of the new instruments being utilized, more research needs to be done to compare the effectiveness of the methods such as Evans and Macdonald (2011) who compare LSCM to differential focus microscopy.

Focus Variation Microscopy

The first use of focus variation microscopy was used within Evans and Macdonald's (2011) pilot study. In 2014, Macdonald furthered this study with the application of focus variation microscopy to an experimental dataset with an Alicona InfiniteFocus microscope. The principle of focus variation is that the microscope looks for the best focus by moving the objectives vertically in relation to the sample,

constantly bringing the object in and out of focus (Macdonald 2014, 28). A sensor within the microscope measures where the object was best in focus and does this repeatedly laterally to build an image.

Macdonald (2014) measures surface roughness and surface topography on eight experimental pieces.

This is a small sample set, which is a common criticism of experimental studies; however, given the amount of time these machines take to analyze the surface, it would be difficult to do much more. Focus variation microscopy seems to be the most promising method for future research and creates an amazingly accurate image of the stone tool surface.

Counterparts to Microwear

Two complementary ways to investigate function in lithic technology is through macrofractures and residues. In more recent studies, it has become common to have a multi-faceted approach to use-wear including low and high powered microwear analysis with various technologies, descriptions of macrofractures if applicable, and residue analysis. These three approaches in tandem can provide a much more holistic view of stone tool use at an archaeological site. Although residue analysis will not be a part of this thesis, it is possible for macrofractures to occur on handaxes from percussive activities (Viallet 2016a) so understanding them is important for identifying their presence within the assemblages.

Macrofractures

The counterpart to microwear analysis is the study of macrofractures. Macrofractures are fractures on stone tools that are visible with the naked eye or a hand lens and are typically associated with hunting activities that involve impact during use (Pargeter 2011, 2882). The isolation and definition of macrofractures was first explored by Fischer et al. (1984) through experimental replication of hunting activities. Certain macrofractures, known as diagnostic impact fractures (DIFs), can be indicative of use-wear produced by hafted hunting weapons (e.g., spears and projectile points) (Fischer et al. 1984;

Lombard and Pargeter 2008). In their early study, Fischer and colleagues (1984, 23) describe eight different macroscopic fracture types on projectile points. Pargeter (2011, 2882) explains that out of these eight different fractures, there are four primary diagnostic impact types: step terminating bending fractures; spin-off fractures that are greater than six millimeters; bifacial spin off fractures; and lastly, impact burinations. Fischer et al. (1984, 23) describe step-terminating bending fractures as fractures with a bending initiation that prior to meeting the opposite edge makes an abrupt change in direction to meet the surface at a right angle, whereas a spin off fracture is a cone fracture that starts from a bending fracture that removes some of the surface. Moreover, Lombard (2005, 284) states that spin-off fractures that occur bifacially from the same bending fracture are almost always produced from use with a hafted implement. To help strengthen evidence of hafting in the archaeological record, it has also been assessed using microwear signatures (Rots et al. 2006; Rots 2010). Hafted Levallois flakes with a bitumen adhesive have been documented from excavations at Middle Paleolithic sites Umm el Tlel and El Kowm in Syria (Boëda et al. 1996; Boëda et al. 2002; Boëda et al. 2008). This makes investigating hafting and prehension use-wear signatures at SM-1 a worthwhile future endeavor.

Residue Analysis

Residue analysis is primarily concerned with organic residues that adhere to the stone tool surface. Grace (1989, 5) describes residue analysis as the study of deposits on lithic technology that may or may not be related to use. This differs from use-wear studies in that these deposits can be from non-use factors. Generally, to determine whether or not these residues are adhering to the surface due to use, researchers have to assess the spatial relationship between use-wear signatures such as micropolishes or microflaking and the residues. In these studies, residues that are found include blood (Gurfinkel and Franklin 1988; Kooyman et al. 1992; Loy 1983; Loy and Hardy 1992; Nowell et al. 2016), plant matter such as phytoliths or plant fibers (Hardy and Garufi 1998; Jahren et al. 1997; Kealhofer et

al. 1999; Rots et al. 2015; Rots et al. 2016), and animal products such as meat, feather barbules, fish scales and hair fibers (Hardy and Moncel 2011).

There are various ways to go about conducting residue analyses including microscopy, chemical tests, and immunological methods. Further, Fullager and Matherson (2013) explain residue analysis is based on identifying chemical signatures, diagnostic microfossils, atomic structures, and genetic composition. Considering use-wear analysis is conducted with microscopes, one of the most common forms of residue analysis is with high powered microscopy. There are two approaches to the microscopic analysis of residues related to use and should be conducted in a specific order if possible. The first is detection and marking of residues on the stone tool surface; this is typically while they are being analyzed for use-wear (Langejans 2011; Langejans and Lombard 2015; Rots et al. 2016, 33). Langejans (2011) explores an important and underutilized approach which is a spatial analysis of residue and use-wear signatures on the stone tool surface. This methodology can visually show the spatial connection between use-wear and residues to bolster an argument for the deposition of residues by use related activity. The second method requires the extraction of residues from the surface for examination on a slide, which can be done with an ultrasonic bath or a pipette (Rots et al. 2016).

Approaches to Use Wear Analysis: A Question of Scale

When attempting to analyze an archaeological site for use-wear, it is important to determine the scale of the analysis because different approaches are required to answer certain questions about archaeological data. The two primary scales in use-wear are based around the assemblage and the individual artifacts. It is important for researchers to explicitly state their approach because they require completely different methodologies and interpretations. Typically, assemblage scale approaches utilize low-powered microscopy because they tend to be large sample sizes and high powered microscopy is very time consuming. Schoville and Brown (2010, 36) discuss the assemblage scale approach within their

methodology and argue that edge damage distribution is likely better represented statistically on a population of tools rather than on individual artifacts. Further, the authors argue that comparing distributions of assemblages minimizes observer errors, sampling errors, and use-wear equifinality. Equifinality is the idea that a result can be reached through different pathways, not just one. This is important to consider when thinking about prehistoric tool use and accounting for this issue is a significant contribution.

More recent approaches to use-wear consist of a multi-faceted workflow with multiple analytical methodologies described above. It has become normal to use both low-powered and high-powered approaches combined with residue analysis and experimental datasets. During her research on the Middle Paleolithic in France, Anderson-Gerfaud (1990) utilized low-powered and high-powered microscopy, SEM, and associated residues to interpret stone tool function. By using multiple forms of evidence, researchers are able to create a more holistic and better supported interpretation of stone tool function in prehistoric times. Additionally, the use of both quantitative and qualitative data should be strived for. For example, Stevens and colleagues (2010) use an LSCM with a multiple classifier approach which took into account both quantitative data from the LSCM and qualitative data looking at edge damage with a stereoscope. Moreover, Rots and Williamson (2004) combined use-wear, residue, and ethnographic/enthoarchaeological data to investigate function of an assemblage from Ethiopia.

Recently, Rots and others (2016) proposed a workflow for starting use-wear studies at an archaeological site that will be a primary reference for the current and future direction this project will take. The authors argue that the first step should be at the assemblage scale (Rots et al. 2016, 33). The researchers should analyze a large number of artifacts with low-powered microscopy in an attempt to document use-wear and residues to show they are not taphonomic and to make note of tools that should be looked at in further detail. A low powered approach does not require cleaning which means residues are able to be preserved for future analysis. The second stage in their workflow is a residue

analysis on the artifacts that were most likely used and have the best preservation. During this stage, the residues will be mapped and the researchers should evaluate the frequency of residues and their association with edge damage (Rots et al. 2016, 33). Third, the most relevant residues can be extracted using pipettes for more detailed analysis and identification. The fourth stage would be a more intensive use-wear analysis with tools being cleaned, possibly with an ultrasonic tank to save residues that were not extracted for future study (34). The authors argue that this approach will help make use-wear and residue studies time efficient and help guarantee a more reliable functional interpretation (Rots et al. 2016). Their workflow encompasses major parts of investigating function; however, they do not discuss including quantitative methodologies. There needs to be some form of quantitative analysis to be performed in conjunction with more traditional, qualitative approaches, to help strengthen researchers' interpretations.

Post-depositional Edge Modification

One of the major problem with use-wear studies is being able to decipher between post-depositional edge damage and behavioral edge damage created from use. There is a large body of literature surrounding this issue with various forms of experimental studies done attempting to assess the role post-depositional processes play in artifact damage. This issue is particularly apparent in approaches that deal specifically with edge damage distribution, such as Bird et al. (2007) and Schoville (2010), because it is at the assemblage scale. Moreover, based on research by Tringham et al. (1974), they consider a random distribution to represent taphonomic damage rather than attempting to replicate taphonomic processes in an experimental setting. McPherron and colleagues (2014) constructively criticized the approach created by Schoville (2010) and experimentally tested whether the distribution of taphonomic edge damage is random through trampling experiments. The authors find that not only is the edge damage distribution caused by trampling not random, they conclude that various factors affect the frequency and distribution of edge damage including raw material, edge angle,

and contact face (McPherron et al. 2014, 81). One discrepancy between their paper and Schoville's (2010) methodology is they do not use the same image-based GIS approach, they use a different imaging program to assess the distribution of edge damage. In his later publications, Schoville accounts for post-depositional processes through experimental research and model fitting (Schoville 2014; Schoville et al. 2016). Post-depositional processes not only create edge damage but can also form micropolishes. Early research on this issue conducted by Levi-Sala (1986) has shown that it can be highly difficult to distinguish between taphonomic and behaviorally created polish.

Blind Testing

Common criticisms of use-wear analyses stem from the qualitative and subjective nature of the method, which relies heavily on expert knowledge that varies between researchers (Shea 1987) and comparative experimental collections. Additionally, it can be difficult to determine the difference between post-depositional surface modifications and true use-wear signatures (Levi Sala 1986). According to the critical review of blind testing in archaeological science by Evans (2014), most researchers do not include post-depositional wear in their experimental protocol. This is an important issue when attempting to answer questions about use-wear on both the artifact and assemblage scale. Considering use-wear studies are primarily concerned with questions of human behavior and tool function, it is imperative for analysts to show that the use-wear signatures formed from deliberate use and are not taphonomic in origin

One way researchers are able to show the accuracy of use-wear methodology is through blind tests (Bamforth et al. 1990; Evans 2014; Lombard and Wadley 2007; Newcomer et al. 1986; Odell and Odell-Vereecken 1980; Rots et al. 2006; Wadley et al. 2004; Wadley and Lombard 2007). A blind test is an objective process of attempting to interpret use-wear signatures from experimental activities without having any knowledge of what activity the tool was used for prior to the analysis. Blind testing has been

used in various archaeological sciences (e.g., faunal analysis, palynology, and human osteology) to assess the accuracy of the given method (Evans 2014, 5). Although blind tests are supposed to help provide a means to increase the credibility of determining use-wear signatures, many tests have tended to do the opposite and have shown the unreliability of the method due to the researchers' inability to effectively discriminate between certain signatures (Rots 2010, 8). One of the most common misidentification occurs between bone or antler and wood. Evans (2014, 10) collated blind test data from past experimental publications and showed that 36.73% of blind test tools that were used for working antler or bone were misidentified for wood, and 28.57% of blind test tools used on wood were misidentified for bone/antler.

An important observation made by Evans (2014) is that blind tests can be used as a way to bolster and test the researcher's methodology and alternatively, it is a way to test the knowledge and credibility of the analyst. In the future of this research, blind tests will be employed as the experimental database grows. For the purpose of this specific study, the blind tests are not needed due to the nature of the approach. As previously stated, the methodology created by Bird and colleagues (2007) and expanded on by Schoville (2010) does not necessarily rely on expert knowledge. The method focuses on the distribution of edge damage at an assemblage scale to determine the occurrence of an activity rather than attempting to characterize specific uses from individual scars. However, considering no other researchers have adopted this methodology, conducting blind tests using the edge damage distribution approach might be worthwhile. By incorporating blind tests into this methodology, I can potentially assess how accurate this methodology is in determining functional activity and distinguishing between deliberate tool use and taphonomic edge wear. Due to time limits, blind testing will not be incorporated into this project but is a future endeavor in the overall research project.

Summary

Investigating function in lithic technology is one avenue of research that can provide researchers with insight to hominin behavior. This research typically involves a mixture of microwear analysis, experimental archaeology, and residue analysis. A major criticism of this type of research is that it is qualitative and highly dependent on expert opinion. Over the past 25 years, there has been an effort to quantify use-wear studies through new techniques and technologies such as Laser Scanning Confocal Microscopy, Focus Variation Microscopy, and other forms of surface metrology. These devices measure the microtopography of the stone tool surface and can potentially help discern nuances between use-wear signatures. Another promising avenue of research that this project is utilizing is an assemblage scale, image-based GIS approach to investigate edge-damage distribution of the handaxes at SM-1. This approach is a great starting point for learning use-wear because there is no characterization of edge-damage. The following chapter will provide a background to the Acheulean of Jordan and outline the history of functional studies surrounding handaxes in the archaeological literature.

Chapter 3: Contextualizing the Acheulean at Shishan Marsh - 1

Introduction

Present day Jordan is in a region known as the Levant which includes Israel, Syria, and Lebanon. This region is critical to understanding the evolution and dispersal of the hominin lineage because it lies at the cross-roads of Africa, western Asia, and Europe. The Levant has a rich archaeological record and provides some of the earliest evidence for hominins outside of Africa at the archaeological site 'Ubeidiya, which dates to approximately 1.5 million years ago (mya) (Tchernov 1988; Repenning and Fejfar 1982). In a broader regional context, Dmanisi, an archaeological site in Georgia, is the earliest known evidence of hominin expansion in western Asia, dating to approximately 1.8 mya (Gabunia et al. 2000). The hominin remains at both sites are attributed to *Homo erectus/ergaster*. The dispersal of hominins out of Africa would have required access to water and calories to ensure survival and reproduction. The Middle Pleistocene archaeological site, Shishan Marsh – 1 (SM-1), in al-Azraq, Jordan provides a unique insight into a specific environmental context – a desert refugia – that likely would have facilitated the dispersal and survival of hominins in the region. More importantly, SM-1 offers an opportunity to investigate the behavioral and technological adaptations of these Middle Pleistocene hominins within this environmental context through stratified *in situ* Acheulean artifacts (Nowell et al. 2016). This chapter will begin with a discussion of the Acheulean industry in a global context to identify the gap in the archaeological literature surrounding handaxe function. Next, I will discuss some major Acheulean sites within the Levant. Finally, I will contextualize the archaeological assemblage at SM-1 in relation to other Acheulean sites in Jordan.

The Acheulean in a Global Context

Generally, the Acheulean is a stone tool industry dominated by bifacial tools (flaked on both sides) known as Large Cutting Tools - or Long Core Tools (Shea 2017) – commonly abbreviated LCTs. The Acheulean is the longest lasting toolkit in human evolution and spans across all of the Old World. The

unchanging toolkit of the Acheulean across time and space has led to archaeologists to consider it static and homogeneous (Isaac 1972). In consideration of this “technological conservatism”, Nowell and White (2010, 70) argue that our inability to see trends within the Acheulean over time and space is partially due to weak chronology and scattered datasets. Even within the longer and more established chronologies, any trends will be lost because these datasets are likely created over many generations (Nowell and White 2010, 71). Despite the shortcomings of the archaeological record, Nowell and White (2010, 72-73) posit that there is much more variability within these assemblages than what is normally discussed and the various tool modifications within are due to “inventiveness” and the adaptability of the Acheulean toolkit which catered to the mobile lifestyle of these hominins.

Typically LCTs are defined as symmetrical artifacts, typically greater than 10 cm long, found in the archaeological record after 1.6 mya (Shea 2013, 55). Shea (2013, 55) recognizes five major types of LCTs: picks, handaxes, cleavers, protobifaces, and massive scrapers. A pick is an elongated bifacial core with a thick distal tip formed where two concave edges meet. The tips of picks can be retouched on up to three (trihedral pick) or four sides (quadrihedral picks). A handaxe is a large bifacial core with fairly straight edges that converge to create a sharp symmetrical distal point (Shea 2013, 58). There are many sub-types of handaxes designated by researchers that describe overall shape (e.g., ovate, Micoquian, limande, cordiform). A cleaver is an elongated bifacial core or flake with a distal end that has a broad edge transverse to the long axis. This edge is generally unretouched (Shea 2013, 60). A protobiface is a pointed core that is less than 10 cm with a blunt proximal end with remnant cortex. These are argued to have been elongated discoid bifaces or sometimes considered heavily resharpened or used LCTs (Shea 2013, 60 citing Jones 1994). Shea (2010, 50) describes protobifaces as an intermediate form between pebble-cores and LCTs. Massive scrapers or “core-scrapers” are flakes longer than 10 cm, with steep unifacial retouch along one or more of the edges (Shea 2013, 60). These massive scrapers primarily

differ from other types of scrapers mainly in their size. The hominins most associated with the Acheulean industry are *Homo erectus sensu lato* and *Homo heidelbergensis*.

The Handaxe Dilemma

Although handaxes have been found as far as East Asia, there is a difference between handaxes manufactured in Africa and Europe, and those found east of India. Originally, it was observed that there was a complete absence of complex tools such as handaxes and prepared cores in eastern Asia – this was first described by Hallam Movius in the 1940's, which led the phenomenon to become known as the "Movius Line" (Lycett and Norton 2010, 55; Movius 1948). Movius argued that the hominins in East Asia were in a "cultural backwater", with technology and culture that was inferior to that of Europe, Africa, and western Asia. More recent research in this area has led to the discovery of handaxes in many East Asian assemblages such as Chongokni in Korea (Norton 2000: 814). Although the discovery of handaxes in East Asia provides evidence against the existence of the Movius Line *sensu stricto*, there is still an obvious difference in both frequency and form between handaxes in East Asia and the western areas of the Old World (Lycett and Norton 2010, 56). Christopher Norton and colleagues proposed that the "Movius Line *sensu lato*" should replace the "Movius Line *sensu stricto*" due to three features of the archaeological record in East Asia: a lower frequency of handaxes compared to East Africa and India, a lower percentage of bifaces per site, and a difference in morphology (Norton et al. 2006, 534). Handaxes in East Asia tend to be thicker and less refined with little invasive flaking (Lycett and Norton 2010, 56). An interesting argument for these differences is the use of bamboo as a raw material rather than the poor crypto-crystalline river cobbles present in East Asia (Bar-Yosef et al. 2012; Pope 1989; West and Louys 2007). Bar-Yosef and colleagues (2012) experimentally test whether or not the low grade raw materials would have been successful at processing bamboo and found that bamboo knives can be created but were unsuccessful in cutting thicker hides. Additionally, there is variation in the quality of bamboo which is a constraint in itself (Bar-Yosef et al. 2012, 19). Petraglia and Shipton (2008), however,

argue that there are some overlapping similarities between crude handaxes west of the Movius Line and those found to the east.

The stagnant nature of the Acheulean and the similarities between handaxes across the world is an interesting phenomenon despite the differences in frequency between both sides of the Movius Line. The similarities and variability within handaxe form across continents has led to many arguments involving cultural transmission (Lycett and Norton 2010; Lycett and Gowlett 2008; Lycett et al. 2016; Richerson and Boyd 2005; Wynn and Tierson 1990), function (Roe 1981), raw material (Eren et al. 2014; White 1998), reduction during resharpening events (artifact life histories) (Archer and Braun 2010; Iovita and McPherron 2011; Li et al. 2016; McPherron 1994, 2000; Shipton and Clarkson 2015), and the fact that there is a limited spectrum of modifications possible within this technocomplex (Nowell and White 2010). Although it is not a new idea (see Richerson and Boyd 2005), more recently researchers have started to take the argument that there is a genetic component to handaxe form more seriously (Corbey et al. 2016). Supporting this view, Tennie et al. (2016) show that a high-fidelity (i.e., accurate) transmission model – or one that requires teaching and imitation – for early Paleolithic technology is not viable and likely involves biological, cultural (excluding high-fidelity transmission), and environmental factors. The combination of these three factors is known as “triple inheritance” (Odling-Smee et al. 2003). This conclusion, along with Machin’s (2009) results of her exploration of the complex factors that result in handaxe form (e.g., the individual, function, knapping skill level), suggests researchers need to approach this topic with a multi-faceted and possibly inter-disciplinary perspective.

One approach to this question that has been given little attention is function. Functional studies are not absent in the Paleolithic (Hardy et al. 2001; Lemorini et al. 2006; Shea 1988), but tend to focus on flakes or small tools such as scrapers or points. The function of handaxes has been speculated for the past fifty years but very little experimental work has been done to examine these hypotheses (Nowell and Chang 2009; Roe 2006, 320; Whittaker and McCall 2001). Researchers have argued that

handaxes are multifunctional tools (Keeley 1980; Keeley and Toth 1981; Posnansky 1959) which are well suited for butchery, woodworking, and other tasks. These activities are thought to be undertaken with handaxes being used in the hand rather than being hafted (Shea 2007). Some examples of unambiguous evidence of handaxe use in the archaeological record are those found with phytoliths from Peninj, Tanzania (Domínguez-Rodrigo et al. 2001), protein residue from rhinoceros and horse found on two handaxes from the Shishan Marsh in Jordan (Nowell et al. 2016), and animal fat on one biface at Revadim in Israel (Solodenka et al. 2015). These findings support the idea of handaxes being used on various materials across the world. Another hypothesis is that handaxes were used as projectile weapons (O'Brien 1981; Samson 2006). Whittaker and McCall (2001) tested this hypothesis and their results show the handaxes did not always land on edge, they had unpredictable flight paths, and there is no evidence for edge damage similar to that of projectiles (see also McCall and Whittaker 2007). Additionally, researchers have proposed that handaxes are core tools which serve as a source of flakes while still keeping their functionality as a tool itself (Shea 2007, 220). Lastly, Kohn and Mithen (1999) propose that handaxes are a result of sexual selection and "costly signaling." This argument is difficult to test in the archaeological record, especially since we cannot know how extinct hominins made mating decision (Nowell and Chang 2009, 84). Furthermore, Nowell and Chang (2009) refute this hypothesis arguing that the variation seen in handaxe shape is from various factors and cannot be explained by a single mechanism like sexual selection.

Functional Studies of Handaxes

One of the earliest experimental studies that incorporated handaxes was conducted by Keeley (1980), in which he utilized handaxes in four different experimental settings. The handaxes replicated for his study are similar in size to those used in this study (approximately 10 cm long and 6 cm wide). The first handaxe used in his experimental work was for digging in sandy, alluvial topsoil (Keeley 1980, 79). Keeley notes that at 10 minutes only slight abrasions were noticeable and by 20 minutes the tip was

crushed with deep striations. The second experimental handaxe was used for cutting meat. Keeley (1980, 81) describes the use wear signatures of this activity to be primarily polish with utilization damage being difficult to distinguish from retouch. Regardless, he explains that the traces found are very similar to those found in experimental flakes used for meat cutting. The third handaxe was used to scrape and cut pig fat off of a hide. Keeley (1980, 82) notes that this action caused rounding and deep striations, with very little micropolish formed. The last experiment Keeley conducted was cutting and breaking through joints in a bovid vertebral column. During this activity, there was heavy edge damage and invasive scars that led to the tip being broken (1980, 82). After the experiments were outlined, Keeley (1980) argues that the handaxes were excellent for accomplishing these tasks and two insights were clear from these results: wear traces on handaxes are comparable to those that form on flakes; and the severe wear traces formed by intense activities such as digging are easily recognizable in the archaeological record. This experimental work helped show the various tasks at which handaxes can be used efficiently.

Since Keeley (1980), approximately fifteen publications have investigated handaxe function – less than half of which consist of an experimental work. Of this research, there seems to be three overarching approaches to investigating handaxe function: first, a traditional microwear approach (Binneman and Beaumont 1992; Claud 2008; Claud et al. 2015; Ollé et al. 2014; Lambert-Law de Lauriston 2015; Solodenka et al. 2015; Viallet 2016a, 2016b); second, a macroscopic approach that considers handaxe function by describing functional edges with or without performing experiments (Albrecht and Müller-Beck 1988; Machin et al. 2005, 2007; Mitchell 1995; Phillipson 1997); and lastly, an approach that investigates use and cutting efficiency rather than overall function (Galán and Domínguez-Rodrigo 2014; Key and Lycett 2015, 2016a, 2016b). Due to these different approaches, the results illustrate various aspects of handaxe functionality. The microscopic evaluation of edge damage and polish helps determine contact material and angle of tool use; the macroscopic approach has

implications for activity and zones of use through edge symmetry and distribution of functional edges; and lastly, the lab setting approach allows for an investigation of cutting efficiency and tool manipulation with a large sample size.

Microwear Studies

The microwear studies of handaxes have resulted in various interpretations of prehistoric handaxe function. Claud (2008) argues that prehistoric handaxes with convergent points were used for butchery and those with transverse distal ends were for woodworking. Additionally, she argues that their function changes through their use-life, with small discoidal bifaces being used for retouching other tools. More recently, Claud and colleagues (2015) investigate flake cleaver function in the Middle Paleolithic. Although cleavers are not the primary focus of this thesis, her work is relevant because of the experimental activities conducted within her research such as the inclusion of “percussive activities” which produce large, invasive scars, and crushing of the edge (Claud et al. 2015, 115). They argue that cleavers were specialized for these high intensity activities on medium-hard materials that are specific to environmental contexts (125). Binneman and Beaumont (1992) utilized a high powered approach to analyze micropolish on handaxes from Wonderwerk Cave in South Africa. The authors argue the micropolish is from working plant material – possibly sedge worked under “dirty” conditions, wood worked with abrasive materials present, or various other plants worked under “clean” conditions (Binneman and Beaumont 1992, 95). In their conclusion, the researchers posit that the handaxes were possibly used to cut wood or bedding and potentially for manufacturing wooden spears or pointed sticks (Binneman and Beaumont 1992, 96).

Functional Edges

The analysis of functional edges in the second approach to handaxe function uses qualitative descriptions of handaxe edges to describe the various possible cutting edges on the tool. The

methodologies between each study varies, but all of which are concerned with functional edges rather than edges that have evidence of utilization. Albrecht and Müller-Beck (1988) analyze individual handaxes for possible functional edges and mapped them on drawings of the artifacts. An important observation by the authors is the potential for a cutting edge to be present near the base of the handaxe. Alternatively, Machin et al. (2007) divided the edges of 60 experimental ovate and cordiform bifaces into various sections and used video footage of people using handaxes to score their effectiveness. There was a total of 15 variables analyzed from 18 hours of video footage. Their results show that handaxes become less effective during use and that higher tip symmetry increases the effectiveness of handaxes as butchery tools (Machin et al. 2007, 891). These results are interesting and potentially have implications for tip shape and function. Possibly even more enlightening is that there is no statistically significant results for lateral symmetry and effectiveness for butchery. This might support the idea that the mesial-distal end of handaxes are used for butchery. Contrary to this argument, Mitchell (1995, 67) found that a butcher using a handaxe to process a deer thought the tip was the least effective part and preferred using the tool from base to tip, in an “arc” motion.

Factors Affecting Handaxe Use and Effectiveness

The last category of studies investigating handaxe function involves highly controlled laboratory experiments. Rather than testing questions of prehistoric function, this approach deals with answering questions about the morphology of handaxes and their use. Key and Lycett (2015) investigated the differences in efficiency between large flakes, small flakes, and handaxes in a laboratory setting (e.g., tasks were cutting rope, cardboard). The authors found that handaxes were more efficient at completing large, difficult tasks, whereas flakes were more efficient at smaller tasks. Despite this finding, they note that there was very little difference in efficiency between flakes that were similar in size to handaxes. Expanding this research, Key and Lycett (2016a) explored the influence of handaxe size and shape on cutting efficiency with a sample size of 500 bifaces that have a high degree of variation in morphology.

Their results show that there is no obvious evidence that shape and size has an impact on cutting efficiency (2016a, 24). However, Key and Lycett (2016a) show that there is a threshold for effectiveness and the small handaxes were less efficient than larger and heavier tools. Additionally, Key and Lycett (2016b) used biometrics to find that hand size is a strong predictor of handaxe efficiency.

Current Approach

All of these approaches have elucidated various components of handaxe use and functional potential but none have attempted to quantify the distribution of use-wear at an assemblage scale. Understanding how use-wear is distributed at a large scale can help archaeologists shed light on the types of activities these tools were used in (e.g., chopping, sawing, butchery) and make more robust behavioral interpretations. Moreover, the assemblage scale approach can allow for comparisons of handaxe function across environmental contexts because the focus of the interpretation is on activity rather than contact material. Considering handaxes have a massive spatio-temporal range, they were likely used on numerous materials in their surrounding environment. This makes large scale comparisons difficult because the materials hominins were processing will naturally vary between environments. By investigating function through activity, comparing *how* tools were used – regardless of on what – opens an avenue of research that can help expand our understanding of functional variation within and between archaeological assemblages and typologies.

Acheulean of the Levant

The Acheulean of the Levant dates from approximately 1.5 million to 250,000 years ago (Shea 2013). Within Near Eastern contexts, Gilead (1970) divides the Acheulean into three stages: the Early Acheulean, the Middle Acheulean, and the Upper Acheulean.

Two major Early Acheulean assemblages in the Levant are found at the archaeological sites 'Ubeidiya (Bar-Yosef and Goren-Inbar 1993) in the Jordan Valley and Latamne in Syria (Clark 1967). The

earliest sequence at 'Ubeidiya dates to approximately 1.5 million years ago (Tchernov 1988; Repenning and Fejfar 1982) whereas Latamne is suggested to date from approximately 700 – 500 kya (Bar-Yosef 1994, 240). The paleoenvironmental data at 'Ubeidiya indicates an alluvial and deltaic history with a fluctuating lakeshore (Bar-Yosef 1994). The lithic artifacts were created using basalts, flint, and limestone. Each raw material was used to create a different tool type: core-choppers and smaller tools were made of flint, handaxes were made out of basalt, and limestone was used to make spheroids (Bar-Yosef 1994, 232). In the earliest layers bifaces are absent, however, they are present in various frequencies throughout the other layers. Bar-Yosef and Goren-Inbar (1993, 144) describe the majority of bifaces found at 'Ubeidiya as Abbevillian – with a pointed distal end and a proximal end of primarily cortex. The assemblage lacks true ovates, but contains “irregular ovates”, along with proto-bifaces, picks, cleavers, and “square butt bifaces” (Bar-Yosef and Goren-Inbar 1993, 147). Similar to 'Ubeidiya, the artifacts found at Latamne were made of flint, limestone, and basalt (240). Clark (1967, 220) describes Latamne as a waterside site with Middle Pleistocene hominins doing various activities with specialized tools and possibly using local large blocks of limestone for shelter. The assemblage at Latamne (n = 370) consists of 36% bifaces (Bar-Yosef 1994, 240). The Latamne bifaces were primarily lanceolate and elongated ovates with sinuous edges (Clark 1966). Twenty-eight of the bifaces are pointed and twenty-one have transverse or obliquely truncated ends which Clark (1966) describes as “ultra-convergent cleavers”.

Gesher Benot Ya'acov (GBY) is an important and well documented Middle Acheulean site located in the upper Jordan Valley on the border of present day Jordan and Syria is (Bar-Yosef 1994, 241). GBY dates to OIS 19, approximately 780,000 years ago, and is unlike most other Levantine Middle Acheulean sites in that it consists of an African-type lithic assemblage (Goren-Inbar et al. 2000). Interestingly, the bifaces were minimally modified and manufactured on large flakes created with the Kombewa and Levallois technique which makes them the first such found outside of Africa (Goren-Inbar

et al. 2000, 946). Just as we see at 'Ubeidiya and Latamne, the three primary raw materials used for manufacturing stone tools are limestone, basalt, and flint. The flint was used for cores, flakes, and flake tools, basalt was used for handaxes and cleavers, and the limestone was used to make chopping tools (Goren-Inbar et al. 2000, 946). Additionally, GBY has some of the earliest evidence for controlled use of fire in the Middle Pleistocene in the form of burned flint, wood, and seeds in discrete locations throughout the site (Goren-Inbar et al. 2004). Considering the assemblage is unlike anything found throughout Eurasia at this time, and the fact that hominins were already present in the Levant at 1.5 million years ago, it is likely that the hominins at GBY represent a separate dispersal out of Africa with a different technology (Goren-Inbar et al. 2000, 947).

Although most Late Acheulean sites in the Levant come from surface finds, early insights into the Late Acheulean come from Berekhat Ram in the Golan Heights of Syria (Goren-Inbar 1985) and the Tabun cave site in Mount Carmel, Israel (Jelinek 1982). The Berekhat Ram assemblage was primarily made on flint, with only one artifact made of basalt, which differs from earlier Acheulean sites in the Levant such as 'Ubeidiya and Latamne (Goren-Inbar 1985, 12). The lithics are dominated by debitage with only about 4-7% shaped tools. Of the 7% of shaped tools, bifaces comprise of only 1.98% (n = 8). There are five amygdaloids, one discoid, and two nucleiform. Only one biface has cortex, approximately 0-20%, with the rest of them being completely worked. Based on the drawings by Goren-Inbar (1985, 6) almost all of the bifaces have a square edge on the proximal end, which is a common trait within the SM-1 assemblage. The Tabun assemblage has produced an extensive Lower and Middle Paleolithic archaeological assemblage with almost 2,000 bifacial tools present (McPherron 2003, 58). Within McPherron's (2003, 60) re-analysis of the Tabun bifaces, he describes the typology as "relatively thick, broad, and more rounded than pointed." The bifacial assemblage has amygdaloids, thick ovates, thick discoids, diverse, and a substantial amount of cleavers with tranchet removals or distal retouch (60).

Similar to some bifaces at SM-1, McPherron (2003) notes the presence of double tranchet removals which requires a tranchet blow from both sides of the tool.

The Acheulean of Jordan

In Jordan, the major Acheulean sites typically post-date 500,000 years ago (al-Nahar and Clark 2009). The low frequency of early Acheulean sites in Jordan is due to post-depositional transportation throughout the wadi systems (Olszewski 2001). Considering the lack early sites in Jordan there is no undisputable evidence for the Oldowan (al-Nahar and Clark 2009). Although there are no *in situ* Early Acheulean sites in Jordan, surveys along Wadi as-Sirhan by Whalen and Kolley (2001) have found Early Acheulean artifacts such as choppers, cleavers, picks, scrapers, and other small tools with no handaxes present. Following al-Nahar and Clark's (2009, 4) review of the Lower Paleolithic in Jordan, I am dividing

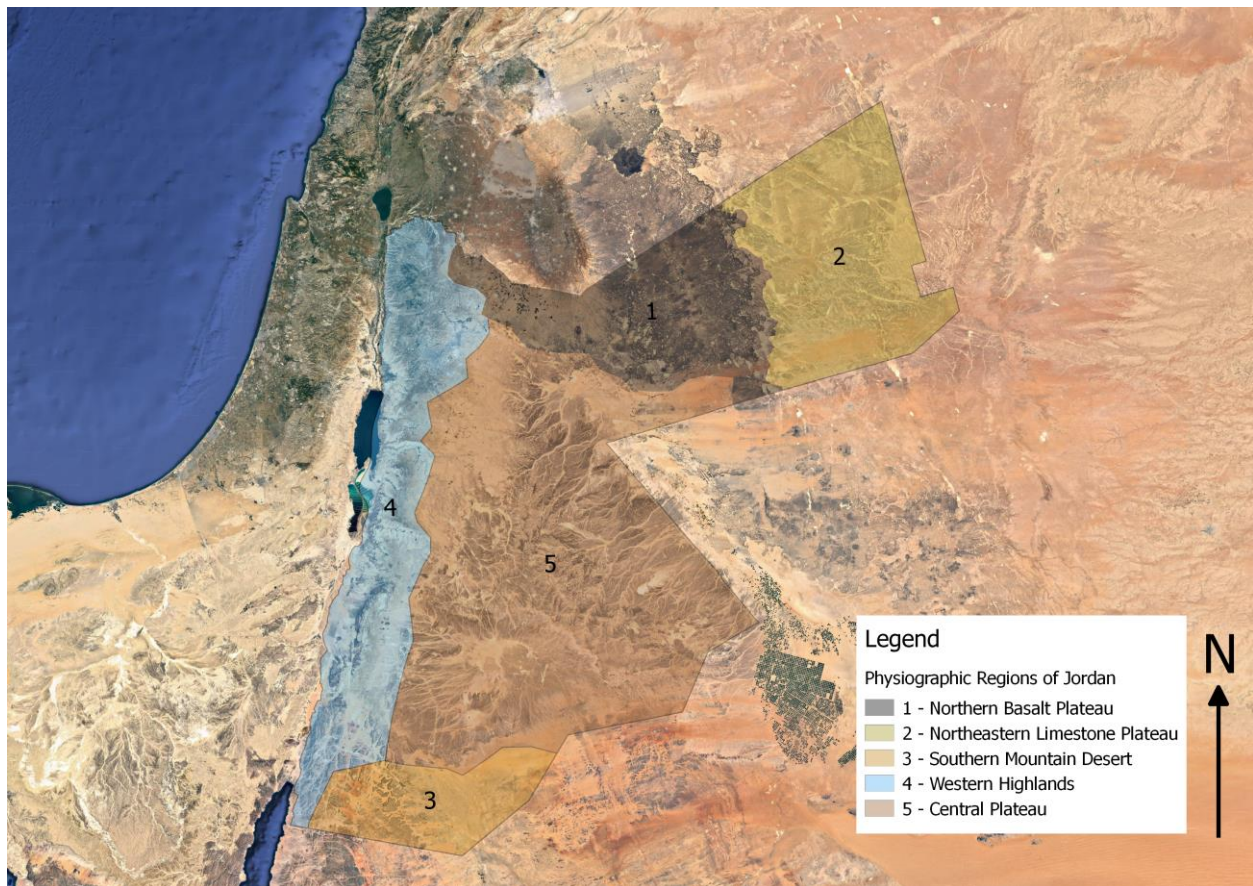


Figure 3.1 – Physiographic regions of Jordan (modified from al-Nahar and Clark 2009)

Jordan's landscape using Macumber's (2008) five physiographic provinces: the Central Plateau (the Jafr and Azraq/Wadi Sirhan basins), the Northern Basalt Plateau, the Northeastern Limestone Plateau, the Southern Mountain Desert, and lastly, the Western Highlands (Figure 3.1). For this research, the Central Plateau, the Southern Mountain Desert, and the Western Highlands will be compared. Considering most of the data we have from the Early Acheulean in Jordan is from surveys, the primary focus of this section will be on the Middle and Late Acheulean sites.

The major Acheulean sites in Jordan are found in the Central Plateau, the Southern Mountain Desert, and the Western Highlands. The Central Plateau is one of the most important areas for this research because SM-1 is found there, along with major Acheulean sites Lion's Spring, C-Spring, 'Ain el-Assad, and 'Ain Soda. The Southern Mountain Desert has only one major Acheulean site, Wadi Qalkha (Henry 1982). The major sites found in the Western Highlands are Fjaje and the Mashari'a site cluster.

Southern Mountain Desert

Wadi Qalkha is a Late Acheulean surface site found in Southern Mountain Desert province of Jordan. 66 artifacts were recovered with light patination (Henry 1982). The Wadi Qalkha lithic assemblage is dominated by chert bifacial tools with some retouched pieces, scrapers, notches, perforators, and truncations. In particular, the bifacial assemblage consists of 50% cordiforms, 20% lanceolate, 20% amygdaloid, and 10% irregular. Of these forms, there are two broad sizes of bifaces – 10 cm or greater in length and a smaller size group – that are comprised of different shapes with amygdaloids being the only commonality. The larger group consists of cordiforms and the smaller group is mainly ovates, irregulars, and some broken bifaces (Henry 1995, 44). Interestingly, almost all of the bifaces were manufactured from large flakes rather than being reduced from cores (Henry 1982, 420). The specimens have regular, non-sinuuous edges with marginal retouch (Henry 1995, 44). The high proportion of bifaces in association with Levallois technology supports this site as a Late Acheulean

occupation, however, the high proportions of side scrapers brings up the possibility of an affiliation to the Acheulo-Yabrudian industry (Henry 1995, 44). Henry (1995, 47) argues that the assemblages found within Wadi Qalkha differ from those found in the Azraq Oasis, such as 'Ain el-Assad, due to its lack of Levallois technology and its large cleaver component. He argues this is due to the difference in environmental setting, with the oasis sites requiring different foraging activities than the higher elevation sites such as Wadi Qalkha. Contrary to this observation, recent excavations such as those at SM-1, have revealed Levallois technology within the Azraq Oasis in the Upper Acheulean

Western Highlands

The Mashari'a site cluster is located at in the northern portion of the Jordan Valley in the Western Highlands and contains five occupational layers. Mashari'a 2, 4, and 5 are stratigraphically older than 1 and 3 found within the lower conglomerate (al-Nahar and Clark 2009). Mashari'a 2, 4, and 5 are undated but thought to be around 560,000 years old based on the similarities between handaxes found in Mashari'a 4 and those in Latamne (al-Nahar and Clark 2009). Mashari'a 1 and 3 are a part of the Tabaqat Fahl Formation (al-Nahar and Clark 2009). Mashari'a 1 is the most significant of the sites and is an open air *in situ* Late Acheulean occupation (Macumber and Edwards 1997, 27) within a resource rich spring or marsh area (al-Nahar and Clark 2009). The chert artifacts collected are primarily biface-thinning flakes, notched flakes, retouched flakes, and retouched scrapers, with very few bifaces present. The bifaces found were Micoquian, cordiform, ovate, and "D-shaped" (Macumber and Edwards 1997, 28). The high presence of biface-thinning flakes and low number of bifaces suggests the tools were curated or manufactured there and transported to another area in which they were used and discarded (al-Nahar and Clark 2009).

Fjaje is a Late Acheulean surface site that spans over 20km in the Western Highlands and is thought to be in primary context, but not *in situ*, because the artifacts are deflated in place rather than having been moved by fluvial action (al-Nahar and Clark 2009). The bifacial assemblage includes 159 bifaces with a relatively high frequency of lanceolate, cordiform, ovate, and diverse classes with very little cleavers (Rollefson 1981, 7). Rollefson (1981, 9) indicates the presence of “D-shaped” bifaces which are rare but found at Tabun and ‘Ain el-Assad. Most of the bifaces are non-cortical (73%) and patinated (82.4%) (Rollefson 1981, 15). Additionally, 24 of the bifaces underwent considerable chemical and physical post-depositional alteration, leaving them with a chalky texture. Overall, the Fjaje assemblage has a consistent distribution of biface types which contrasts with other Acheulean sites within Jordan which typically are dominated by one or two bifaces types (Rollefson 1981, 18). Rollefson (1981) concludes the overall lithic assemblage at Fjaje is most similar to Tabun Bed 80 and differs from sites such as ‘Ain el-Assad, supporting the idea that the non-bifacial components are just as important as the bifaces in development of the Levantine Acheulean (Rollefson 1981, 20).

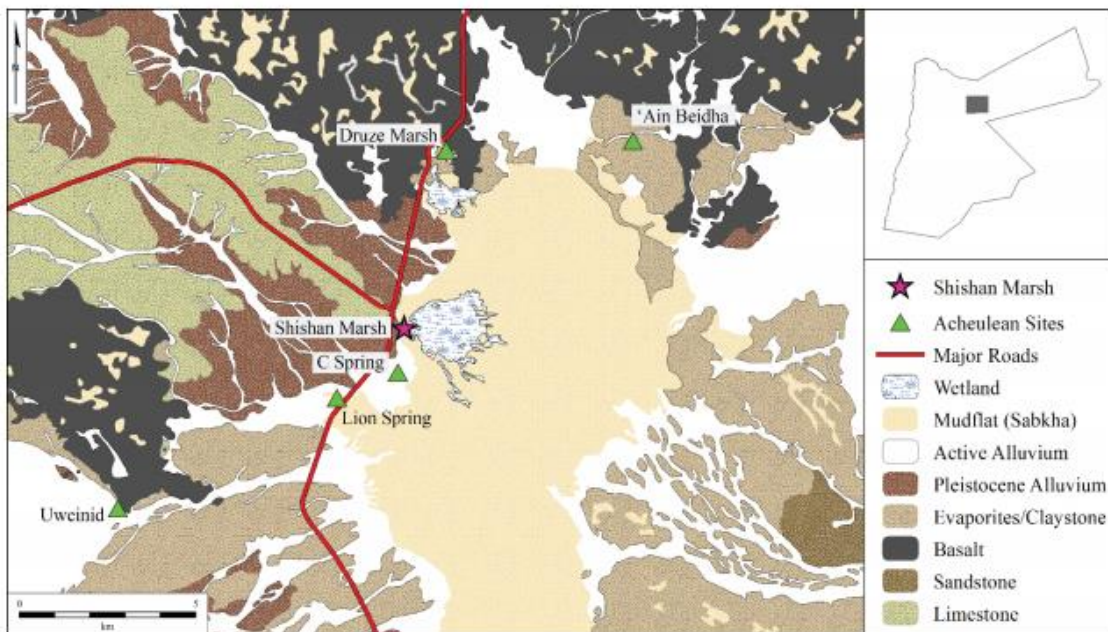


Figure 3.2 - Azraq region of Jordan with designated Acheulean sites (Figure by Dr. Chris Ames with permission of Dr. April Nowell).

Central Plateau

The most important region within the Central Plateau is a wetland oasis in present day Azraq that consists of two major springs: the northern Druze Marsh and the southern Shishan Marsh (Figure 3.2). Combined, this zone is known as the Greater Azraq Oasis Area (GAOA) (Cordova et al. 2013). Both marshes dried out in the 1980's and the Druze Marsh has remained that way ever since (El-Naqa 2010). However, the Shishan Marsh has been revitalized and maintained through conservation efforts by the Royal Society for the Conservation of Nature (France 2010). The GAOA has significant archaeological sites ranging from the Lower Paleolithic to the Neolithic (Copeland 1988; Copeland and Hours 1989; Garrard 1975; Rollefson et al. 1997; Richter et al. 2009). In the Shishan Marsh, surveys and excavations include sites such as C-Spring (Copeland 1988, 1989), 'Ain el-Assad or Lion's Spring (Rollefson 1983), and 'Ain Soda (Rollefson et al. 1997). The Druze Marsh has produced similar archaeological material as the Shishan Marsh (Ames and Cordova 2015; Ames et al. 2014; Cordova et al. 2009). This region would have acted as a desert refugium for populations in the surrounding region. Generally, a refugium is an area where populations are able to survive adverse or variable climatic periods. Cordova et al. (2013, 97) explain that a desert refugium is a spring, lacustrine basin, or floodplain found in a dryland region where there was a concentration of vital resources that would have been difficult to find in the surrounding region. Moreover, Brown et al. (2013) argue that wetlands and floodplains provide access to a diversity of both macronutrients and micronutrients from plants and animals, including aquatic resources, making it an optimal niche for hominins that promotes reproductive success and population stability. Maintaining population size and fertility is essential for increasing cultural complexity and sustaining innovations within a population, which in turn can help facilitate or sustain dispersals into new regions and environments (Lycett and Norton 2010). Therefore, a desert refugia would have provided a highly resource rich area that would have attracted and sustained hominin populations during dispersal events out of Africa.

Preliminary survey results of the Azraq region conducted by Garrard et al. (1975) produced many sites ranging from the Lower Paleolithic to the Chalcolithic. In their first locality, the researchers found Acheulean discoidal bifaces, pointed bifaces, and Yabrudian-like racloirs made of black chert patinating to grey. Physically, this raw material seems to be similar to that found in SM-1. All together their survey found 11 sites with Acheulean/Yabrudian and/or Middle Paleolithic lithic technology and an additional nine localities with probable Lower-Middle Paleolithic assemblages (Garrard et al. 1975, 119). The major localities within the Azraq Basin are outlined below, some of which were further explorations of these previous surveys.

C-Spring is an archaeological site in the Azraq Basin where Lower and Middle Paleolithic artifacts and animal bones have been found. The faunal assemblage includes *Equus hemionus*, *E. hydruntinus*, *Camelus dromedaries*, *Boselaphus* sp., *Alcelaphus* sp., *Dicerorhinus* sp, and large bovids (Garrard et al. 1987, 17). These species are primarily identified by the remains of teeth and were first described by Clutton-Brock (1979) and later reevaluated (Clutton-Brock 1989). Based off the faunal data, the paleoenvironment is considered a semi-desert with seasonal water sources (Clutton-Brock 1989, 395).

The lithic assemblage was described by Copeland (1988; 1991) in which the site was determined to be defined as the industry “Late Acheulean of Azraq Facies.” This industry differs from the material found elsewhere in Jordan, known as the “Desert Wadi Acheulean” or DWA, in both typology and the fact that it is excavated *in situ* from stratified outcrops (Copeland 1988, 71). The DWA industries are typically surface finds. Copeland (1988, 72) describes the artifacts in “pristine condition [...] still razor-sharp.” The bifaces are typically ovate or discoid, medium to small in size, with the presence of many bifacial cleavers – approximately 20%, which is unique in the Near East. The debitage has presence of “Levallois-like” small biface preparation flakes, tranchet flakes from bifacial cleavers, with almost no blades (Copeland 1988, 72). Copeland (1991) argues that C-Spring is a biface factory-site due to the high

quantity of bifacial trimming flakes, but also a place that may have been inhabited at some points in time due to the presence of faunal remains.

‘Ain Soda is another archaeological site in the Azraq Basin where there is the high presence of bifaces, particularly cleavers, and faunal remains. The site is thought to have occupations during the Late Acheulean (250-150,000 years ago) and the Levantine Mousterian (150,000-60,000 years ago) which is consistent with the dates at SM-1 (Rollefson et al. 1997). The faunal remains are similar to those found in C-Spring and SM-1. Rollefson and colleagues (1997) note the presence of *Elephas* sp. and Rhinoceros. The lithic assemblage consists of a 218 bifaces that are similar in overall size to those found at SM-1. ‘Ain Soda varies from the other Azraq sites in that it is dominated by cleavers – specifically they represent 63% of the assemblage (Rollefson et al. 1997, 53). The term “Azraq Acheulean Cleaver” was used by Rollefson and others (1997) to describe the typological characterization and frequency of cleavers found at ‘Ain Soda. The Azraq Cleaver is defined primarily by the presence of one or many tranchet scars across the distal portion of the tool and dulled lateral edges. The authors speculate that the dulling might be deliberate to protect the hands, but also note that some Azraq Cleavers have naturally blunt facets or edges, which includes some with cortex (Rollefson et al. 1997). Further, they argue that the high frequency of cleavers may be reflective of the activities performed in this area, particularly with a greater emphasis of butchery, especially because the cleavers found at ‘Ain Soda are highly utilized (Rollefson et al. 1997). The edge damage associated with their use is sometimes so great that the tranchet removal is difficult to identify (Rollefson et al. 1997, 51).

‘Ain el-Assad, or Lion’s Spring, is a Late Acheulean archaeological site near the Azraq Basin (Rollefson 1980). There have been multiple excavations at ‘Ain el-Assad with over 300 bifaces excavated in total. Over the field seasons from 1979-1981 (Rollefson 1980; 1983) the bifaces collected are dominated by cleavers (32.1%) with ovates, amygdaloids, and “diverse” making up the majority of the remaining assemblage. Within the “diverse” category, Rollefson (1983) argues there may be distinctive

tool types in Levantine assemblages that are outside the European traditions that typologies are based on. Examples of these are bifacial knives, biface-raclours, and bifacial wedge (Rollefson 1983, 33).

SM-1

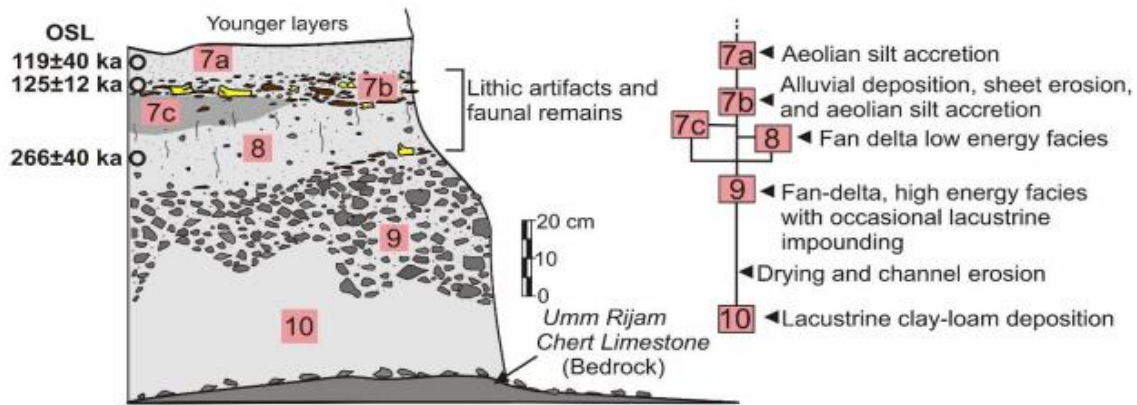


Figure 3.3 – Stratigraphy of SM-1 (Figure by Dr. Chris Ames, used with permission of Dr. April Nowell)

SM-1 is an archaeological site located in the Shishan Marsh of al-Azraq. SM-1 consists of two occupations spanning from the Late Lower Paleolithic to the Middle Paleolithic, approximately 260,000 and 125,000 years ago, respectively. The cultural and faunal layers are associated with layers 8, 7c, and 7b. Using Optically Stimulated Luminescence (OSL), layer 8 is dated to 266,000 ± 40,000 years ago; and layer 7b is dated to at least 220,000 years ago (Figure 2) (Nowell et al. 2016). Based on the paleoenvironmental data and geomorphic reconstructions, the age of the cultural material is most likely near the age of layer 8 (266,000 ± 40,000 years ago). Nowell et al. (2016, 37) explain that the surface of 7a was likely exposed to aeolian forces for an extended period of time. The constant aeolian reworking would result in the age of the sediment being much younger than the original onset of deposition. Further supporting this argument, pollen data was recovered from layers 8 and 7b, but not from 7a, indicating the lithic material was buried quickly and in primary context (37).

As mentioned previously, SM-1 is an archaeological site within the GAOA, which would have acted as a desert refugium in the past. This region would have provided the necessary resources to sustain dispersing hominins during periods of harsh and variable climate. The stratigraphy at SM-1

suggests the Lower and Middle Paleolithic occupations in layers 8 and 7b correlate to a “marshy pond with gentle alluvial sediment influx” (Nowell et al. 2016, 37). The pollen and phytolith data of the archaeological layers point to an abundance of aquatic vegetation and desert shrubs which are found in the deserts of the modern day Levant (Nowell et al. 2016, 37). These include *Poaceae* (grasses, majority of which were reeds), *Juncaceae* (rushes), *Typha* (cattails), and *Cyperaceae* (sedges). While there is excellent preservation of lithic materials, the bone preservation is poor – thus, the faunal remains are minimal. Currently, the faunal assemblage includes *Elephas hysudricus* (an extinct elephant), *Gazella* sp. (gazelle), *Camelus* sp. (camel), *Bos* cf. *primigenius* (wild cattle), cf. *Panthera leo* (lion), *Equus* cf. *hemionus/hydruntinus* (Asiatic/European wild ass), and *Stephanorhinus hemitoechus* (steppe rhinoceros). Similar taxa can be found in the nearby sites of C-Spring (Clutton-Brock 1970) and ‘Ain Soda (Rollefson et al. 1997). The faunal data is suggestive of a dry, open, steppe environment (Nowell et al. 2016, 37). There have been no hominin remains discovered, therefore the manufacturer of the lithic assemblage is unknown. However, due to the region and time period, potential candidates are *Homo erectus* and *Homo heidelbergensis*.

Using Shea’s (2013: 158) technologically defined Modes A-I, the lithic assemblage at SM-1 consists of Mode D1 (retouched flake-tools), Mode D2 (backed/truncated flakes), Mode D3 (burins), Mode E1 (large cutting tools), Mode E2 (thinned bifaces), and Mode F (bifacial hierarchical cores or BHC). Additionally, there are many small pebble tools that appear to be utilized. Within Levantine contexts, the lithic assemblage could be described as a Late Acheulean of Azraq facies industry (Copeland 1988, 73) because of the presence of small to medium sized discoid and ovate bifaces and flake tools (Nowell et al. 2016).

The bifacial tools found within SM-1 vary in size and shape (Figure 3.4). Although the assemblage is dominated by ovate and discoidal handaxes like C-Spring, SM-1 has some cordiforms and cleaver-like handaxes. The exact frequency of cleavers is currently unknown so it cannot be compared to the nearby site of 'Ain Soda. There is a high frequency of tranchet removals creating large cutting edges on the distal ends of the bifaces. Not all of these removals are transverse – some are oblique to the edges. Most bifaces have obvious areas of use-wear, particularly noticeable rounding of the edges. In addition to the bifaces, other tool types such as Levallois points and blades, and flakes, have obvious areas of use-wear. Using Cross-over immunoelectrophoresis, seventeen lithics from SM-1 have produced positive protein residue results for rhinoceros, duck, horse, camel, bovids (Nowell et al. 2016),

Figure 3.4 – Subsample of handaxes from the SM-1 showing the variation in size and shape. The assemblage consists primarily of ovate and discoids with a smaller percentage of cordiforms and cleaver-like handaxes. 1st row: SM1 – 331 (left); SM1-475 (middle); SM1-556 (right). 2nd row: SM1-2005 (left); SM1-4622 (middle); SM1-3547 (right). 3rd row: SM1-4179 (left); SM1-3153 (middle); SM1-4751 (right). Photo credit: Dan Stueber





and Asian elephant (April Nowell pers. comm. 2016) corroborating the interpretation of 'Ain Soda as a butchery site (Rollefson et al. 1997) and the idea of the oasis being a place for ambushing prey. Cross-over immunoelectrophoresis detects residues from reactions between antibodies and antigens and is more sensitive to protein residue than any other method currently known (Nowell et al. 2016, 38).

Although the lithic assemblage is typologically similar to other Acheulean sites in the GAOA, it differs due to the low frequency of cleavers and high occurrence of Levallois. Table 3.1 is an adapted chart from Rollefson et al. (1997) and contains a basic quantitative description of the bifacial assemblages from the Azraq Basin sites with the addition of SM-1. When compared to surrounding sites, the bifaces from SM-1 are relatively big; not only are they larger on average in length, but they are also the thickest and widest. When considering the dimensional ratios, the SM-1 bifaces are most similar to those at 'Ain el Assad, but most similar to 'Ain Soda in mean length, width, and thickness. This difference in ratios is between 'Ain Soda and SM-1 might be reflective of differences in measuring techniques and the assemblages may actually be more similar than what the data projects. The similarities to 'Ain Soda makes sense as they are very close in proximity to one another. A more comprehensive typological analysis is ongoing and will help shed light on the intra-site variability in the bifacial assemblage.

Table 3.1: Comparison of Mean Length, Width, and Thickness of Azraq Assemblages (Adapted from Rollefson et al. 1997)						
Site	Length	Width	Thickness	W/L Ratio	TH/W Ratio	Th/L Ratio
'Ain Soda	108.7	73.2	28.4	.673	.388	.261
C-Spring	103.7	N/A	N/A	N/A	N/A	N/A
'Ain el-Assad	99.1	67.5	29.3	.681	.434	.296
SM-1	109.0	79.0	32.2	.724	.408	.295

Summary

The Acheulean stone tool industry is the longest lasting toolkit in human history and is dominated by bifacial tools such as handaxes. It has been argued to be homogeneous and stagnant due to the presence of these tools across all of the old world for such a long period of time. Within a global context, there is a discrepancy in handaxe frequency and form between Acheulean sites in western Eurasia and Africa and those in eastern Asia, but the presence of bifacial tools throughout the Middle Pleistocene is unequivocal. The arguments surrounding the ubiquitous nature of handaxes involve genes, social transmission, and environment. The complex nature of human evolution makes it difficult to elucidate the role each of these factors play, but it is likely that it is a combination of all three and varies between environmental contexts. Functional studies in handaxes can help shed light on this issue by investigating how and why these tools were being used, but are currently lacking in the archaeological literature. SM-1 presents a unique opportunity to not only reveal how hominins were using handaxes, but also can provide insights to landscape use and behavioral strategies in within one of the most important environments for hominin dispersal – desert refugia. The following chapter will

present the materials and methodology used within this study to attempt to address this gap in archaeological knowledge through a combination of qualitative and quantitative approaches.

Chapter 4: Materials and Methods

Materials

This chapter will outline the methodology of this research from the collection of artifacts at SM-1 to the use-wear approaches undertaken for the use-wear analysis. The first half of this section will describe the process of data collection in the field (see Figure 4.1). Afterward, I will discuss in detail the experimental activities employed for each stone tool and provide photographs and video of the process when applicable. Next, this chapter will describe the approach to use-wear this project utilizes with a detailed explanation of the methodology. Lastly, I will discuss confounding factors associated with the experimental process.

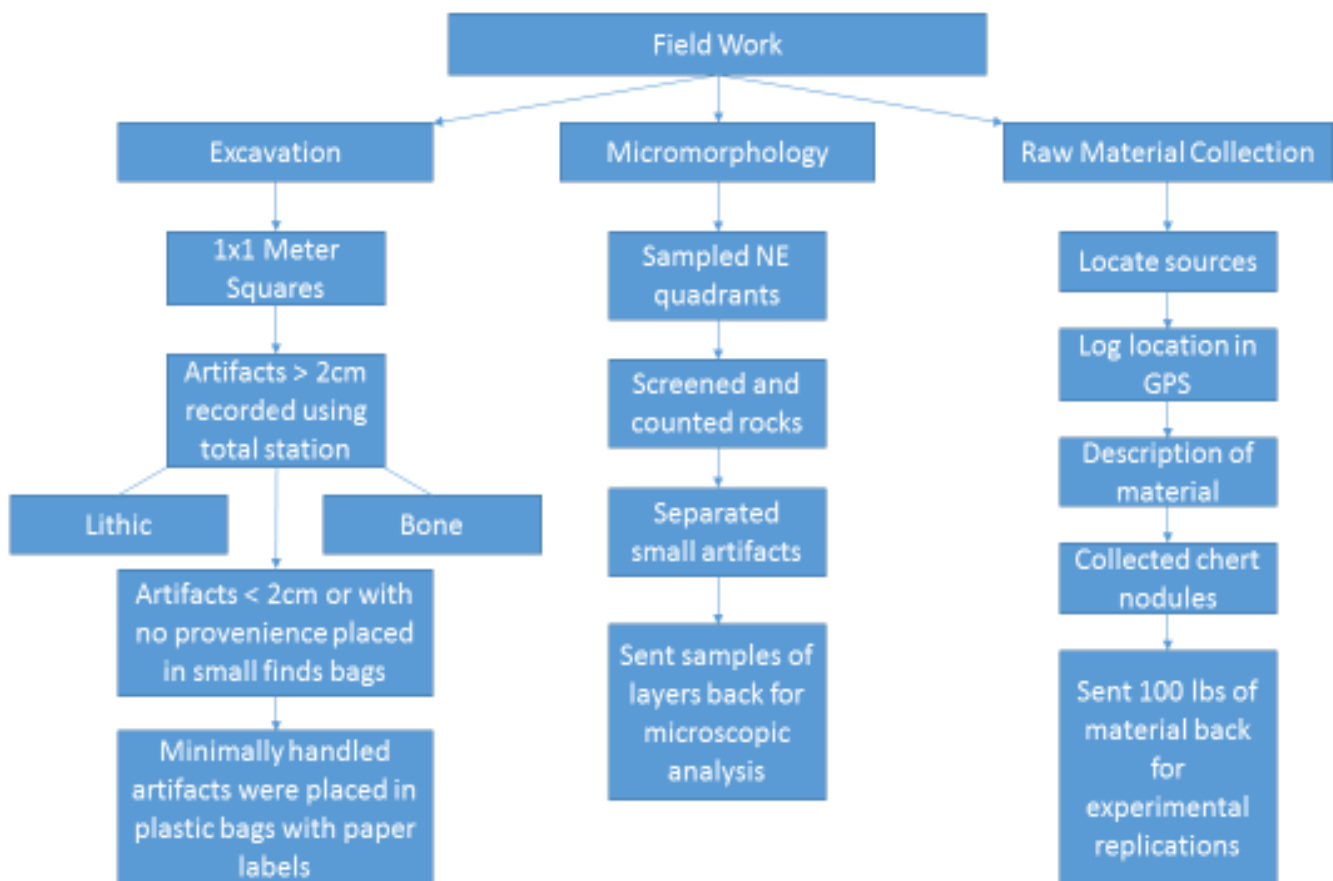


Figure 4.1 - Workflow for field work

Excavation

The archaeological material from SM-1 being analyzed for this research was collected over field seasons 2013, 2014, and 2015. The author was present during field seasons 2014 and 2015. The excavation was divided by units from east to west in alphabetical order and north to south in numerical order. The total station used to record artifacts is made by Leica. When artifacts greater than 2-cm were uncovered, the GPS location was recorded by the total station and the artifact was immediately tagged and placed in a plastic bag. The paper tag included in the plastic bag had the same information as the total station data. The site, date, artifact number, quadrant, layer, depth, and description (bone or lithic) were noted. Artifacts that were less than 2-cm in size were placed in unit small finds bags. These small find bags were also used for collecting artifacts during screening. Additionally, for artifacts that had a length 1.5 times their width, two points were recorded (an A and a B) in the total station for future orientation statistics.

Micromorphology

A second component of field work and excavation consisted of assisting in geomorphological studies at SM-1, primarily through micromorphology. This is a component of Dr. Christopher Ames's larger site formation processes research. This is relevant for use-wear studies because exploring the context and taphonomic processes influencing the formation of the site is essential to showing that the artifacts are in primary context both spatially and physically. During the excavation, the NE quadrants of each unit were flagged and all of the sediment post-screening was kept, including non-cultural material. Once the excavation for the day was completed, the material from the NE quadrants was wet-screened to get rid of sand size particles. After being wet-screened, the material was sieved and sorted with smaller geological screens and were then placed into bags based on screen size. The analysis consisted of counting each individual rock and separating cultural material from non-cultural material. After the

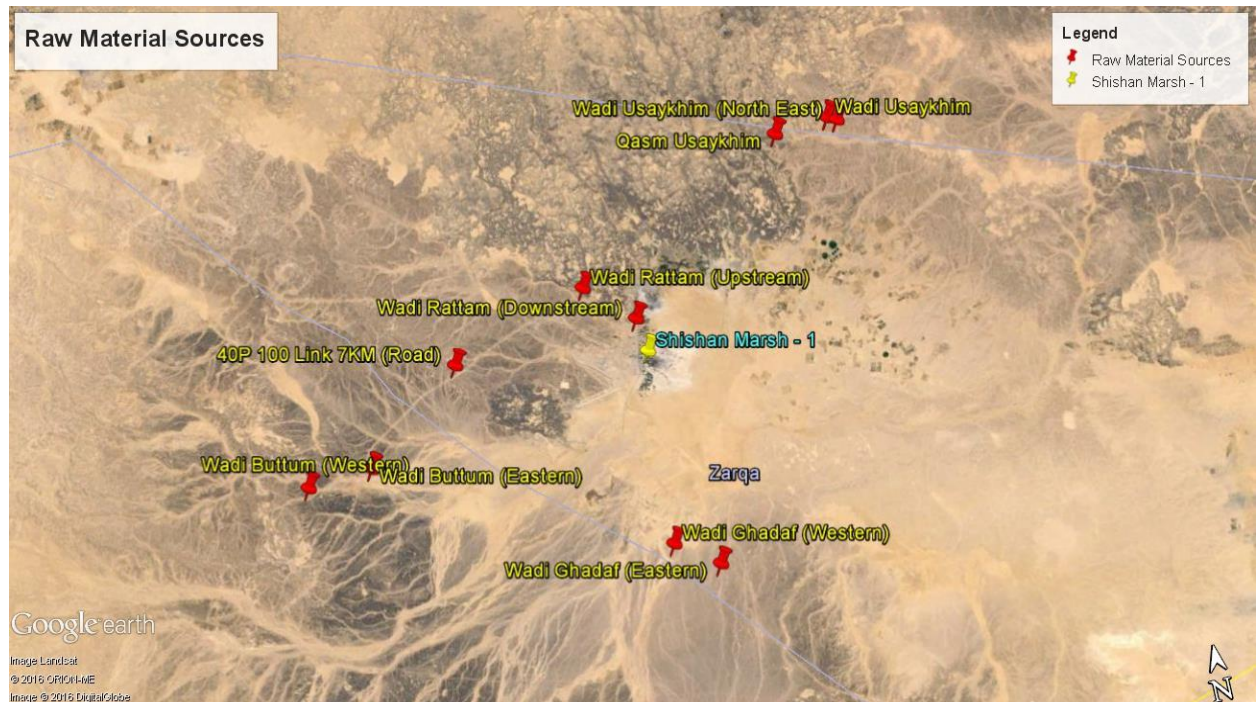


Figure 4.2 - Location of raw material sources surrounding SM-1

rocks were counted, they were weighed and a morphological analysis for shape was conducted by Dr. Ames. In addition to counting rocks, Dr. Ames collected samples of stratigraphic sections to create micromorphology slides for microscopic analysis. Future work with this data will consist of spatial and orientation statistics.

Collection of Chert



Figure 4.3 - Documentation of chert collection during the 2015 field season

The chert needed for replicating the stone tools found at SM-1 was collected during the 2015 field season. I visited various locations within the Greater Azraq Oasis Area in search of potential locations the hominins at SM-1 could have been gathering their raw materials from (Figure 4.2). We used a geologic map to find the possible chert outcrops. The two major chert formations present throughout the region are the Umm Rijam Chert-Limestone Formation (URC) and the Muwvaqar Chalk-Marl Formation (MCM). Once we arrived at the outcrops, the location was logged using a GPS unit and a basic description of the chert was recorded. When material was found that seemed to be the correct size and shape for creating replicas, the nodule was labeled with a marker and a photo was taken (Figure 4.3). After gathering material from seven locations, I had collected approximately 150 pounds of chert, of which 100 pounds was sent back to the University of Victoria for the replications. The color of the chert ranged from grey to reddish to blue. Additionally, some nodules were highly siliceous limestone with favorable flaking attributes.

Flintknapping Replications

The experimental database was created over three days in Portland, Oregon with the help of Daniel Stueber, an expert flintknapper. A total of 32 handaxes were created out of the 100 pounds of chert sent back from Jordan (Figure 4.4). Not all of the raw material was used to leave room for future experiments with different tool types. During the replication process, Dan and I attempted to replicate the typological and technological characteristics of the prehistoric assemblage. The toolkit consisted of soft percussion implements of varying size and material, and leather pads for protection (Figure 4.5). The soft percussion implements were moose antler and elk antler billets and soft sandstone river cobbles. No hard hammer percussion implements were used in the experiments. Two primary features associated with the handaxes found at SM-1 are the presence of tranchet removals and unworked

Figure 4.4 - Experimental assemblage replicated by John Murray and Dan Stueber (top two rows DS; bottom two rows JM).



square sections left near the base of the tool. Amazingly, some of these tools have double tranchet removals, one on each face of the tool, but replication of this was not attempted during the replication process.

The unworked squared edge found in many of the handaxes could have been left for various reasons. One possible reason that was noted during the flintknapping process was the breakage of raw material. The chert is high quality, however, it has certain morphological characteristics that sometimes make it difficult to successfully knap. One of these characteristics is a banded internal structure. This band was not always an issue, but for some nodules the band was much coarser than the rest of the material and tended to cause breaks. These breaks did not always make the material unusable,



Figure 4.5 - Flintknapping toolkit used during the biface replications consisted of antler billets and soft sandstone hammerstones.

especially for larger nodules, but with smaller sized nodules, handaxes could not be created with the broken pieces. These breaks tended to create square edges that quite possibly explain what is seen in the archaeological material. This was recorded during the replication process. A second characteristic of the chert that sometimes caused breaks was the tabular nature of the nodules. The large and tabular material made excellent handaxes; however, the smaller, thinner tabular pieces tended to break with insufficient support, and sometimes even with adequate support.

After the replications were completed, basic data was recorded about morphology. Following the Debénath and Dibble (1994), measurements were taken (in millimeters) such as maximum length, maximum width, width at midpoint, width at $\frac{3}{4}$ length from the base, distance from base to max width, maximum thickness, and weight (Table 4.1). Three weight measurements were recorded: weight of raw

material, weight of tool, and weight of debitage. Unfortunately, due to an oversight on the first day of replications, I did not record weight of raw material prior to flintknapping for about half the tools. The weight information can be used in a future debitage analysis for bifacial reduction at SM-1.

Table 4.1 : Measurements of Handaxes in Experimental Assemblage (mm)

ID	Material Source	Weight(g)	Length	Width	WM	W 3/4	DBMW	T
DS-1	Shishan Marsh	114.9	143.1	55.3	50.3	32.4	43.9	14.8
JM-1	Shishan Marsh	200.0	147.5	60.5	50.5	37.1	35.4	21.1
DS-2	N/A	618.1	180.0	92.4	86.1	64.7	70.1	36.3
JM-2	Shishan Marsh	202.2	115.9	67.0	60.2	45.9	27.0	27.6
DS-3	Wadi Rattam (DS)	379.8	154.6	85.7	77.4	60.3	43.8	25.4
JM-3	Wadi Rattam (DS)	157.0	101.8	72.1	71.8	58.4	57.7	18.2
DS-4A	Shishan Marsh	412.5	140.5	89.4	88.4	56.3	76.4	35.0
DS-4B	Shishan Marsh	268.7	127.7	84.7	81.0	50.4	51.0	27.9
JM-4	Wadi Rattam (US)	387.3	154.4	92.1	83.8	57.2	40.5	27.2
DS-5A	Wadi Ghadaf (W)	34.6	71.4	46.6	42.7	28.1	16.7	9.2
DS-5B	Wadi Ghadaf (W)	25.9	71.0	39.5	38.8	32.9	32.8	8.8
JM-5A	Shishan Marsh	67.5	102.6	46.6	36.6	24.3	32.6	14.1
JM-5B	Shishan Marsh	71.2	78.9	51.9	38.2	27.7	13.5	17.5
DS-6	Shishan Marsh	248.1	136.9	87.8	68.7	46.5	46.2	22.9
JM-6	Wadi Buttum (E)	544.7	136.0	105.3	100.9	81.1	60.2	34.4
DS-7	Qasm Usaykhim	402.8	163.6	94.5	88.8	65.7	54.4	26.5
JM-7	Shishan Marsh	Failed	N/A	N/A	N/A	N/A	N/A	N/A
JM-8	Shishan Marsh	157.0	133.7	60.7	57.9	27.9	52.8	21.3
JM-9A	Qasm Usaykhim	89.7	90.2	65.8	60.1	36.7	34.3	16.9
JM-9B	Qasm Usaykhim	95.1	78.8	59.4	57.7	41.6	14.8	19.5
JM-9C	Qasm Usaykhim	49.2	75.8	41.9	40.7	31.2	22.8	14.9
DS-8	Wadi Rattam (DS)	Failed	N/A	N/A	N/A	N/A	N/A	N/A
JM-10	Wadi Buttum (E)	260.1	104.0	77.6	74.7	43.4	44.9	35.4
DS-9	Wadi Buttum (E)	179.9	146.7	66.3	61.4	42.1	40.1	20.2
JM-11	Shishan Marsh	102.3	106.0	48.3	47.4	37.0	28.5	18.5
DS-10	Wadi Buttum (W)	657.9	206.2	106.8	98.7	70.9	83.5	28.9
JM-12	Wadi Usaykhim	89.4	108.7	43.5	42.6	34.6	45.0	19.8
JM-13	Shishan Marsh	96.4	102.2	53.2	42.9	37.9	31.6	19.9
DS-11	Wadi Ghadaf (W)	605.6	129.0	93.3	92.1	84.4	90.4	39.5
DS-12A	Wadi Buttum (E)	317.7	134.6	93.4	87.3	61.2	52.6	26.4
DS-12B	Wadi Buttum (E)	132.0	106.2	61.6	59.7	44.0	41.1	21.7
ES-1	Shishan Marsh	519.0	186.1	102.2	97.7	69.2	80.8	31.3

Key to abbreviations: **WM** – width at midpoint, **W3/4** – width at ¾ of the length, **DBMW** – distance from base to max width, **T** – thickness. Under “Material source”: **E** – eastern, **W** – western, **US** – upstream, **DS** – downstream.

Prehistoric Assemblage

The prehistoric lithic assemblage consists of 58 LCT's, which are primarily handaxes with some cleavers, and possibly Levallois cores. The majority of the assemblage seems to be made of local, on site raw material – a blueish chert with some gray variations. This material is very high quality. Further research into the raw material sourcing by colleague Jeremy Beller will help shed more light on this (Beller in prep). Similar to the experimental dataset, the artifacts were measured for the same attributes (Debénath and Dibble 1994) (Table 4.2).

Artifact ID	Depth	Layer	Weight(g)	Length	Width	WM	W3/4	DBMW	T	Cortex
152	N/A	8	304.2	129.7	78.2	74.7	59.5	55.3	26.3	45%
246	N/A	7b	190.7	90.7	80.1	79.0	56.5	31.1	28.7	15%
331	N/A	8	249.9	113.6	89.9	88.2	64.3	51.0	24.2	20%
420	N/A	8	200.7	86.9	84.3	75.0	45.1	11.0	37.5	0%
437	N/A	8	139.2	83.6	65.9	61.1	40.6	23.1	25.5	<10%
457	N/A	8	301.1	101.5	86.9	84.0	62.7	45.5	34.1	30%
475	N/A	8	528.7	153.1	114.2	110.1	81.5	56.1	34.2	<10%
556	0 - 1	7c	802.4	159.3	107.6	105.3	82.0	89.9	58.0	0
1200	1 - 2	7c	201.1	88.6	60.3	60.1	51.9	48.1	49.5	0
1767	2 - 3	7b	317.6	122.3	87.3	75.6	45.4	36.1	39.2	15%
2005	3 - 4	7b	284.4	129.5	92.7	89.9	67.7	46.0	25.1	0
2556	3 - 4	7b	145.6	96.7	66.8	62.8	49.8	34.8	20.8	75%
2585	5 - 6	7b	270.7	114.7	79.2	78.7	60.6	58.1	29.7	50%
2684	5 - 6	8	287.3	127.3	81.4	75.5	55.7	38.3	32.5	0%
2689	5 - 6	8	645.9	140.3	91.3	90.2	65.0	65.7	58.2	0%
2695	5 - 6	8	251.1	116.1	88.3	87.8	69.4	56.0	23.4	<10%
2706	5 - 6	8	327.4	110.5	76.6	67.7	50.5	25.8	35.6	15%
2716	5 - 6	8	493.7	137.1	85.2	81.0	82.0	99.8	39.0	75%
2941	3 - 4	7b	170.3	99.7	67.7	66.0	50.7	37.2	14.8	<10%
2947	8 - 9	8	284.0	106.6	82.1	78.8	70.3	43.6	32.3	25%
3082	10 - 11	8	233.1	122.5	89.0	88.4	62.9	57.1	20.9	20%
3118	9 - 10	7b	415.8	116.8	97.1	85.1	55.2	43.7	32.3	60%
3131	9 - 10	7b	128.1	90.6	59.8	58.0	47.1	38.0	22.2	60%
3153	4 - 5	8	295.9	119.0	83.5	78.4	56.3	44.8	33.0	0%
3468	2 - 3	7b	285.0	109.3	83.8	83.6	64.9	49.3	33.0	25%
3547	3 - 4	7b	190.5	82.9	72.6	71.1	62.2	49.9	36.0	0%
3591	5 - 6	8	354.8	100.6	67.4	66.4	58.8	39.8	54.2	0%

3603	2 - 3	7b	158.3	93.3	59.8	58.6	49.0	56.3	25.9	<10%
3711	4 - 5	8	257.8	98.8	77.6	76.2	68.0	41.2	32.3	10%
3747	3 - 4	7b	189.6	99.9	66.7	60.4	44.5	25.5	30.1	0
3776	4 - 5	8	139.4	98.9	67.7	58.3	40.4	31.8	21.4	50-60%
3805	3 - 4	8	434.8	122.7	78.5	74.3	63.3	57.8	49.1	0
3806	3 - 4	8	242.4	94.3	83.3	82.6	73.2	52.0	30.7	15%
3882	2 - 3	7b	218.7	102.4	78.4	76.4	43.0	43.7	31.6	0
3912	2 - 3	7b	73.1	78.8	52.6	51.7	35.6	32.5	16.0	0
4033	4 - 5	8	416.1	143.4	103.9	98.0	68.0	56.9	28.1	20%
4038	2 - 3	7b	153.9	96.6	64.1	57.0	39.3	33.4	29.8	0
4134	2 - 3	7b	163.8	95.5	68.5	62.3	42.3	35.8	30.1	<10%
4172	2 - 3	7b	156.2	87.1	82.1	81.3	66.0	44.8	24.7	<10%
4192	3 - 4	8	151.4	82.2	62.7	61.2	42.1	36.0	29.8	25%
4197	4 - 5	8	315.7	140.8	88.7	75.6	43.2	47.9	30.0	<10%
4215	4 - 5	8	333.5	129.6	93.2	92.2	68.5	56.0	30.4	30%
4278	5 - 6	8	69.0	58.4	54.0	51.4	39.4	19.8	25.4	<10%
4396	3 - 4	8	414.0	127.0	101.2	100.8	85.0	55.9	31.2	25%
4425	3 - 4	8	245.8	100.1	81.9	81.2	70.2	41.0	31.4	0
4488	2 - 3	7b	338.5	119.6	80.9	80.5	49.4	50.0	45.8	0
4495	5 - 6	7c	236.7	100.4	84.2	80.7	59.6	37.8	26.2	30%
4522	4 - 5	8	253.7	106.8	79.2	79.0	63.8	40.4	34.7	<10%
4530	4 - 5	8	77.2	71.7	51.4	50.8	34.4	34.4	24.6	15%
4548	3 - 4	8	157.3	118.0	77.4	70.5	49.3	34.7	21.1	20%
4622	5 - 6	8	341.7	112.5	100.5	99.8	77.2	53.8	30.3	30%
4651	4 - 5	8	201.3	121.2	69.7	59.2	46.1	36.5	26.8	<10%
4671	5 - 6	8	115.0	72.5	63.4	62.1	49.0	26.4	23.0	<10%
4673	5 - 6	8	384.7	131.8	83.6	78.5	42.1	42.2	39.4	<10
4675	0 - 1	7b	179.5	93.3	59.1	55.1	38.4	28.9	35.0	20%
4751	2 - 3	7b	409.3	130.6	81	80.1	75.9	67.0	44.2	15%
4752	1 - 2	7b	295.4	111.2	75.3	74.3	59.1	50.2	43.2	0
4826	4 - 5	8	254.7	118.8	88.6	83.9	57.9	47.6	26.6	15%
Key to variables: WM – width at midpoint, W3/4 – width at $\frac{3}{4}$ of the length, DBMW – distance from base to max width, T – thickness.										

Methods

Pre-experimental Procedure

As stated in Chapter 2, this research has pursued a way for students and researchers to teach themselves use-wear analysis through inclusion of a pre-experimental documentation of the replicated tools. Additionally, this procedure is one way for researchers to show that the use-wear scars being discussed actually resulted from use while simultaneously being pedagogical as it trains the user to

recognize use-wear signatures. The pre-experimental protocol started with documentation of the experimental lithics under a dissection microscope in the Department of Biology at the University of Victoria. The microscope used for the analysis was a Wild M420 Makroskop. The focus of this analysis was to document any residual knapping traces, such as platform preparation or a failed flake removal, which might be confused with use-wear by an amateur. Further, this procedure allowed me to record areas that might be conducive to the accumulation of use-wear signatures due to area of tool and the straight, unmodified edge. Moreover, I documented areas with residues for future residue analysis. Photographs were taken at 72x with a SPOT Flex camera and the accompanying SPOT software.

During documentation, the stone tools were divided by faces. Considering there are no obvious ways the dorsal and/or ventral sides can be determined on a biface, side A was declared as the side with more invasive flaking and side B was the side with more cortex (Lycett et al. 2006). After the faces were determined, a rough outline of both sides of the stone tool was traced. During inspection of the edges, I

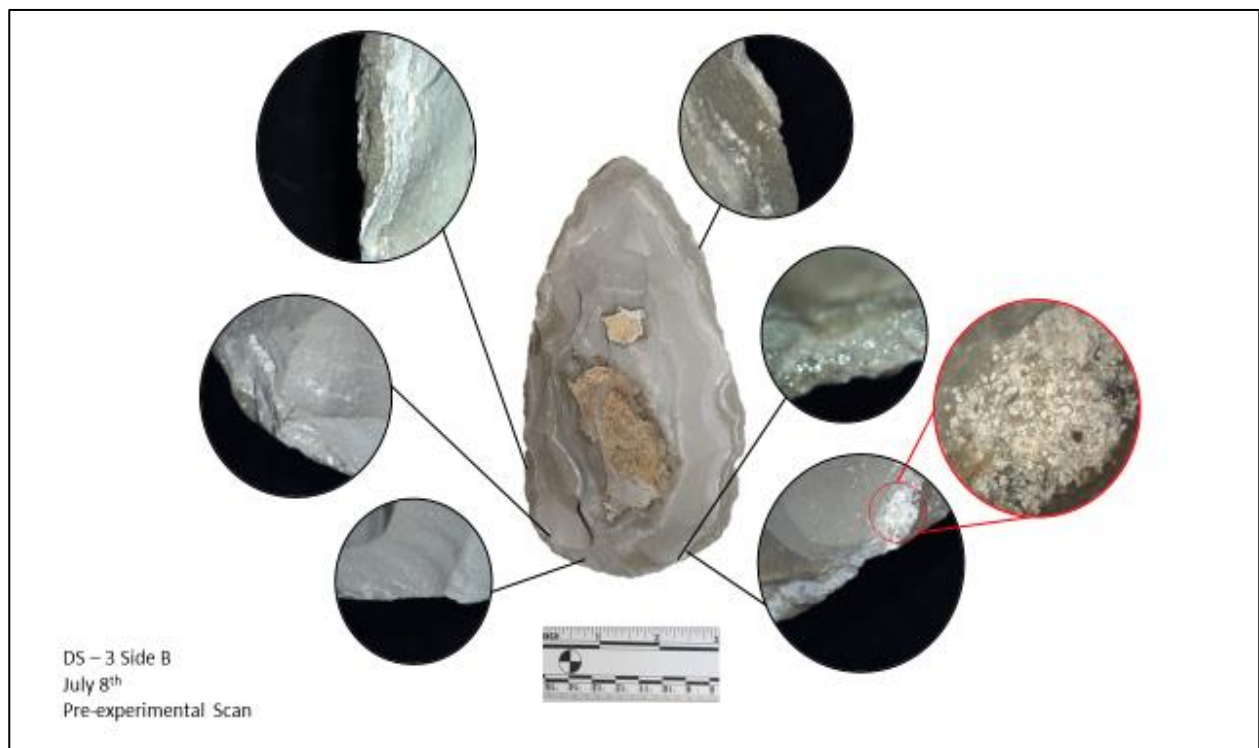


Figure 4.6 – Example PowerPoint slide of the pre-experimental scans with microphotographic documentation of edges and residue

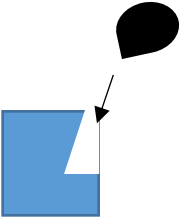
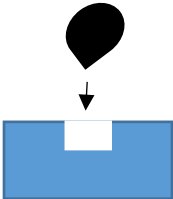
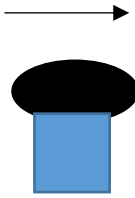
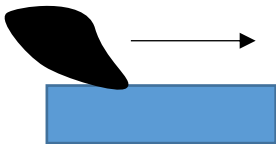
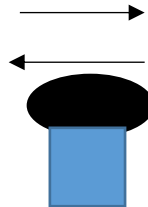
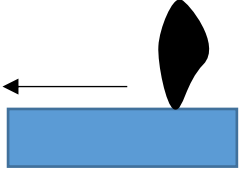
documented on the hand drawing where photographs were being taken for future analysis. This is an important step for two reasons: first, it is essential to know the spatial arrangement of the use-wear to help determine whether or not it is purposeful use; second, it allows me to easily refer back to the drawing when analyzing the edges of the replicated tool post-experiment. The edges were documented counter-clockwise starting at the left edge of the tip. I attempted to be consistent in this system; however, sometimes important places on the edges were overlooked and I had to backtrack and photograph an area that was already looked over.

The pre-experimental documentation of the replicated tools resulted in approximately 300 photographs of edge damage from knapping, residue, and undisturbed areas. The next step in this process was creating diagrams in Microsoft PowerPoint to help digitize and merge the hand drawn documentation with the photographs (Figure 4.6). Being able to view all of the information in one picture helps when doing the post-experimental analysis. Unfortunately, due to time restrictions not all diagrams were completed.

Experimental Protocol

In order to investigate how handaxes were being used at SM-1 and to ultimately answer the research questions posed in Chapter 1, I used the replicated handaxes in activities that potentially reflect how they were used in the past. I chose to use each handaxe in a specific motion or “kinematic” based on previous experimental work by Keeley (1980) (Table 4.3). During each experiment I recorded how long each tool was used. For an explicit description of each activity, picture documentation of the experimental procedure, and the associated replicated handaxe see Appendix II.

Table 4.3 : Summary of Activities for Experimental Protocol (adapted from Keeley 1980)

Action	Angle to Material	Description	Diagram
Adzing	45°-60°	Quick low force blows to the contact material with a low angle of attack.	
Chopping	60°-90°	Slow, high force blows repeated on the worked material at a high angle of attack.	
Cutting	90°	Typically unidirectional. This terminology is typically used for softer materials such as plants and vegetables.	
Planing	45°	Shaving off material with the lithic held at a low angle in a pushing motion; ventral side is held at a low angle to the worked material.	
Sawing	90°	Can be bidirectional or unidirectional. The lithic is held at approximately a right angle to the worked material. This terminology is typically used for working hard materials such as antler, wood, and bone.	
Scraping	90°	Edge is held at a high angle to the material being worked; pulling motion rather than pushing.	

For this thesis, I combined activities defined in Table 4.3 into groups with similar kinematics. Following Tringham and colleagues (1974), cutting and sawing are considered “longitudinal motions” and planing and scraping are grouped as “transverse motions”. Additionally, I amalgamated high intensity activities utilizing the distal end of the tool (e.g., chopping, adzing, digging, and shucking) into “percussive activities” (Claud et al. 2015; Lambert-Law de Lauriston 2015; Viallet 2016a). In addition to these controlled motions, I conducted a butchery experiment and post-depositional experiments – both of which are considered their own group because multiple handaxes were used within the activity (Schoville et al. 2016). The post-depositional experiments were included in this thesis to investigate the role of fluvial processes in the formation of edge damage at SM-1. Furthermore, I decided to focus on experiments with longitudinal and percussive activities rather than activities with transverse motions because most of the archaeological evidence suggests handaxes were used for the former (Binneman and Beaumont 1992; Claud 2008; Claud et al. 2015; Viallet 2016a, 2016b). Lastly, by creating an experimental dataset with multiple activity groups, I am able to test the idea that handaxes are multi-functional or “poly-functional” tools (Viallet 2016a) at an assemblage scale.

As discussed in Chapter 3, previous experimental work has demonstrated that handaxes are effective at butchery (Keeley 1980; Mitchell 1995) and woodworking (Claud 2008; Viallet 2016b). Use-wear analyses on archaeological handaxes have shown that these tools were used on similar materials in prehistoric times (Binneman and Beaumont 1992; Claud 2008; Viallet 2016a, b). Furthermore, animal fat residue (Solodenka et al. 2015), protein residue (Nowell et al. 2016), and phytoliths (Domínguez-Rodrigo et al. 2001) corroborate handaxes being used for activities involving both fauna and flora. Considering this evidence, I used wood (fir), bone, and meat as my primary contact materials for the experiments. In addition to these materials, I utilized handaxes in tasks involving bamboo, antler, potatoes, oysters, and grass to explore their highly variable functional potential (Viallet 2016a) (see Table 4.4 for summary).

Table 4.4: Summary of Experimental Activities with Handaxes					
ID	Experimental Tool	Activity	Raw Material	Edge (L or R)	Duration (mins)
1	DS -3	Cutting	Bamboo	L	58
2	JM-3	Sawing	Dried Antler	L	61
3	JM-3	Planing	Dried Antler	R	45
4	DS-2	Sawing	Bone	L	30
5	DS-11	Chopping	Bovid Bone	Tip	10
6	DS-5B	Defleshing	Bovid Bone	L&R	35
7	JM-4	Sawing	Wood - fir	L	40
8	JM-9A	Post-depositional	SM1 Pebbles	L&R	210
9	DS-1	Butchery	Deer	L&R	40
10	DS-10	Butchery	Deer	L	28
11	DS-7	Butchery	Deer	L&R	44
12	DS-9	Butchery	Deer	L&R	46
13	ES-1	Butchery	Deer	L&R	44
14	DS-12a	Adzing	Wood - fir	Tip	50
15	DS 6	Shucking	Oysters	Tip	13
16	JM-1	Planing and Scraping	Wood - dried	L&R	50
17	JM-6	Chopping	Wood - fir	Tip	20
18	JM-10	Chopping	Wood - fir	Tip	21
19	JM-2	Post-depositional	SM1 Pebbles	L&R	60
20	JM-11	Post-depositional	SM1 Pebbles	L&R	60
21	DS-12b	Post-depositional	SM1 Pebbles	L&R	27
22	DS-4b	Adzing	Wood - fir	Tip	12
23	JM-8	Cutting	Potatoes (6)	L	12
24	DS-4a	Digging	Grass	Tip	18

Longitudinal Activities

Six handaxes were used in longitudinal activities on multiple contact materials. These activities include sawing bone, sawing antler, cutting potatoes, cutting wood, and cutting bamboo. I used bamboo

as a contact material to explore the previous study by Bar-Yosef et al. (2012) surrounding the Movius Line and the use of bamboo as an alternate raw material to stone in eastern Asia. Additionally, I chose potatoes as a contact material to represent Underground Storage Organs (USOs) which are thought to be an important resource for hominins (Laden and Wrangham 2005).

Percussive Activities

The percussive activities in this thesis involve seven handaxes. These tools were used for chopping wood, adzing wood, chopping bone, digging, and shucking oysters. Digging was selected as an experimental activity to simulate digging for Underground Storage Organs (USOs) and to replicate the experiment performed by Keeley (1980). Considering marine and coastal resource exploitation is argued to be an important dietary adaptation in human evolution (Erlandson 2001; Marean 2014), I wanted to investigate effectiveness of handaxes in processing shellfish. I chose oysters as a contact material because they are common in the Pacific Northwest. The oysters were found on Quadra Island, British Columbia and were approximately 6 cm long.

Transverse Activities

As mentioned above, I focused on percussive and longitudinal activities for the majority of the experimental research; however, I used two handaxes in transverse motions – planing and scraping – to examine their effectiveness at making organic tools such as spears (Binneman and Beaumont 1992).

Butchery

The butchery experiments were done using a road-killed black-tailed deer carcass that had minimal damage considering its untimely death. The deer was provided by Helen Schwantje, the provincial veterinarian of the Fish and Wildlife branch in the Ministry of Forests, Lands, and Natural Resource Operations. The butchery was done in the necropsy lab at their facility in Nanaimo, British

Columbia with the help of colleague and MA candidate Jenny Francoeur. The deer was a fresh kill (within 24 hours). In order to accomplish this task we used five handaxes. The whole process took four hours.

Post-depositional Experiments

As mentioned in Chapters 1 and 2, a major concern with investigating edge damage is determining whether or not the edge damage is behavioral and not due to taphonomic processes such as trampling or fluvial transport. The stratigraphy at SM-1 indicates the marshland was likely a low-energy alluvial context. Specifically, Nowell et al. (2016) describe Layer 8 as a “fan-delta, low energy facies” and Layer 7b as an “alluvial deposition with sheet erosion and aeolian silt accretion”, both of which contain lithics and faunal remains. In order to better understand the distribution of edge damage at SM-1, we need to uncover more about how low-energy fluvial contexts affect the surface and edges of stone tools.

Many previous studies that investigate the formation of edge damage and surface modification of handaxes in fluvial contexts used large scale machinery such as geologic flumes or massive tumblers (Chambers 2003; Chu et al. 2015; Grosman et al. 2011). Considering there was no way for me to get access to this type of technology, I adopted the technique used by Schoville et al. (2016) which was a small rock tumbler – specifically, a Thumblers Tumbler Model A (Figure 4.7). An unused paint can was chosen for the container because of its durability and known volume (one gallon). The can was modified



Figure 4.7– Thumblers Tumbler Model A used in taphonomic experiments

slightly to make it fit the tumbler by clipping off the handle attachment using metal snips and placing waterproof tape over the holes to help prevent possible leaks. Four handaxes were used in these post-depositional experiments. Along with the handaxes, pebbles from SM-1 that were mistaken for artifacts during excavation were included in the tumbler. These rocks, therefore, are true examples of the rocks found in prehistoric contexts at SM-1 and reflect the fluvial context once present.

Not only does this help shed light on taphonomic processes at SM-1, these data address McPherron et al.'s (2014) criticism of Schoville's (2010) use of random to describe the distribution of post-depositional edge damage. This allows me to create a model for post-depositional edge damage to compare to the distributions for the prehistoric handaxes rather than relying on a random distribution (Schoville et al. 2016).

Edge Damage Distribution Method

As mentioned in Chapter 2, the primary approach this research is utilizing is an assemblage scale, image-based GIS investigation of edge damage distribution. I have adopted this approach from Dr. Benjamin Schoville and colleagues (Schoville 2010, 2014; Schoville and Brown 2010; Schoville et al. 2016; Wilkins and Schoville 2016). I am using this method as the first step towards a large-scale use-wear analysis for multiple reasons. First, this approach only requires low-powered microscopy and does not attempt to assign contact material to edge damage. This makes it a conservative approach, but appropriate for the timescale and resources available to me. Additionally, this methodology is a good starting point because it helps inform future use-wear methodologies that require more time intensive high powered microscopy and residue analysis. Having the edge damage distributions allows for more efficient individual artifact analysis because these data provide a good starting area on the stone tool surface to begin a use-wear and residue analysis. Moreover, this method helps differentiate between

taphonomic and use-related edge damage distribution which has implications regarding site formation and preservation.

Following Schoville (2010), the first step in this methodology is to photograph all of the artifacts individually on top of a grid with known measurements. The center of each lithic was estimated and placed on the center of the 17x20cm grid with the long axis following the Y axis of the grid. The handaxes were photographed with a Canon Rebel XTi on a tripod 58.5 centimeters above the table's surface. Two pictures were taken of each lithic – one of each side. Considering the nature of the typology, there is no ventral-dorsal distinction; therefore, the sides are arbitrary. For the purpose of this thesis, I considered "Side A" the side with less cortex and "Side B" the one with more cortex based on previous work involving geometric morphometric landmarks (Lycett et al. 2006). There were two exceptions to this, artifact 4278 and artifact 3912, which were photographed only once due to their

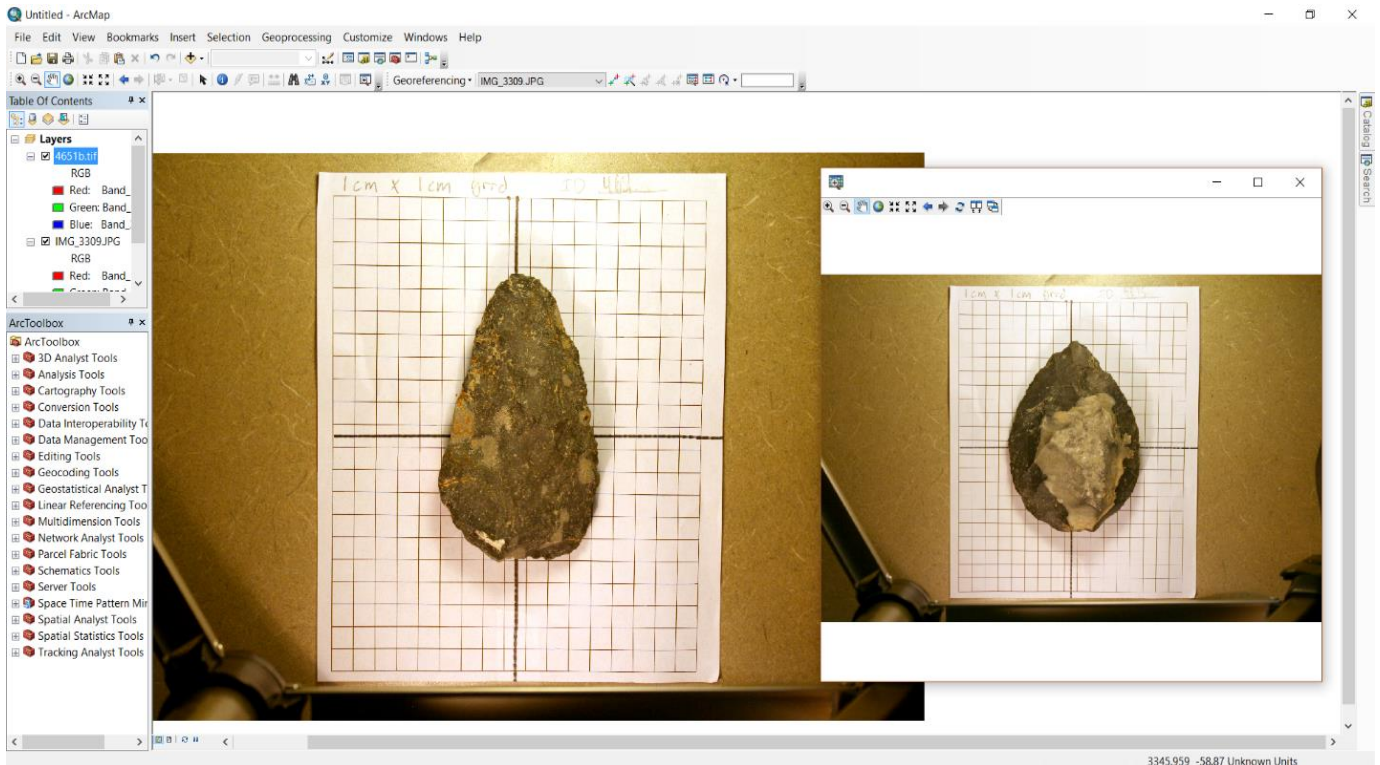


Figure 4.8 – Georeferencing the images of handaxes in order to help control for any distortion in the imagery.

post-depositional fractures. This was done to help create a more uniform representation of the edge rather than potentially altering the calculation due to variation when aligning the two halves.

After the pictures were taken, I georeferenced the images to help control for distortion and defined the coordinates of the grid (Figure 4.8). The top left corner of the grid was defined as (0,0), the top right as (17,0), the bottom right as (17, -21), and lastly the bottom left was defined as (0, -21). This is a critical step in the process as it is essential for getting an accurate edge length during the next stage of the methodology. Once the images of both datasets had their grids defined, I created shapefiles for each side of the tool.

After a shapefile was created for all of the experimental and prehistoric tools, I analyzed the edges of each tool with a low-powered microscope in search of areas of potential edge damage (PED) (Bird et al. 2007; Schoville 2010). When I found edge damage, I mapped it in ArcMap using the “Cut Polygon” tool (Figure 4.9). Similar to the way the shapefiles were created, I examined the tools starting at the bottom of the shapefile in a clockwise motion. During this process, I recorded what type of

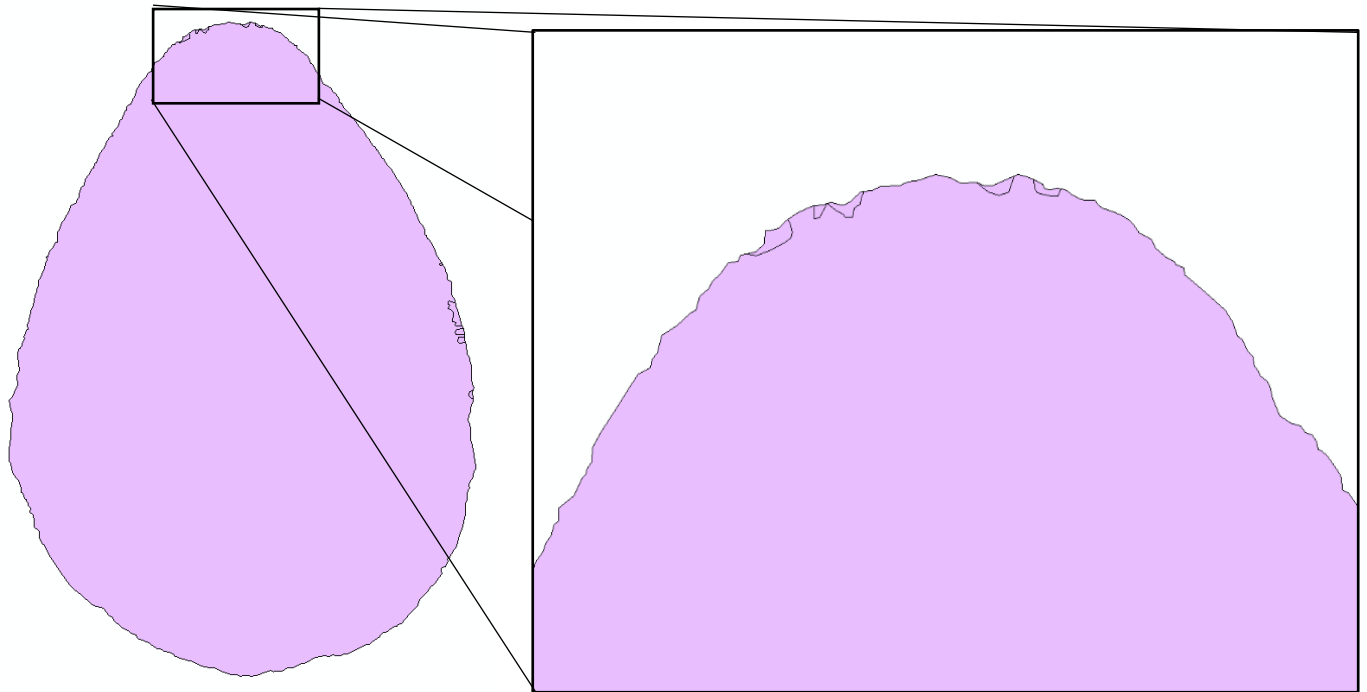


Figure 4.9 – Example of a shapefile representing handaxe SM-1 4033 and the edge damage cut out of the polygon.

damage was present (e.g., microflaking, rounding, crushing) for approximately half of the dataset. Once the PED's were mapped, I used the tool "Polygon to Line" found in the Data Management Toolbox to transform the shapefile into a polyline. This allows for each individual line on the shapefile to be selected. Two fields were added to the attribute table of the polyline: "Edge_Damage", which is a short integer field to document whether or not the line is damaged or undamaged with "1" representing edge damage and "0" representing no damage; and "Edge_Number", a short integer field which was used as a recording system to put the lines in chronological order to make post-processing the data more efficient.

After the shapefile was converted to a polyline, the tool was split in half vertically to designate the left and right edge. Starting at the base of the tool working in a clockwise motion, each edge line was defined as damage or undamaged and assigned a number in the Edge_Number field. Once the tool was completely processed, the necessary information was copied and pasted from the table (Figure 4.10) in ArcMap to a Microsoft Excel spreadsheet. The remaining steps to complete the analysis using this methodology was done solely with Microsoft Excel.

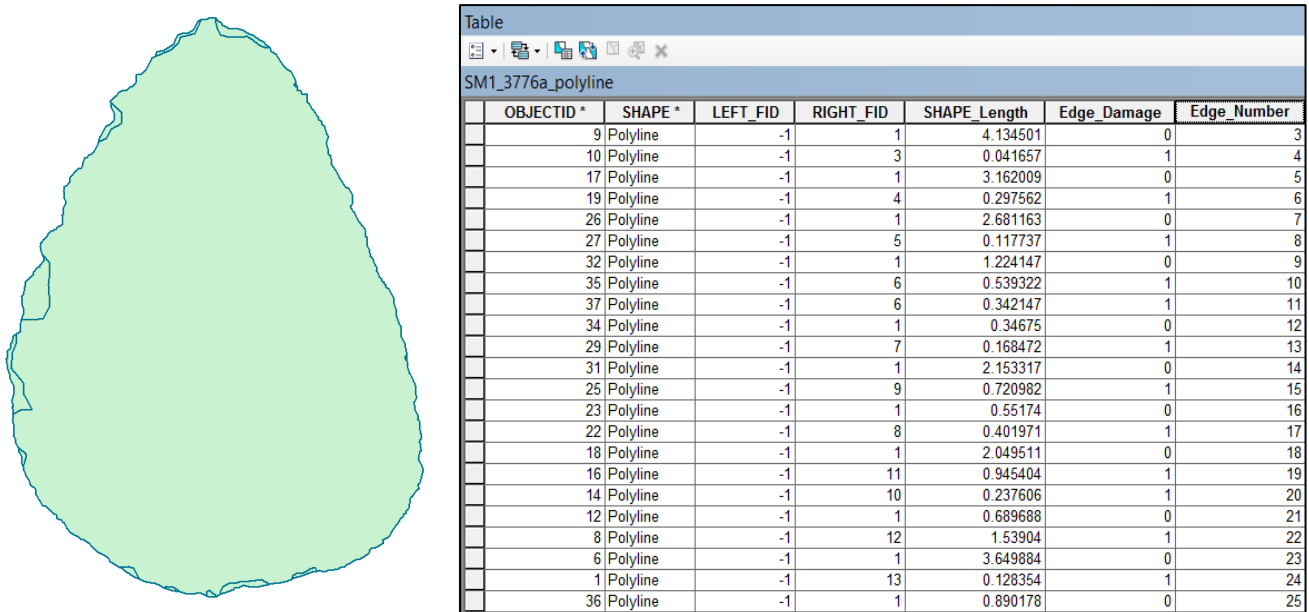


Figure 4.10 – Example of a polygon shapefile converted into a polyline (left) and the associated table for documentation of edge damage

After the data from ArcMap was copied into a blank Excel sheet, the first step was to standardize the edges to take away variability in the length (Schoville 2010). In order to accomplish this, I divided each edge into 100 points that can be subjected to damage. Based on Schoville et al. (2016), I designated the left edge and right edge of side A as points 1-200 and the left and right edge of side B as 201-400 (Figure 4.11). This helped streamline data collection and gave me the ability to create overall distribution charts (Schoville et al. 2016). Once the edges were standardized, I aggregated the occurrence of edge damage at each point of the edge for all tools in the assemblage. There are a total of 22,000 possible locations that can be subjected to edge damage (56 stone tools x 4 edges x 100 possible locations of damage). The aggregated data was used to find the overall distribution of edge damage for each activity (Schoville et al. 2016). Additionally, I calculated the frequency of edge damage for each edge on individual tools in order to test differences in frequency between faces and edges at the artifact level (Schoville 2010). Lastly, I transformed the frequency of edge damage into relative frequency of

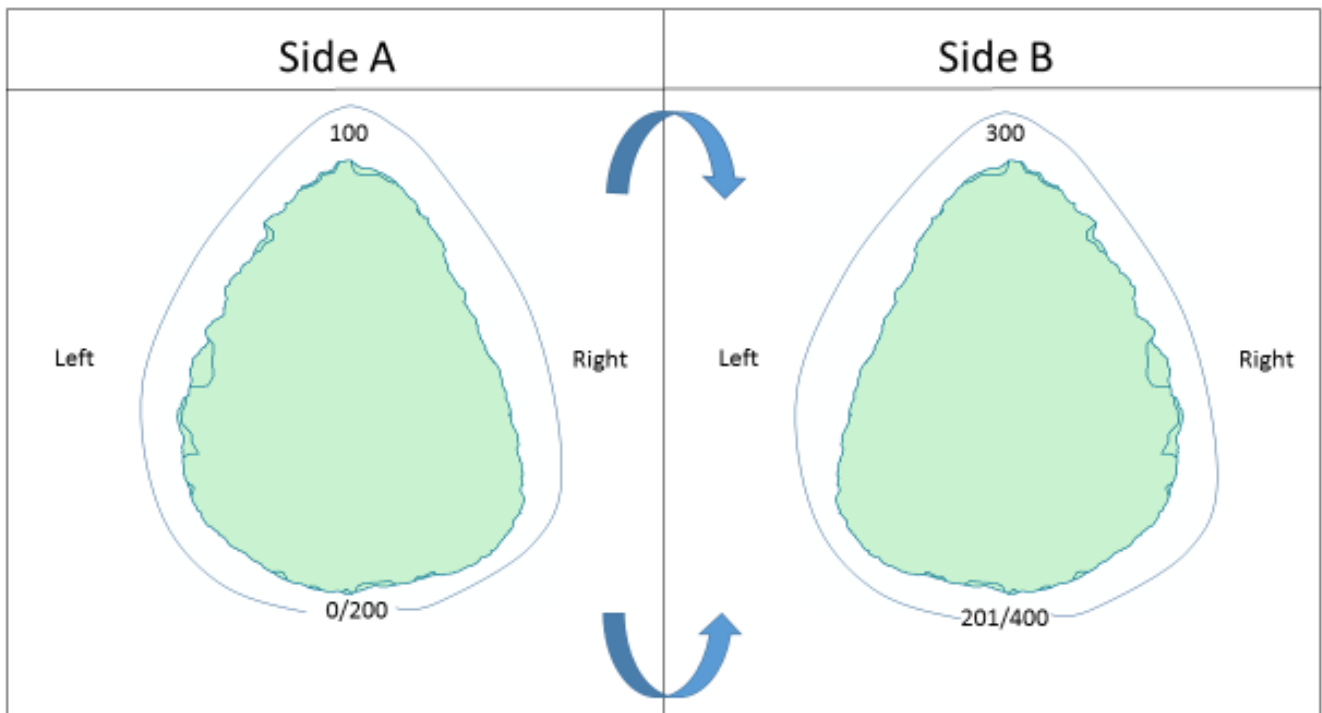


Figure 4.11 – visual representation of the data points on each edge and face. The left side represents face A and the right side represents side B. Each edge is divided into 100 points that are possible areas for edge damage.

edge damage by dividing the number of edge damage occurrences at each point by the total number of occurrences for the edge. Using the relative frequency of edge damage, I created a cumulative distribution of edge damage frequency for each edge and face combination in order to compare these data using the KS test (Schoville 2010; Wilkins and Schoville 2016). Moreover, calculating the relative frequency of edge damage allowed me to create vertical line charts to qualitatively compare differences in the distribution of edge damage between edges (Wilkins and Schoville 2016). Overall, the methodology used in this thesis differs from that of Schoville (2010) in the fact that I combined qualitative aspects of microwear to help inform my interpretations of handaxe use at SM-1 and provide insight to individual handaxe use.

Statistical Procedures

In order to analyze the results of the edge damage distribution data, multiple statistical procedures were conducted. Following Schoville (2010), I used the paired T-test, the Wilcoxon signed-rank test, and the Kolmogorov-Smirnov test. The paired T-test and the Wilcoxon signed-rank test calculations were done using R-studio.

Paired T-test

The paired T-test is a statistical analysis that is used to determine whether or not the mean difference between two paired datasets is zero. When the mean difference between groups is zero that means the two groups must be equal. This test assumes a normal distribution of data. I will use this test to compare frequency of edge damage at the individual artifact level (Schoville 2010).

Wilcoxon signed-rank Test

Similar to the paired T-test, the Wilcoxon signed-rank test compares two matched samples to determine whether or not their mean differences are equal. However, unlike the paired T-test, the

Wilcoxon signed-rank test is nonparametric therefore it does not assume a normal distribution for the data (Thomas 1986, 332). I used this test in conjunction with the paired T-test to assess edge damage frequency at the individual artifact level (Schoville 2010) – it is likely a better indicator of statistical differences because the edge damage data are not normally distributed.

Kolmogrov-Smirnov (KS) Test

The KS test is a non-parametric statistical method that is used to determine whether two cumulative distributions are drawn from the same population (Schoville 2010; Shennan 1997). Rather than using R Studio, I used Excel to calculate this statistic. In order to determine the relationship between both populations, two numbers must be found. The first, D_{obs} , is the maximum difference between both populations. The second, D_{max} , is calculated at a confidence level (α) of .05, using the formula below:

$$1.36 \sqrt{\frac{n_1+n_2}{n_1 n_2}}$$

For determining the similarities between the edge damage distributions, n is represented by the total number of locations that have edge damage. If D_{obs} is greater than D_{max} then there is less than 5% chance that the distributions are from the same populations so the null hypothesis may be rejected. It is important to remember that even if the null hypothesis is not rejected, this does not necessarily mean that the distributions are from the *same* population – it just means there is not enough evidence to say they are different (Shennan 1997, 61).

Confounding Factors

There were many confounding factors that might possibly affect the results of this analysis. The most major of these is the designation of side A and side B. It is unknown whether or not the distinction of face A as one with less cortex is valid. Additionally, it is impossible to know whether or not the SM-1 hominins would have viewed the faces as I do. Another factor that might have influenced the results of this analysis is the variability in handaxe shape and size. Little is known about how overall handaxe shape and size effects the distribution and frequency of edge damage and whether or not these are significant factors in determining function. Moreover, there is no true platform in most of the handaxes so they were simply orientated along their long axis. This means that the position of squared edges discussed earlier was not controlled for. Lastly, edge angle was not recorded so it is not known how this influences the distribution of edge damage on the SM-1 handaxes.

Summary

The experimental use-wear approach used within this research was adopted from Schoville (2010) in order to address the complexity surrounding functional studies discussed in Chapter 2. The methodology approaches use-wear at an assemblage scale in order to decrease the possibility of equifinality during my interpretation of edge damage. In particular, this methodology allowed me to quantify and statistically analyze the frequency and distribution of edge damage within the handaxes found at SM-1. This chapter has outlined the experimental protocol and described the steps taken to conduct the analysis. The next chapter will provide the qualitative descriptions of use-wear in conjunction with the results of the statistical analyses in order to answer the research questions outlined in Chapter 1.

Chapter 5: Results

Introduction

This chapter will begin comparing the measurements and shape of the experimental assemblage to the archaeological data. Next, I will discuss the results of the use-wear analysis with emphasis on the edge damage and residues found on a subsample of the SM-1 artifacts. Although the methodology used in this research does not assign behavioral interpretations to individual areas of edge damage, understanding the type of edge damage found at SM-1 will aid in the interpretation of the edge damage distribution analysis. In particular, I can speculate about the hardness of the contact materials based on the intensity of edge damage found on the SM-1 tools. Identifying the hardness of worked material is one of the least ambiguous aspects of use-wear analysis and it is generally agreed that it can be reliably determined (Grace 1989). Next, the research questions will be tested with a combination of qualitative descriptions of the distribution and frequency of edge damage and quantitative statistical procedures such paired T-tests, Wilcoxon signed-rank tests, and Kolmogorov-Smirnov (KS) tests, which were described in the previous chapter.

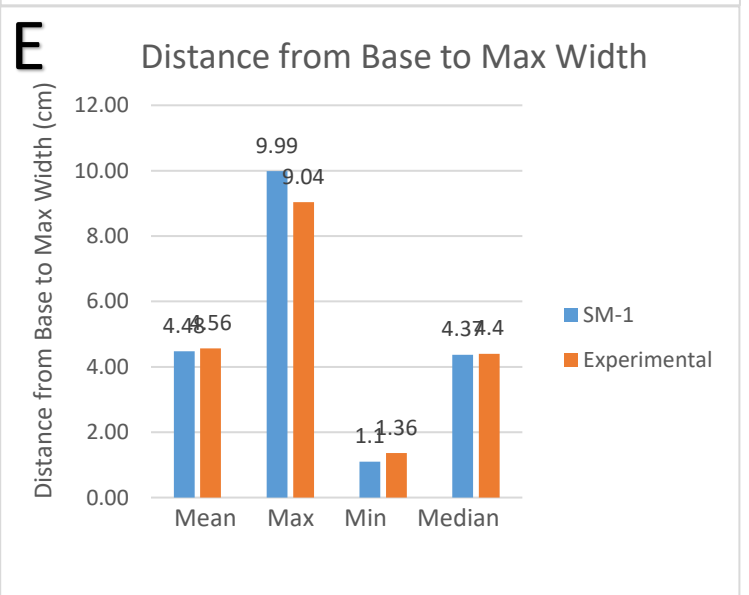
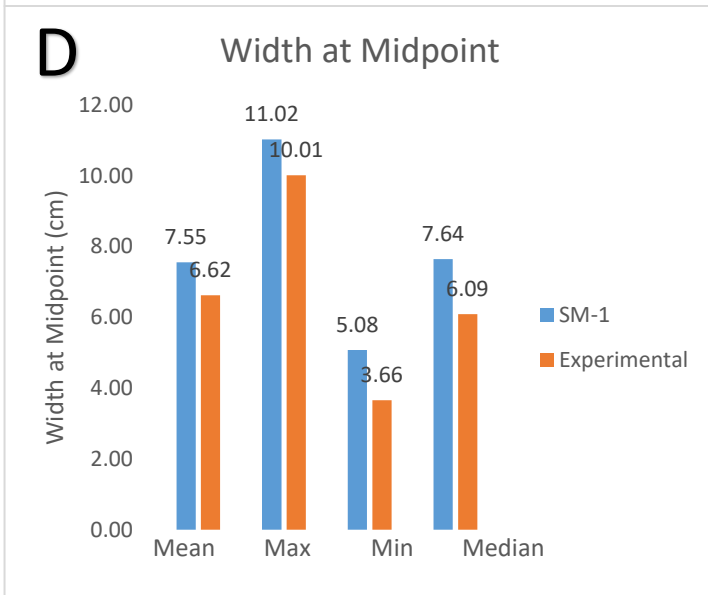
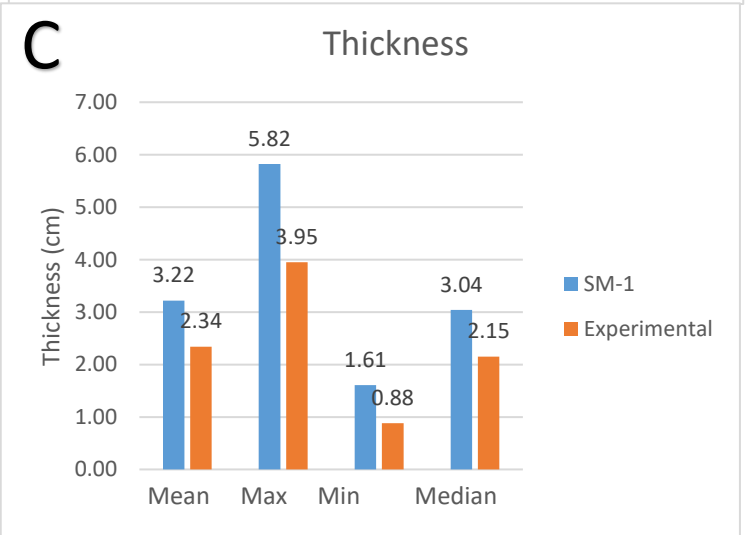
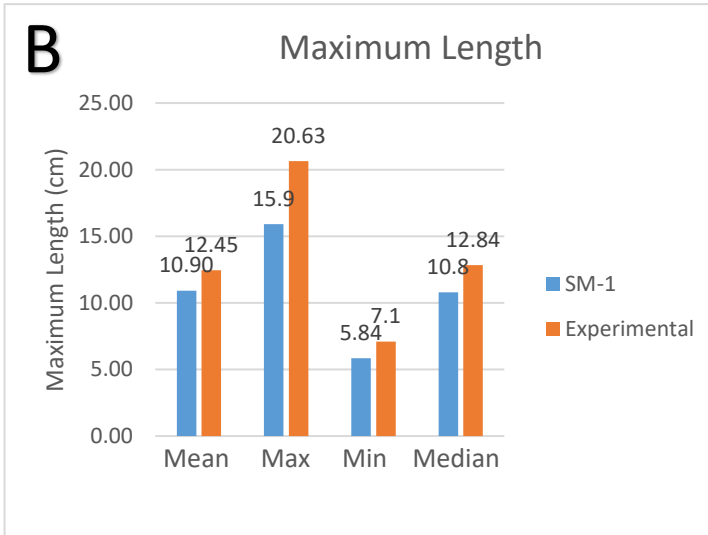
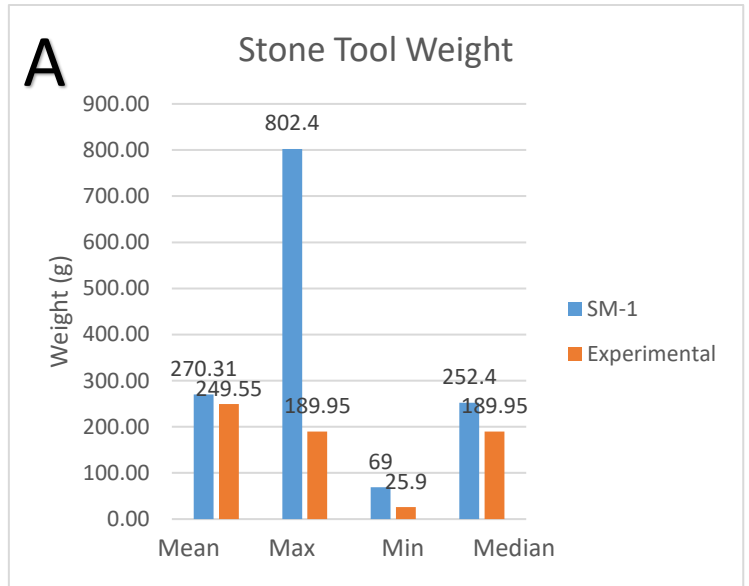
Comparative Summary of Lithic Assemblages

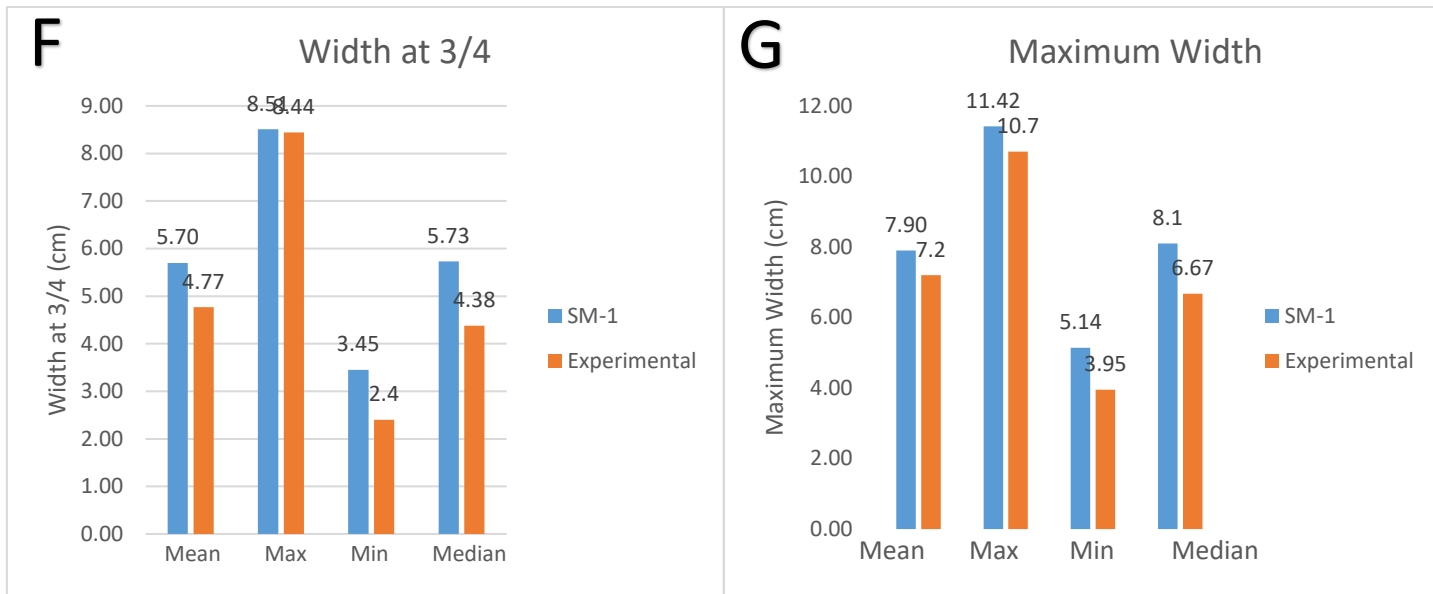
Summary Statistics

After the measurements were taken, the mean, median, minimum, and maximum were calculated for each category for both the prehistoric and experimental assemblage. The results of each measurement were then graphed comparing the two datasets (Figure 5.1 – A-G). As seen in the graphs, the lithic assemblages are quite similar.

Figure 5.1 - A-G

Summary statistics comparing the basic measurements of the prehistoric SM-1 assemblage and the experimental assemblage created by John Murray and Dan Stueber. (A) weight (B) maximum length (C) thickness (D) width at midpoint (E) distance from base to maximum width (F) width at $\frac{1}{4}$ length (G) maximum width





Shape

Once the measurements were completed on both assemblages, the Location of Max Width and the Roundness value were calculated for each tool (Debénath and Dibble 1994). By comparing these two calculations, I can quantitatively describe the shape of each tool and visually describe the overall shape of the assemblages. The formulas for these calculations are as follows:

Location of Maximum Width

$$\frac{\text{Length}}{\text{Distance to Maximum Width}}$$

Roundness

$$\frac{\text{Width at Midpoint}}{\text{Maximum Width}}$$

After these calculations were made, four scatter plots were created: the first showing experimental shape (Figure 5.2), the second showing the prehistoric assemblage shape (Figure 5.3); the third comparing the experimental dataset to the prehistoric dataset (Figure 5.4); and lastly, one comparing shape between stratigraphic layers in the prehistoric data (Figure 5.5).

Figure 5.2 – Shape graph of the replicated bifaces. Consists of various biface shapes including ovate, discoid, triangular, and cordiform.

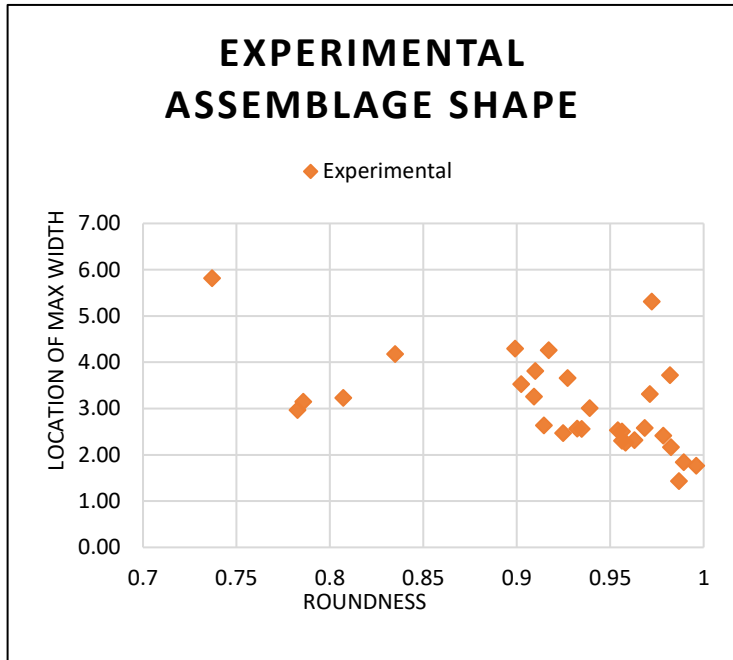


Figure 5.4 – Shape graph comparing the two previous graphs on one. The experimental shape graph is slightly fairly similar, but has a higher frequency of elongated bifaces.

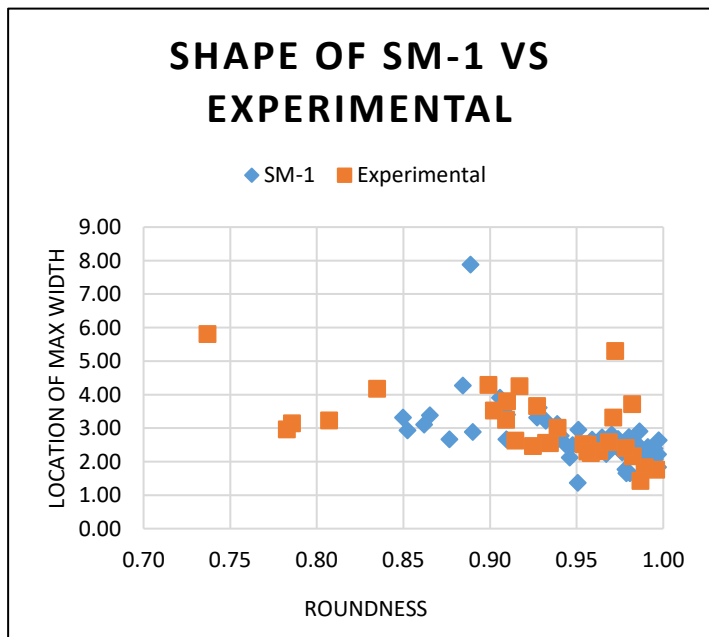


Figure 5.3 – Shape graph of the prehistoric biface assemblage from SM-1. The assemblage is dominated by ovate and discoidal bifaces with some pointed and elongated bifaces.

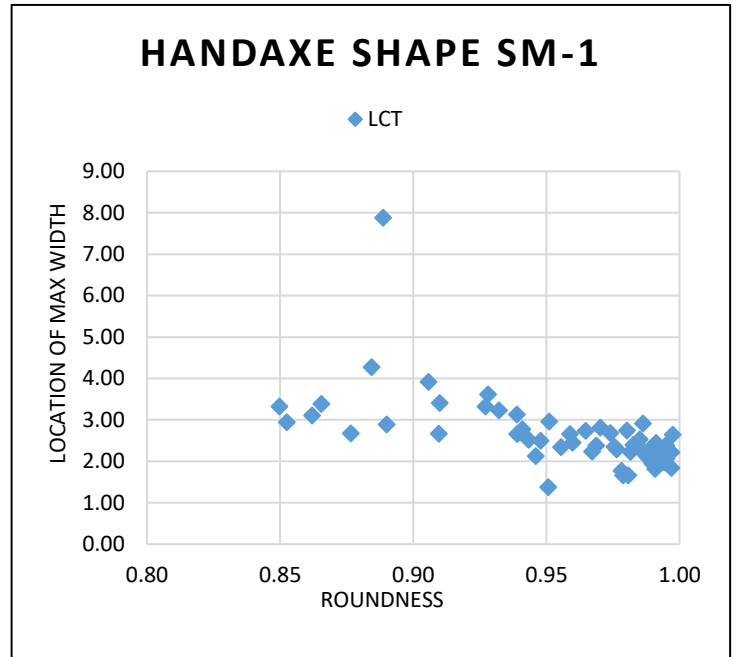
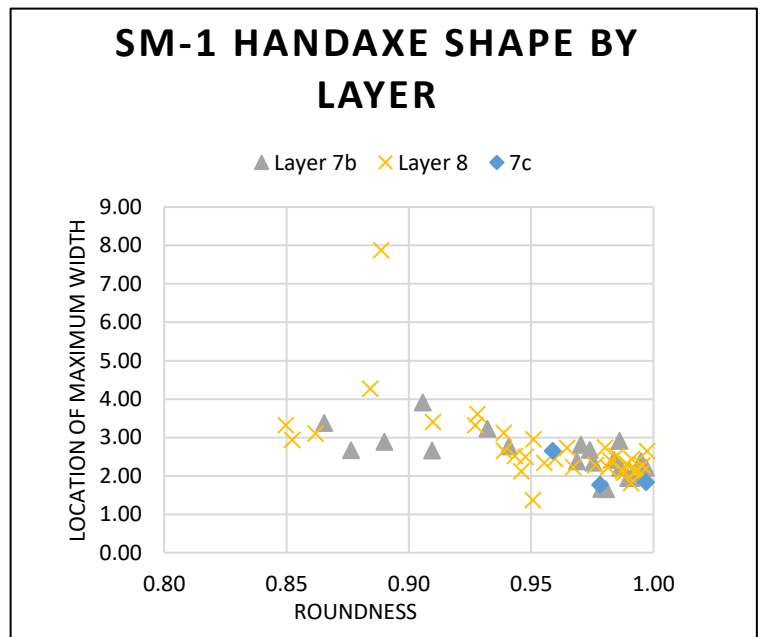


Figure 5.5 – Intra-site shape analysis between geologic layers at SM-1. Layer 8 is the oldest, dating to ~260,000 years ago with layers 7b and 7c dating to at least 125,000 years ago. The shapes between layers is similar.



Results of the Experimental Use-wear Analysis

The results of the experimental portion of this project are presented below. Due to limited access to a microscope with a camera, not all tools will have microscopic images associated with them. I will provide observations about the primary type of edge damage found within each experimental activity and describe my experience in using the handaxes during each activity.

Butchery

Overall, the five handaxes used in the experimental butchery were highly successful in accomplishing their task – whether it was skinning, dismembering, or cutting meat (Figure 5.6). The handaxes selected for this activity are fairly large and the most symmetrical of the assemblage. Considering I had never butchered an animal before, I felt that it would be more efficient and practical



Figure 5.6 – Photograph of experimental butchery – skinning process



Figure 5.7 – Microphotograph of a flake used in butchery exhibiting microflaking and rounding (50x).

to use the tools I perceived as most effective. Although, it is likely that any handaxe would have been effective considering previous research has shown that symmetry does not improve cutting efficiency (Machin et al. 2007).

All of the handaxes used in the butchery showed signs of edge damage. The primary type of edge damage associated with the experimental butchery is rounding and microflaking – typically found together – on both the handaxes and flakes (Figure 5.7). The microflaking was likely caused by contact with bone. Interestingly, despite cleaning the handaxes with soap and water immediately after using them, they stained red from the blood due to the porous nature of the chert.

Longitudinal Actions

The effectiveness (ability to accomplish task) of the handaxes used for longitudinal motions varied between contact materials. For hard material such as bone and antler, the handaxes were less effective than when used to process medium-soft materials like wood and bamboo. However, similar difficulties arose when sawing through antler, bone, and wood. In particular, as the handaxe cut deeper into the bone or antler, it became more difficult to saw through because of the contact between the

worked material and the faces of the tool. Although the effectiveness was variable between materials, the edges were durable regardless of activity.

Using handaxes in longitudinal actions on hard materials produced more edge damage than when used on softer materials. The primary edge damage found on handaxes used for sawing bone and antler was rounding and microflaking. On softer materials such as the wood and bamboo, slight rounding formed but microflaking was rare.

Percussive Actions

Similar to the longitudinal experiments, the handaxes used for percussive activities had variable effectiveness depending on the contact material. Considering the nature of percussive activities is similar to that of flintknapping, flakes were produced during these activities. In particular, percussive activities on hard materials such as chopping bone produced highly noticeable and invasive edge damage that resulted in flaking (Figure 5.8). Interestingly, these flakes were comparable to flakes found from the process of biface reduction (Figure 5.9). The activity essentially created a small lithic assemblage in itself. Although the tool used for chopping bone was effective, it is likely there is a more

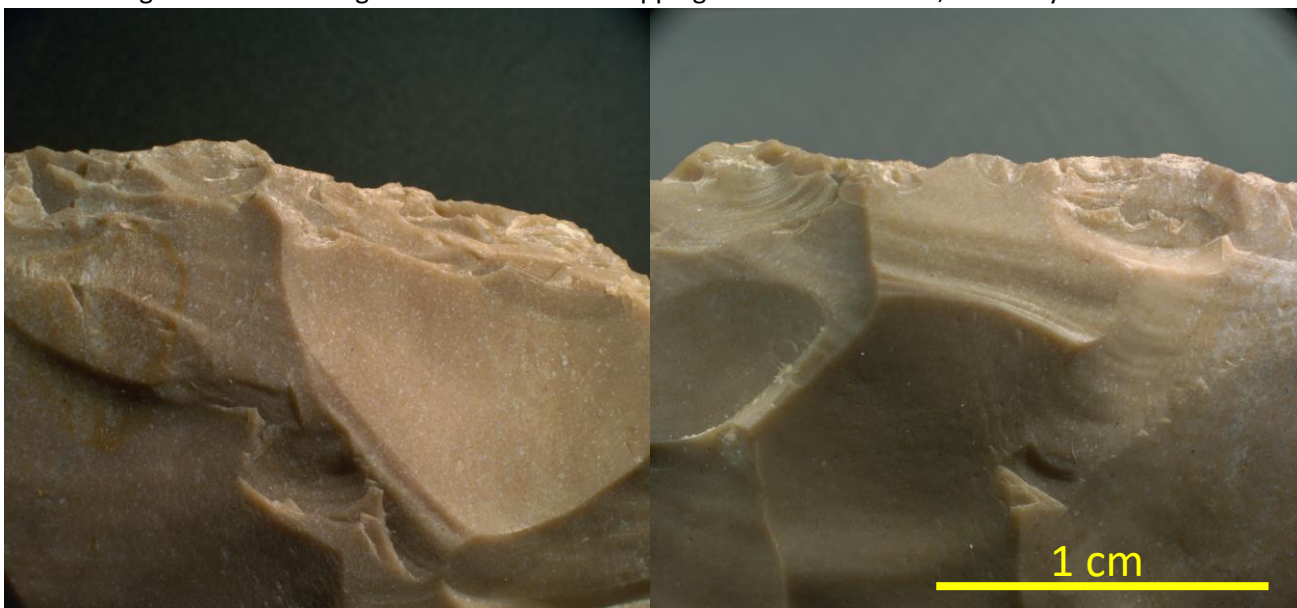


Figure 5.8 – Microphotograph of DS-11 used in chopping bone exhibiting microflaking, invasive flaking, and crushing (25x).



Figure 5.9 – Documentation of flakes produced from chopping bone.

parsimonious solution to accessing marrow such as using a hammerstone or large rock near the kill or butchery site. In addition to chopping bone, shucking oysters produced intense crushing and edge damage that included debitage. The type of use-wear produced by percussion on hard materials would be easily recognizable if it was present in an archaeological assemblage.

Unlike percussive activities on hard materials, working soft-medium materials such as digging in the grass and adzing/chopping wood produced much less edge damage – sometimes it was almost non-existent. Considering the durability of the distal end of the handaxes in these experiments, it will likely be difficult to recognize high intensity activities on softer materials in the archaeological assemblage; however, previous research has shown that percussive experiments on wood produces recognizable – although considerably less intense – edge damage (Viallet 2016b). One interesting observation from these experiments is that tip shape seems to influence the effectiveness of percussion on wood. The

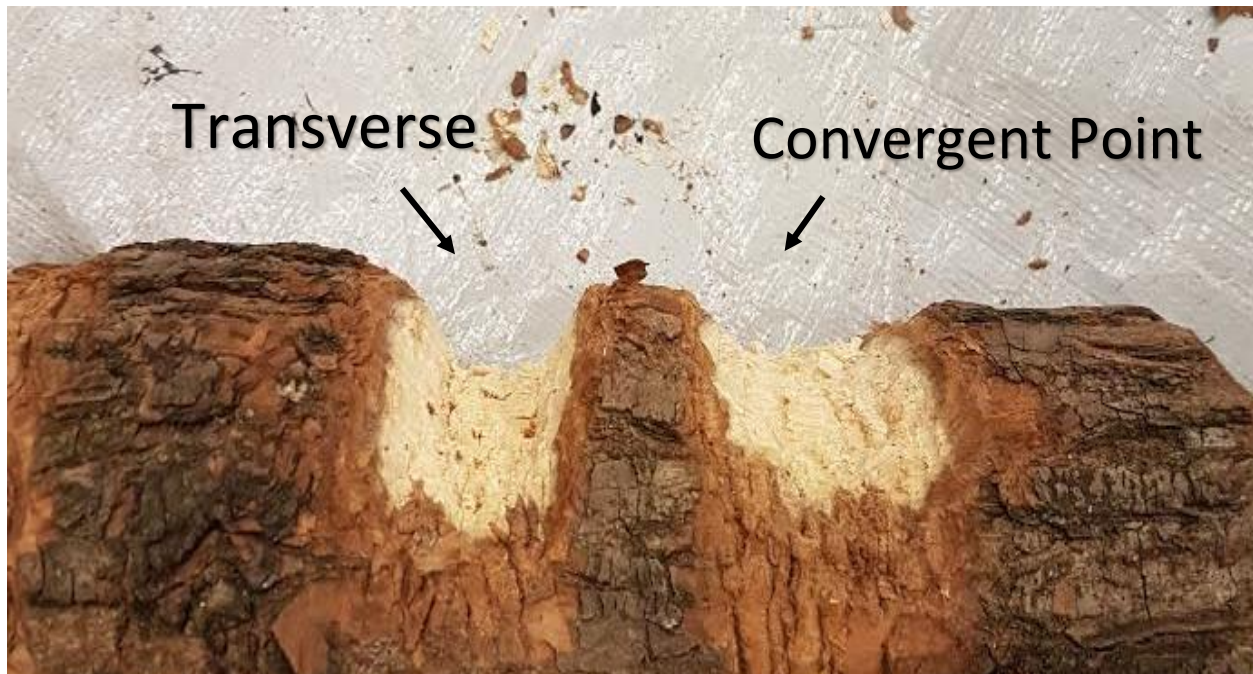


Figure 5.10 – Image showing the difference in effectiveness between a handaxe with a convergent point and a handaxe with a cleaver-like tip.

handaxe with a convergent point was less effective than the handaxe with a transverse distal end – which is more cleaver-like – for chopping wood (Figure 5.10).

Transverse Actions

As mentioned in Chapter 4, I did not include many transverse activities within the experimental protocol. I used two handaxes in transverse motions: planing antler and planing/scraping wood. The handaxes were effective in both circumstances. The handaxe was more effective at planing antler than it was when used for sawing antler. Additionally, the handaxe used for planing and scraping was successful in creating a spearhead out of dry wood (Figure 5.11). The primary edge damage seen in these activities was microflaking with some areas of rounding.



Figure 5.11 – Documentation of processing dried wood to create a spear tip

Post Depositional Experiments

The post-depositional experiments in this project were limited to simulating low energy fluvial contexts with the use of a tumbler. The first trials with the tumbler ended up completely damaging the tools with 100% of the edges damaged. These tools had edge damage that consisted of heavy rounding. I had not realized how much of an affect the tumbler would have on the edges and for the later trials, I lowered the time the tools were left in the tumbler. These tools still had a high amount of edge damage but there was both rounding and microflaking present. In the future, the post-depositional experiments will be expanded to trampling and a more precise tumbling experiments that include the addition of similar sediments to those found at SM-1.

Results of the Prehistoric Use-Wear Analysis

The bifacial tools at SM-1 are noticeably utilized with an average edge damage of 31.63% when all edges are combined. There were very few tools with less than 10% of the edge damaged. After further inspection, it is likely that these tools are cores – possibly early Levallois cores. Further details will be discussed in the edge damage distribution section. The most common form of use-wear seen on these tools is rounding, along with microflaking, and some areas of crushing. On heavily used areas, there was the presence of both microflaking and rounding. The intense degree of rounding on these bifacial tools is likely due to contact with medium-hard materials (Grace 1989). During the experimental studies, soft materials such as wood or plants created very little use-wear, even when used during a high intensity activity such as adzing or chopping. Crushing seems to be more common closer to the base. To provide the reader with examples of the edge damage being found on the artifacts, a sub-sample of artifacts will be discussed below.

SM1-3547

SM1-3547 is a small discoidal biface that has an average edge damage of 31.76%. The tool measures 8.3 cm in length, 7.26 cm in width, and 3.6 cm in thickness. This biface exhibits microflaking, rounding, and has preserved a transparent green residue in association with edge damage (Figure 5.12). It

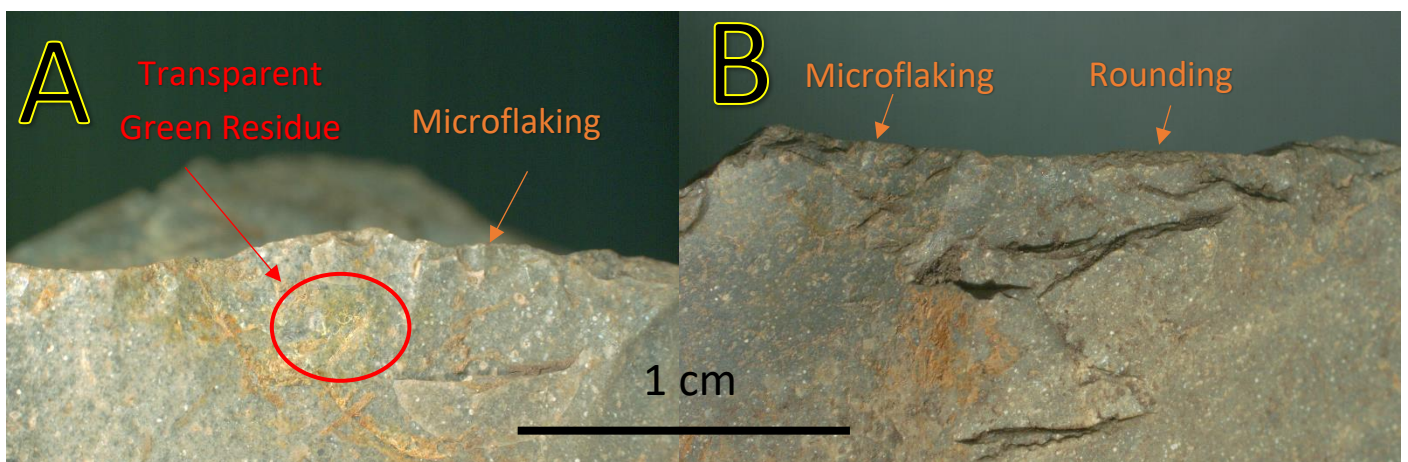


Figure 5.12 – Microphotograph of SM-3547 use-wear; microflaking and residue (A) rounding and microflaking (B) (75x).

is difficult to see the green residue in the picture primarily because it is highly reflective. I attempted to change color schemes and brighten/darken the image, however, nothing seemed to help. The microflaking and rounding in Figure 5.12b is associated with superimposed step-fractures. The association of rounding and superimposed step-fractures has been argued to be evidence of hafting (Lambert-Law de Lauriston 2015; Rots 2013).

SM1 – 3805

SM1-3805 is a large cleaver-like bifacial tool with intensive tip damage. SM1-3805 has a length of 12.27 cm, a width of 7.85 cm, and a thickness of 4.91 cm, with an average of 37.73% of the edge damaged. There is edge damage associated with both sides of the tip (Figure 5.13a). Additionally, there is evidence of intense rounding and microflaking on the right portion of the distal end of side A (Figure 5.13b).

In addition to the edge damage on the distal portion of SM1-3805, there are a variety of possibly organic residues found on the surface of the stone tool. There is evidence of red staining (Figure 5.14a) and sap or some type of plant residue (Figure 5.14b). Further analysis and documentation is required to

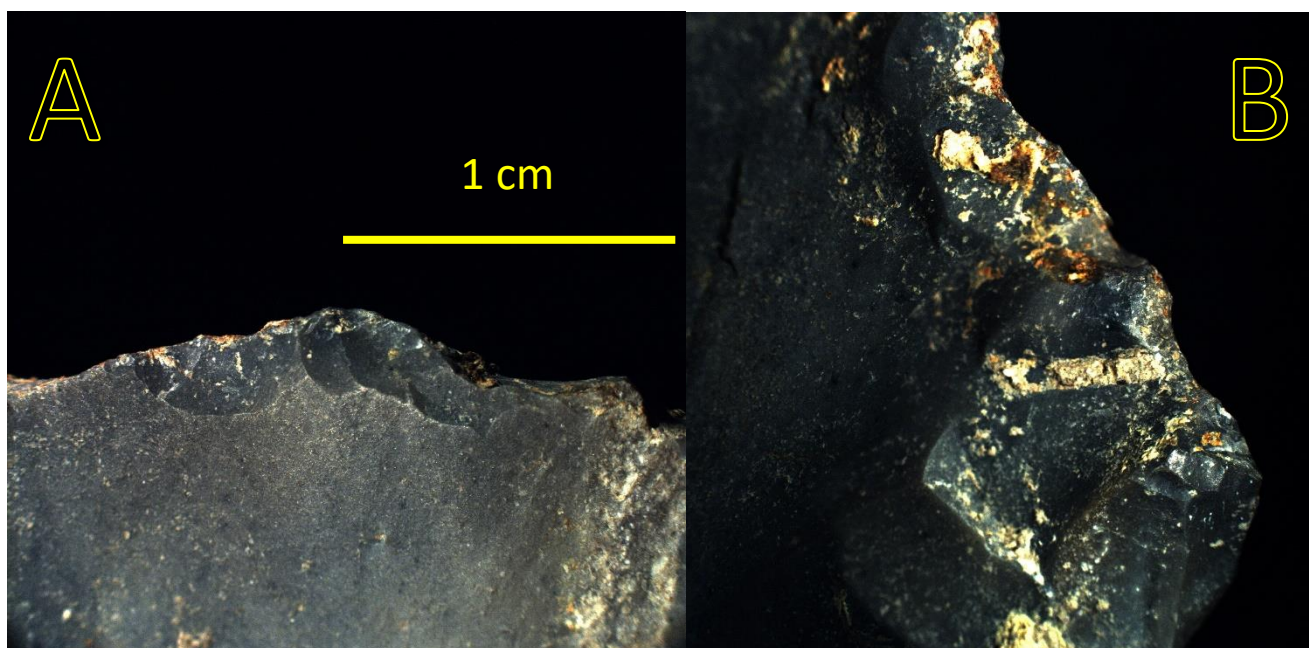


Figure 5.13 – Microphotograph of SM-3805 use-wear; microflaking (A) heavy rounding and microflaking (B) (50x).

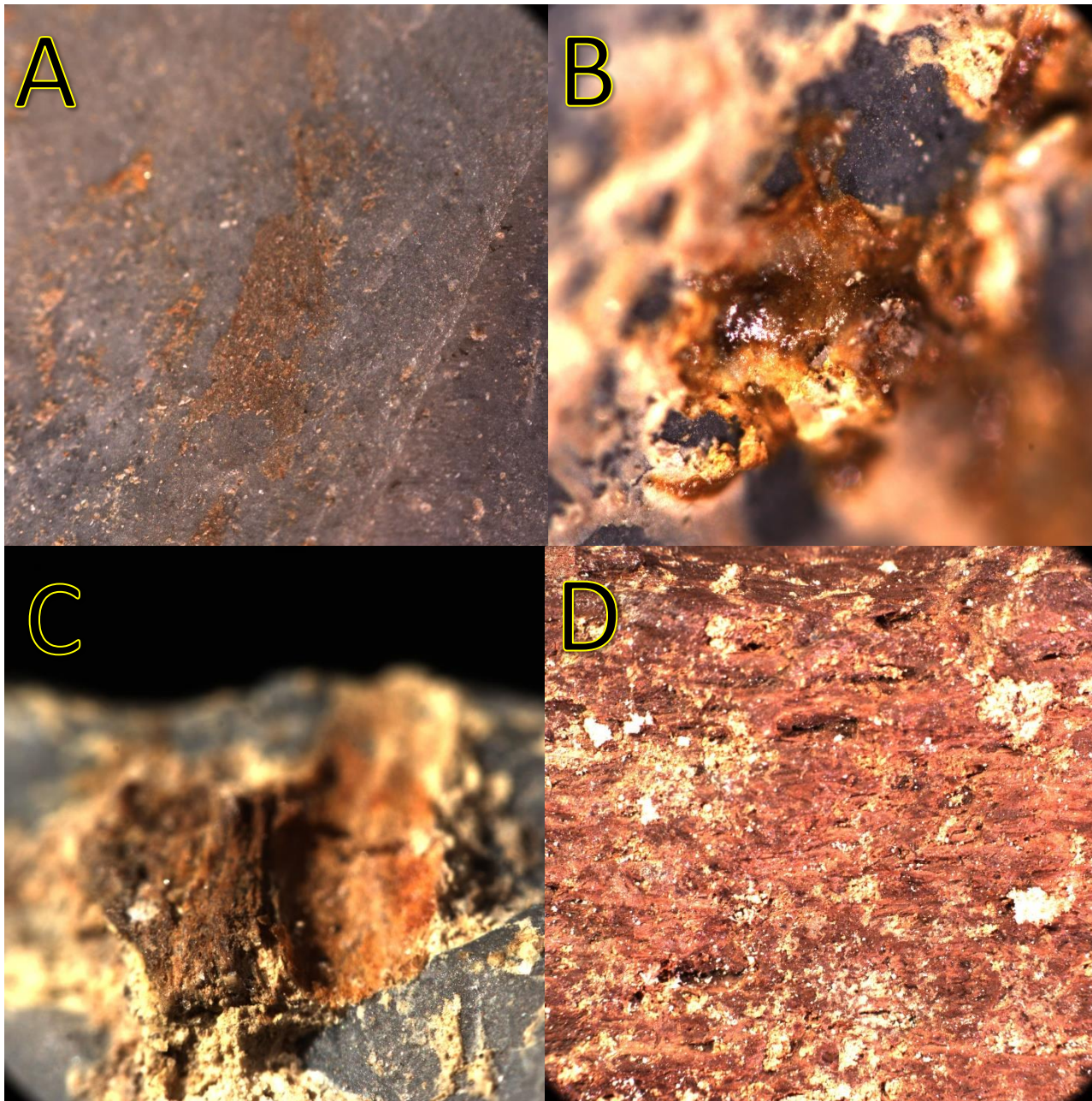


Figure 5.14 – Microphotographs of potential organic residue – A) orange staining B) possible sap or plant residue C) possible bone adhering to the distal end D) surface of bone fragment from the site.

be sure whether this is actually organic. Moreover, there is an interesting material that seems to have adhered to the surface of SM1-3805 at the distal end of the tool. I believe this to be a small piece of bone – possibly from use. Alternatively, the material could have just adhered to the tool post-depositionally. In order to investigate whether or not this is bone, a piece of bone found in the excavation was documented under the microscope at 120x. The comparison of the material found on

the tool and the microphotograph of the bone can be seen in Figure 5.14d. There are similarities to the surface of the bone and the material found on the tool; in particular, they share the same linear grooves. Moreover, based on my own experiences excavating faunal material from the site, the residue found next to the bone looks exactly like the imprint the bone would leave in the sediment when it was excavated. Although further analysis is required to confirm this is bone, it is interesting to note the possibility of bone working in the prehistoric assemblage based off of adhering residue.

SM1-4751

SM1-4751 is a large handaxe that is primarily worked on the distal portion of the tool. It has a large squared base that is highly unworked. Interestingly, the tool looks as though it is the result of an expedient or opportunistic. SM1-4751 has a length of 13.6 cm, a width of 8.1 cm, and a thickness of 4.42 cm. There is evidence of patination on a large flake removal in the bottom right portion of side A. There is evidence of intensive rounding and crushing on the distal end of the tool can be seen in Figure 5.15. This edge damage is quite interesting and not seen in any of the experimental artifacts, but is very common in the archaeological assemblage. The damage is more intense on one side of the tool in this area which is indicative of the edge used at less than 90° to the surface material.

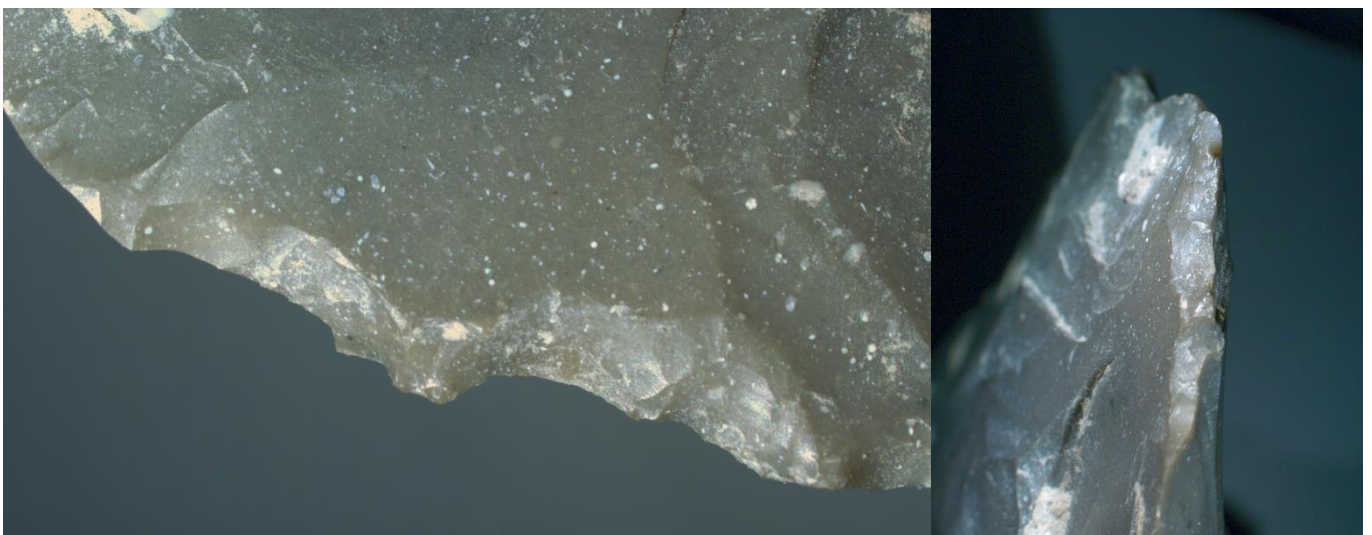
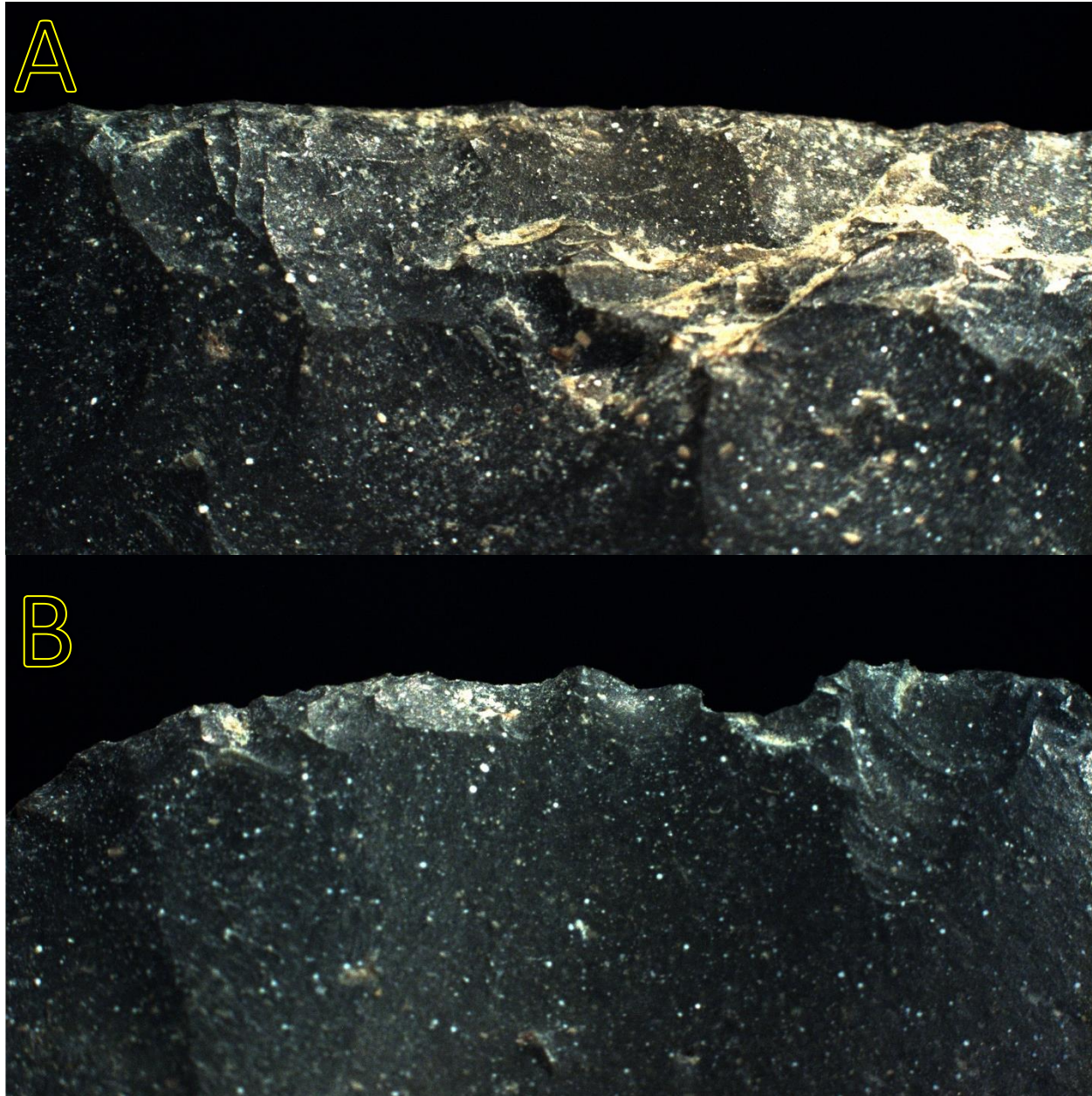


Figure 5.15 – Microphotograph of SM-4751 use-wear – heavy rounding (75x)

SM1-4826

SM1-4826 is a thin ovate biface that has approximately 15% cortex on Side B. The biface measures 11.8 cm in length, 8.86 cm in width, and 2.66 cm in thickness. The tool is more refined and intensely flaked that most others. The tool has evidence of use-wear on the lateral portion of side A (Figure 5.16a).



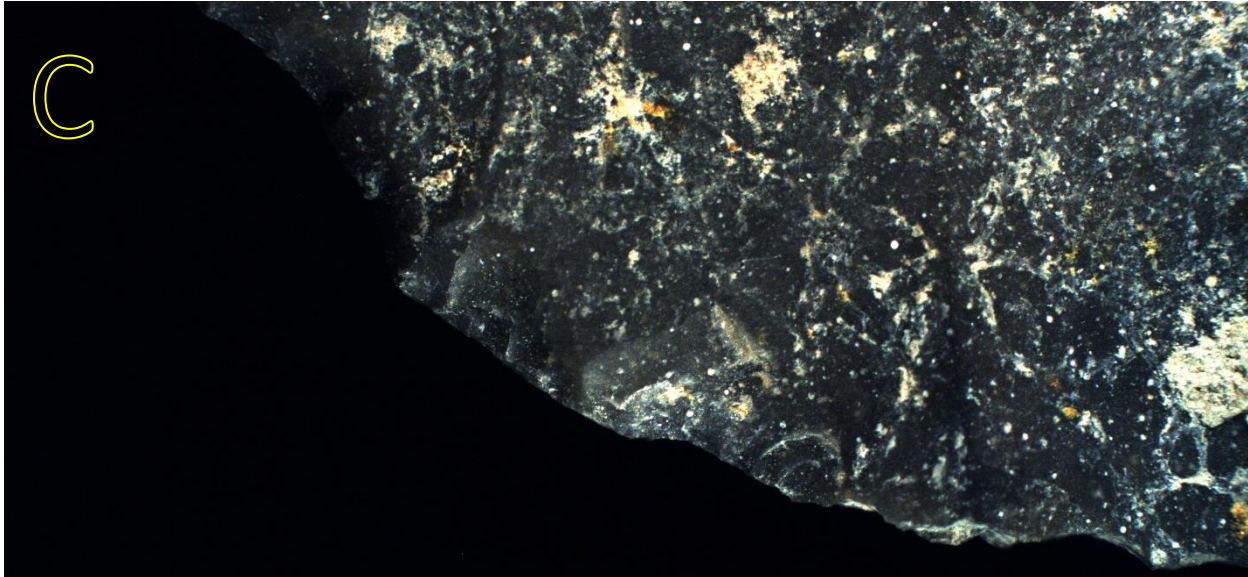


Figure 5.16 – Microphotograph of SM-4826 use-wear - rounding with invasive step fractures (A) rounding and microflaking (B) microflaking (C) (50x).

and the distal end of both sides (Figure 5.15 B-C). There is evidence of both rounding and microflaking.

In addition to evidence of use related edge damage, there are a number of residues found on the surface of the stone tool during the pre-experimental scan. There is a black material or sediment that is possibly charcoal but further high powered microscopic analysis is required to confirm this (Figure 5.17).

Figure 5.17 – Microphotograph of possible charcoal residue on SM1 - 4826



Results of the Experimental Edge Damage Distribution Analysis

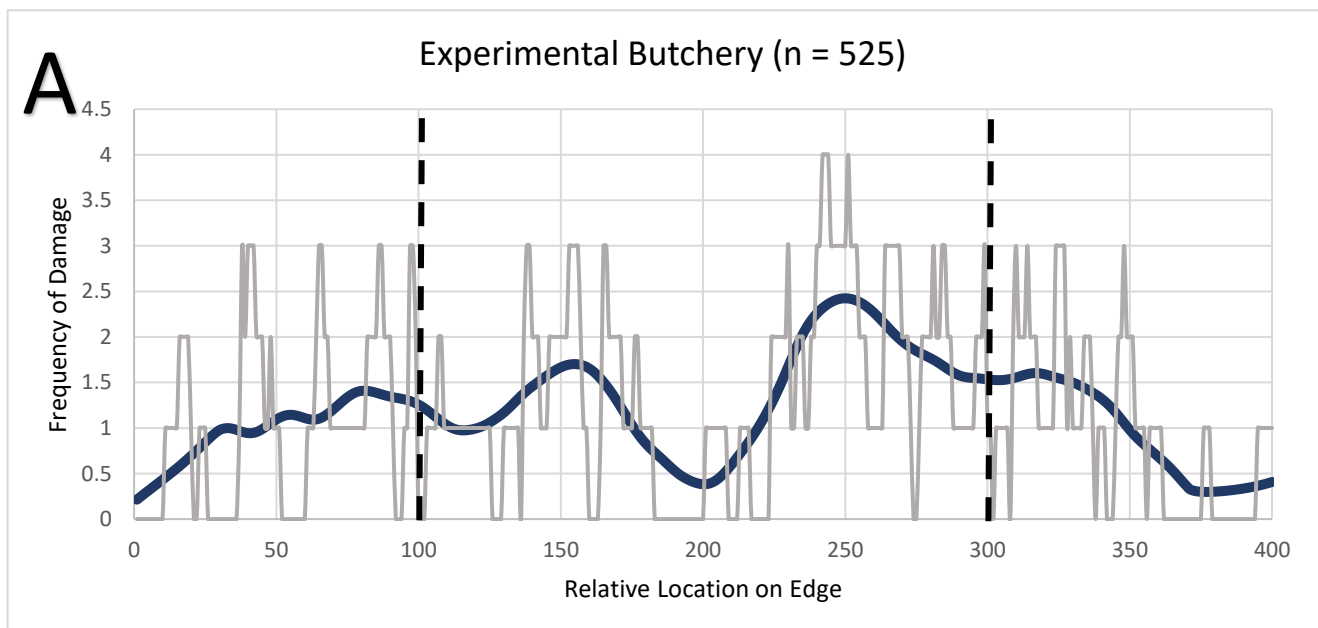
This section provides the results of the edge damage distribution analysis (Schoville 2010; Schoville et al. 2016; Wilkins and Schoville 2016) for both the experimental and prehistoric assemblage. As mentioned in Chapter 4, I have adopted a variety of statistical analyses from Dr. Schoville's work (Schoville 2010) including the associated graphical representations (Schoville et al. 2016; Wilkins and Schoville 2016). Moreover, these data will be interpreted based on previous experimental work that included low-powered use-wear analyses (Grace 1989; Tringham et al. 1974; Vaughan 1985). The results of these analyses have suggested that certain motions (e.g., transverse, longitudinal) will produce specific patterns and distribution of use-wear signatures.

Question 1: Is there a significant difference in edge damage distribution between activity groups?

H₀ – There are no significant differences in the distribution of edge damage between groups.

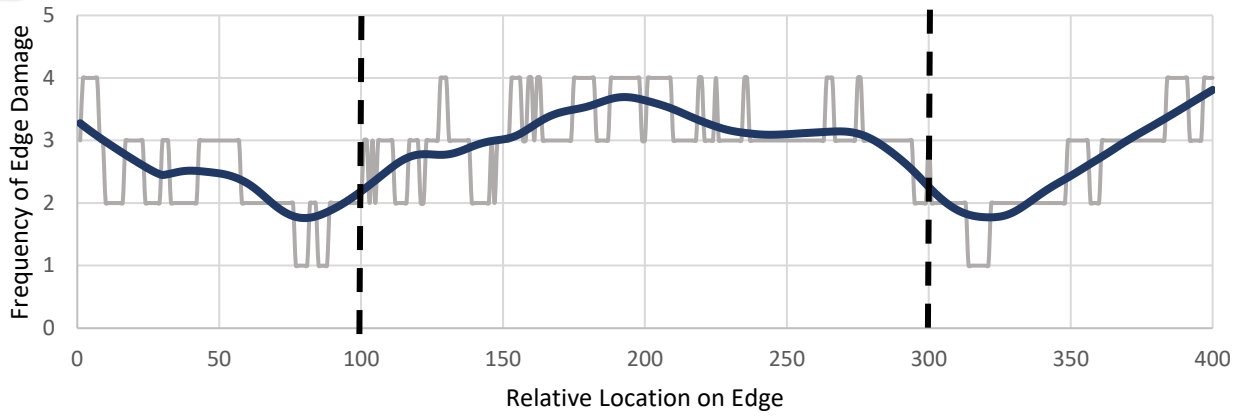
H₁ – There are statistically significant differences in the distribution of edge damage between groups.

The first step in determining whether or not I can use the experimental dataset to distinguish between activity groups in the archaeological record is to determine if they have different distributions from one another (Figure 5.18a-e). Qualitatively speaking, the graphs have a noticeably different distributions.

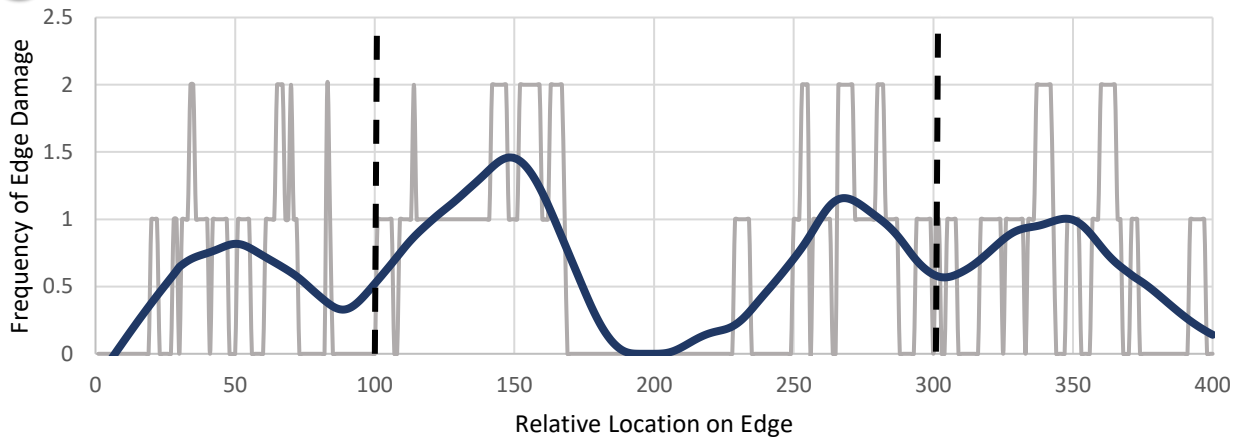


B

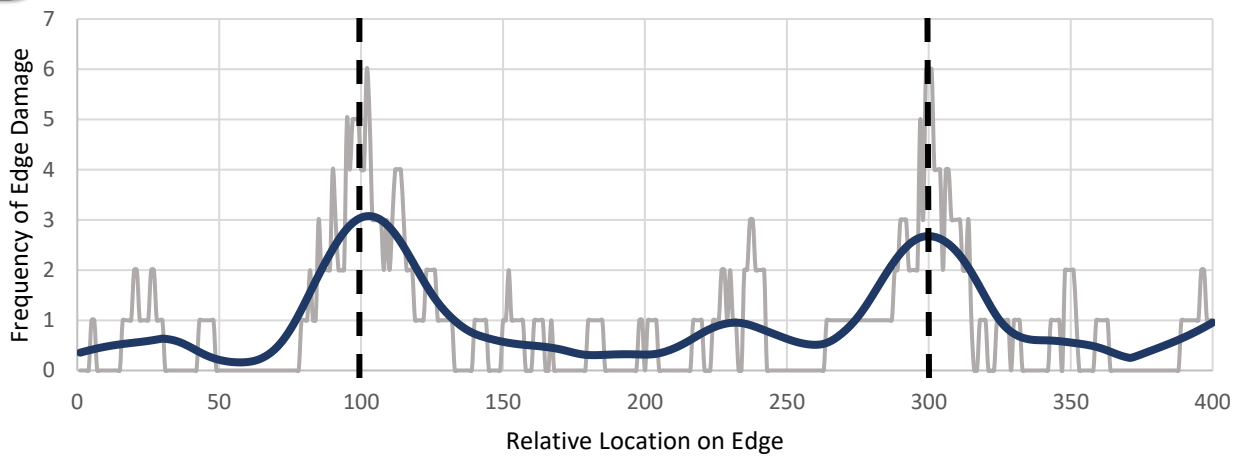
Post-Depositional Experiments (n = 1110)

**C**

Longitudinal Experiments (n = 260)

**D**

Percussive Activities (n = 383)



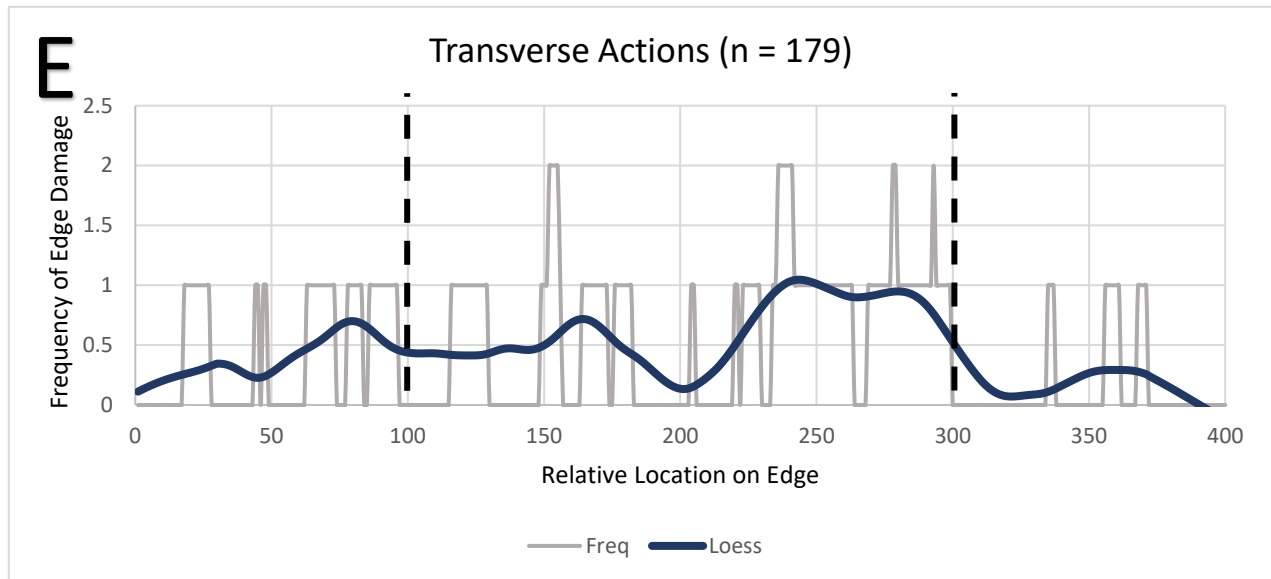


Figure 5.18 – Overall distribution of edge damage frequency for each group of experimental activities: (a) butchery (b) post-depositional (c) longitudinal (d) percussive (e) transverse. The sample size (n) is the total number of edge damage occurrences. The x – axis represents the relative location on the edge of each face starting on the bottom left edge of face A (1) to the bottom right of face B (400) (face A – 1-200; face B – 201-400). Refer to methods section for further details. The y-axis represents the frequency of edge damage at each location of the edge. A LOESS smoothing spline was applied to the data at .15 to account for user-error. The black dotted line represents the tip of each face and the black dot represents the base.

The post-depositional graph is the most uniform of the five groups with a fairly stable frequency along all of the edges (Figure 5.18b). The most noticeable difference in the post-depositional distribution compared to the other groups is the high frequency of edge damage towards the base of the tools. The most similar distributions for butchery (Figure 5.18a), longitudinal activities (Figure 5.18c), and transverse activities (Figure 5.18e). This is likely because these three distributions have the highest frequency of edge damage at the midpoint of the lateral edge. This differs from the high frequency of edge damage present at the distal end of the handaxes when used for the percussive activities.

In order to determine whether each activity has a specific distribution that is distinguishable from the other activity groups, each analogous edge (i.e., AL and AL) was subjected to a two-sample Kolmogorov-Smirnov (KS) test for all activity groups (e.g., Longitudinal and Transverse) (Table 5.1). As described in Chapter 4, this test determines whether or not two distributions come from the same population. The following KS tests resulted in all four analogous edges having significant differences:

Question 2: What is the overall distribution of edge damage in the experimental dataset?

As discussed throughout this thesis, previous research has shown that handaxes have been used for various activities and are thought of as being multi-functional or poly-functional tools (Viallet 2016a). I am able to test this hypothesis using by aggregating the edge damage frequencies for all activity groups in the overall experimental dataset (Figure 5.19a). Considering a main goal of this research is to help elucidate the role of taphonomic processes in the formation of edge damage, I created an overall

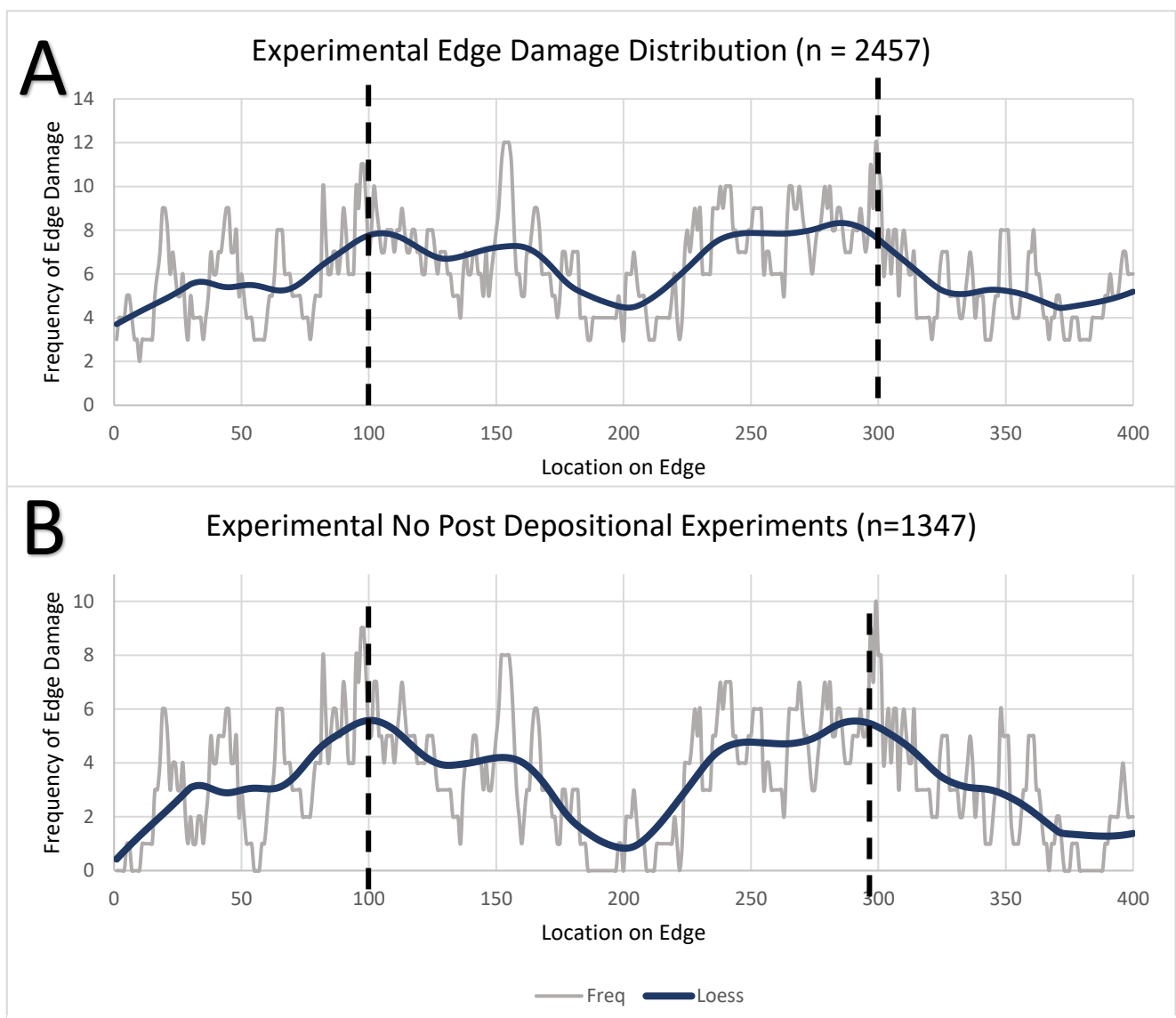


Figure 19 – Edge damage distribution of (a) aggregated experimental activities (b) aggregated excluding post-depositional experiments.

distribution excluding the post-depositional experiments (Figure 5.19b). The overall distribution of edge damage including the post-depositional experiments is more uniform and has a higher frequency of edge damage near the base of the handaxes.

Question 3: Does grip influence the distribution of edge damage?

H_0 – There is no difference in edge damage distribution between grips

H_1 – There is a statistically significant difference in edge damage distribution between grips

The question of how handedness and grip might influence the distribution of edge damage has been discussed within Schoville’s work (Schoville 2010; Schoville et al. 2016); however, no tests were conducted to investigate this. During the experiments, it quickly became apparent that I held the handaxes differently for certain activities. In particular, I held the tools by the proximal end, perpendicular to my hand for percussive activities (Figure 5.20a). Alternatively, for butchery, transverse,

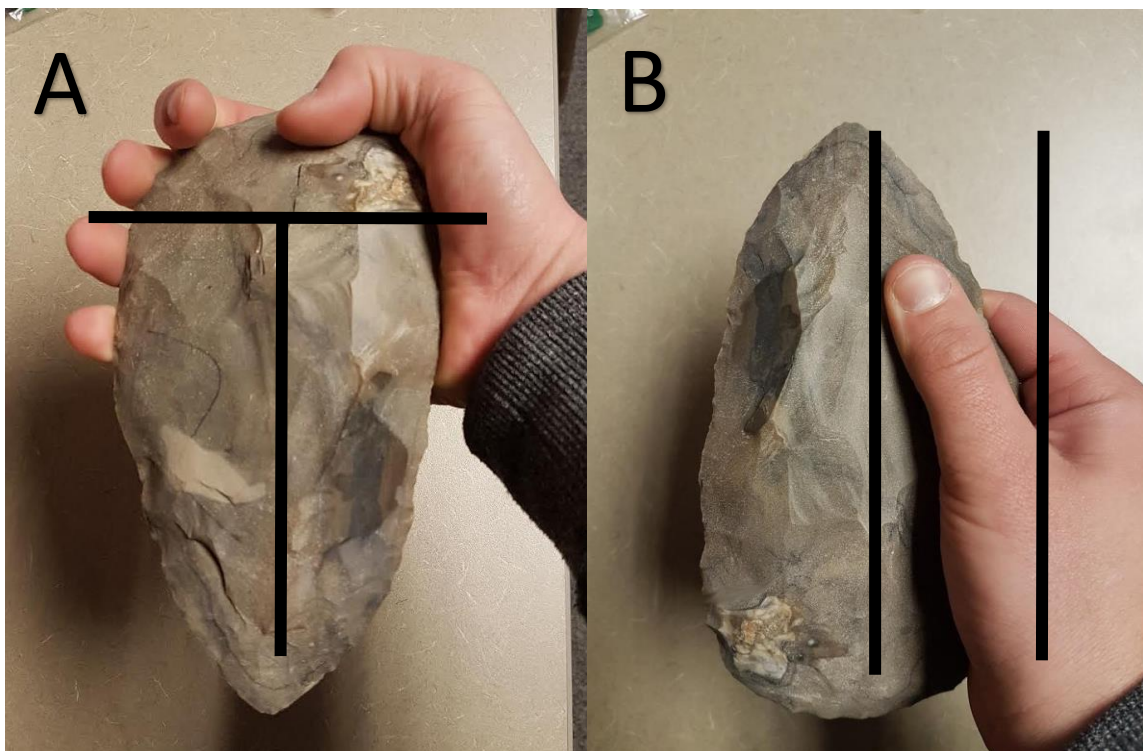


Figure 5.20 – Depiction of handaxes (a) held with tip perpendicular to hand (b) held parallel to hand.

and longitudinal activities I held the handaxes by the lateral edge, parallel to my hand (Figure 5.20b) which is similar to how modern humans in the Western world would hold a knife.

The distribution of edge damage for handaxes held perpendicular to the hand was the same distribution as the graph created for percussive activities (Figure 5.18d – page). In order to create the distribution for the handaxes held parallel to my hand, I aggregated the data from longitudinal, transverse, and butchery experiments (Figure 5.21). As expected, the primary difference between these

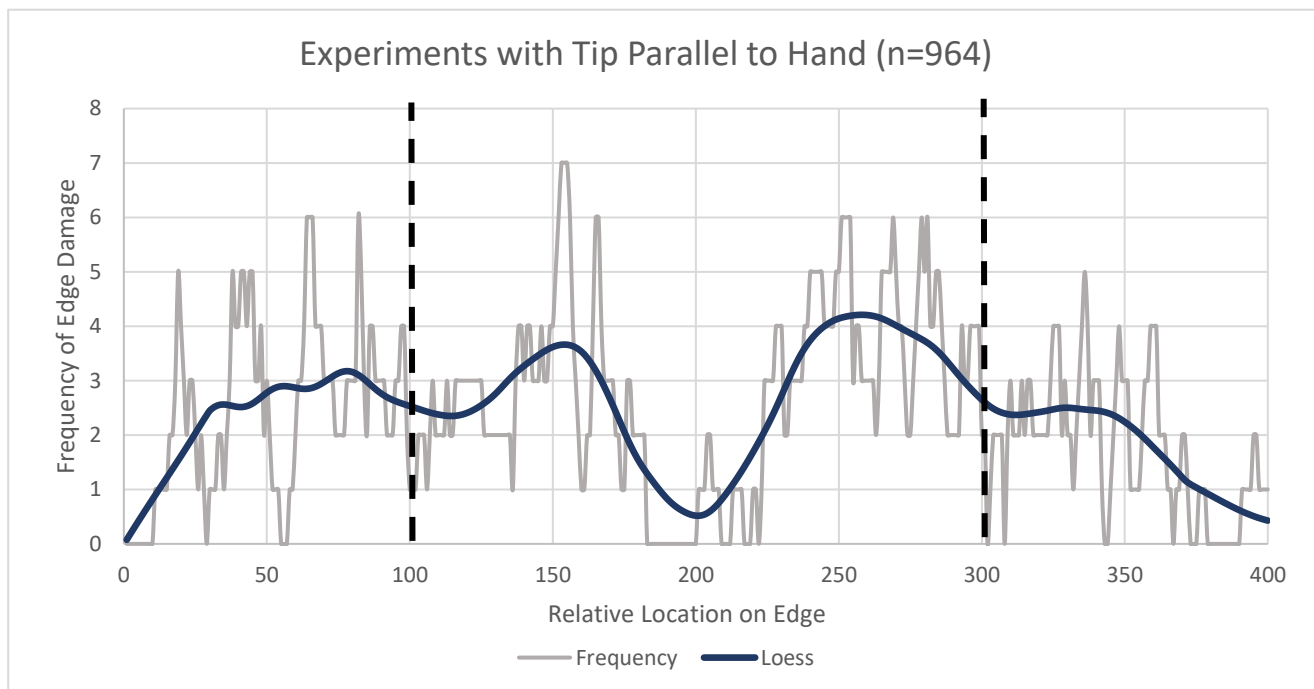


Figure 5.21 – Edge damage distribution of experimental handaxes help with tip parallel to the hand

distributions is the highest frequency of edge damage in experiments with the tool held parallel to the hand is in the mesial portion of the edge whereas the highest frequency of edge damage for the experiments with the tool held perpendicular to the hand is on the distal portion of the tool.

In order to determine whether or not grip influences the distribution of edge damage on handaxes, KS tests were conducted between analogous edges (i.e., AL and AL) of the tip perpendicular and tip parallel experiments. The results indicate that there are statistically significant differences in the

distribution of edge damage for all edges (Table 5.22). This suggests that grip does influence the distribution of edge damage.

Edge	D_{obs}	D_{max}
AL*	.419465	.170641
AR*	.428542	.160606
BL*	.276356	.154549
BR*	.371975	.176115
* = Statistically significant at p < .05		

Results of the Prehistoric Edge Damage Distribution Analysis

The prehistoric edge damage distribution analysis will differ from the experimental section in that I will be providing more detailed explanations and statistical tests (Schoville 2010) to bolster my interpretation of the analysis. The results of the edge damage distribution analysis of the bifacial assemblage indicate that they were being used quite intensively (Table 5.3). To reiterate, side A represents the face with less cortex. The average percent damage for the left edge of side A (AL) is 32.38%. The average percent damage for the right edge of side A is 31.22%. The highest amount of damage is seen on the left edge of side B which is 33.84% and interestingly, the right edge of side B had the least damaged at 29.5%.

Edge	Average Edge Length (cm)	Average Total Length Damaged (cm)	Average Percent Damaged
AL	16.37	5.53	32.38%
AR	16.55	5.28	31.45%
BL	16.49	5.63	33.70%
BR	16.46	4.64	27.71%
Overall	16.47	5.27	31.31%

The total number of scarred locations on the archaeological assemblage is 7053 out of a total of 22000 possible locations of damage (56 stone tools x 4 edges x 100 possible locations of damage) (Table 5.4). The left edge of side A has 1854 locations of edge damage whereas the right has 1751. The left edge of side B has 1906 scarred locations and the

Face/Edge	Number of Scarred Locations (n = 7053)
A	3605
B	3448
L	3760
R	3293
AL	1854
AR	1751
BL	1906
BR	1542
AL+BR	3396
AR+BL	3657

right has 1542. Overall, side A of the bifacial tools have the most occurrences of edge damage (n = 3605). The left sides of the faces have higher edge damage than the right sides.

Following Schoville (2010), paired T-tests and Wilcoxon matched pair signed rank tests were applied to the edge damage frequencies for each combination of edges to investigate whether the differences between edges seen in Table 5.4 apply to individual artifacts and are not simply being caused by a small sample of artifacts. The results of the tests can be seen in Table 5.5.

Edge	Mean	STDev	T-Value	P Value	Wilcoxon P Value
A	64.37	27.14			
B	61.57	22.46	.8350	0.40	0.5
L	67.14	25.42			
R	58.80	22.49	2.933	0.004*	.003*
AL	33.10	16.54			
AR	31.26	14.26	0.932	0.355	0.259
AL	33.10	16.54			
BL	34.03	15.62	-0.352	0.726	.6507
AL	33.10	16.54			
BR	27.53	13.76	2.694	0.009*	0.01*
AR	31.26	14.26			
BR	27.53	13.76	1.668	0.101	0.111
AR	31.26	14.26			
BL	34.03	15.62	-1.19	0.238	0.278
BL	34.03	15.62			

BR	27.53	13.76	2.55	0.013*	0.014*
AL+BR	60.64	26.21			
AR+BL	65.30	24.35	-1.31	0.19	.2585
*= Statistically significant at $\alpha = 0.05$					

There are three statistically significant results from the paired T-test and Wilcoxon calculations done in RStudio. These tests show that at an individual artifact level there is a difference between the following faces and edges: L vs. R, AL vs. BR, and BL vs. BR. The left edges of both faces have a higher frequency of edge damage than the right. On face B, the left edge has a higher occurrence of edge damage than the right, but on face A, the left and right sides are not statistically different. Considering the edges of stone tools are formed by both faces, it important to consider the combined edge damage of opposing faces. On the left edge, AL has a higher occurrence of edge damage than BR, which suggests that the tool was used at an angle less than 90° to the worked material (Tringham et al. 1974). These results are also confirmed by the summation of edge damage (Table 5.4).

Question 4: What is the overall distribution of edge damage at SM-1?

In order to analyze the overall distribution of edge damage on the SM-1 bifaces, a frequency graph was created with the Y-axis representing the frequency and the X – axis representing the Relative Location on Edge starting at 0 (start of the left edge of Side A) and ending at 400 (end of the right edge of side B). A LOESS smoothing spline was applied to account for user error (Schoville et al. 2016) (Figure 5.22).

As seen in Figure 5.22, the distribution of the edge damage is not uniform across the edge but is concentrated at the distal end of the tools. The edge damage of the archaeological assemblage is similar for both sides of the bifaces, with the lowest frequency of edge damage at the base and the highest at the tip of the tool. The average edge damage is almost triple in the top 25% of the tool than the basal

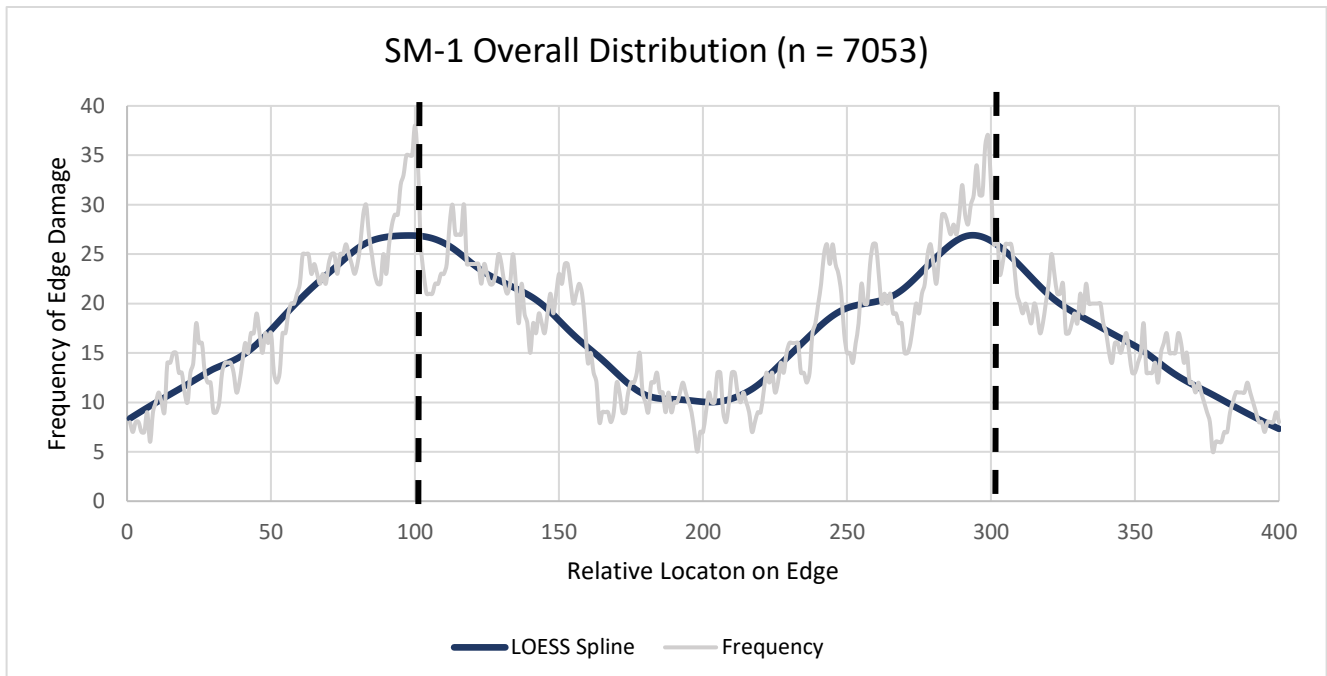


Figure 5.22 – Overall distribution of edge damage frequency along the edges of both faces

25% (Figure 5.23). This is what would have been expected, especially considering it is more likely that the base of the tool has an unworked portion. Interestingly, there is a high degree of edge damage at the midpoint of the left edge of side B, however, for side A, the edge damage at the midpoint of the left edge is less significant. Additionally, the faces have a similar frequency at the tip. This observation, combined with the insignificant paired t-test results comparing the faces of A and B, possibly reflects the distal end of the tool being used in an activity where there is equal probability that both faces of the edge will be damaged. Moreover, considering there is a high frequency of edge damage at the midpoint of the tool as well as the tip, it is possible that the bifaces were being used for multiple purposes or in various activities. If

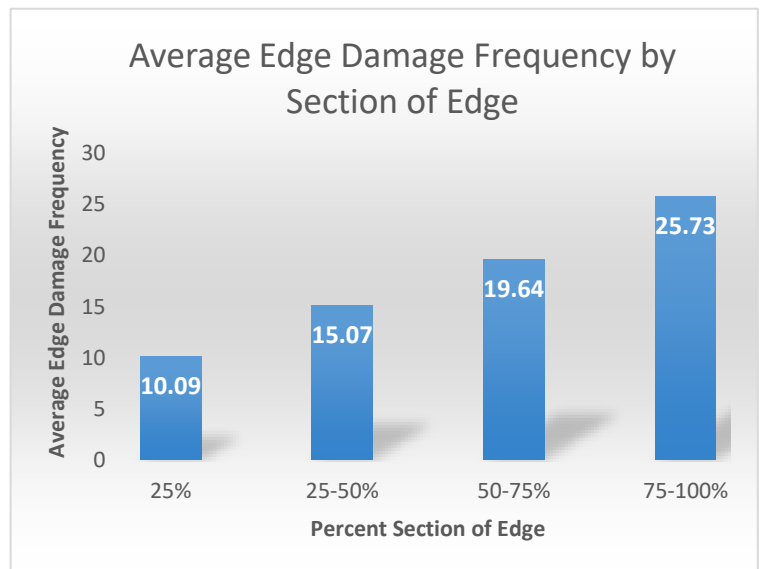


Figure 5.23 – Average edge damage frequency by section of edge with 25% being the basal end and 75-100% being the distal end.

true, this bolsters the idea of handaxes as “Swiss Army Knives” of the Paleolithic, being used primarily as a cutting edge for various activities or tasks without one specific purpose (Keeley 1980; Keeley and Toth 1981; Schick and Toth 1994; Shea 2007).

According to Tringham and colleagues (1974) certain actions create specific distributions of edge damage. In order to investigate this within the SM-1 assemblage, intra-sample KS tests were applied to all edge combinations (Table 5.6). All of the results were not significant with one exception: AL and BL. The difference in edge damage distribution potentially implies differing function between edges; however, considering they do not form a single edge when combined the difference is not be functionally relevant. The most interesting observation is that the combinations AR vs. BL and AL vs. BR, which when viewed together create a single edge, do not have statistically significant differences in distribution. This potentially implies the edges were used at a high angle – close to 90° - where there is a high probability both faces of the edge are damaged (Tringham et al. 1974). The similarity in distributions across most edges is surprising due to the variability within the assemblage.

Edge	D_{obs}	D_{max}
AL vs AR	.03782	.04532
AL vs BL*	.04592	.04436
AL vs BR	.03283	.04687
AR vs BR	.03564	.04749
AR vs BL	.03566	.04501
BL vs BR	.03214	.04658
* = Statistically significant at p < .05		

To further elucidate the differences in edge damage frequency among the edges in the SM-1 bifacial assemblage, I created vertical line graphs to help compare edges side by side (Wilkins and Schoville 2016) (Figure 5.24). These graphs can show immediate differences in frequency of edge damage along the edge. Additionally, different activities will likely have the different distributions of edge damage and create different looking line graphs. The various combinations of edge damage will be compared and discussed below.

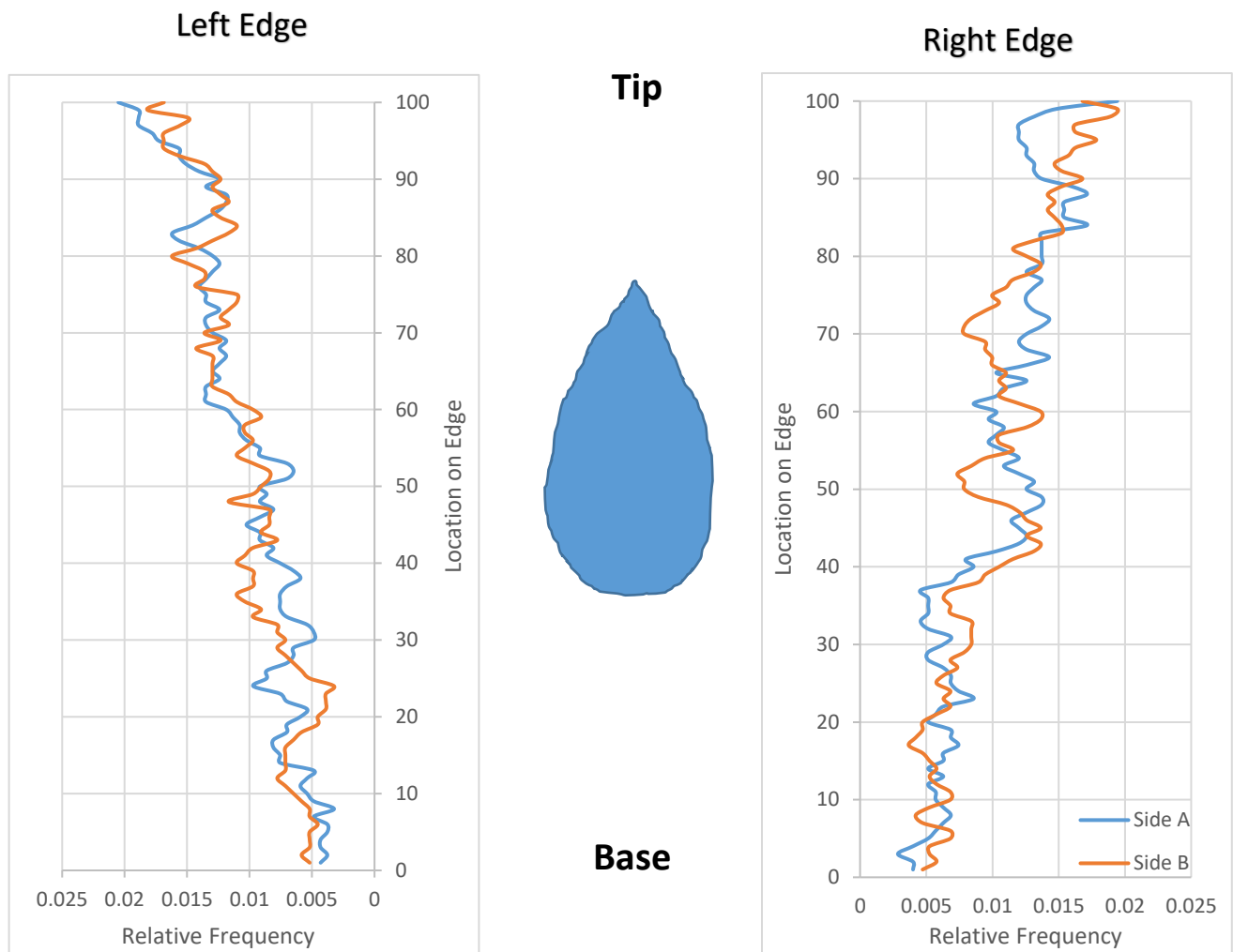


Figure 5.24 – Vertical line graphs showing the relative frequency of edge damage along both faces of each edge. The Y-axis represents the location on edge with 0 as the base and 100 as the tip.

When compared, it is clear that the left edge, comprised of AL and BR, have much more similar distributions than does the right edge (AR+BL). The major differences between faces on the right edge are from 45 to 55, 65 to 75, and 90 to 100. The most significant differences on the left edge are from 15 to 25, and 30 to 40. Interestingly, in the middle of the right edge side A has a higher frequency of edge damage than side B, however towards the tip, side B has a higher frequency of edge damage. Generally, the relative frequency of edge damage is similar on both edges with the distal portion of the tool having the highest frequency and the base having the lowest.

Question 5: Does the distribution of edge damage at SM-1 differ from a random distribution?

H₀ – The SM-1 distribution does not differ from a random

H₁ – The SM-1 distribution has a statistically significant difference from a random distribution

Tringham and colleagues (1974) suggest that behavioral use-wear causes non-random patterning along the edge, whereas post-depositional damage may be random. Schoville (2010) uses this to bolster the argument that the edge damage on points at PP13B is behavioral. Although for certain taphonomic processes it has been discovered that this is not always the case – post-

Edge	D _{obs}	D _{max}
AL vs Random*	.172977	.036931
AR vs Random*	.166139	.037717
BL vs Random*	.144984	.036560
BR vs Random*	.141543	.039569

depositional damage can cause patterned edge damage distributions, particularly due to differences in edge angle (McPherron et al. 2014). Considering edge angle was not recorded for this study, it is unknown how edge angle might affect the frequency and distribution of edge damage on handaxes at SM-1, therefore KS tests against random will be included to strengthen the case that the patterns seen are of behavioral origin. When compared to random, all edges have a statistically significant difference at $p < .05$ (Table 5.7), as seen in Figure 5.25.

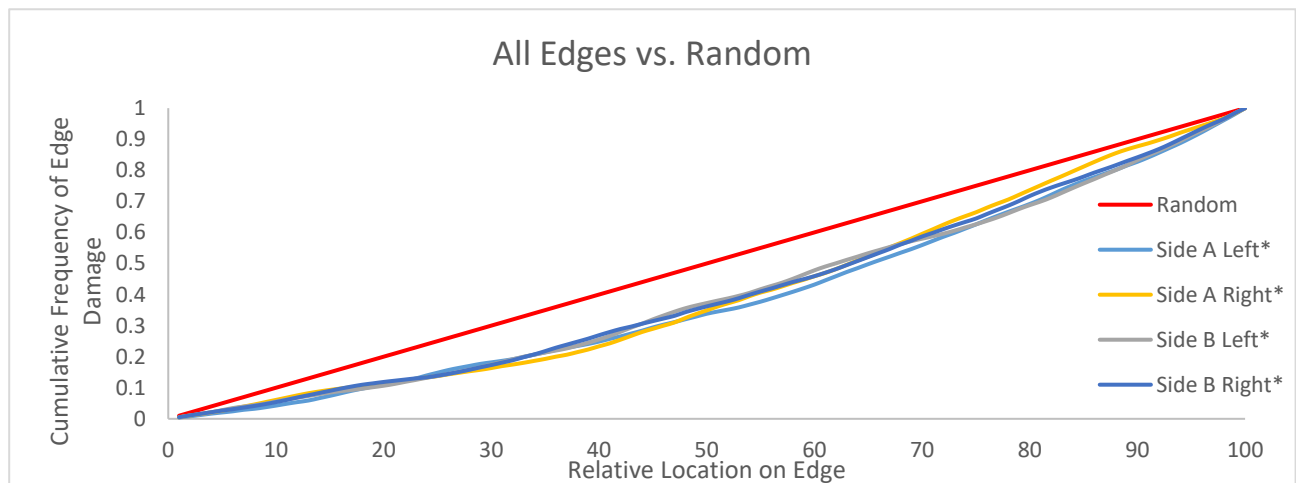


Figure 5.25 – Cumulative distributions of all edges vs random (* = KS test shows statistically significant at $p < .05$)

Question 6: Does tool use change over time?

H_0 – Tool use doesn't change over time (layer 8 and layer 7 have similar distributions and edge damage frequencies)

H_1 – Layer 7 and layer 8 will have different distributions and frequency of edge damage

In order to answer this question, each layer will be examined separately and then an inter-sample analysis will be conducted to statistically test whether or not the distributions come from the same population.

Table 5.8 : Average Edge Damage Layer 8 (n=33 tools)

Edge	Edge Length (cm)	Total Length Damaged (cm)	Percent Damaged (cm)
AL	16.83	5.57	32.45%
AR	16.98	5.32	30.85%
BL	16.94	5.6	32.74%
BR	16.87	4.52	26.19%
Overall	16.83	5.26	30.56%

Table 5.9 : Layer 8 Total Edge Damage Per Edge

Face/Edge	Number of Scarred Locations (n= 4051)
A	2094
B	1957
L	2177
R	1874
AL	1078
AR	1016
BL	1099
BR	858
AL+BR	1936
AR+BL	2115

Layer 8 is the older layer which dates to approximately 260,000 years ago and has a total of 34 bifacial tools. One was excluded because it was only the distal portion of the tool. Overall, the bifaces within layer 8 have an average of 30.56% of their edges damaged (Table 5.7). Similar to the overall edge damage for SM-1, the left edge of side B has the highest average edge damage at 32.74% and the right edge of side B has the lowest average edge damage at 26.19%. The left edge of side A has a higher

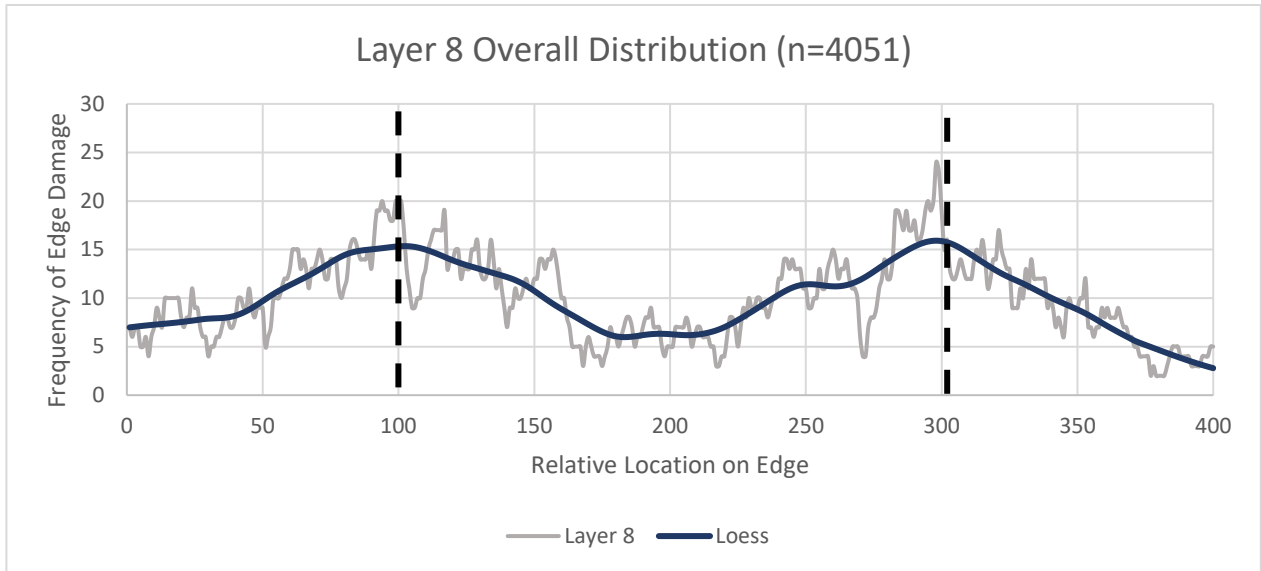


Figure 5.26– Overall distribution of edge damage frequency along Layer 8 handaxes.

percent of edge damage at 32.45% whereas the right edge has 30.85%. The combined left and right edges differ in number of scarred locations with the right edges more damaged (Table 5.8).

The overall distribution of edge damage shows a slight difference between both faces (Figure 5.26). Side A does not have an obvious peak at the tip of the tool, which is seen in side B, but rather it has a high frequency of damage that is fairly consistent between 50 -150. On side B, there is a small increase on the left side between 245-255 and then a sharp increase in frequency between 255 and 300 that ends in a fairly sharp peak on the left edge of side B. The right side of face B declines steadily.

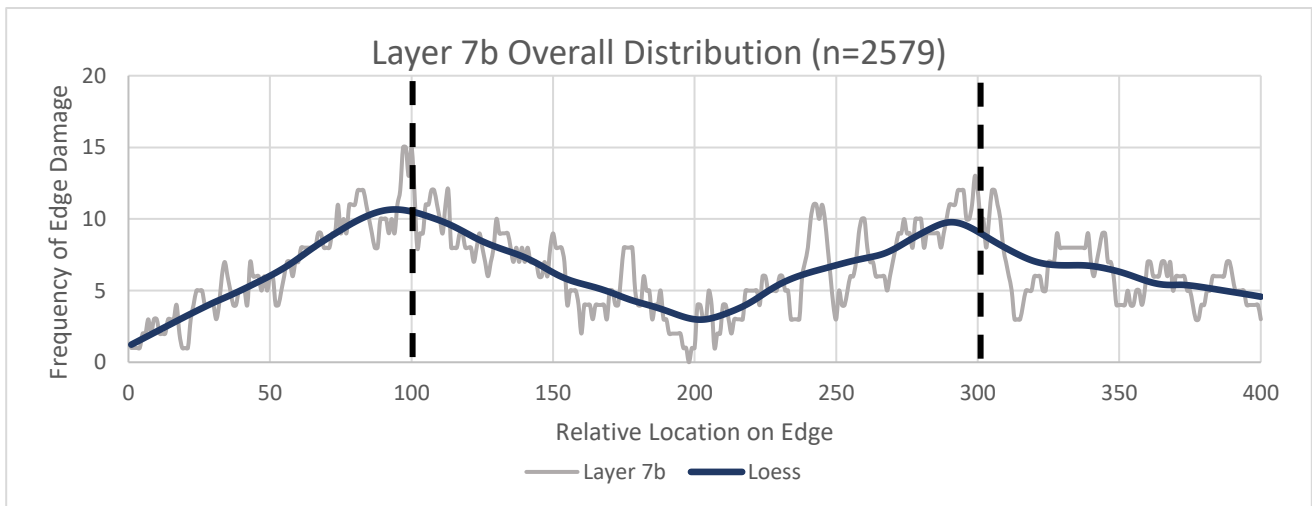


Figure 5.27 – Overall distribution of edge damage frequency in layer 7b.

Layer 7b is a younger layer that dates to approximately 125,000 years ago. In contrast to layer 8, both faces of the handaxes within this assemblage follow different distributions (Figure 5.27). On both edges of side A, there is a steady increase in edge damage from the proximal end to the distal tip. Side B has a more variable distribution of edge damage. The most significant similarity is the distal end has the highest amount of edge damage. One major difference seen in the graph is on the right edge of side A, in between 150-200, there is a small portion of the edge that has a spike in frequency. Overall, layer 7b has a higher percentage of edge damage at 32.44% (Table 5.10). Similar to layer 8, the number of the left edge of both faces have more occurrences of edge damage (Table 5.11).

Table 5.10: Average Edge Damage Layer 7b (n=21 tools)

Edge	Edge Length (cm)	Total Length Damaged (cm)	Percent Damaged (cm)
AL	15.46	5.33	34.02%
AR	15.71	5.0	31.38%
BL	15.48	5.15	32.73%
BR	15.52	4.85	31.64%
Overall	15.55	5.09	32.44%

Table 5.11: Layer 7b Total Edge Damage Per Edge

Face/Edge	Number of Scarred Locations (n= 2579)
A	1282
B	1297
L	1326
R	1253
AL	646
AR	636
BL	680
BR	617
AL+BR	1263
AR+BL	1316

In order to statistically test whether or not there is a difference between the analogous edges between layer 8 and layer 7b, a KS test was conducted to determine whether or not the cumulative distribution of edge damage comes from the same population at $p < .05$ (Figure 5.28). Interestingly, the only comparison that was statistically significant was BR vs BR; the other three edges do not have enough differences in the cumulative distribution of edge damage to argue they do not come from the same population (Table 5.12). The results of the KS tests comparing edges between layers supports the

null hypothesis that there is no change in edge damage distribution over time. Although there is not enough of a difference to argue there is a difference in edge damage distribution over time, this does not necessarily support the idea that there was not a change in activity between layers and the similarities might be due to factors that were not considered in this analysis.

Edge	D _{obs}	D _{max}
AL	.049601	.067667
AR	.046117	.068765
BL	.030316	.066355
BR*	.127671	.071787

*= Statistically significant at p < .05

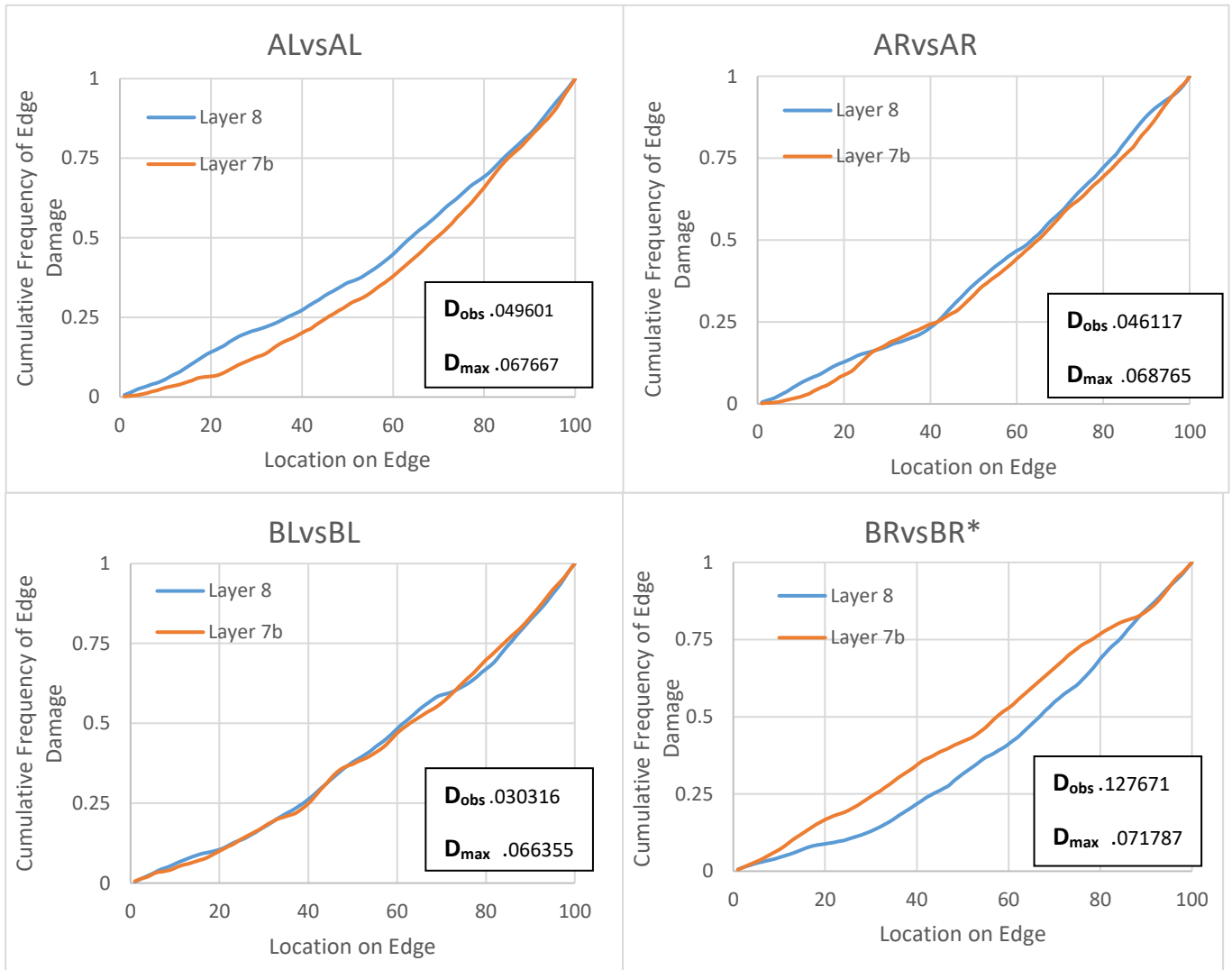


Figure 5.28 – KS tests comparing cumulative distributions of edge damage between layers (* = significant at p < .05)

In order to further compare layers, vertical line graphs of relative frequency can help show the specific regions of the tools that vary in edge damage frequency (Figure 5.29).

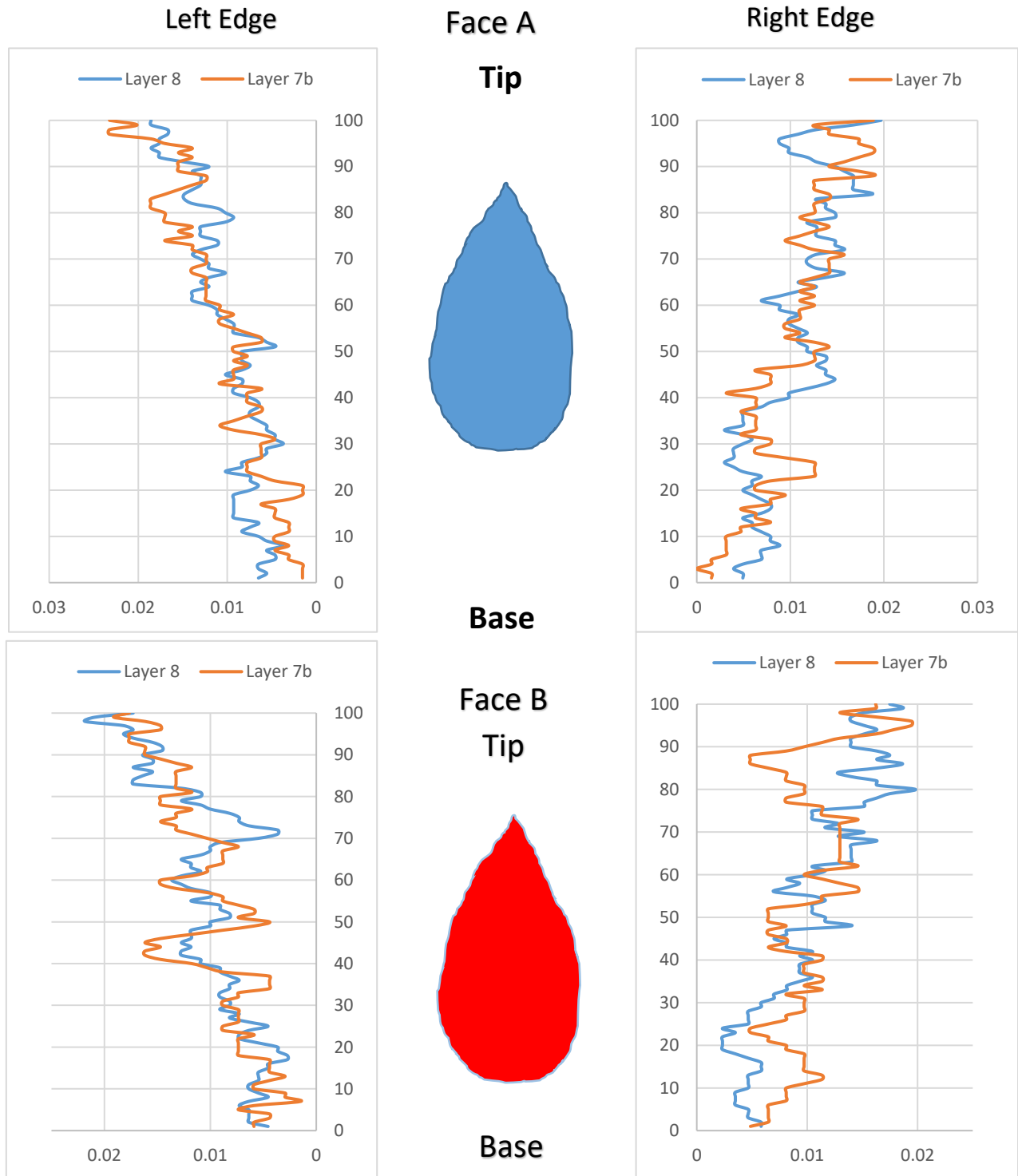


Figure 5.29 – Vertical line graph comparing the left and right edge of face A and B for layers 8 and 7b. X – axis represents the relative frequency of edge damage and the y-axis represents the location on edge.

Generally, the vertical line graphs show a similar overall trend in between layers – the frequency of edge damage increases towards the tip of the tool. The most noticeable differences between layers occurs in various areas depending on the edge and face of the tool but side B has the most significant differences between layers. On side A the left edges are similar, but on the right, layer 8 has less damage towards the base of the tool and increases in edge damage around 30, whereas layer 7b stays relatively consistent until 50 with only a small increase around 25. On side B, the left edge has minor differences between 40 and 50 and again between 70 and 80. The largest difference occurs on the right edge between 70 and 90, layer 8 has almost four times more edge damage than layer 8. Layer 7b declines in edge damage frequency at 70 and hits a low at around 85, but skyrockets at 89.

Question 7: Do the experimental distributions reflect SM-1 handaxe use?

The overall distributions created for Question 1 were created to act as models to test whether or not these distributions reflect handaxe use at SM-1. All distributions were compared to SM-1 using the KS test (Table 5.13). Based on these results, the model that best fits the edge damage distribution at SM-1 is the overall experimental distribution without post-depositional experiments (3 out of 4 edges are not significant). Additionally, it is possible that activities where handaxes were held parallel to the hand explain the distribution of edge damage on the left edge (AL+BR) of the SM-1 handaxes.

Table 5.13 : KS Test Results Comparing Analogous Edges of Activity Groups to SM1				
Activity	AL	AR	BL	BR
Longitudinal	Dobs = 0.343 Dmax = 0.198*	Dobs = 0.193 Dmax = 0.151*	Dobs = .255 Dmax = .178*	Dobs = 0.147 Dmax = 0.169
Transverse	Dobs = 0.125 Dmax = 0.212	Dobs = 0.294 Dmax = 0.209*	Dobs = 0.077 Dmax = 0.154	Dobs = 0.466 Dmax = 0.378*
Post-Depositional	Dobs = 0.268 Dmax = 0.094*	Dobs = 0.221 Dmax = 0.083*	Dobs = 0.172 Dmax = 0.082*	Dobs = 0.272 Dmax = 0.092*

Percussion (and Tip Perpendicular)	Dobs = 0.358 Dmax = 0.152*	Dobs = 0.321 Dmax = 0.140*	Dobs = 0.175 Dmax = 0.140*	Dobs = 0.298 Dmax = 0.149*
Overall with Post-Depositional	Dobs = 0.117 Dmax = 0.070*	Dobs = 0.105 Dmax = 0.068*	Dobs = 0.097 Dmax = 0.064*	Dobs = 0.159 Dmax = 0.075*
Overall without Post-Depositional	Dobs = 0.075 Dmax = 0.085	Dobs = 0.102 Dmax = 0.085*	Dobs = 0.064 Dmax = 0.078	Dobs = 0.054 Dmax = 0.095
Tip Parallel	Dobs = 0.077 Dmax = 0.096	Dobs = 0.154 Dmax = 0.098*	Dobs = 0.117 Dmax = 0.087*	Dobs = 0.105 Dmax = 0.113
Shaded = not significant *= statistically significant (Dobs>Dmax) at p < .05				

The KS test result comparing analogous edges between the experimental activity groups and layer 7b are slightly different than the results of layer 8 and the overall distribution at SM-1 (Table 5.15). In particular, none of the distributions potentially reflect the distribution. Although, the overall experimental distribution without post-depositional experiments might explain the right edge (AR+BL) of handaxes in layer 7b.

Table 5.15 : KS Test Results Comparing Analogous Edges of Activity Groups to Layer 7b				
Activity	AL	AR	BL	BR
Longitudinal	Dobs = 0.398 Dmax = 0.203*	Dobs = 0.201 Dmax = 0.157*	Dobs = .261 Dmax = .183*	Dobs = 0.146 Dmax = 0.174
Transverse	Dobs = 0.131 Dmax = 0.216	Dobs = 0.315 Dmax = 0.214*	Dobs = 0.079 Dmax = 0.159	Dobs = 0.393 Dmax = 0.381*
Post-Depositional	Dobs = 0.318 Dmax = 0.104*	Dobs = 0.239 Dmax = 0.093*	Dobs = 0.181 Dmax = 0.092*	Dobs = 0.218 Dmax = 0.101*
Butchery	Dobs = 0.136 Dmax = 0.122*	Dobs = 0.222 Dmax = 0.141*	Dobs = 0.150 Dmax = 0.116*	Dobs = 0.236 Dmax = 0.151*
Percussion (and Tip Perpendicular)	Dobs = 0.335 Dmax = 0.156*	Dobs = 0.299 Dmax = 0.144*	Dobs = 0.186 Dmax = 0.143*	Dobs = 0.336 Dmax = 0.152*
Overall with Post-Depositional	Dobs = 0.183 Dmax = 0.078*	Dobs = 0.136 Dmax = 0.075*	Dobs = 0.091 Dmax = 0.072*	Dobs = 0.063 Dmax = 0.081
Overall without Post-Depositional	Dobs = 0.109 Dmax = 0.092*	Dobs = 0.086 Dmax = 0.091	Dobs = 0.060 Dmax = 0.084	Dobs = 0.161 Dmax = 0.100*
Tip Parallel	Dobs = 0.135 Dmax = 0.102*	Dobs = 0.170 Dmax = 0.103*	Dobs = 0.094 Dmax = 0.092*	Dobs = 0.164 Dmax = 0.117*
Shaded = not significant *= statistically significant (Dobs>Dmax) at p < .05				

Overarching Question: How were hominins using handaxes at SM-1?

Based on the preliminary results of the use-wear analysis combined with the inter- and intra-sample statistical analyses conducted, I can make preliminary inferences about the edge damage seen at SM-1:

- 1) Considering the type of use-wear present and observations of experimental use-wear, it is likely the majority of the handaxes were being used on medium-hard materials – indicated by the high degree of rounding and microflaking seen on the artifacts. Grace (1989, 96) explains that heavy rounding occurs from working materials such as bone or hide, whereas soft-medium materials may cause very little rounding. Additionally, the use of animals is known at SM-1 through protein residues. Further investigation with high powered microscopy can help confirm this within the sub-sample of artifacts.
- 2) Handaxes were primarily used with the tip of the tool. Further investigation into how edge angle affects the distribution of edge damage on these artifacts is needed to confirm this is due to deliberate and preferential use of the distal end. The use of the tip of the tool is interesting and disagrees with the description of handaxe use by Mitchell (1995), but is corroborated by the importance of tip symmetry in tool effectiveness for butchery (Machin et al. 2007). Moreover, the woodworking experiments show that tip shape might affect the effectiveness for percussive actions. This warrants future investigation into the role of tip shape and function.
- 3) Taphonomic processes are not the only cause of the edge damage on the SM-1 handaxes. This is supported by the low abundance of post-depositional scarring and the fact that all

edges differ from random in the KS test, but more experimental data needs to be considered involving post-depositional damage to confirm this.

- 4) The intra-sample KS results indicate that the combined left edge (AL+BR) was used in a longitudinal motion. This is supported by the bi-lateral rounding – a longitudinal motion produces edge damage on both edges with equal probability (Grace 1989; Tringham et al. 1974). Additionally, the results of the paired T-test and Wilcoxon tests (Table 5.5) indicate that the left edge of side A has a higher amount of damage throughout the assemblage than the right edge of side B suggesting it was consistently in more contact with the material being worked. This might mean the angle of use was less than 90° to the contact material.
- 5) Generally, the experimental edge damage distribution without post-depositional experiments is a good model for the archaeological assemblage. This supports the idea of individual handaxes being used for different purposes within an assemblage.
- 6) The majority of the KS tests indicate there are not statistically significant differences in edge damage distribution between layers, however, when comparing the experimental models to the layers separately, the results vary with layer 7b having less similarities to the experimental distributions. Additionally, the tip-parallel and butchery models potentially reflect the distribution of the left edge (AL+BR) in layer 8.

The results of this analysis suggest that more research needs to be done to investigate the complexity surrounding handaxe function. In particular, the next stage of this analysis will include the incorporation of edge angle, tip shape, and overall artifact shape to create sub-samples of artifacts that can be used to determine whether or not these factors influence function.

Summary

Despite the difficulties surrounding use-wear studies, the pristine condition of the SM-1 handaxes has allowed a glimpse into the potential of handaxe functional studies. Although the major results of this research are limited to use-activity, the preliminary use-wear analysis provides evidence of processing medium-hard materials in the form of intense rounding and microflaking. The results of the edge damage distribution analysis shows that with the current sample size and experimental data, the aggregated experimental model generally supports the SM-1 edge damage distribution with only one edge having significant differences. Regardless, the distribution and frequency of edge damage at SM-1 indicates preferential use of the distal end of the tool which is contrary to earlier experimental work done where the mesial portion of the tool is thought to be desired. These findings suggest that handaxe use-wear studies need to be expanded upon and in particular, there needs to be more consideration of the factors that might influence how edge damaged is formed on these tools. In the next, and final chapter, I will discuss the major aspects of this research, including my interpretation of the results and its implications for SM-1 hominin behavior and handaxe function, along with some concluding remarks and future directions of this research.

Chapter 6: Discussion and Conclusion

Introduction

Stone tools have been manufactured (Harmand et al. 2015) and used for the past 3.3 million years (McPherron et al. 2010, 857). Investigating how stone tools were used in the past is paramount to understanding hominin behavior within certain environmental contexts. Functional studies in lithic technology come in various forms, but generally require the microscopic analysis of the stone tool's edge in order to identify fractures or polishes that originated from use. Since Semenov's (1964) seminal work, use-wear analysis has become an essential methodology to reconstruct how stone tools were used in prehistoric times. Recent approaches in use-wear combine low powered microscopy (Kamminga 1982; Odell 1981; Tringham et al. 1974), high powered microscopy (Fullagar 1991; Hardy 1994; Juel Jensen 1988; Keeley 1980; Keeley and Toth 1981; Marrieros et al. 2015; Rots et al. 2016), and residue analysis (Gurfinkel and Franklin 1988; Hardy and Garufi 1998; Hardy and Moncel 2011; Jahren 1997; Kealhofer et al. 1999; Kooyman et al. 1992; Loy 1983; Loy and Hardy 1992; Nowell et al. 2016; Rots et al. 2015; Rots et al. 2016; Vaughan 1985). Additionally, there has been a push for the development of quantitative use-wear methodology that relies less on subjective expert opinion. With advances in technology, researchers are constantly trying new techniques and furthering our knowledge of how the surface of stone tools are affected by use. In particular, the application of focus variation microscopy (Evans and Macdonald 2011; Macdonald 2014) and laser scanning confocal microscopy (Evans and Donahue 2008; Stemp et al. 2015) which allows for the creation of 3D elevation maps of the stone tool surface, is offering unique insight into the past.

An essential aspect of use-wear studies is experimental archaeology in the form of hypothesis testing and stone tool replication (Eren et al. 2016). Stone tool replication is defined by Metin Eren and colleagues (2016, 105) as "the act of creating or using non-artifactual flaked-stone specimens for the

purpose of investigating archaeological hypotheses, questions, and methods.” The difficulty with experimental archaeology and stone tool replication is applying what we learn throughout our endeavors to the archaeological record. I chose to approach the stone tool replication and experimental strategy with humans rather than machines because there are important variables that accompany stone tool use that cannot be easily incorporated with machines. These variables include fatigue, variation in grip, knapping errors, knapper skill level, and decision making in response to difficulty or obstacles during use. This is not to argue that modern human stone tool use is an accurate reflection of hominin stone tool use in the past – the past cannot be truly replicated in modern day – however, it is important to consider the fact that hominins have biological similarities to humans and their use of tools is driven by an entanglement of biological, social, and environmental factors.

Additions to Use-Wear Methodology

As technology continues to develop, new pathways for observing and quantifying use-wear will become available. This notion will help address the subjective nature of use-wear studies; however, another large issue with use-wear methodology will still be left untouched: the experimental protocol. This is lacking in not only microwear studies, but in residue analysis. Unfortunately and for various reasons, experimental methodology and protocols have been left unchanged. On top of deficiencies in descriptions and documentation, researchers do not always disseminate results in the most accessible way. For example, Rots and colleagues (2016) provides one paragraph to describe experimental protocol and an additional paragraph to discuss how experimental data was created and how it will be analyzed. Descriptions are great ways to inform readers about the experiments, but a push needs to be made to provide experimental information via online databases with the inclusion of pictures and videos. In addition to lacking sufficient pictures of experimental protocols, Van Gijn (2014) argues that picture documentation of microwear alone is insufficient. Particularly, she explains that the field of view is too

small, with only a small line of the image in focus. She proposes more thorough documentation with techniques such as photo-stacking done by Plisson and Lompré (2008) or Vergès and Morales (2014).

Pictures and videos are two examples of ways to supplement and bolster descriptions of experiments. Additionally, this data can be easily made public through the internet or through supplementary information and links to data spreadsheets. Schoville et al. (2016) is a great example of this – the authors provide multiple forms of supplementary data, including the shapefiles used for the analyses. Moreover, one potential way to help support the research can be through a webpage. This is not only important for other researchers in that they are able to reproduce and assess the protocol more specifically, but it provides a starting point and reference for students new to use-wear analysis and experimental archaeology. As mentioned in Chapter 2, the expert knowledge and subjectivity associated with use-wear is viewed as a major problem by some researchers. It has been almost forty years since Semenov published his work and only now, in 2016, is there something close to a guide to use-wear and residue analysis (see Marreiros et al. 2015). Considering I am both a student and newcomer to use-wear, having no major reference or guidelines was a significant obstacle to surpass.

In order to address this, I argue for a more standardized and documented approach to experimental use-wear analysis. In addition to providing more visual aids and explicit experimental descriptions, new students and researchers can bolster their experimental evidence by providing pre- and post-experimental documentation of edges (Ollé et al. 2012) – similar to what I attempted in this thesis. This is a simple but effective way to teach oneself use-wear. A pre-experimental procedure can also provide valuable information for new experimental databases by showing how different raw materials used in the experiments alter depending on activities performed. Additionally, creating a standardized blind test for new users would be a useful endeavor. Blind tests are important for many reasons, but without proper guidance, blind test participants might accidentally step outside the researcher's parameters. In order to help establish a standardized recording procedure, I created a

guideline called “Directions for Blind Testing Function in Lithic Technology” (see Appendix I). By providing a recording procedure that includes photographs and videos, along with traditional questions and drawings, the researcher can refer back to the guidelines and associated media to help answer possible questions or inconsistencies in the data.

Another criticism of the experimental protocol used in use-wear studies is the lack of consideration for the human experience. Van Gijn (2014) explains that the simplicity of experimentation does not express the unlimited possibilities and relationships between humans and objects. To further this criticism, I argue that the experimentation does not consider the variability of human-environment interactions, nor does it acknowledge cultural evolution and inheritance. Therefore, a strictly “scientific” approach with specific kinematics and individual worked materials does not account for the environmental, behavioral, and biological variability that is likely present in the archaeological record. Further, stone tools span from 3.3 million years ago (Harmand et al. 2015) and are present across geographic regions with considerable variations in paleoenvironmental conditions. Since one of the major reasons functional analyses are conducted is to help understand hominin behavior, taking into account this variation in use-wear studies is integral to our understanding of the past. This is not to say that we, as modern humans, can accurately reflect hominin environmental, behavioral, and biological variability of our hominin ancestors, but by understanding the entanglement of these factors can lead to new insights to stone tool use. To address this concern, researchers should attempt to include a “humanistic” aspect within their experimental protocols – similar to what Clark and Woods (2015) describe.

A “humanistic” approach to experimental protocol would attempt to conduct experiments that more accurately reflect human tool use. Traditional experimental procedures involve conducting certain kinematics for an extensive amount of time, such as sawing wood for 45-60 minutes straight. This activity might mirror creating wooden tools which is a time consuming activity; however, it is unlikely

that all activities would have required such intensive work. Additionally, tools probably were used for various functions and in various movements, rather than just one specific motion for one specific function. It is more likely that hominins would have used lithics when encountering various tasks in the landscape. For example, the same handaxe could have been used for multiple episodes digging or various other activities before the tool is discarded or retouched. This type of use-wear might accumulate differently than in an instance where the handaxe was used to dig for a certain amount of time straight. One possible way to replicate this is through a phenomenological approach.

In contrast to using one tool for one task, on one specific raw material for a specified amount of time, a phenomenological approach would require a tool being used in specific environmental contexts (e.g., beach, wetland, woodland, and savannah) with documentation of use-wear signatures intermittent throughout. A great way this can be accomplished is by creating a focus group within a primitive skills class where participants are supposed to “survive” in certain landscapes over a few days. Rather than using modern tools, these participants could be given a prehistoric toolkit with a variety of stone tool technologies to accompany them through their expedition. This sort of experimental process can potentially shed light not only on tool use, but tool life-cycles (e.g., manufacture, use, and discard). Two underlying theoretical concepts to this idea are Ingold’s (1993) notion of landscapes and “taskscape”, and Niche Construction Theory (Laland et al. 2015; Odling-Smee 1988; Odling-Smee et al. 2003; Scott-Phillips et al. 2013).

Ingold (1993, 156) argues that the landscape is the world that is known to those who dwell within it and journey along paths connecting them. He contrasts this to the term environment, which is typically described and discussed in terms of resource availability, arguing that landscape puts an emphasis on form, rather than function. However, it is important we think about both of these concepts when we think about human-environment interactions. He states, “The forms of the landscape are not, however, prepared in advance for creatures to occupy, nor are the bodily forms of those creatures

independently specified in their genetic makeup. Both sets of forms are generated and sustained in and through the processual unfolding of a total field of relations that cuts across the emergent interface between organism and environment.” (Ingold 1993, 156) This explanation mirrors essential concepts in Niche Construction Theory, which will be described below. The term “task” is defined by Ingold as “any practical operation, carried out by a skilled agent in an environment, as part of his or her normal business of life” (1993, 158). Thus, a “taskscape” is an entire ensemble of mutually interlocking tasks or “an array of related activities.” These tasks are typically performed in succession or simultaneously within a group of people working together. Although Ingold (1993) argues that the “taskscape” is not cultural and tasks are not something people bring along with them, but are performative, I would consider the idea of “taskscape” as being integral to our understanding of human biocultural evolution.

Niche Construction Theory is a part of the emerging conceptual framework in evolution known as the Extended Evolutionary Synthesis (EES) put forth by Massimo Piglucci and Gerd Müller (2010). This paradigm differs from its predecessor, the Modern Synthesis (MS) (Huxley 1942), in numerous ways. The Modern Synthesis was an integration of Darwinian natural selection and Mendelian inheritance, which primarily focuses on population genetics (Laland et al. 2015, 1). The EES is not a complete overhaul of the MS, nor does it deny the significance and value it brought to the field of biology. However, through recent work in evolutionary developmental biology, inclusive inheritance, developmental plasticity, and niche construction some core assumptions in the MS have been challenged (Laland et al. 2015, 3). However, some evolutionary biologists do not consider the EES a challenge to the standard evolutionary theory; to them, the aforementioned phenomena are contiguous causes of evolution, but are not able to provide evolutionary explanations for diversity or adaptation themselves (Laland et al. 2015, 4). On the contrary, other researchers agree EES provides an alternate conceptual framework for understanding evolution and considers developmental bias, plasticity, inclusive inheritance, and niche construction as forces for evolutionary change. Niche construction is the process by which organisms

alter, modify, or stabilize the environment through their metabolism, activities, and choices, which in turn alters the selective pressures acting on themselves and other species (Laland et al. 2015; Odling-Smee et al. 2003; Scott-Phillips et al. 2013). The term was first coined by University of Oxford biologist John Odling-Smee (1988). In the conventional view of evolution, organisms are shaped by their environments, and express traits and characteristics that increase their survival and reproductive success within these areas (Laland et al. 2014, 2). Conversely, niche construction accounts for an organism's ability to modify environmental states to fit their genotype, creating a feedback loop between the environment and the organism (Lewontin 1983). This idea is reflective of "reciprocal causation" which is the notion that "process A is a cause of process B and, subsequently, process B is a cause of process A, with this feedback potentially repeated in causal chains" (Laland et al. 2015, 6). Ingold (1993, 162) describes landscapes as always being a work in progress, which reflects this reciprocal relationship between organism and environment very well.

Typical examples of niche construction are animals that create burrows, nests, and webs, but this also includes biota such as bacteria that decompose organic matter which excrete compounds that alter their environment. An integral part of niche construction is the concept of ecological inheritance. Ecological inheritance is defined by Odling-Smee et al. (2003, 42) as any circumstance where an organism encounters a modified environmental state where selective pressures have changed through niche construction. There are four forms of niche construction: inceptive perturbation, counteractive perturbation, inceptive relocation, and counteractive relocation (see table in Odling-Smee 2003, 47). Inceptive perturbation niche construction is when an organism initiates a change in the environment by physical modification that alters selection, whereas counteractive perturbation is a response to a change in the environment through physical modification. Inceptive relocation niche construction is when an organism moves into a new area exposing themselves to a new selective environment, while counteractive relocation is when an organism acts on a change in the environment by moving locations.

Moreover, niche construction can be considered either positive or negative, depending on how the modified environment affects the average fitness of an organism (Odling-Smee 2003, 47).

Benefits of Humanistic Experimental Protocols

As archaeologists, we strive to be objective in our approach to experimental research, sometimes limiting our involvement in the experiments themselves – such as Mitchell’s (1995) and Schoville et al.’s (2016) use of a professional butcher – but is that actually beneficial in every situation? Above, I argued for an alternative approach to experimental protocols, such as a “humanistic” (Clark and Woods 2015) or phenomenological approach, which takes into consideration the engagement of biological, social, and environmental factors and their influence on tool manufacture and use. As previously mentioned, this does not mean that archaeologists can replicate the spheres of influence acting on hominin tool use in the present day; however, an approach that considers these interactions within the experimental framework can possibly develop new ways of thinking about how we investigate prehistoric tool use and more importantly, how we interpret our results. Additionally, a phenomenological approach to stone tool use is important because we are directly involved in the activities; therefore, we are observing what is happening while simultaneously *experiencing* how it feels to use a stone tool or manufacture a stone tool, which can have profound impacts on the way we think about the archaeological record. The experiential aspect of experimental archaeology can lead to generating novel methods and new archaeological questions. A prime example of this is discussed by Clark and Woods (2015, 197) in which they grapple with the “human side of replication experiments.” In particular, they argue that although archaeologists generally accept that lithic technology and function can be replicated in the present and used to make inferences about the past, they are much more reluctant to accept the behaviors, feelings, and thoughts associated with stone tool replication and use for interpreting prehistory (Clark and Woods 2015, 200). After a description of one of Clark’s first use-wear experiments, they reflect on the experimental protocol stating: “In hindsight, we think Clark should

have use the experimental tools for tasks that mattered in ways meant to conserve their edges and prolong their use-lives, rather than trying to damage stone tools in documented ways for the cause of science” (Clark and Woods 2015, 201). This view of experimental use-wear protocols should be welcomed and can provide more insight into our interpretations of prehistoric stone tool function. I am not arguing that this type of approach should take precedence over an objective and standardized experimental protocol. I think that they are both necessary and equally important to the advancement of experimental archaeology and our understanding of the past

In my research, I attempted to incorporate a “task-orientated” aspect to the experimental protocol by focusing on experiments with goals such as making a spear or processing bamboo stalks from felling that included my own experience performing the experiments. I think this approach might be useful in future experimental studies and can be refined and expanded to include larger tasks such as cutting down small trees or processing hides from start to finish. Conducting these tasks myself allowed me to gain insight into how it felt to use the handaxes for various tasks. Additionally, this allowed me to make connections that might have been missed if I had not been involved. One example of this is the production of debitage from high intensity activities on medium-hard materials. In particular, chopping bone created a small assemblage from use with flakes as large as four cm. As I heard that unmistakable “popping” sound caused by flakes releasing from contacting with the hard bovid femur it occurred to me that I had never read any literature discussing flakes produced by use. After a preliminary search, I found nothing discussed in the literature, although an initial inspection by Dan Stueber (pers. comm.) suggests they have certain attributes that differ from flakes produced by knapping. It is likely that this has not been discussed because there are more parsimonious ways to process bone than using a handaxe; however, flakes were also produced by other activities such as shucking oysters and adzing wood. Another possible reason is what Clark and Woods (2015) allude to previously – maybe these hominins were using handaxes for activities that help conserve cutting edge and raw material to prolong the

artifact's use-life. A future examination of flake attributes between those produced by use-wear and those produced from knapping can possibly provide insights for early hominin tool use. For example, if early hominins were using rocks similar to chimpanzees, it is possible that flakes were detached during these pounding activities which begs the question, did early hominins make the same connection as I did?

As mentioned previously, I had the help of my colleague Jenny Francouer during the butchery experiments. Jenny did not have any background information on how archaeologists think hominins used handaxes so it was interesting to compare my use of the handaxes, which is influenced by the archaeological literature, to Jenny's. Generally, there were aspects of her grip that was similar to mine but there were some slight differences. A consistency between our grips was our tendency to hold handaxes where there was a squared edge; however, if a squared edge was missing our grips differed. In particular, if there was no obvious unworked or blunted edge, she held the tool by both edges and used the tip of the tool rather than holding the tool in the same manner to access the large cutting edge. Contrary to this, I held the tool near the butt of the unused edge regardless of whether or not there was a squared portion present. This difference influenced me to consider investigating how tool grip effected the distribution of edge damage and frequency. The observation that grip may play a role in the distribution of edge damage was alluded to by Schoville et al. (2016, 17) in their butchery experiments, but they did not formally test this. The results of the experimental research from this project suggest that how the tool is held does effect the distribution of edge damage.

The last example of the insight I gained by participating in the experimental activities surrounds the use of handaxes as handheld tools. During some of the high intensity activities such as adzing or chopping wood, shucking oysters, and chopping bone, the force of the blows damaged my hands. Additionally, for tools that were completely flaked with sharp edges along the whole tool I needed leather pads and gloves to protect my skin. Of course we cannot know how durable hominins hands

were, but we can investigate whether or not these tools were hafted or used with pads of hide in the past. Hafting and prehension can create specific wear patterns that are detectable during analysis (Rots 2010; Rots et al. 2016; Rots et al. 2017). Furthermore, experimental and archaeological data from the Cave of Hearths' in South Africa suggests some handaxes and cleavers exhibited signs of hafting (Lambert-Law de Lauriston 2015).

A Multi-Stranded Approach

The methodology used for this research is a combination of low powered use-wear analysis and non-parametric statistical analysis which combines the qualitative nature of use-wear with a quantitative description. The edge damage frequency and distribution approach created by Schoville (2010) not only differs from traditional use-wear studies in its quantitative statistical approach, but it looks at use-wear and tool function at an assemblage scale. By approaching functional studies at an assemblage scale, archaeologists can address some of the common criticisms of use-wear methods. In particular, it minimizes the issues of equifinality and user error by not assigning behavioral interpretations to individual scars (Wilkins and Schoville 2016, 114). Additionally, we can evaluate differences between taphonomic and behavioral processes through the distribution of edge damage frequency and possibly elucidate when the distribution is a combination of taphonomic and behavioral processes (Wilkins and Schoville 2016, 114). Furthermore, by approaching use-wear at an assemblage scale, patterns in tool use and function can be uncovered that might be missed on an individual tool (114). For these reasons, this approach is a great way to begin a use-wear analysis, especially as a student with various technological and time constraints.

Although a major benefit of this approach is the use of "Potential Edge Damage" (PED) and the purposeful avoidance of assigning specific interpretations to use-wear, implementing specific wear signatures through low-powered microscopy can bolster our understanding of tool function at an

assemblage scale. During the data collection, it became apparent that at an assemblage scale there was a lot of variation in use-wear signatures. Considering individual use-wear signatures tell us a lot about the specific contact materials being exploited by hominins, incorporating this in the methodology can reveal the range of materials being used within certain tool types or possibly whether or not certain tools were specialized for working specific materials. Additionally, understanding how types of use-wear signatures are distributed can determine whether or not tools were used for multiple purposes within the assemblage and at an individual artifact level. Expanding on this notion, another future endeavor is comparing the frequency and distribution of edge damage across tool types. By applying this method to multiple tool types we can better recognize hominin behavioral variability and adaptive strategies within certain environmental contexts at an assemblage scale.

In the introduction to this thesis, I stated a primary goal of this thesis is to test the application of the edge damage distribution method on a bifacial tool type. Considering the goal of the method is to distinguish use-activity based on the distribution of edge damage, the majority of these results show the method can be applied to bifaces successfully. Most activities were able to be distinguished from one another with one exception – butchery and transverse activities are difficult to distinguish in this dataset. This is interesting and I did not expect this result. If anything, I thought it would be difficult to distinguish longitudinal actions and butchery. The similarities between these distributions may be due to handedness and angle of use.

Overall, this thesis should be considered a pilot study due to the minimal number of variables recorded and the fact that the methodology created by Schoville (2010) has been exclusively used in his own research (see McPherron et al. 2014 for alternative method in edge damage distribution). This thesis is, as far as I know, the first attempt to replicate the methodology outside of Schoville and his colleagues. Further, this project was the first application of this methodology on a bifacial tool type. The previous research using this method has focused on stone points (Schoville 2010; Schoville and Brown

2010; Schoville et al. 2016; Wilkins and Schoville 2016; Wilkins et al. 2012). All of this considered, there are many unknown factors that are potentially at play when analyzing handaxes. McPherron and colleagues (2014) promote the approach created by Schoville (2010), but argue that more research needs to be done to better understand the various influences on the way edge damage forms on artifacts. In their experimental study, they consider edge angle, substrate grain size, raw material properties, and which face of the tool is exposed (McPherron et al. 2014) and test how it effects the distribution of edge damage. The most significant of their results is the correlation between edge angle and likelihood of edge damage. The authors found that as edge angle increases, the amount of edge damage decreases (McPherron et al. 2014, 77). This observation is important for handaxes due to the likelihood that they have unworked or lightly worked proximal ends and will be considered in the future to reassess the results of this project.

Interpreting Prehistory

Applying what we learn through experimental studies to our interpretation of the archaeological record is a difficult task. The archaeological record has high “internal validity” but low “external validity”, meaning it is the most direct empirical evidence we have about the past but it is incomplete and biased (Eren et al. 2016, 106). Experimental studies vary somewhere in the middle of the spectrum between high internal validity and high external validity (Eren et al. 2016, 107). Metin Eren and colleagues (2016) divide experimental stone tool replication studies to three archetypes: replications as a test, replications as models, and replications as method validation. Replications as a test are used to test a hypothesis or question about stone tools (109). Replications as models are used to generate predictions from “empirically documented situations” (Eren et al. 2016, 115 citing Lycett and Chauhan 2010, 10). Lastly, replications as method validation involves using experimental datasets as control groups to assess quantitative methods that will then be applied to the archaeological record (118). Each of these

archetypes have relevance to what we think we know about the past and are not mutually exclusive. The methodology used within this research fits into all three categories.

Archaeologists make many assumptions when applying experimentally generated data to the past so it is important to acknowledge these assumptions when we are making our interpretations. The primary assumption in stone tool replication studies is based on the principles of uniformitarianism, which is the idea that the natural processes we observe today occurred the same way in the past. For stone tool replication, it is the mechanics behind conchoidal fracture in rocks that we assume to act the same way today as they did in the past (Bradfield 2016, 295). Considering the formation of edge damage is a mechanical and physical process in stones – some of which are an extension of this fracturing – we can assume that the way use-wear forms from activities in experiments today can be applied to our interpretation of the past. Bradfield (2016, 299) makes a compelling argument about the importance of being conservative in our interpretations by acknowledging the methodological constraints and refraining from using language that is “over-confident.” By providing “definitive” conclusions when discussing use-wear patterns in the prehistory, researchers shroud the subjective nature of use-wear analysis and make an unwarranted link between the present and past. For example, he discusses arguments surrounding stone points and the interpretation of macro-fractures to the use of points as prehistoric projectiles. He argues that these traces alone just show that the tool underwent longitudinal impact, not that they were used for projectile weaponry – that is the researchers’ subjective interpretation of the longitudinal impact (Bradfield 2016, 298-299). As archaeologists, we need to be cognizant that our experiments are simply ways of informing our interpretations – they are not answers themselves – and help rule out other possible causes.

Investigating function is based on mechanical and physical processes; therefore, it is important to remember that humans are not the only possible cause of edge damage and use-wear. Post-depositional experiments and taphonomic studies help elucidate the role of site formation processes in

the development of edge damage, but even with knowledge of site formation, it can be difficult to definitively argue that the edge damage seen on artifacts at an assemblage scale is solely due to the specific activities that created similar edge damage in the experimental dataset. Additionally, results of blind tests show that it can be challenging to distinguish between use-wear signatures on individual artifacts and typically only the hardness of the material and direction of the activity can be inferred with confidence (Grace 1989). Despite the shortcomings of functional studies and “over-confident” interpretations, use-wear analyses provide invaluable insights into stone tool use and hominin behavior as long as our limitations are recognized.

Tip Shape and Handaxe Function

The experimental activities showed that handaxes are highly versatile tools and can be used for various tasks successfully which supports the majority of previous experimental studies involving handaxes (Claud 2008; Keeley 1980; Viallet 2016b). I was amazed at how durable the edges were on most of the materials. The only time they were easily damaged was during high intensity activities on hard materials. I speculated that chopping wood or adzing wood might cause considerable damage to the edge but they did not have a significant impact at all. Even with a highly convergent tip that seemed easily breakable, adzing wood did not snap it. The durability of these edges in the experimental activities provides clues to the intensity or duration of use and the hardness of the contact materials that must have been worked in SM-1 assemblage to create the sort of damage that is present. Additionally, the durability of these edges might have implications for re-use of tools after previous discard events.

The results of the damage distribution analysis indicate that handaxes at SM-1 were primarily used with the distal end of the tool. This suggests the most important aspect of the tool is the tip. In Timothy Lambert-Law de Lauriston’s (2015) MA research, he utilized McNabb et al.’s (2004) definition of tip shape to separate the LCTs used within his experiments to investigate whether or not they had

statistically significant differences in use-action (e.g., transverse, longitudinal, etc.). Although his results were insignificant, the importance of the tip illustrated in this research warrants further investigation into tip shape and function. In particular, I plan to adopt McNabb and Rivett's (2015) quantitatively defined categories of LCT tip shape. Moreover, Lambert-Law de Lauriston (2015) found evidence of hafting in the LCT assemblage at the archaeological site called Cave of Hearths which might be a factor leading to a high frequency of edge damage on the distal end of handaxes. Further research into how edge damage is distributed on handaxes that are hafted is necessary to investigate this.

Handaxe Use and Hominin Behavior at SM-1

SM-1 is in one of the most important regions when considering the dispersal and evolution of the hominin lineage because it lies at the crossroads of Europe, Africa, and Asia. Considering SM-1 is in an area that acted as a desert refugia makes the site even more significant because of its rich and abundant natural resources (Cordova et al. 2013). This oasis would have attracted all types of species – both predators and prey – making it a crucial but potentially dangerous habitat for hominins. The faunal remains indicate the presence of a large variety of organisms from rhinoceros and elephant to lion and gazelle. Results from protein residue analysis indicate that the hominins present at SM-1 were exploiting most of the animals present in the refugia including ducks. The adaptive strategies required to acquire ducks would have been vastly different than the one needed to access megafauna regardless if they were being hunted or scavenged (Nowell et al. 2016). Nowell and colleagues (2016, 42) argue that ducks were possibly hunted at night by throwing a hide over the nests or during the day with throwing sticks, nets, or rocks. Two handaxes were included in the protein residue analysis with positive results, one for rhinoceros and one for horse.

The handaxes with positive protein residue provide unequivocal evidence of handaxes being used to process animal remains; however, the results of this analysis do not provide any insight into the

specific activities handaxes were used in. Processing animal remains typically requires various stages from skinning to dismembering and potentially hide working. More detailed use-wear analyses will help shed light on this. My preliminary observations indicate that the handaxes were possibly being used to process medium to hard materials such as bone, antler, wood, carcasses, or reeds due to the high degree of rounding and microflaking. As we currently understand it, all of these materials except for antler were present at SM-1 in the past. The high intensity of the edge damage seen on most of the artifacts suggests these tools might have been used for long amounts of time (Vaughan 1985). Additionally, there was a mixture of bifacial and unifacial rounding and microflaking indicating there may be multiple activities involved within the assemblage. Vaughan (1985, 26) explains that transverse actions such as scraping or planing causes a higher degree of rounding on the surface facing the edge, whereas longitudinal actions such as sawing and cutting typically cause bi-lateral or bifacial rounding. The degree of rounding on faces also depends on the angle of the edge to the contact material. It is possible that if the tool is being used in a longitudinal motion but at an angle not perpendicular to the material, there might be more rounding on one face than the other (Vaughan 1985, 26).

The KS test results between edge AL and edge BR, which form the left edge when combined, do not have statistically significant differences, possibly indicating the majority of the left edges were used in a longitudinal motion. The significant results of the paired T-test and Wilcoxon signed-rank test (Table 5.5) suggests this edge was used at an angle less than 90° with face A having more contact with the material being worked. Similar to the left edge, the result of the KS test of the right edge (AR + BL) is not statistically significant indicating this edge may have been used in a longitudinal motion. Unlike the left edge, the paired-T test and Wilcoxon signed-rank suggests it was used at an angle around 90° to the worked material. I'm not sure how plausible it would be to argue that the majority of the handaxes at SM-1 were consistently used at a 90° angle on the right edge because it is quite easy to alter the angle unknowingly during use without it having an effect on your productivity or success. Moreover, Vaughan

(1985) demonstrates that certain activities don't always follow the typical distribution described by Tringham et al (1974) so there are exceptions to these observations. Overall, the combination of these results indicate that handaxes at SM-1 were being used in various activities but primarily on harder contact materials.

In order to narrow down the type of contact materials that were exploited at SM-1, the incorporation of high-powered microscopy is needed. Moreover, the lack of high powered microscopy bias these results; in particular, it excludes the possibility of the use of plant materials by the SM-1 hominins because soft materials do not damage the edges as easily therefore the low-powered approach is not as capable of detecting plant use as its counterpart. This is compounded by the fact that plants are already underrepresented in the archaeological record due to preservation bias, although it is well known that hominins consumed plants based on studies of the dental calculus (Henry et al. 2011), dental microwear (El Zataari et al. 2011), and recovery of charred seeds and fruits (Hardy 2010, 665).

The use-wear analysis and edge damage distribution of handaxes at SM-1 seems to indicate a "generalized" use. Based on the results of the KS tests, the best model for the distribution of edge damage at SM-1 is the aggregated experimental dataset (excluding post-depositional experiments). This supports the argument that handaxes were multi-functional tools that were selected for due to their long life histories and ease of transport (Keeley 1980; Nowell and White 2010). The lack of debitage from bifacial reductions make it likely that these tools were being brought in from another area where they were first manufactured or picked up and used from a previous discard event. Based on the blood residue results, we know that these hominins had a broad ecological niche and exploited various types of fauna at SM-1. This generalist adaptive strategy would require a tool that would be capable of exploiting the wide range of resources while also being a source of flakes and a means of making wooden tools or structures.

Conclusions

At the most preliminary level, the highest frequency of edge damage on the handaxes at SM-1 occur at the tip of the tools suggesting it is the most utilized part of the edge; therefore, it is possible that it is the most important aspect of the tool when being used. In particular, this is supported by the experimental activities in which handaxes were used for percussion; however, the edge damage distribution model for percussion did not reflect the distribution seen at SM-1. Rather, the model that best explains the distribution at SM-1 is the aggregated experimental data which included multiple activities, but excluded post-depositional experiments. This supports the idea that handaxes are multi-functional (Claud 2008; Keeley 1980; Viallet 2016a, b). The preliminary microwear data suggest handaxes were being used on medium to hard materials, but this result is bias due to the lack of high powered microscopy in the use-wear analysis and small sample size (n=4). Although found in different geographic contexts, handaxe use on medium-hard materials is seen in Africa (Lambert-Law de Lauriston 2015) and the Mediterranean (Viallet 2016 a, b).

The use of the methodology created by Schoville (2010) provides unique insight on the formation of edge damage at an assemblage scale. The method was successful in elucidating patterns of use within the archaeological and experimental datasets and can help archaeologists create a more holistic picture of hominin landscape use and technological variability. In the future, applying this method to other handaxe assemblages around the world might uncover geographic and temporal patterns in handaxe function. The influence of grip and handedness has been mentioned by Schoville various times (Schoville 2010; Schoville et al. 2016). The experimental results in this research suggest grip does have an affect on the distribution of edge damage; however, future experiments are needed that include variation in grip within the same activity.

Considering this is the first application of this method on this tool type, the results are very preliminary, but nonetheless provide some insight into the variability of handaxe use at SM-1. There are two possible scenarios that might account for the variability within the assemblage:

- 1) Handaxes were used in multiple ways, confirming their use as multifunctional tools.
- 2) The variability is due to an unknown factor that influences the formation and distribution of edge damage. For example, these results might simply be due to the aggregation of artifacts that vary in size and/or shape – in which size and shape are significant factors in determining function.

These scenarios are not mutually exclusive and it is more likely that they both have played a role in the variability. In order to make more robust behavioral interpretations about the interaction between hominins and their environment at SM-1, the use-wear analysis needs to be expanded to include high powered microscopy and residue analysis beyond CIEP. The experimental activities provide evidence for the functional potential of handaxes and their ability to exploit a wide variety of materials in multiple ways. By investigating other organic residues and micropolishes, we can confirm the multifunctionality of these tools and better understand how the SM-1 hominins were adapting and surviving during dispersal events, particularly when the surrounding region had a climate that was variable and harsh.

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References

- Albrecht, Gerd, and Hansjürgen Müller-Beck. 1988. "The Palaeolithic of Sehremuz Near Samsat on the Euphrates River. Summary of the Excavation Findings and Morphology of the Handaxes." *Paléorient*: 76-86.
- Ames, Christopher JH, April Nowell, Carlos E. Cordova, James T. Pokines, and Michael S. Bisson. 2014. "Paleoenvironmental change and settlement dynamics in the Druze Marsh: results of recent excavation at an open-air Paleolithic site." *Quaternary International* 331: 60-73.
- Ames, Christopher JH, and Carlos E. Cordova. 2015. "Middle and Late Pleistocene landscape evolution at the Druze Marsh Site in northeast Jordan: implications for population continuity and hominin dispersal." *Geoarchaeology* 30 (4): 307-329.
- Anderson-Gerfaud, Patricia C. 1980. "A testimony of prehistoric tasks: diagnostic residues on stone tool working edges." *World Archaeology* 12 (2): 181-194.
- Anderson-Gerfaud, Patricia. 1990. "Aspects of behaviour in the Middle Palaeolithic: functional analysis of stone tools from southwest France." *The Emergence of Modern Humans*: 389-418.
- Anderson, P., Georges, J.-M., Vargiolu, R., Zahouani, H., 2006. "Insights from a tribological analysis of the tribulum." *Journal of Archaeological Science*. 33: 1559-1568.
- Archer, Will, and David R. Braun. 2010. "Variability in bifacial technology at Elandsfontein, Western cape, South Africa: a geometric morphometric approach." *Journal of Archaeological Science* 37 (1): 201-209.
- Bamforth, Douglas B. 1988. "Investigating microwear polishes with blind tests: the Institute results in context." *Journal of Archaeological Science* 15(1): 11-23.
- Bamforth, Douglas B., George R. Burns, and Craig Woodman. 1990. "Ambiguous use traces and blind test results: new data." *Journal of Archaeological Science* 17 (4): 413-430.
- Bar-Yosef, O., and N. Goren-Inbar. 1993. "The lithic assemblage of Ubeidiya." *A Lower Palaeolithic Site in the Jordan Valley. Jerusalem: Institute of Archaeology, Hebrew University of Jerusalem*.
- Bar-Yosef, Ofer. 1994. "The lower paleolithic of the Near East." *Journal of World Prehistory* 8 (3): 211-265.
- Bar-Yosef, Ofer, Metin I. Eren, Jiarong Yuan, David J. Cohen, and Yiyuan Li. 2012. "Were bamboo tools made in prehistoric Southeast Asia? An experimental view from South China." *Quaternary International* 269: 9-21.
- Binneman, Johan, and Peter Beaumont. 1992. "Use-wear analysis of two Acheulean handaxes from Wonderwerk Cave, Northern Cape." *South African Field Archaeology* 1: 92-97.
- Binford, Lewis R. 1977. "General introduction". In *For Theory Building in Archaeology: Essays on Faunal Remains, Aquatic Resources, Spatial Analysis, and Systemic Modeling* edited by Lewis Binford, pp 1-10. New York: Academic Press.

- Binford, Lewis R. 1983. *Working at Archaeology*. Orlando: Academic Press.
- Bird, Catherine, Tom Minichillo, and Curtis W. Marean. 2007. "Edge damage distribution at the assemblage level on Middle Stone Age lithics: an image-based GIS approach." *Journal of Archaeological Science* 34 (5): 771-780.
- Boëda, Eric, Jacques Connan, Daniel Dessort, Sultan Muhesen, Norbert Mercier, H  l  ne Valladas, and Nadine Tisn  rat. 1996. "Bitumen as a hafting material on Middle Palaeolithic artefacts." *Nature* 380 (6572):336-338.
- Bo  da, Eric, Jacques Connan, and Sultan Muhesen. 2002. "Bitumen as hafting material on Middle Paleolithic artifacts from the El Kowm Basin, Syria." In *Neandertals and modern humans in Western Asia*, pp. 181-204. Springer.
- Bo  da,   ric, St  phanie Bonilauri, Jacques Connan, Dan Jarvie, Norbert Mercier, Mark Tobey, H  l  ne Valladas, and Heba al Sakhel. 2008. "New evidence for significant use of bitumen in Middle Palaeolithic technical systems at Umm el Tlel (Syria) around 70,000 BP." *Pal  orient*: 67-83.
- Brown, Antony G., Laura S. Basell, Sian Robinson, and Graham C. Burdge. 2013. "Site distribution at the edge of the Palaeolithic world: a nutritional niche approach." *PloS one* 8 (12): e81476.
- Clark, John D. 1966. *The middle Acheulian occupation site at Latamne northern Syria*. Direction g  n  rale des antiquit  s et des mus  es.
- Clark, John D., 1967. "The Middle Acheulian occupation site of Latamne, Northern Syria". *Quaternaria* 9, 1-68.
- Clark, G. 1969. *World Prehistory: A New Synthesis*. Cambridge: Cambridge University Press.
- Clark, Geoffrey A., J. Schuldenrein, M. L. Donaldson, H. P. Schwarcz, W. J. Rink, and S. K. Fish. 1997. "Chronostratigraphic contexts of Middle Paleolithic horizons at the 'Ain Difla rockshelter (WHS 634), west-central Jordan." *The Prehistory of Jordan, II. Perspectives from 1997*: 77-100.
- Clark, Geoffrey A., and John M. Lindly. 1991. "On Paradigmatic Biases and Paleolithic Research Traditions." *Current Anthropology* 32 (5): 577-587.
- Clark, E. John, and James C. Woods. 2015. "Squeezing Life from Stones: The Human Side of Replication Experiments" in *Works in Stone* edited by Michael J. Shott. Salt Lake City: University of Utah Press.
- Claud, Emilie. 2008. "Le statut fonctionnel des bifaces au Pal  olithique moyen r  cent dans le Sud-Ouest de la France.   tude trac  ologique int  gr  e des outillages des sites de La Graulet, La Conne de Bergerac, Combe Brune 2, Fonseigner et Chez-Pinaud/Jonzac." PhD dissertation, Universit   Sciences et Technologies-Bordeaux I.

- Claud, Emilie. 2015. "The use of biface manufacturing flakes: Functional analysis of three Middle Palaeolithic assemblages from southwestern and northern France." *Quaternary International* 361: 131-141.
- Claud, Émilie, Marianne Deschamps, David Colonge, Vincent Mourre, and Céline Thiébaud. 2015. "Experimental and functional analysis of late Middle Paleolithic flake cleavers from southwestern Europe (France and Spain)." *Journal of Archaeological Science* 62: 105-127.
- Clutton-Brock, Juliet. 1979 "The fossil fauna from an Upper Pleistocene site in Jordan." *Journal of Zoology* 162 (1): 19-29.
- Clutton-Brock, J. 1989. "A re-consideration of the fossil fauna from C-Spring, Azraq." *The hammer on the rock: studies on the early Paleolithic of Azraq, Jordan, BAR international series* 540: 391-397.
- Copeland, L. 1988. "Environment, Chronology and Lower-Middle Paleolithic Occupations of the Azraq Basin, Jordan." *Paleorient* 14(2):66-75.
- Copeland, Lorraine, and Francis Hours. 1989. "The lower and middle paleolithic of the desert wadis in the Azraq Basin: survey results, 1982-1986." In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* edited by Lorraine Copeland and Francis Hours. British Archaeological Reports, pp. 65-152. Oxford.
- Copeland, Lorraine. 1991. "The Late Acheulean knapping-floor at C-Spring, Azraq oasis, Jordan." *Levant* 23 (1): 1-6.
- Corbey, Raymond, Adam Jagich, Krist Vaesen, and Mark Collard. 2016. "The Acheulean Handaxe: More like a bird's song than a beetles' tune?" *Evolutionary Anthropology: Issues, News, and Reviews* 25 (1): 6-19.
- Cordova, Carlos E., April Nowell, Michael Bisson, James Pokines, Christopher JH Ames, and Maysoon al-Nahar. 2009. "The Druze Marsh Paleolithic Project, North Azraq: Jordan Stratigraphic Sequences from the 2008 and 2009 Seasons." *Annual of the Department of Antiquities of Jordan* 53: 311-320
- Cordova, Carlos E., April Nowell, Michael Bisson, Christopher JH Ames, James Pokines, Melanie Chang, and Maysoon al-Nahar. 2013. "Interglacial and glacial desert refugia and the Middle Paleolithic of the Azraq Oasis, Jordan." *Quaternary International* 300: 94-110.
- Costa, August G. 2010. "A geometric morphometric assessment of plan shape in bone and stone Acheulean bifaces from the Middle Pleistocene site of Castel di Guido, Latium, Italy." In *New Perspectives on Old Stones*, pp. 23-41. Springer New York.
- Debénath, André, and Harold L. Dibble. 1994. *Handbook of Paleolithic Typology: Lower and middle paleolithic of Europe*. Vol. 1. UPenn Museum of Archaeology.
- Domínguez-Rodrigo, Manuel, Jordi Serrallonga, Jordi Juan-Tresserras, Luis Alcalá, and Luis Luque. 2001. "Woodworking activities by early humans: a plant residue analysis on Acheulian stone tools from Peninj (Tanzania)." *Journal of Human Evolution* 40 (4): 289-299.

- El-Naqa, A., 2010. "Study of Saltwater Intrusion in the Upper Aquifer in Azraq." Final Report. International Union for the Conservation of Nature (IUCN) and the University of Jordan, Amman.
- Eren, Metin I., Christopher I. Roos, Brett A. Story, Noreen von Cramon-Taubadel, and Stephen J. Lycett. 2014. "The role of raw material differences in stone tool shape variation: an experimental assessment." *Journal of Archaeological Science* 49: 472-487.
- Eren, Metin I., Stephen J. Lycett, Robert J. Patten, Briggs Buchanan, Justin Pargeter, and Michael J. O'Brien. 2016. "Test, Model, and Method Validation: The Role of Experimental Stone Artifact Replication in Hypothesis-driven Archaeology." *Ethnoarchaeology* 8 (2): 103-136.
- Evans, Adrian A., and Randolph E. Donahue. 2008. "Laser scanning confocal microscopy: a potential technique for the study of lithic microwear." *Journal of Archaeological Science* 35(8): 2223-2230.
- Evans, A. A., and D. Macdonald. 2011. "Using metrology in early prehistoric stone tool research: further work and a brief instrument comparison." *Scanning* 33 (5): 294-303.
- Evans, Adrian Anthony. 2014. "On the Importance of Blind Testing in Archaeological Science: the Example from Lithic Functional Studies." *Journal of Archaeological Science* 48: 5-14.
- Faulks, N., Kimball, L.R., Hidjrati, N., Coffey, T., 2011. "Atomic force microscopy of microwear traces on Mousterian tools from Myshtylagty Lagat (Weasel Cave), Russia." *Scanning* 33: 304-315.
- Fischer, Anders, Peter Vemming Hansen, and Peter Rasmussen. 1984. "Macro and micro wear traces on lithic projectile points: experimental results and prehistoric examples." *Journal of Danish Archaeology* 3 (1): 19-46.
- France, R., 2010. "Rehabilitation of a Historic Wetland: Jordan's Azraq Oasis." In: *Restorative Redevelopment of Devastated Ecocultural Landscapes*. CRC Press. pp85-115.
- Fullagar, Richard LK. 1991. "The role of silica in polish formation." *Journal of Archaeological Science* 18 (1): 1-24.
- Fullagar, R., & Matherson, M. (2013). Traceology: A summary. In C. Smith (Ed.), *Encyclopedia of global archaeology* (pp. 73–85). New York: Springer.
- Fuentes, Agustín. "Integrative Anthropology and the Human Niche: Toward a Contemporary Approach to Human Evolution." *American Anthropologist* Vol. 117, No 2 (2015): 302-315.
- Gabunia, Leo, Abesalom Vekua, David Lordkipanidze, Carl C. Swisher, Reid Ferring, Antje Justus, Medea Nioradze et al. 2000. "Earliest Pleistocene hominid cranial remains from Dmanisi, Republic of Georgia: taxonomy, geological setting, and age." *Science* 288 (5468): 1019-1025.
- Galán, A. B., and M. Domínguez-Rodrigo. 2014. "Testing the efficiency of simple flakes, retouched flakes and small handaxes during butchery." *Archaeometry* 56 (6): 1054-1074.
- Galván, Bertila et al. 2014. "New Evidence of Early Neanderthal Disappearance in the Iberian Peninsula." *Journal of Human Evolution* 75: 16–27.

- Garrard, Andrew N., N.P Stanley Price, and L. Copeland. 1975. "A survey of prehistoric sites in the Azraq Basin, eastern Jordan." *Paléorient* 3 (1): 109-126.
- Garrard, Andrew, Alison Betts, Brian Byrd, and Christopher Hunt. 1987. "Prehistoric environment and settlement in the Azraq Basin: an interim report on the 1985 excavation season." *Levant* 19 (1): 5-25.
- Gilead, David. 1970. "Handaxe industries in Israel and the Near East." *World Archaeology* 2 (1): 1-11.
- González-Urquijo, Jesús Emilio, and Juan José Ibáñez-Estévez. 2003. "The quantification of use-wear polish using image analysis. First results." *Journal of Archaeological Science* 30 (4): 481-489.
- Goren-Inbar, Naama. 1985. "The lithic assemblage of the Berekhat Ram Acheulian site, Golan Heights." *Paléorient* 11(1): 7-28.
- Goren-Inbar, Naama, Craig S. Feibel, Kenneth L. Verosub, Yoel Melamed, Mordechai E. Kislev, Eitan Tchernov, and Idit Saragusti. 2000. "Pleistocene milestones on the out-of-Africa corridor at Gesher Benot Ya'aqov, Israel." *Science* 289 (5481): 944-947.
- Grace, Roger. 1996. "Use-wear analysis: the state of the art." *Archaeometry* 38 (2): 209-229.
- Grace, Roger. 1989. *Interpreting the Function of Stone Tools: the quantification and computerisation of microwear analysis*. British Archaeological Reports International
- Grace, R., Graham, D.G., Newcomer, M.H., 1985. "The quantification of microwear polishes." *World Archaeology*. 17: 112-120.
- Gurfinkel, D. M., and U. M. Franklin. 1988. "A study of the feasibility of detecting blood residue on artifacts." *Journal of Archaeological Science* 15(1): 83-97.
- Hardy, Bruce L., and Gary T. Garufi. 1998. "Identification of woodworking on stone tools through residue and use-wear analyses: experimental results." *Journal of Archaeological Science* 25 (2): 177-184.
- Hardy, Bruce L., Marvin Kay, Anthony E. Marks, and Katherine Monigal. 2001. "Stone tool function at the paleolithic sites of Starosele and Buran Kaya III, Crimea: Behavioral implications." *Proceedings of the National Academy of Sciences* 98 (19): 10972-10977.
- Hardy, Bruce L. 2004. "Neanderthal behaviour and stone tool function at the Middle Palaeolithic site of La Quina, France." *Antiquity* 78 (301): 547-565.
- Hardy, Bruce L. 2010. "Climatic variability and plant food distribution in Pleistocene Europe: Implications for Neanderthal diet and subsistence." *Quaternary Science Reviews* 29 (5): 662-679.
- Hardy, Bruce L., and Marie-Hélène Moncel. 2011. "Neanderthal use of fish, mammals, birds, starchy plants and wood 125-250,000 years ago." *PloS one* 6(8): e23768.
- Harmand, Sonia, Jason E. Lewis, Craig S. Feibel, Christopher J. Lepre, Sandrine Prat, Arnaud Lenoble, Xavier Boës et al. 2015. "3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya." *Nature* 521(7552): 310-315.

- Hayden, Brian. 1979. "Lithic Use-wear Analysis." New York, NY: Academic Press
- Henry, Donald O. 1982. "The prehistory of southern Jordan and relationships with the Levant." *Journal of Field Archaeology* 9 (4): 417-444.
- Henry, Donald O. 1995. "The middle Paleolithic sites." *Prehistoric Cultural Ecology and Evolution*, pp. 49-84. Springer US.
- Hurcombe, Linda. 1988. "Some criticisms and suggestions in response to Newcomer et al. (1986)." *Journal of Archaeological Science* 15 (1): 1-10.
- Huxley, Julian S., 1942. *Evolution, the modern synthesis*. London: Allen & Unwin.
- Ingold, Tim. 1993. "The temporality of the landscape." *World Archaeology* 25 (2): 152-174.
- Iovita, Radu, and Shannon P. McPherron. 2011. "The handaxe reloaded: A morphometric reassessment of Acheulian and Middle Paleolithic handaxes." *Journal of Human Evolution* 61 (1): 61-74.
- Isaac, Glynn L. 1972. "Chronology and the tempo of cultural change during the Pleistocene." *Calibration of hominoid evolution*: 381-430.
- Jahren, A. H., N. Toth, K. Schick, J. D. Clark, and R. G. Amundson. 1997. "Determining stone tool use: chemical and morphological analyses of residues on experimentally manufactured stone tools." *Journal of Archaeological Science* 24 (3): 245-250.
- Jelinek, Arthur J. "The Tabun cave and Paleolithic man in the Levant." *Science* 216 (4553): 1369-1375.
- Jensen, Helle Juel. 1988. "Functional analysis of prehistoric flint tools by high-power microscopy: A review of west European research." *Journal of World Prehistory* 2 (1): 53-88.
- Kamminga, Johan. 1982. *Over the Edge: Functional Analysis of Australian Stone Tools*. 12. University of Queensland.
- Kimball, Larry R., John F. Kimball, and Patricia E. Allen. 1995. "Microwear polishes as viewed through the atomic force microscope." *Lithic Technology*: 6-28.
- Kealhofer, Lisa, Robin Torrence, and Richard Fullagar. 1999. "Integrating phytoliths within use-wear/residue studies of stone tools." *Journal of Archaeological Science* 26 (5): 527-546.
- Keeley, Lawrence H. 1974. "Technique and methodology in microwear studies: a critical review." *World Archaeology* 5 (3): 323-336.
- Keeley, Lawrence H., and Mark H. Newcomer. 1977. "Microwear analysis of experimental flint tools: a test case." *Journal of Archaeological Science* 4 (1): 29-62.
- Keeley, Lawrence H. 1980. *Experimental determination of stone tool uses: a microwear analysis*. Chicago: University of Chicago Press.

- Keeley, Lawrence H., and Nicholas Toth. 1981. "Microwear polishes on early stone tools from Koobi Fora, Kenya." *Nature*: 464-465.
- Key, Alastair JM, and Stephen J. Lycett. 2015. "Reassessing the production of handaxes versus flakes from a functional perspective." *Archaeological and Anthropological Sciences*: 1-17.
- Key, Alastair JM, and Stephen J. Lycett. 2016a. "Influence of handaxe size and shape on cutting efficiency: a large-scale experiment and morphometric analysis." *Journal of Archaeological Method and Theory*: 1-28.
- Key, Alastair JM, and Stephen J. Lycett. 2016b. "Investigating interrelationships between Lower Palaeolithic stone tool effectiveness and tool user biometric variation: implications for technological and evolutionary changes." *Archaeological and Anthropological Sciences*: 1-18.
- Kohn, Marek, and Steven Mithen. 1999. "Handaxes: products of sexual selection?" *Antiquity* 73 (281): 518-526.
- Kooyman, Brian, Margaret E. Newman, and Howard Ceri. 1992. "Verifying the reliability of blood residue analysis on archaeological tools." *Journal of Archaeological Science* 19(3): 265-269.
- Laland, Kevin, Gregory A. Wray, and Hopi E. Hoekstra. 2014. "Does evolutionary theory need a rethink?." *Nature* 514 (7521): 161.
- Laland, Kevin N., Tobias Uller, Marcus W. Feldman, Kim Sterelny, Gerd B. Müller, Armin Moczek, Eva Jablonka, and John Odling-Smee. 2015. "The extended evolutionary synthesis: its structure, assumptions and predictions." *Proceedings of Royal Society B: Biological Sciences* 282 (1813): 20151019.
- Lambert-Law de Lauriston, Timothy Stephen. 2015. "An exploration of use-wear analysis on Acheulean large cutting tools: the Cave of Hearths' Bed 3 assemblage." MA Thesis. University of Witwatersrand
- Langejans, Geeske HJ. 2011. "Discerning use-related micro-residues on tools: testing the multi-stranded approach for archaeological studies." *Journal of Archaeological Science* 38 (5): 985-1000.
- Langejans, Geeske HJ, and Marlize Lombard. 2015. "About small things and bigger pictures: An introduction to the morphological identification of micro-residues on stone tools." In *Use-Wear and Residue Analysis in Archaeology*, pp. 199-219. Springer International Publishing.
- Lemorini, Cristina, Mary C. Stiner, Avi Gopher, Ron Shimelmitz, and Ran Barkai. 2006. "Use-wear analysis of an Amudian laminar assemblage from the Acheuleo-Yabrudian of Qesem Cave, Israel." *Journal of Archaeological Science* 33 (7): 921-934.
- Lepre, Christopher J., Hélène Roche, Dennis V. Kent, Sonia Harmand, Rhonda L. Quinn, Jean-Philippe Brugal, Pierre-Jean Texier, Arnaud Lenoble, and Craig S. Feibel. 2011. "An earlier origin for the Acheulian." *Nature* 477 (7362): 82-85.
- Levi Sala, Irene. 1986. "Use wear and post-depositional surface modification: a word of caution." *Journal of Archaeological Science* 13 (3): 229-244.

- Lewontin, Richard. C. 1983. "Gene, organism and environment." In *Evolution from Molecules to Men* edited by DS Bendall. Cambridge: Cambridge University Press.
- Li, Hao, Kathleen Kuman, and Chaorong Li. 2015. "Quantifying the Reduction Intensity of Handaxes with 3D Technology: A Pilot Study on Handaxes in the Danjiangkou Reservoir Region, Central China." *PloS one* 10 (9): e0135613.
- Lombard, Marlize. 2004. "Evidence of hunting and hafting during the Middle Stone Age at Sibidu Cave, KwaZulu-Natal, South Africa: a multianalytical approach." *Journal of Human Evolution* 48 (3): 279-300.
- Lombard, Marlize. 2005. "Evidence of hunting and hafting during the Middle Stone Age at Sibidu Cave, KwaZulu-Natal, South Africa: a multianalytical approach." *Journal of Human Evolution* 48 (3): 279-300.
- Lombard, Marlize, and Lyn Wadley. 2007. "The morphological identification of micro-residues on stone tools using light microscopy: progress and difficulties based on blind tests." *Journal of Archaeological Science* 34 (1): 155-165.
- Lombard, Marlize, and Justin Pargeter. 2008. "Hunting with Howiesons Poort segments: pilot experimental study and the functional interpretation of archaeological tools." *Journal of Archaeological Science* 35 (9): 2523-2531.
- Loy, Thomas H. 1983. "Prehistoric blood residues: detection on tool surfaces and identification of species of origin." *Science* 220 (4603): 1269-1271.
- Loy, Thomas H., and Bruce L. Hardy. 1992. "Blood residue analysis of 90,000-year-old stone tools from Tabun Cave, Israel." *Antiquity* 66 (250):24-35.
- Lycett, Stephen J., and John AJ Gowlett. 2008. "On questions surrounding the Acheulean 'tradition'." *World Archaeology* 40 (3): 295-315.
- Lycett, Stephen J., and Christopher J. Norton. 2010. "A demographic model for Palaeolithic technological evolution: the case of East Asia and the Movius Line." *Quaternary International* 211 (1): 55-65.
- Lycett, Stephen J., Kerstin Schillinger, Metin I. Eren, Noreen von Cramon-Taubadel, and Alex Mesoudi. 2016. "Factors affecting Acheulean handaxe variation: experimental insights, microevolutionary processes, and macroevolutionary outcomes." *Quaternary International* 411: 386-401.
- Macdonald, Danielle A. 2014. "The application of focus variation microscopy for lithic use-wear quantification." *Journal of Archaeological Science* 48: 26-33.
- Machin, Anna J., Hosfield, Robert. & Mithen, Steven. J. 2005. "Testing the functional utility of handaxe symmetry: fallow deer butchery with replica handaxes." *Lithics: The Journal of the Lithic Studies Society* 26: 23-37
- Machin, Anna J., Robert T. Hosfield, and Steven J. Mithen. 2007. "Why are some handaxes symmetrical? Testing the influence of handaxe morphology on butchery effectiveness." *Journal of Archaeological Science* 34 (6): 883-893.

- Machin, Anna. 2009. "The role of the individual agent in Acheulean biface variability A multi-factorial model." *Journal of Social Archaeology* 9 (1): 35-58.
- Macumber, P. G., and P. C. Edwards. 1997. "Preliminary results from the Acheulian site of Mashari'a 1, and a new stratigraphic framework for the Lower Palaeolithic of the East Jordan Valley." *The Prehistory of Jordan II. Perspectives from 1997*: 23-43.
- Macumber, Phillip. 2008. "Evolving landscape and environment in Jordan." *Equinox Publishing*: 7-34.
- Marreiros, João Manuel, Juan Francisco Gibaja Bao, and Nuno Ferreira Bicho. 2015. *Use-wear and residue analysis in archaeology*. Springer International Publishing.
- McCall, Grant S., and John Whittaker. 2007. "Handaxes still don't fly." *Lithic Technology* 32 (2): 195-202.
- McNabb, John, Francesca Binyon, and Lee Hazelwood. 2004. "The large cutting tools from the South African Acheulean and the question of social traditions." *Current Anthropology* 45 (5): 653-677.
- McNabb, John, and C. Rivett. 2015. "Getting round to the point: biface tip shape in the British Lower Palaeolithic." *Lithics: The Journal of the Lithic Studies Society* 28: 20-32.
- McPherron, Shannon P., 1994. "A reduction model for variability in Acheulian biface morphology." PhD Dissertation. University of Pennsylvania.
- McPherron, Shannon P., 2000. "Handaxes as a measure of the mental capabilities of early hominids." *Journal of Archaeological Science* 27 (8): 655-663.
- McPherron, Shannon P. 2003. "Technological and typological variability in the bifaces from Tabun Cave, Israel." *Multiple approaches to the study of bifacial technologies* edited by Marie Soressi and Harold Dibble: 55-75. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.
- McPherron, Shannon P., Zeresenay Alemseged, Curtis W. Marean, Jonathan G. Wynn, Denné Reed, Denis Geraads, René Bobe, and Hamdallah A. Béarat. 2010. "Evidence for stone-tool-assisted consumption of animal tissues before 3.39 million years ago at Dikika, Ethiopia." *Nature* 466 (7308): 857-860.
- McPherron, Shannon P., David R. Braun, Tamara Dogandžić, Will Archer, Dawit Desta, and Sam C. Lin. 2014. "An experimental assessment of the influences on edge damage to lithic artifacts: a consideration of edge angle, substrate grain size, raw material properties, and exposed face." *Journal of Archaeological Science* 49: 70-82.
- Meeks, N.D., Sieveking, G. de G., Tite, M.S., Cook, J., 1982. "Gloss and use-wear traces on flint sickles and similar phenomena." *Journal of Archaeological Science*. 9: 317-340.
- Mitchell, J. 1995. "Studying biface butchery at Boxgrove: roe deer butchery with replica handaxes." *Lithics—The Journal of the Lithic Studies Society* 16: 64.
- Monnier, Gilliane F., Jammi L. Ladwig, and Samantha T. Porter. 2012. "Swept under the rug: the problem of unacknowledged ambiguity in lithic residue identification." *Journal of Archaeological Science* 39 (10): 3284-3300.

- Moss, Emily H. 1987. "A review of "Investigating microwear polishes with blind tests"." *Journal of Archaeological Science* 14 (5): 473-481.
- Movius, Hallam L. 1948. "The Lower Palaeolithic cultures of southern and eastern Asia." *Transactions of the American Philosophical Society* 38 (4): 329-420.
- al-Nahar, Maysoon, and Geoffrey A. Clark. "The Lower Paleolithic in Jordan." (2013).
- Newcomer, Mark, Roger Grace, and Romana Unger-Hamilton. 1986. "Investigating microwear polishes with blind tests." *Journal of Archaeological Science* 13 (3): 203-217.
- Newcomer, Mark H., Roger Grace, and Romana Unger-Hamilton. 1988. "Microwear methodology: a reply to Moss, Hurcombe and Bamforth." *Journal of Archaeological Science* 15 (1): 25-33.
- Norton, Christopher J. 2000. "The current state of Korean paleoanthropology." *Journal of Human Evolution* 38 (6): 803-825.
- Norton, Christopher J., Kidong Bae, John WK Harris, and Hanyong Lee. 2006. "Middle Pleistocene handaxes from the Korean peninsula." *Journal of Human Evolution* 51 (5): 527-536.
- Nowell, April, and Melanie L. Chang. 2009. "The case against sexual selection as an explanation of handaxe morphology." *Paleoanthropology* 2009: 77-88.
- Nowell, April, and Mark White. 2010. "Growing up in the Middle Pleistocene." *Stone Tools and the Evolution of Human Cognition*. Boulder: University Press of Colorado: 67-82.
- Nowell, A., C. Walker, C. E. Cordova, C. J. H. Ames, J. T. Pokines, D. Stueber, R. DeWitt, and A. S. A. al-Souliman. 2016. "Middle Pleistocene subsistence in the Azraq Oasis, Jordan: Protein residue and other proxies." *Journal of Archaeological Science* 73: 36-44.
- O'Brien, Eileen M. 1981. "The projectile capabilities of an Acheulian handaxe from Olorgesailie." *Current Anthropology* 22 (1): 76-79.
- Odell, George Hamley, and Frieda Odell-Vereecken. 1980. "Verifying the reliability of lithic use-wear assessments by 'blind tests': the low-power approach." *Journal of Field Archaeology* 7(1): 87-120.
- Odell, George H. 1981. "The mechanics of use-breakage of stone tools: some testable hypotheses." *Journal of Field Archaeology* 8 (2): 197-209.
- Odling-Smee, F. John. 1988. "Niche constructing phenotypes." In *The role of behavior in evolution* edited by Henry Plotkin. Cambridge: MIT Press.
- Odling-Smee, F. John, Kevin N. Laland, and Marcus W. Feldman. 2003. *Niche construction: the neglected process in evolution*. 37. Princeton University Press.
- Ollé, Andreu, Josep Maria Vergès, Luna Peña, Victoria Aranda, Antoni Canals, and Eudald Carbonell. 2014. "Chapter Twenty Four: A Microwear Analysis of Handaxes from Santa Ana Cave (Caceres, Extremadura, Spain)" in *International Conference on Use-Wear Analysis: Use-Wear 2012* edited by João Marreiros, Nuno Bicho, and Juan F. Gibaja. Newcastle: Cambridge Scholars Publishing.

- Olszewski DI. 2001. "The Palaeolithic, including the Epipalaeolithic." In *The Archaeology of Jordan* edited by Burton MacDonald, pp 31–65. Sheffield: Sheffield Academic Press.
- Pargeter, Justin. 2011 "Assessing the macrofracture method for identifying Stone Age hunting weaponry." *Journal of Archaeological Science* 38 (11): 2882-2888.
- Petraglia, Michael D., and Ceri Shipton. 2008. "Large cutting tool variation west and east of the Movius Line." *Journal of Human Evolution* 55(6): 962-966.
- Phillipson, Laurel.1997. "Edge modification as an indicator of function and handedness of Acheulian handaxes from Kariandusi, Kenya." *Lithic Technology* 22 (2): 171-183.
- Pigliucci, Massimo, and Gerd B. Müller. 2010. *Evolution: the extended synthesis*. Cambridge, MA: MIT Press
- Plisson, Hugues, and Aliette Lompré. "Technician or researcher? A visual answer." *Prehistoric technology* 40 (2008): 503-508.
- Posnansky, Merrick. 1959. "Some Functional Considerations on the Handaxe." *Man* 59: 42-44.
- Pope, Geoffrey G. 1989. "Bamboo and human evolution." *Natural history* 10 (89): 49-56.
- Repenning, Charles A., and Oldrich Fejfar.1982. "Evidence for earlier date of 'Ubeidiya, Israel, hominid site." *Nature* 299 (5881): 344-347.
- Richerson, Peter J., and Robert Boyd. 2005. *Not by Genes Alone*. Chicago: University of Chicago Press.
- Richter, Tobias, Lisa Maher, Jay Stock, Samantha Allcock, Matthew Jones, Louise Martin, and Brittany Thorne. 2009. "New light on Final Pleistocene settlement diversity in the Azraq Basin (Jordan): recent excavations at 'Ayn Qasiyya." *Paléorient*: 49-68.
- Roe, Derek A. 1981. *The Lower and Middle Paleolithic Periods in Britain*. Routledge and Kegan Paul, London
- Roe, Derek A. 2006. "Some thoughts about Acheulian cleavers." *Axe age: Acheulian tool-making from quarry to discard* edited by Naama Goren-Inbar and Gonen Sharon, pp 313-333. London: Equinox.
- Rollefson, Gary O. 1980. Late Acheulian Artifacts from 'Ain el-Assad ("Lion's Spring"), near Azraq, Eastern Jordan." *Bulletin of the American Schools of Oriental Research*: 1-20.
- Rollefson, Gary O. 1981. "The Late Acheulean site at Fjaje, Wadi El-Bustan, southern Jordan." *Paléorient*: 5-21.
- Rollefson, Gary O. 1983. "Two Seasons of Excavations at 'Ain el-Assad near Azraq, Eastern Jordan, 1980-1981." *Bulletin of the American Schools of Oriental Research*: 25-34.
- Rollefson, G., D. Schnurrenberger, L. Quintero, R. P. Watson, and R. Low. "Ain Soda and 'Ayn Qasiya: new late Pleistocene and early Holocene sites in the Azraq Shishan area, eastern Jordan." *The Prehistory of Jordan II: Perspectives from 1997*: 45-58.

- Rots, Veerle, and Bonny S. Williamson. 2004. "Microwear and residue analyses in perspective: the contribution of ethnoarchaeological evidence." *Journal of Archaeological Science* 31 (9): 1287-1299.
- Rots, Veerle, Louis Pirnay, Ph Pirson, and Odette Baudoux. 2006. "Blind tests shed light on possibilities and limitations for identifying stone tool prehension and hafting." *Journal of Archaeological Science* 33 (7): 935-952.
- Rots, Veerle. 2010. *Prehension and hafting traces on flint tools: a methodology*. Universitaire Pers Leuven.
- Rots, Veerle. 2013. "Insights into early Middle Palaeolithic tool use and hafting in Western Europe. The functional analysis of level IIa of the early Middle Palaeolithic site of Biache-Saint-Vaast (France)." *Journal of Archaeological Science* 40 (1): 497-506.
- Rots, Veerle, and Hugues Plisson. 2014. "Projectiles and the abuse of the use-wear method in a search for impact." *Journal of Archaeological Science* 48: 154-165.
- Rots, Veerle, Bruce L. Hardy, Jordi Serangeli, and Nicholas J. Conard. 2015. "Residue and microwear analyses of the stone artifacts from Schöningen." *Journal of Human Evolution* 89: 298-308.
- Rots, Veerle, Elspeth Hayes, Dries Cnuts, Christian Lepers, and Richard Fullagar. 2016. "Making sense of residues on flaked stone artefacts: learning from blind tests." *PloS one* 11 (3): e0150437.
- Sala, Irene Levi. 1986. "Use wear and Post-depositional Surface Modification: a Word of Caution." *Journal of Archaeological Science* 13 (3): 229-244
- Samson, David R. 2006. "Stones of contention: the Acheulean handaxe lethal projectile controversy." *Lithic Technology* 31 (2): 127-135.
- Schoch, Werner H., Gerlinde Bigga, Utz Böhner, Pascale Richter, and Thomas Terberger. 2015. "New insights on the wooden weapons from the Paleolithic site of Schöningen." *Journal of Human Evolution* 89: 214-225.
- Schoville, Benjamin J. 2010. "Frequency and distribution of edge damage on Middle Stone Age lithic points, Pinnacle Point 13B, South Africa." *Journal of human evolution* 59 (3): 378-391.
- Schoville, Benjamin, and Kyle S. Brown. 2010. "Comparing lithic assemblage edge damage distributions: examples from the late Pleistocene and preliminary experimental results." *vis-à-vis: Explorations in Anthropology* 10(2). 35-49.
- Schoville, Benjamin J. 2014. "Testing a taphonomic predictive model of edge damage formation with Middle Stone Age points from Pinnacle Point Cave 13B and Die Kelders Cave 1, South Africa." *Journal of Archaeological Science* 48: 84-95.
- Schoville, Benjamin J., Kyle S. Brown, Jacob A. Harris, and Jayne Wilkins. 2016. "New Experiments and a Model-Driven Approach for Interpreting Middle Stone Age Lithic Point Function Using the Edge Damage Distribution Method." *PloS one* 11 (10): e0164088.

- Scott-Phillips, Thomas C., et al. 2013. "The niche construction perspective: a critical appraisal." *Evolution* 68.5: 1231-1243.
- Semenov, Sergei Aristarkhovich. 1964. "Prehistoric technology."
- Shea, John J. 1987. "On accuracy and relevance in lithic use-wear analysis." *Lithic Technology*: 44-50.
- Shea, John J. 1988. "Spear points from the Middle Paleolithic of the Levant." *Journal of Field Archaeology* 15 (4): 441-450.
- Shea, John J., 1993. "Lithic Use-Wear Evidence for Hunting by Neandertals and Early Modern Humans from the Levantine Mousterian." *Archeological Papers of the American Anthropological Association* 4 (1): 189-197.
- Shea, John J. 2007. "Lithic archaeology, or, what stone tools can (and can't) tell us about early hominin diets." In *Evolution of the Human Diet: the known, the unknown and the unknowable* edited by Peter Ungar, pp 321-351. Oxford: Oxford University Press.
- Shea, John J. 2010. "Stone Age visiting cards revisited: A strategic perspective on the lithic technology of early hominin dispersal." In *Out of Africa I*, pp. 47-64. Springer Netherlands.
- Shea, John J., 2013. "Lithic Modes A-I: A New Framework for Describing Global-Scale Variation in Stone Tool Technology Illustrated with Evidence from the East Mediterranean Levant." *Journal of Archaeological Method and Theory* 20 (1): 151-186.
- Shea, John J., 2014. "Sink the Mousterian: Named stone tool industries (NASTIES) as obstacles to investigating hominin evolutionary relationships in the Later Middle Paleolithic Levant." In Huw Groucutt and Eleanor Scerri (Eds.) *Lithics of the Late Middle Palaeolithic: post MIS-5 technological variability and its implications*. Special Issue of *Quaternary International* 350: 169-179.
- Shea, John J., 2017. *Stone Tools in Human Evolution: Behavioral Differences among Technological Primates*. Cambridge: Cambridge University Press.
- Shennan, Stephen. 1997. *Quantifying Archaeology*. Iowa City: University of Iowa Press.
- Shipton, C., and C. Clarkson. 2015. "Flake scar density and handaxe reduction intensity." *Journal of Archaeological Science: Reports* 2: 169-175.
- Solodenko, Natalya, Andrea Zupancich, Stella Nunziante Cesaro, Ofer Marder, Cristina Lemorini, and Ran Barkai. 2015. "Fat residue and use-wear found on Acheulian biface and scraper associated with butchered elephant remains at the site of Revadim, Israel." *PloS one* 10 (3): e0118572.
- Stemp, W. James, and Michael Stemp. 2001. "UBM laser profilometry and lithic use-wear analysis: a variable length scale investigation of surface topography." *Journal of Archaeological Science* 28 (1): 81-88.
- Stemp, W. James, and Michael Stemp. 2003. "Documenting stages of polish development on experimental stone tools: surface characterization by fractal geometry using UBM laser profilometry." *Journal of archaeological science* 30(3): 287-296.

- Stemp, W. James, Benjamin E. Childs, Samuel Vionnet, and Christopher A. Brown. 2009. "Quantification and Discrimination of Lithic Use-wear: Surface Profile Measurements and Length-Scale Fractal Analysis." *Archaeometry* 51(3): 366-382.
- Stemp, W. James, Mason D. Andruskiewicz, Matthew A. Gleason, and Yusuf H. Rashid. 2015. "Experiments in ancient Maya bloodletting: quantification of surface wear on obsidian blades." *Archaeological and Anthropological Sciences* 7(4): 423-439.
- Stevens, Nathan E., Douglas R. Harro, and Alan Hicklin. 2010. "Practical quantitative lithic use-wear analysis using multiple classifiers." *Journal of Archaeological Science* 37 (10): 2671-2678.
- Tchernov, Eitan. 1988. "The age of Ubeidiya Formation (Jordan Valley, Israel) and the earliest hominids in the Levant." *Paléorient*: 63-65.
- Tennie, Claudio, David R. Braun, L. S. Premo, and Shannon P. McPherron. 2016. "The Island test for cumulative culture in the Paleolithic." In *The Nature of Culture*, pp. 121-133. Springer Netherlands.
- Thieme, Hartmut. 1997. "Lower Palaeolithic hunting spears from Germany." *Nature* 385 (6619): 807-810.
- Thieme, Hartmut. 2000. "Lower Paleolithic hunting weapons from Schöningen, Germany—the oldest spears in the world." *Acta Anthropologica* 19: 140-7.
- Thomas, David Hurst. 1987. *Refiguring Anthropology*. Illinois: Waveland Press.
- Tringham, R., Cooper, G., Odell, G., Voytek, B., Whitman, A., 1974. "Experimentation in the formation of edge damage: a new approach to lithic analysis." *Journal of Field Archaeology* 1:171-196.
- Unger-Hamilton, Romana. 1984. "The formation of use-wear polish on flint: beyond the "deposit versus abrasion" controversy." *Journal of Archaeological Science* 11 (1): 91-98.
- Van Gijn, A. L. 2014. "Science and interpretation in microwear studies." *Journal of Archaeological Science* 48: 166-169.
- Vaughan, Patrick C. 1985. *Use-wear analysis of flaked stone tools*. Tucson: University of Arizona Press.
- Vergès, Josep M., and Juan I. Morales. 2014. "The gigapixel image concept for graphic SEM documentation. Applications in archeological use-wear studies." *Micron* 65: 15-19.
- Viallet, Cyril. 2016a. "Macrotraces of Middle Pleistocene bifaces from two Mediterranean sites: Structural and functional analysis." *Quaternary International* 411: 202-211.
- Viallet, Cyril. 2016b. "Bifaces used for percussion? Experimental approach to percussion marks and functional analysis of the bifaces from Terra Amata (Nice, France)." *Quaternary International* 409: 174-181.
- Wadley, Lyn, Marlize Lombard, and Bonny Williamson. 2004. "The first residue analysis blind tests: results and lessons learnt." *Journal of Archaeological Science* 31 (11): 1491-1501.

- Wadley, Lyn, and Marlize Lombard. 2007. "Small things in perspective: the contribution of our blind tests to micro-residue studies on archaeological stone tools." *Journal of Archaeological Science* 34 (6): 1001-1010.
- West, Jolee A., and Julien Louys. 2007. "Differentiating bamboo from stone tool cut marks in the zooarchaeological record, with a discussion on the use of bamboo knives." *Journal of Archaeological Science* 34 (4) : 512-518.
- Whittaker, John C, and Grant McCall. 2001. "Handaxe-hurling hominids: an unlikely story." *Current Anthropology* 42 (4): 566-572.
- White, Mark J. 1998. "On the Significance of Acheulean Biface Variability in Southern Britain." In *Proceedings of the Prehistoric Society*, vol. 64, pp. 15-44. Cambridge: Cambridge University Press.
- Wilkins, Jayne, Benjamin J. Schoville, Kyle S. Brown, and Michael Chazan. 2012. "Evidence for early hafted hunting technology." *Science* 338 (6109): 942-946.
- Wilkins, Jayne, Benjamin J. Schoville, and Kyle S. Brown. 2014. "An experimental investigation of the functional hypothesis and evolutionary advantage of stone-tipped spears." *PloS one* 9(8): e104514.
- Wilkins, Jayne, Benjamin J. Schoville, Kyle S. Brown, and Michael Chazan. 2015. "Kathu Pan 1 points and the assemblage-scale, probabilistic approach: A response to Rots and Plisson, "Projectiles and the abuse of the use-wear method in a search for impact"." *Journal of Archaeological Science* 54: 294-299.
- Wilkins, Jayne, and Benjamin J. Schoville. 2016. "Edge damage on 500-thousand-year-old spear tips from Kathu Pan 1, South Africa: The combined effects of spear use and taphonomic processes." In *Multidisciplinary approaches to the study of Stone Age weaponry*, pp. 101-117. Springer Netherlands.
- Wynn, Thomas, and Forrest Tierson. 1990. "Regional comparison of the shapes of later Acheulean handaxes." *American Anthropologist* 92 (1): 73-84.
- Zutovski, Katia, and Ran Barkai. 2016. "The use of elephant bones for making Acheulian handaxes: A fresh look at old bones." *Quaternary International* 406: 227-238.

Appendix I

Directions for Blind Testing Function in Lithic Technology

This form is to help guide you through blind testing function in lithic technology, specifically regarding the experimental material associated with the Azraq Marshes Archaeological and Paleoecological Project (AMAPP). I have created these directions to help standardize the procedure for blind testing in hopes of increasing my understanding of use-wear formation and establishing a more reliable experimental dataset.

What is a blind test?

A blind test is an objective tactic used by researchers to assess the accuracy of their methodology. Blind testing in lithic functional studies entails attempting to interpret experimental activities without knowing the activity prior to analyzing it. Moreover, blind tests are a way for researchers to show their ability to recognize and potentially interpret use-wear signatures.

Stage 1: Fill out user and lithic information:

User Information

Name: _____

Date: _____

Relationship to Researcher: _____

Location of Blind Test (please be descriptive):

Have you been a part of a blind test before?	Y	N	
Are you experienced in using stone tools?	Y	N	
Are you experienced in flintknapping?	Y	N	
Do you practice any primitive skills?	Y	N	(If yes, please list them below)

Experimental Lithic Information

Identification Number: _____

Is your lithic hafted? Y N

Did you haft it yourself? Y N

If yes, how was it hafted?

Please draw an outline of the lithic material below:

Please describe your initial thoughts about the lithic material prior to use (include information about shape, size, function, how it feels to hold, etc.):

Stage 2: Documenting Experimental Activities

1. Photograph experimental lithic and raw material prior to use
 - A) Name lithic file: userinitials_blindtest#_lithic#_beforeuse
 - B) Name raw material file: userinitials_blindtest#_rawmaterial_beforeuse
2. Photograph location of blind testing
 - A) Name file: userinitials_blindtest#_location
3. Photograph and/or video yourself conducting activity
 - A) If you provide a video, record approximately 1-2 minutes of use.
 - B) Name file: userinitials_blindtest#_activity
4. Photograph experimental lithic and raw material post-use
 - A) Name file: userinitials_blindtest#_lithic#_postuse
 - B) Name raw material file: userinitials_blindtest#_rawmaterial_postuse
5. Create folder and include all pictures/videos
 - A) Name folder: Lithic#_Blindtest_userinitials

How do you think your tool performed in your task/activity? Do you think it could have been used for this in prehistoric times?

Describe any general observations you had while conducting activity:

Stage 4: Label line drawing

*****----Don't forget to take a picture of your experimental material after use! ----*****

During experimentation and after you have completed your activity, please label areas (e.g., edges) that were used for your accomplishing your task/activity on the line drawing above. If it was unused, please leave unlabeled.

Stage 5: Wrapping up

After you have completed your activity, go back through this form to make sure you have done everything required and then follow these final steps for handing in documentation and experimental material.

- 1) Hand in this form to Jindra, the graduate secretary in the Department of Anthropology, located in the B-wing of Cornett. She will keep this until I am completed with my analysis.
- 2) Email the folder of photographs and videos to blindtestSM1@gmail.com . The password to this email is not known by me, therefore I cannot gain access to the files until I have completed my analysis. My colleague and fellow MA student, Colton Vogelaar, has access to the email if you need to change or confirm your entry.
- 3) To hand in your experimental lithic, please email me at johnkurtmurray@gmail.com to set up a meeting time and/or drop it off to Jindra and ask her to put it in my mailbox.

Please leave any other feedback or comments below:

Thank you so much for all of your time and help. It is very much appreciated.

Respectfully,
John Murray

Adzing

A series of quick, low force blows, with a low angle of attack on the worked material; similar to chopping.

Boring

lithic material should be held at a right angle to the worked material and used in a rotary motion; typically used to make a hole in hard object.

Chopping

Lithic material used with slow, high force blows, repeated on the worked material at a high angle of attack (between 60-90 degrees).

Cutting

Lithic material used in a bidirectional or unidirectional motion, parallel to the worked material. This terminology is typically used for softer materials such as plants and vegetables.

Planing

Lithic material held at a low angle and used in a pushing motion to shave off worked material; **ventral side*** is held at a low angle to the worked material.

Sawing

Lithic material used in a bidirectional motion parallel to the object. The lithic will be held at approximately a right angle to the worked material. This terminology is typically used for working hard materials such as antler, wood, and bone.

*- ventral side may not be able to be determined in bifacially worked lithics. Please document whether or not side A (with label and date) or side B is facing the worked material.

Scraping

Lithic material edge is held at a high angle to the material being worked and used in a pulling motion to shave off material.

Wedging

indirect percussion with a hard or soft hammer on a lithic held parallel to the worked surface; can be used to split hard materials.

Whittling

shaving off material with the lithic held at a right angle to the worked material; the lithic should have an **acute edge angle**.

Appendix II: Detailed Descriptions of Experiments

Flake experiments used in butchery:

Although the primary focus of this thesis is to investigate handaxe function, I used the deer butchery as an opportunity to begin expanding the use-wear analysis to flakes for future research (see Table 1 for an overview).

Flake ID	Contact Material	Activity	Time (mins)	Strokes	Cortex	L (cm)	MW (cm)	T (cm)	PW (cm)	PT (cm)
JM10-1	Deer meat	Cutting	2	Not recorded	45%	9.9	4.7	2.0	2.8	1.3
DS3-3	Deer meat	Cutting	2	100 strokes	0	4.3	5.3	5.2	1.5	0.4
DS5-1	Deer meat	Defleshing	4	Not recorded	<10%	5.6	3.8	0.9	n/a	n/a
DS5-2	Deer scapula	Boring	1.5	110 half rotations	<10%	4.5	2.9	1.6	2.2	0.7
DS7-2	Deer	Disembowling	8	Not recorded	15%	6.9	6.3	0.7	1.7	0.4
DS7-3	Deer scapula	Cutting	2	50 strokes	<10%	7.2	3.9	0.7	1.2	0.2
DS7-4	Deer hide - fresh	Cutting	6	300 strokes	<10%	5.2	8.5	0.7	1.0	0.3
DS12-1	Deer hide - fresh	Scraping	9	400 strokes	10%	8.1	8.5	2.4	4.0	2.2
DS11-1	Deer bone	Planing	7	200 strokes	15%	11.0	6.7	1.8	1.8	0.5
DS11-2	Deer bone/meat	Defleshing	11	Not recorded	<10%	6.7	4.8	1.3	2.5	1.0
DS11-3	Deer bone	Sawing	7	250 strokes	25%	14.0	5.7	2.6	3.7	1.7
DS11-4	Deer meat	Cutting	7	Not recorded	<10%	8.8	5.1	1.4	3.1	1.2

Butchery

Considering that neither Jenny, nor I, had ever conducted a butchery of an animal this size, the experience was highly enlightening. Even with little knowledge of butchery, the handaxes and flakes proved highly useful in almost every activity attempted throughout the day. Additionally, Jenny had very little prior knowledge about stone tools, let alone handaxes, and received little information about theories behind their use or function. The overall butchery took four hours from the initial cut to dismemberment and disposal. First, we attempted to cut through the abdomen but failed due to the strength of the hide and hair. Luckily this failed, as we later learned from bystanders that rupturing the stomach would have been a foul and messy experience. The first cut was made on the ankle of the back leg and I proceeded to skin the animal up the leg to the haunches. The skinning became easier and easier as we proceeded. After the animal was skinned until the thorax completely exposed, a flake was used to eviscerate the carcass in order to prevent the stomach from being punctured. Both Jenny and I thought it would be easier to control with a flake rather than a larger handaxe with more cutting edge. After the animal was disemboweled, we dismembered and defleshed the remains with handaxes.

After the carcass was completely butchered, controlled flake experiments began. Thirteen out of 16 flakes were used for various activities outlined below. The time used, strokes, activity, contact material, and angle of use was recorded for each experimental flake. For all of these activities, including the handaxes, the tools were immediately washed under water and placed to soak in a bucket of water to help reduce the amount of residues left on the edges. Some of the tools required rubbing to get rid of large chunks of meat still left on the edges. Additionally, some blood soaked into the stone and stained red. Afterward a quick, final inspection for missed residues, the tools were dried off with paper towel and placed back into their plastic bags.

DS-1

DS-1 was the first tool used in the butchery experiments because I thought the straight edges would be effective in getting through the thick hide. This biface is elongated and thin with a pointed tip (McNabb and Rivett 2015, 24). The overall shape of DS-1 is fairly unrepresentative of the LCT's found at SM-1, but is a great example of raw material constraints from the tabular nature of the raw material. It quickly became apparent that the tool was unable to pierce the hide around the abdomen, even with considerable amount of force so the tool was used to begin cutting around the ankle. Once the initial cut was made and the inside of the animal was exposed, the skinning became much easier. Both the left and right edge of the tool were used. The total time of utilization was 40 minutes. Strokes were not recorded as the nature of the activity was multi-faceted.



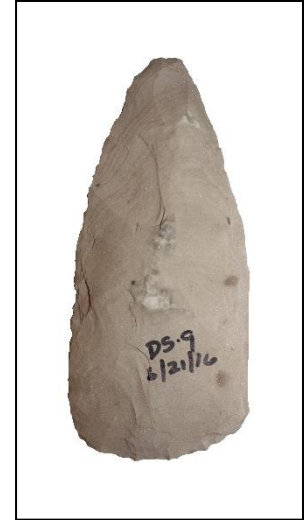
DS-7

DS-7 was used for two activities: dismembering and defleshing the front legs of the deer carcass. DS-7 is a large biface with a convex-oblique tip (McNabb and Rivett 2015, 24). Both sides of this tool were used to accomplish these tasks and the tool was used for 44 minutes total. The dismemberment of the front legs took less than a minute each; the effectiveness of the tool was simply amazing. During the defleshing activity, Jenny cut and scraped meat off the bone. There was substantial contact with the bone while cutting.



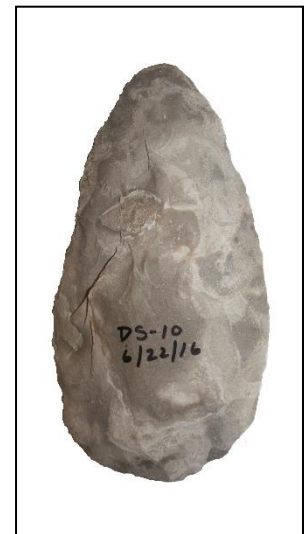
DS-9

DS-9 was used for skinning the deer carcass. The biface is elongated with a slightly oblique tip (McNabb and Rivett 2015, 24). The tool had both edges used for a total of 46 minutes by Jenny. During the skinning process, she noted that she tended to use the tip of the tool for most of the activity, regardless of which edge she was utilizing. Interestingly, Jenny used this handaxe in a different way than DS-7, which has a squared edge in the proximal left portion of the tool. Rather than holding DS-9 by the base, she held it at the midpoint by the edges, with the distal and proximal ends perpendicular to her fingers.



DS-10

DS-10 is a massive handaxe created from the hard siliceous limestone. This raw material is difficult to work but created a highly durable working edge. DS-10 is ovoid in shape with a convex tip (McNabb and Rivett 2015, 24). The biface was used for skinning the deer with the left edge for 28 minutes. The majority of the activity was done with the mesial and distal portion of the tool. Overall, the biface was highly effective in removing the deer hide, however, its large size sometimes made it difficult to handle. Surprisingly, even after the tool was left to soak in water for 30 minutes, and rubbed to remove any excess meat or residue from the carcass the blood from the deer stained parts of the tool red. Seeing this happen during the experimental activity puts the argument for the preservation of protein residue on tools from SM-1 into perspective. If the raw materials these hominins were using were slightly porous it means that the blood potentially can be preserved in the rock itself, not just the cracks.



ES-1

ES-1 was the first biface created in the flintknapping process. It is labeled ES because it was created at a separate time from the other bifaces so was not included in the initial data collection. The biface was made by Dan Stueber and is another massive tool. Due to a raw material flaw, there is a large hole on Side B of the tool; an inclusion led to a knapping accident. ES-1 is an ovoid biface with a long and narrow tip (McNabb and Rivett 2015, 24). The biface was used to deflesh and dismember the back legs of the deer, and to cut the meat. The mesial-distal ends of both sides of the tool were used for a total of 44 minutes.



Flakes

Table 2 : Flakes Used in Deer Butchery						
Handaxe	DS-11	DS-5	DS-7	DS-10	JM-10	DS-3
Number of Flakes	4	3	4	1	1	3

Flakes used within the butchery experiment were taken from four of the experimental biface reductions (Table 2). I attempted to pick fairly complete flakes but no preference was given for shape or size. The flakes were chosen from different raw material localities to help investigate how each type of raw material accumulates use-wear, if any. Out of the sixteen flakes only twelve were used during the deer butchery.

Table 3 : DS-11 Flake Measurements					Photograph of Flakes
Flake ID	<i>DS-11-1</i>	<i>DS-11-2</i>	<i>DS-11-3</i>	<i>DS-11-4</i>	
Length (cm)	10.95	6.72	14	8.8	
Width (cm)	6.7	4.8	5.7	5.1	
Thickness (cm)	1.81	1.25	2.6	1.4	
Platform Width (cm)	1.8	2.5	3.7	3.1	
Platform Thickness (cm)	.46	1.02	1.7	1.2	

The flakes were used for various activities after the butchery was completed. Prior to use, each flake was measured and photographed. The flakes range in size and shape. For each activity the amount of time the flake was used and the number of strokes were recorded. During some activities, videos and pictures were taken. Flakes that do not have obvious edge damage will not have their pictures included in this portion of the research. Each experiment is described in detail below.

DS-11 Flakes

The raw material used to create the flakes for DS-11 was acquired in western Wadi Ghadaf (see map on page). This material seems to be much softer than the other localities which will make for an interesting comparison of use-wear signatures in the future. For measurements see Table 3.

DS-11-1

DS-11-1 was used for planing deer bone (Figure 1). The flake was used for 7 minutes and 200 strokes. The dorsal surface has approximately 50% cortex. The flake was used with the ventral surface making contact with the bone. As seen in the image, the flake was successful in removing bone by planing, however, after 7 minutes, not much mass was removed from the bone. Planing could be an activity to remove flesh stuck to the the bone or

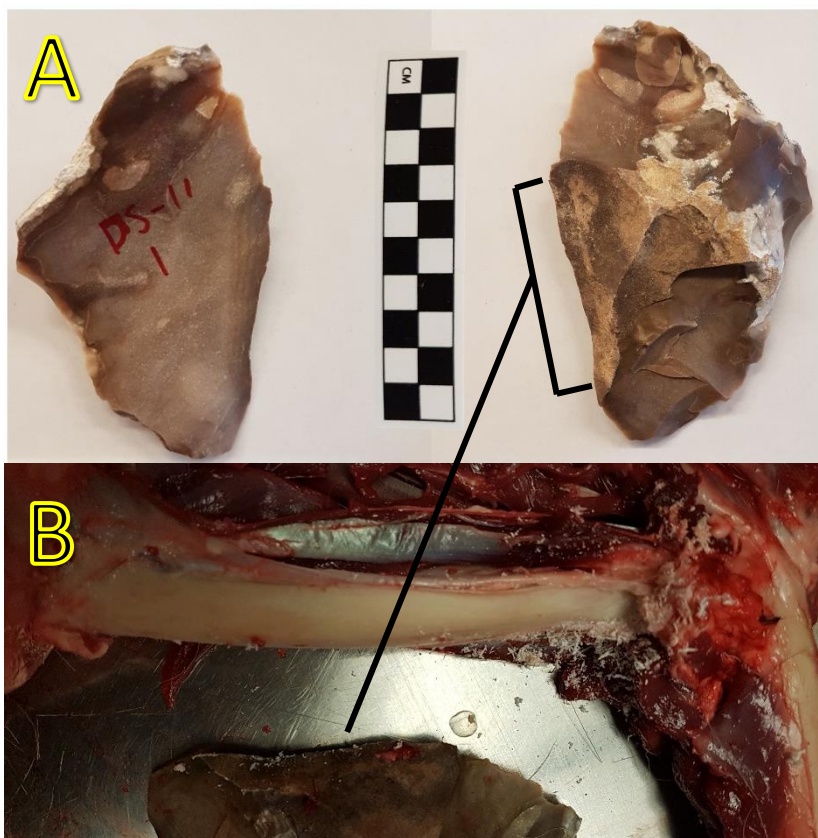


Figure 1 - Documentation of DS-11-1 experimental activity

possibly to shape the bone into another tool or ornament. The latter activity would take a large investment of time and energy. After inspection of the used edge with the naked eye, there is noticeable “nibbling” and small microfractures on the dorsal surface – the noncontact surface.

DS-11-2

DS-11-2 was used for defleshing and scraping meat off deer bone. The flake was used for 11 minutes. Strokes were not recorded due to the multi-directional nature of the activity. After inspection of the flake, there is very little damage to the edges. There is the beginning of rounding and small areas of chipping but no obvious microflaking.

DS-11-3

DS-11-3 was used for sawing bone. The flake was used with the right mesial edge for 7 minutes and 250 strokes. The flake is a first stage reduction flake with approximately 20% cortex.



DS-11-4

DS-11-4 was used for cutting meat. The flake was used for 7 minutes with the mesial-distal portion of the left edge. After initial inspection with the naked eye, there is very little edge damage. It is likely that a combination of low powered and high powered microscopy is needed to fully investigate the use-wear signatures for meat cutting.

Table 4: DS-11 Flake Measurements				Photograph of Flakes
Flake ID	<i>DS-5-1</i>	<i>DS-5-2</i>	<i>DS-5-3</i>	
Length (cm)	5.6	4.5	4.2	
Width (cm)	3.8	2.9	3	
Thickness (cm)	.89	1.6	.47	
Platform Width (cm)	N/A	2.2	1.3	
Platform Thickness (cm)	N/A	.73	.45	

DS-5 Flakes

Out of the three DS-5 flakes, only two of them were used in the deer butchery experiments (DS-5-3 was excluded). Prior to use, each flake was photographed and measured (see Table 4). These flakes were made from raw material found in western Wadi Ghadaf. Although different in color, this raw material is similar in texture and hardness to the flakes used from DS-11.

DS-5-1

DS-5-1 is a flake with a feather terminating bending fracture which detached the platform from the flake. This flake was used to deflesh the ribs for 4 minutes. The tool was useful, but does not exhibit any noticeable use wear. High powered microscopy will be needed to further investigate the signatures on this flake, if there are any present.

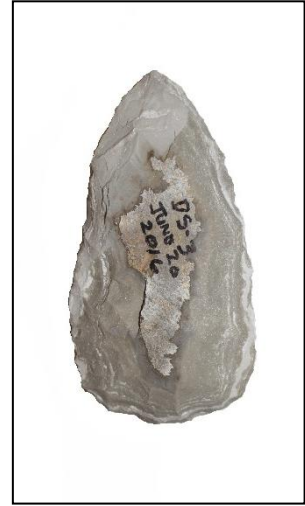
DS-5-2

DS-5-2 was used in a boring action on the deer scapula. The flake was used for 110 half rotations – back and forth in a drilling motion – which equates to approximately 55 full circle rotations. The flake was successful in drilling through the bone and only took approximately 1.5 minutes to accomplish this task. There is noticeable crushing and rounding on the distal portion of the flake.

Plant Processing

DS-3

DS-3 was used in a longitudinal cutting motion on bamboo with the left edge for approximately 58 minutes. The tool was used to cut down the bamboo stalk from the ground and then cut it up into pieces at the nodes (Figure 2). Three stalks were cut down: the first took 3 minutes and 37 seconds, the second took 2 minutes 40 seconds, and the third was the fastest at 2 minutes and 19 seconds. As I got accustomed to using the stone tool, the process of cutting down the stalks was more efficient and faster. The first stalk was very large and needed to be cut in half, which took 1 minute and 30 seconds. Thus, the process of obtaining the stalks took 10 minutes and 6 seconds.



After the stalks were down, they were transported to a new location for processing. The first stalk was cut into four smaller pieces and took 6 minutes to complete in total. Similarly, the second stalk was cut into four smaller pieces, however, it took 18 minutes and 20 seconds to complete. The third stalk was cut into five smaller pieces and required 18 minutes and 30 seconds to complete. Lastly, the fourth stalk was cut into four pieces and took 6 minutes and 30 seconds. The differences time likely has to do with thickness of bamboo stalk and the need for retouch in certain areas. The tool was primarily used in the mid-section and the lower corner of the base. These were the most comfortable positions to carry out the cutting motion. The point and upper half of the edge was used very little because



Figure 2– Documentation of bamboo processing

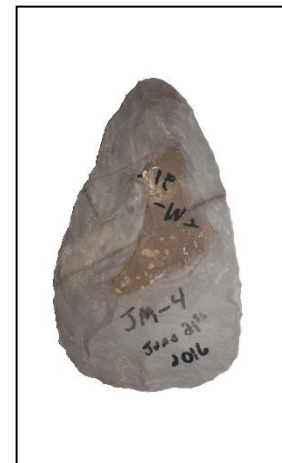
it is not conducive to the motion. Additionally, there was a prominent hump near the upper part of the edge making it difficult to successfully utilize the whole edge during the cutting motion. When looked at by the naked eye and under 25x magnification, there are no obvious signs of use-wear. There is the presence of rounding in the areas of high use, but no notable microflaking. This is likely do to the hardness of the raw material in comparison to the softness of bamboo. This material was the siliceous limestone and was very difficult to knap. It is more likely that there is polish and striations due to the silica content of bamboo, along with the presence of residues such as phytoliths, however, investigating this is beyond of the scope of this project. Not surprisingly, the bamboo stained the edge green and was very difficult to remove even with the use of warm water. The unused edge was also stained green from residue transferred by my hand.

JM-4



Figure 3 – Documentation of sawing wood with JM-4. The wood used as the contact material was fir.

JM-4 was used in a longitudinal action to saw wood. The wood utilized for the experiment was fir, taken from a tree that was cut down around my neighborhood. This activity was unsuccessful in cutting through the whole branch, however, the tool was efficient at cutting through the material - as seen in Figure 3. The tool was used with the left edge for 40 minutes. For activities that require longitudinal action such as sawing, it is quite effective to use the edge at various portions. In fact, sometimes using the edge towards the base of the tool is more effective than using edge towards the tip. The tip tends to slip off the material at certain points. In order to avoid this, the tool needed to be used at a slight angle and with short and fast strokes.



JM-1

JM-1 was used in order to make a spear out of a thin piece of dried wood. This task related activity required the use of the tool in both a planing and scraping motion. The whole tool was utilized and at some points, the tool was used at its base. With gloves on, using the tool by holding the distal end was just as comfortable and useful as using it “normally” held the base.



DS-12a

DS-12a is a large flake cleaver that was used for adzing wood. The wood used in this experiment was fir. At first, this tool was hafted on a short stick and was quite effective at removing the bark from the fir log (Figure 4). Unfortunately, the haft did not hold. The haft did not hold for multiple reasons: the string and

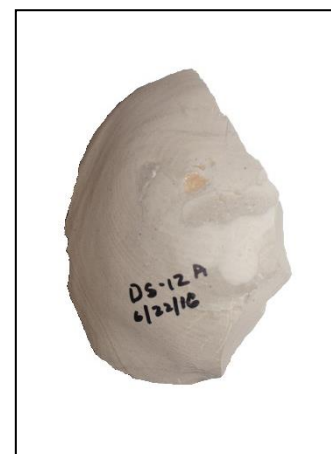




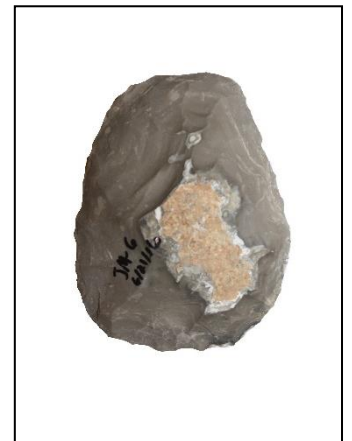
Figure 4 – DS-12b hafted to dried wood

glue used to haft the cleaver onto the wood was not strong enough; secondly, the way the tool was hafted onto the wood was at the midpoint and was primarily used with the mesial distal portion of the left edge. The force of this activity would have required the whole tool to be secured in order to be effective.

After the haft failed, the tool was used with the tip for 50 minutes. DS-12a was very useful for adzing and the tip held surprisingly well. After about 15 minutes, the tip broke because of an error in my strike. The tool hit the top of the wood log at a 90 degree angle rather than striking the side of the log at an oblique angle.

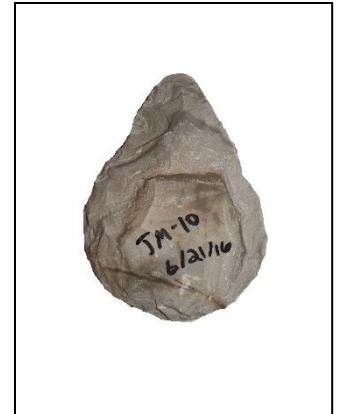
JM-6

JM-6 is a large cleaver-like discoidal biface used for chopping wood. The tool was used with the distal end for 20 minutes. In order to successfully carry out this high intensity activity, both gloves and a small piece of leather protection were needed. When performed with just bare hands, my palm was cut quickly considering most of the biface had been worked and had a sharp edge. Similar to that of the adzing activity, the biface was highly effective at chopping the wood and there is very little damage to the tip.



JM-10

JM-10 was used in a similar way to JM-6. It was used to chop wood for 21 minutes. Unlike JM-6 which has a convex distal end, JM-10 has a fairly convergent point. Additionally, JM-10 is smaller and lighter than JM-6. Even though JM-10 was smaller and easier to grip, a small leather pad and gloves were required to perform this high intensity activity. Interestingly, there was a significant difference between the effectiveness of these two tools and it is likely that the surface area of the tip has much to do with this.



DS-4b

DS-4b was used for adzing fir for 20 minutes and 35 seconds. The tip of this handaxe is difficult to describe using McNabb and Rivett (2015) due to its asymmetrical distal end, but it is closest to their description of long and narrow. Similar to DS-12a, DS-4b was moderately effective at adzing wood; its smaller size, combined with the pointed tip, made it difficult to remove mass from the wood. Despite being used in a high intensity activity, there was no major damage.



JM-8

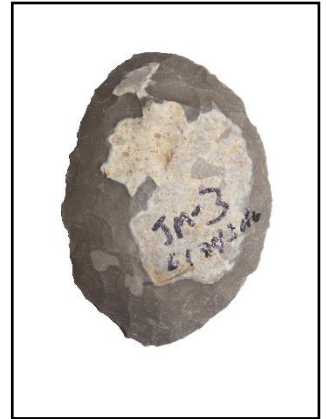
JM-8 was used to process 6 small potatoes placed on the grass. Processing potatoes was chosen as an experimental activity to possibly represent processing USOs. JM-8 was used in a cutting motion for 12 minutes. The tip is pointed (McNabb and Rivett 2015, 27) and seems particularly fragile, but did not break during use. The biface easily cut through the potatoes and did not seem to dull at all. In future experiments, more potatoes will be used.



Working Antler

JM-3

JM-3 was utilized in two ways: first, a longitudinal sawing motion on dried antler with the left edge for 61 minutes and secondly, in a planing motion with the right edge for the 45 minutes (Figure 7). Both edges of this tool was used because it was small enough that there was not much pressure on the unused edge during the sawing activity therefore it is unlikely there was edge wear from prehension. The antler that was used was a former flintknapping soft hammer or billet. The sawing activity became increasingly more difficult as one got deeper in the antler. When the tool was unable to successfully complete the motion, I started sawing in a new area. By the end of the 61 minutes, there were four areas subject to sawing.



Similar to the cutting of bamboo with DS-3, there are almost no areas with obvious use-wear. This is potentially due to the hardness of the chert, but may also be due to the nature of the activity. There is signs of residue which might help identify antler working in the prehistoric assemblage.



Figure 7 – Documentation of processing antler with a small ovate handaxe.

Working Bone

DS-11

DS-11 was the first experiment done using a cleaver-like tool. The experiment was chopping bovid bone acquired from a local butcher (Figure 4.15). The tool was used for a short duration of 10 minutes and contacted the bone approximately 50 times. Due to the nature of chopping as an activity, flakes were produced while the DS-11 was being used. Interestingly, these flakes were comparable to flakes found from the process of biface reduction. The activity essentially created a small lithic assemblage in itself. Although these flakes looked similar to biface reduction.



Figure 8 – Documentation of processing bone. (A) result of chopping bone (B) debitage created from high intensity use-wear (C) bifaces used in experiments.

There was highly noticeable use-wear on DS-11. The chopping activity caused visible crushing, microflaking, and macroflaking such as step terminating fractures. This was not surprising because chopping is a high intensity activity and mimics direct percussion flaking mechanics. It was interesting to observe the flakes detach from use and quite possibly is an area that needs to be researched further. This will be expanded on in the next chapter.

DS-2

DS-2 is a large, heavy biface made out of siliceous limestone. This material is highly durable. It was used to saw bovid bone for 35 minutes (Image 9). The tool was used with the left edge, primarily with the mesial-distal portion of the tool. Generally, the tool was not very effective in cutting the bone. Although it cut the bone, it would have taken a long time to get through the



Figure 9– Documentation of sawing bone with DS-2

whole bone. If the goal was to access marrow, it's likely that using a hammerstone would have been an easier and more parsimonious way to accomplish this task. However, this activity may reflect edge damage that occurs during butchery when the edge hits the bone.

Shellfish Processing

DS-6

DS-6 was used for opening, or “shucking”, 6 oysters (Figure 10). First, I attempted to pry open the oyster from the hinge but the tip was not strong enough. In order to open them, the tool needed to be put in the hinge while simultaneously hitting the oyster on the ground with the tool held firmly in place. After a few hits, the oyster would crack open and the meat was easily removed with the tool. The tool was used with the distal portion of the tool and sustained heavy use-wear, similar to that of chopping bone. It took 11 minutes



Figure 10 – Documentation of shucking oysters with DS-6, a triangular handaxe

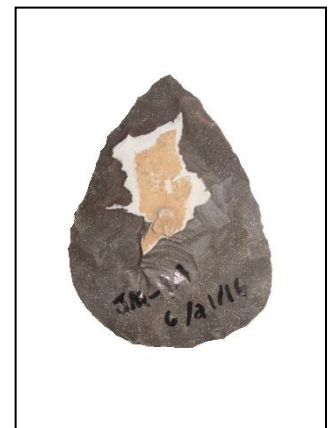
and 30 seconds to open 6 oysters. Considering this is such a high intensity activity, there were small flakes and debitage created which further supports the investigating use-wear related debitage.

Post-depositional Experiments

Taphonomy Experiment 1 – JM-9A

Table 4.7: Measurements of Contents in Post-Depositional Experiments				
<u>Material</u>	<u>Weight (g)</u>	<u>Volume (mL)</u>	<u>Raw Material</u>	<u>Total Number (n)</u>
Non Cultural Rock	806.1	600	SM-1	84
Debitage	86.5	150	Wadi Rattam (Upstream)	9
Tool (s)	89.7	100	Qasm Usaykhim	1
Water	N/A	1300	N/A	N/A
Total time submerged: 46 hours				
Total time tumbled: 6.5 hours Exception: Flake 8A – 3.5 hours				

The pilot experiment for this part of the project was done using water, non-cultural rocks from the site, nine flakes acquired from replications, and one handaxe (JM-9A) (Table 4.7). The rock tumbler was left on for three and one half hours for its first cycle. After this short amount of time, there was noticeable wear on the flakes. Flake 8A was taken out of the can for documentation. The rest of the material stayed in the can overnight. This was repeated for a second time the next day. The tumbler was used for three hours and the lithics were left submerged overnight. The total time submerged was forty six hours with six and a half hours of tumbling. The rest of the flakes and the handaxe were taken out and left to dry prior to photographs.



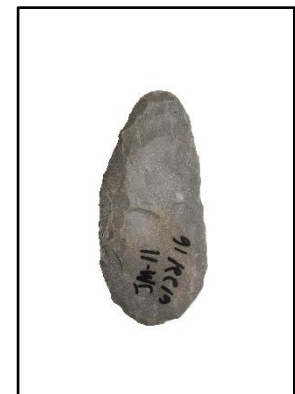
Overall, the edge damage of the flakes was highly noticeable and seemed to be uniform along the edges. The handaxe was noticeably smoother, with some deterioration of the cortex that was present, along with some degree of rounding. There is no noticeable microflaking after inspection with the naked eye, however, when compared to the original, pre-experimental picture the morphology of the handaxe changed slightly in certain areas. It is important to note that although the flakes' edge damage distribution seems to be uniform, the damage itself is unlike the use-wear created by use.

Taphonomy Experiment 2 – JM-2, JM-11, and DS-12b

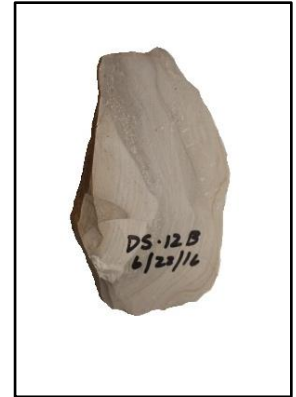
The second tumbling experiment was done with the same non-cultural rocks used in the first experiment with the same amount of water. After inspection of JM9A, it quickly became apparent that 100% of the edge was damaged on both sides and both faces. The 6 hours tumbled was overkill. This experiment was done for only 1 hour with 2 smaller bifaces in the paint can.



Despite the unforeseen error, having a spectrum of experimental results might provide insight into the range of edge damage that can occur in fluvial contexts. It is likely that the low energy fluvial context might not be represented by the first experiment. After inspecting the edges of JM-2 and JM-11 when they were taken out of the tumbler, there is noticeable damage on the edges, particularly microflaking at the base of the tool.



The results of the second taphonomic experiment with tools JM-2 and JM-11 were still highly damaged. One last experiment was done with the same noncultural rocks and amount of water. DS-12b was placed in the paint can and left to tumble for 30 minutes. This amount of time caused noticeable damage, but did not completely damage the tool.



Digging

DS-4A

DS-4A is a large biface that was used for digging in soft grass for 18 minutes. The handaxe was effective at breaking through the dirt and very little damage was done to the tip of the tool.

