The use of stone during the Middle Stone Age at Magubike Rockshelter, Tanzania: an examination of economy and function

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

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ABSTRACT

This dissertation is primarily an examination of the ways in which Middle Stone Age (MSA) hunter-gatherers from Magubike Rockshelter, Iringa Region, Tanzania, acquired, prioritized, transformed, and used stone as tools. The results of several analyses detailed within indicate that MSA peoples in eastern Africa favoured certain high quality stone resources, made an effort to conserve them when possible, and curated them for different tasks. Over time, a trend towards greater economization of all stone resources at the site may be related to a gradual change in settlement strategy perhaps spurred by environmental factors. Experimentation also revealed a flexible approach to the use of stone tools, particularly stone points. Some of these artifacts were likely incorporated into hunting equipment as projectile armatures while others were likely applied to other tasks such as cutting or scraping. While engaging in this work I also developed an interest in the methods used to assess the function of stone tools. This interest led me to develop and test a quantitative method capable of differentiating use-wear signatures using a laser scanning confocal microscope. Although the material from Magubike Rockshelter was found to be unsuitable for analysis using this method, I present the method here in the hopes that it may prove useful to other analysts.

PREFACE

A version of chapter 2 of this dissertation has been published previously as: Werner, J. Jeffrey and Willoughby, Pamela (2017). Middle Stone Age technology and cultural evolution at Magubike rockshelter, southern Tanzania. *African Archaeological Review 34(2):249-273.* I was responsible for the analysis as well as the manuscript composition. P. Willoughby was responsible for the data collection and contributed to manuscript edits.

A version of chapter 3 of this dissertation has been published previously as: Werner, J. Jeffrey and Willoughby, Pamela (2018). Middle Stone Age Point Technology: Blind-testing the damage distribution method. *Journal of Archaeological Science: Reports 19:138-147.* I was responsible for the analysis as well as the manuscript composition. P. Willoughby was responsible for the data collection and contributed to manuscript edits.

A version of chapter 4 of this dissertation has been published previously as: Werner, J. Jeffrey (2018). An Experimental Investigation of the Effects of Post-Depositional Damage on Current Quantitative Use-Wear Methods. *Journal of Archaeological Science: Reports 17:597-604.*

DEDICATION

I would like to dedicate this work to my wonderful wife, Colleen Haukaas, who has been my primary source of support and inspiration throughout this process, and to my parents Beverley Culham and Michael Werner.

ACKNOWLEDGEMENTS

This research was made possible thanks to the contributions of many people over the years. To begin, I would like to thank my supervisor Dr. Pamela Willoughby for her invaluable assistance. I would also like to thank all the current and former members of the Iringa Region Archaeological Project (IRAP) including Jennifer Miller, Dr. Katie Biittner, Amy Reedman, Dr. Frank Masele, and Dr Pastory Bushozi. There are several individuals from the Faculty of Engineering who I would like to thank, including Dr. John Nychka, Peng Li, and Shiua-Yin Wu for their assistance with all things to do with the laser scanning confocal microscope. I would have been totally lost without them. Lastly, I would like to thank the people who have served on my various committees: Dr. Sandra Garvie-Lok, Dr. Lesley Harrington, Dr. John Ives and Dr. Kisha Supernant.

Fieldwork was done thanks to research clearances given to Pamela Willoughby from COSTECH, the Tanzanian Commission on Science and Technology, and through excavation permits from the Division of Antiquities, Ministry of Natural Resources and Tourism, Government of Tanzania. This research was completed with funds from two Standard Research Grants awarded to Pamela Willoughby from SSHRC, the Social Sciences and Humanities Research Council of Canada (grants #410-2008-0061 and #410-2011-0117), as well as a Joseph-Armand Bombardier Canada Graduate Scholarships Program: Masters Scholarship (award # 766-2013-0704) and Joseph-Armand Bombardier Canada Graduate Scholarships Program: Doctoral Scholarship (award # 767-2015-1885), both awarded to J. Jeffrey Werner.

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CHAPTER 1: INTRODUCTION

The first members of *Homo sapiens* are believed to have evolved just before or during the Middle Stone Age (MSA) in Africa, approximately 200,000 years ago (or 200 kya) (Fu et al. 2013; McDougall et al. 2005; White et al. 2003). During a similar span of time (between 300 and 50 kya), the repertoire of hominin behaviours expanded appreciably to include the first signs of hafted tools, the occupation of challenging and marginal environments, and the production of the first artifacts with symbolic content such as art and personal adornment (d'Errico and Henshilwood 2011; Henshilwood and Marean 2003; McBrearty 2013; McBrearty and Brooks 2000; Yellen et al. 1995). These finds do not appear together in any one place or time nor do they necessarily correlate well with the appearance of new fossil human species. This myriad pattern of first emergence suggests that innovation was to a degree decoupled from human biological evolution. Many now believe that behavioural evolution during this time was driven by social, demographic and environmental pressures, potentially initiated by one or more periods of intense glacially induced aridity between ~200 and 30 kya (Basell 2008; Blome et al. 2012; Lane et al. 2013; Powell et al. 2009). Increasingly nuanced paleoclimate and paleoenvironmental data also demonstrate that regional changes in temperature and environments were not consistent across Africa during global periods of glaciation (Basell 2008; Blome et al. 2012). These differences almost certainly had diverse impacts on hominin demography and adaptation, contributing to the highly variable archaeologically signatures of the MSA across space. Given that the archaeological coverage of Africa is in no way uniform substantial gaps in our knowledge may exist. It is therefore vital to examine sites from a range of environmental and geographical contexts to better appreciate the variation in MSA adaptation (Mitchell 2008; Stewart et al. 2012).

The articles contained within this dissertation pertain to materials from one such geographical gap, located between otherwise well studied areas: The Iringa Region of southern Tanzania. Until recently, archaeological research in Tanzania has emphasized localities in the north of the country such as Mumba, Nasera and Olduvai Gorge because of the density of finds there and the fact that these sites were studied early in the history of excavation in the country (Mehlman 1989). A lack of investment south of these sites has left a considerable gulf between the well-established records of Ethiopia and Kenya and the record of southern Africa.

In order to remedy this situation, the Iringa Region Archaeology Project (IRAP) began survey and excavation around the town of Iringa. The team encountered a landscape rich in caves and rockshelters, many of which feature signs of Stone Age and later human occupation. The materials for this dissertation derive from one of these sites, called Magubike rockshelter. Its oldest archaeological level dates to approximately 100-50 kya, which coincides with the socio-demographic and climate events that are thought to have stimulated new modes of adaption and social behaviours in early modern humans. However, the work at the Magubike archaeological site is still in its early stages, and basic questions about how humans made use of the shelter and the surrounding landscape remain to be fully answered.

Two of the key questions I hope to address with this research are:

- Is there evidence of technological change over time that might suggest a response to worsening climatic conditions, as argued by scholars in writing in a southern African context? Such a process should be evident in the economic systems of Iringa foragers, including indications of greater mobility and/or a more intensive use of resources.

- Is Magubike Rockshelter primarily a hunting camp, a staging area for other extractive purposes, or a residential area? It is important to begin to clarify the function of the site to better understand patterns of human mobility and subsistence activity in the Iringa region.
- A related question that emerged during my research is: how reliable are the techniques currently in use to establish tool function, and how might they be improved?

In approaching these questions, I analyzed a portion of the stone artifacts recovered from Magubike over the last decade. These materials also served as the inspiration to explore several different methods of stone tool analysis. Stone artifacts are well suited to archaeological hypothesis testing in general and provide a unique lens into the behaviours of Stone Age peoples. Not only is stone particularly enduring, but the use of stone is also closely integrated into many different aspects of human economic and social life (Speth et al. 2013). What is more, the abundance of lithic materials at many archaeological sites allows their study to be approached using a variety of statistical methods, capable of yielding robust, falsifiable, results.

With respect to the question of technological adaptation, I calculated the intensity with which different stone resources were exploited. I accomplished this task using a modified version of the approach developed by Clarkson (2013) to study cores from South African MSA sites. The approach involves comparing the number of flakes scars corrected for differences in core size. Based on the results of my analysis I argue that some resources like chert were carefully conserved while materials such as quartz and metamorphic stones were used more profligately. This pattern of exploitation likely indicates a preference for certain materials, which is linked with the availability of those materials on the Iringa landscape. I also observed a linear increase in the intensity with which materials were exploited through time. This pattern may be due to declining access to stones, perhaps as a consequence of different settlement strategies, environmental conditions, or competition from other hominin populations.

I was also interested in studying economic activity at the scale of individual tools or groups of tools. Until the 1960s the function of tools was established largely on the basis of morphological similarities with modern tools and their archaeological context. However, owing to the pioneering work of Semenov (1964) and others, archaeologists now have at their disposal numerous powerful means of directly inferring tool function. These methods rely on the comparison of the damage formed as a result of use (use-wear) on experimental tools and archaeological specimens, usually with the aid of a microscope. Analysts make functional arguments based on the similarities and differences they observe between collections. While this approach has been shown to be successful, at least under certain conditions, it is also to some degree a subjective exercise. Findings are difficult to independently verify and the success of these conventional methods are highly dependent on the skill and experience of individual analysts.

One encouraging response to these criticisms has been the development of methods that rely on quantitative, as opposed to strictly visual, comparisons of use-wear signatures. The main advantage of these methods is that they are arguably more objective and transparent than conventional methods. Given the near infinite number of ways in which a surface can be described mathematically numerous techniques using various measurement devices and mathematical formulae have emerged.

In order to statistically reconstruct the ways in which stone tools were used in the past at Magubike I employed two different quantitative analyses. By analyzing the distribution of damage on the margins of triangular flakes from Magubike, I was able to test the hypothesis that they were used as hunting weapons (Bird et al. 2007; Schoville 2010, 2014; Schoville and Brown 2010; Wilkins et al. 2012, 2015). Since regional projectile point styles are thought to have developed during the MSA, identifying the function of these artifacts may be important for situating them in a regional stylistic context (McBrearty and Brooks 2000). This task is challenging because most MSA projectile points were only minimally modified and therefore difficult to recognize as tools on the basis of their morphology and process of manufacture alone. These types of points are also likely to be missed by conventional forms of use-wear analysis for a variety of reasons (Rots and Plisson 2014). However, stone tools used as projectiles do demonstrate a few basic properties that distinguish them from debitage (Pargeter 2011b, 2011a) or assemblages used for cutting and scraping (Schoville 2010; Wilkins et al. 2012). By comparing the edge-damage distribution of the Magubike points to other known assemblages, I was able to classify them to some general functional categories.

Secondly, I consulted with faculty in the Department of Chemical and Materials Engineering at the University of Alberta in order to refine a method of use-wear quantification capable of differentiating tool function with a laser scanning confocal microscope (LSCM). The device is capable of yielding high resolution 3D measurements of tool surfaces, which can then be statistically compared to a reference. I thought that it was also important to test the effects of post-depositional damage on the accuracy of this type of scanning data. The limited work that has been conducted with LSCMs has been promising but entirely experimental – there is little indication of how this method performs on actual artifacts, presumably damaged additionally by a variety of non-cultural processes. It is conceivable that any degree of post-depositional damage would be sufficient to render the technique invalid. To test these effects, I created an experimental collection of tools and subjected them to simulated post-depositional processes capable of modifying use-wear traces. I tracked the progressive change in surface texture of my sample specimens through repeated cycles of damage. My intention was to identify a point at which artifacts become damaged beyond interpretability. Although the artifacts from Magubike proved to be too extensively damaged to make analysis worthwhile, this research should still be of great interest to other use-wear analysts developing similar methods (Evans and Macdonald 2011; Stemp 2014).

1.1 BACKGROUND INFORMATION

1.1.1 THE FIRST ANATOMICALLY MODERN HUMANS

Modern humans (*Homo sapiens*) appeared in the last 200 kya to 300 kya on the continent of Africa. Not long after, we had spread across much of the world and are now the only human species left on the planet. The majority of what we know about our species murky origins comes from a combination of DNA and fossil evidence.

1.1.1.1 DNA EVIDENCE

DNA analysis has proven invaluable for understanding the evolution of modern humans. While the first attempts to apply DNA methods to questions of the human past were met with skepticism, they have since become closely integrated into contemporary understandings of human evolutionary origins (Ambrose 1998; Cann et al. 1987; Green et al. 2010; Ermini et al. 2015; Fu et al. 2013; Ingman et al. 2000; Reich et al. 2010, 2011; Underhill et al. 2001;

Veeramah and Hammer 2014; Vigilant et al. 1991). Perhaps most importantly, DNA research has provided considerable insight into the questions of where and when our species first arose.

The first study of this sort was conducted using mitochondrial DNA (mtDNA) from living humans (Cann et al. 1987). Although most of the cell's genetic material is contained within the cell nucleus the mitochondria also contain genetic information that is inherited maternally without recombination. Furthermore, portions of this DNA are non-coding meaning that they do not directly influence the expression of traits and thus are not altered by selective processes (Ingman et al. 2000). However, these non-coding sequences *do* change at a more or less consistent rate as accidental mutations accumulate in their structure over time (Cann et al. 1987; Fu et al. 2013; Scally and Durbin 2012). Based on an understanding of these principles, Cann et al. (1987) were able to determine the rate of mutation by recording differences in the number of substitutions between human groups that had become removed from each other at a known place in time. This information was then used to estimate when the modern mtDNA pool itself appeared - likely between 143 and 288 kya. Since then, other mtDNA studies have supported a similar genetic origins of *Homo sapiens* around 200 kya and a subsequent dispersal of those genes out of Africa around 50 kya (Fu et al. 2013; Vigilant et al. 1991).

Genetic research has also played an essential role in locating where modern human genes first appeared. In the same foundational paper by Cann et al. (1987), the mtDNA of 147 modern people from five distinct geographic regions was sampled. The genes of the participants from each region were found to differ with respect to their overall variation, with the greatest variation found amongst Africans. Since genetic variation is in part a function of time it was concluded that the African population was the oldest, and thus, likely ancestral to the other human groups sampled. Although some aspects of this project have been criticized (Ayala 1995; Hedges et al.

1992), more recent studies have corroborated the results, and a near consensus has emerged concerning the African origins of *Homo sapiens* (Ingman et al. 2000; Veeramah and Hammer 2014).

Genetic research also suggests that the genetic origins and history of *Homo sapiens* was more complex than previously believed. In particular, it appears as though there was some amount of gene flow between *Homo sapiens* and several archaic human populations. For instance, in 2013 researchers identified a rare basal Y-chromosome in a living human, the origins of which is 338 kya (Mendez et al. 2013). Mendez and colleagues (2013) hypothesized that this Y-chromosome was incorporated into the modern human gene pool through interbreeding with archaic *Homo* at some time in the deep past. Similarly, studies of nuclear DNA suggest past interbreeding with other hominin species such as *Homo neanderthalensis* (Green et al. 2010) and the enigmatic Denisovan hominins (Reich et al. 2011). These findings highlight the genetic fluidity and perhaps multi-regional nature of human populations near the speciation of *Homo sapiens*.

1.1.1.2 FOSSIL EVIDENCE

Current understandings of human origins are the product of genetic and paleontological data with each providing a valuable counterpoint to the other. While there is sometimes discrepancy, both sources of data generally support an origin for *Homo sapiens* around 200 kya in Africa (McDermott et al. 1996; McDougall et al. 2005; Spoor et al. 1998; White et al. 2003). Fossil and genetic evidence also independently indicate that many subsequent demographic and evolutionary events occurred in eastern Africa (Elhassan et al. 2014; Maslin et al. 2015).

However, as new fossils are found and described it is becoming clearer that the evolution of modern humans is not as straight forward as might be hoped. Most notably, early modern and archaic humans exhibited a considerable degree of anatomical variation, making it difficult to confirm precisely when and where *Homo sapiens* morphology first appeared and why (Trinkaus 2013). Early *Homo sapiens* fossils have been recovered from northern, eastern and southern Africa, suggesting that modern human anatomy was widespread by MIS 6. Given the considerable geographic separation of these finds, debate continues as to whether modern anatomy evolved in a single location before becoming dispersed or if multiple modern-like populations arose across Africa, with extensive gene flow between them.

Assuming the first scenario, many would consider eastern Africa to be the likeliest birthplace of *Homo sapiens*. This notion is supported mainly by the antiquity of finds from sites in Ethiopia and Kenya. In fact, the oldest known *Homo sapiens* fossils come from the Omo Kibish Formation in Ethiopia. The two crania recovered from the site are thought to be roughly contemporaneous, although the first skull, Omo 1, is markedly more modern in appearance than Omo 2. The cranial variability between these two skulls suggests either that parent and daughter populations coexisted in place for a time or that there was significant cranial variation in early modern populations (Grine 2016). Advances in chronometric dating methods since the discovery of the Omo Kibish skulls in 1967 have allowed paleoanthropologists to date the remains to 195 kya (McDougall et al. 2005).

Other eastern African finds include the Singa calvarium, recovered in 1924, which reveals a mixture of modern and archaic traits including a pronounced supra-orbital torus contrasted to a modern-looking vault shape. ESR dating shows that the fossil is older than 150 kya, and is likely an early modern *Homo sapiens* (McDermott et al. 1996; Spoor et al. 1998).

Three hominin crania from Herto, Ethiopia, dated to 160 kya, display a similar blend of modern and archaic morphology. Although typically lumped into *Homo sapiens sensu stricto,* White et al. (2003) have argued for a new sub-species designation: *Homo sapiens idaltu.*

Two sites from Zambia have also yielded human fossils dated to sometime during MIS 6. The first, Twin Rivers Kopje, is composed of several fissures infilled with speleothem capped sediments (Grine 2016). In the 1950s, excavators uncovered a fragment of humeral diaphysis from the site, noteworthy because of its remarkably thick cortical walls, more consistent with archaic human morphology. U-series and thermoluminescence dates, however, indicate that the fragment is 178 to 139 kya, and thus falls within the time scale of modern humans. Mumbwa Caves, Zambia, also features an MSA record complete with human post-cranial and dental elements (Grine 2016). The teeth are somewhat larger than most modern human populations, while the limb elements suggest a relatively small body-size. These remains are thought to be roughly contemporaneous to Twin Rivers Kopje at ~172 kya, and both are thought to derive from early *Homo sapiens* populations.

In southern Africa around 40 catalogued specimens have been recovered from the Klasies River site, South Africa. The individuals represented at Klasies are likely MSA in origin and display a mixture of archaic and modern traits including exaggerated levels of sexual dimorphism (Grine et al. 2017). Border Cave, South Africa has also yielded human fossil remains dating to the MSA. Amongst these finds is an infant found in association with a marine shell, possibly a funerary object (Grine 2016). More controvertible is the skull from recovered from Florisbad, South Africa. Many agree that the specimen represents a human species very closely related to modern humans if not immediately ancestral. The shape of the vault is long and low, similar to earlier human forms, while the face is smaller and more retracted than earlier human populations. It is thought to date to approximately 300 kya.

The fossil record of northern Africa during MIS 6 features numerous human specimens, mostly from the sites of Jebel Irhoud and Kebibat, Morocco (Grine 2016). Rabat 1 is a juvenile specimen from Kebibat, discovered in 1933. The specimen is made up of fragments of the maxilla, mandible and vault. Although initially classified as "evolved *Homo erectus*" the fossil has since been reclassified as *Homo sapiens*. The remains are thought to date between 200 and 130 kya. The second of the two sites, Jebel Irhoud, has revealed up to 5 individuals recovered over several decades of excavation. The individuals are described as having commonalities with the skeletal materials from Skhul and Qafzeh (Israel) such as elongated crania and projecting faces and brow-ridges. Much of this material was initially thought to date to approximately 160 kya on the basis of U-series and numerous ESR dates. However, more recent excavation and dating have revealed human remains dating to approximately 300 kya, potentially making them the oldest yet discovered (Hublin et al. 2017).

1.1.2 THE ARCHAEOLOGY OF THE FIRST *HOMO SAPIENS*

The period of time during which *Homo sapiens* has existed is quite short compared to the depth of the archaeological record, which began with the appearance of the first stone tools around 3.3 mya (Harmand et al. 2015). The Stone Age was ushered in by our ape-like ancestors who first began creating sharp flakes of stone and ended with the introduction of village life and early plant and animal domesticates between 15 and 10 kya (Ambrose 2001). The Stone Age system was originally formalized by Goodwin and Van Riet Lowe (1929) to describe South African sites, but has since been expanded to characterize the archaeological record of all of sub-Saharan

Africa. Northern Africa assemblages, conversely, frequently rely on the European Paleolithic framework (although many scholars of northern Africa are now adopting the African Stone Age system to reflect the similarities in material culture between northern and Sub-Saharan Africa). The Stone Age is divided into three main technological units: The Early Stone Age (ESA), The Middle Stone Age, and The Later Stone Age (LSA). Numerous sub-divisions of these basic units have been proposed and phased out since 1929, but the ESA, MSA, and LSA have remained a part of the common archaeological language of Africa.

The ESA encompasses the earliest tools produced by our likely evolutionary ancestors (Semaw 2000; Semaw et al. 1997) and is divided into two main phases: the Oldowan and Acheulean, each of which is also sometimes sub-divided further (Beyene et al. 2013; de la Torre 2011; de la Torre et al. 2012). The first industry of the Early Stone Age, the Oldowan, is named for the place where it was first described: Olduvai Gorge, in northern Tanzania (Leakey 1971, 1976). The oldest materials recovered from the site date to 1.8 mya and were thought to have been made exclusively by *Homo habilis*, the first member of our genus (Harmand et al. 2015). Since then, the age of the Oldowan has been extended to 2.6 mya to include artifacts from Gona, Ethiopia (Semaw 2000; Semaw et al. 1997), and possibly to 3.3 mya at Lomekwi 3, Kenya (Harmand et al. 2015). It has also come to be recognized that many different *Homo* and *Australopithecus* species were likely producing and using stone tools during the Oldowan (Panger et al. 2002).

Oldowan tools are often composed of simple flakes struck opportunistically from cores, which were used with little additional modification. It is also probable that the cores themselves were repurposed as chopping tools (Ambrose 2001; Toth 1985). Although the technical products of this process were simple there is evidence for significant forethought in the acquisition of raw materials for the production of tools (Braun et al. 2008, 2009; Stiles 1991; Toth 1985). Stones were repeatedly accessed from distant source locations and transported to sites, implying that Oldowan hominins were able to differentiate materials on the basis of knapping quality, and could mentally map and potentially communicate the locations of these materials to others.

Bifacial technology subsequently grew in importance during the Acheulean as the reduction strategies of the Oldowan increased in sophistication. From relatively simple choppers, hominins began producing symmetrical bifacially flaked hand-axes in large numbers around 1.75 mya (Ambrose 2001). This new hand-axe technology did not completely replace earlier Oldowan-like tools, and there was considerable overlap in time and space between these two industries. Although the precise mechanism of change is debated, the appearance of the Acheulean is frequently associated with the emergence of a new hominin species, *Homo erectus*. The Acheulean was also one of the longest periods of technological continuity in human history, lasting from 1.75 mya until 300 kya - over a million years – and is found geographically throughout Africa and Europe (Beyene et al. 2013; Lepre et al. 2011).

The ESA was succeeded by the MSA, around 300 kya, which lasted until approximately 30 ka. The MSA is significant because it coincides with the emergence of *Homo sapiens* around 200 ka as well as a series of novel material behaviours (McBrearty and Brooks 2000). Like the Early Stone Age, multiple hominin species were responsible for creating MSA tools, modern humans among them. Although the lithic flaking methods and tool types implemented by MSA hominins emerged in the later Acheulean, the MSA is generally distinguished from this earlier period by a lack of large bifaces and similar heavy-duty tools (Ambrose 2001). MSA assemblages on the other hand are predominantly composed of retouched and unretouched flake and blade tools such as scrapers and points. These tools were commonly manufactured from blanks struck from radial or circular cores, as well as more informal core types. Levallois prepared core methods were also employed to produce tools of uniform shape and size without the need for retouching (Ambrose 2001; Brantingham and Kuhn 2001; Tryon et al. 2005; Van Peer 1992).

Probably the most important technological innovation of the MSA was the composite, or hafted, tool (Ambrose 2010; Scerri 2013; Wilkins et al. 2012). Hafting involves joining a stone tool with a handle made from organic material like wood or bone. This practice has a number of advantages, including allowing the user to apply more pressure to a worked surface, and in the case of hunting weapons like spears, increasing the distance at which a prey animal can be dispatched. Not only does hafting technology amplify the effectiveness of existing tools, it potentially reflects an important shift in human cognition (Ambrose 2010; Lombard and Haidle 2012; Perreault et al. 2013). Ambrose (2010), for instance, argued that the execution of the complex series of steps necessary to haft a tool differs fundamentally in its neural requirements from the way in which technology was organized before.

Given the differences in MSA point typology across Africa, it is tempting to view these artifacts as representing the products of distinct ethno-linguistic groups. Some of the most visible of these potential traditions are Aterian and Still Bay points. Aterian points from across northern Africa feature a distinct "tang" or stem which was likely manufactured to facilitate hafting. While stemmed Aterian points likely tipped hunting weapons, other Aterian tools such as scrapers are sometimes also tanged in a similar fashion. On the opposite coast of Africa, some MSA groups were producing finely-made leaf-shaped points using a technique called pressure flaking which involves pushing off chips of stone rather than striking them off. Aside from these unique styles of point production, most points produced during the MSA are generically referred to as Levallois or Mousterian or MSA points. They are triangular in plan-view and are generally minimally retouched, as the shape of the point is primarily determined by the morphology of the core prior to the removal of the flake. The view that these differences in hunting equipment map onto broader cultural differences has been tentatively accepted by many but remains difficult to prove in the absence of other markers of cultural identity that can be shown to covary with point typology.

Additionally, a number of other behaviours emerged during the MSA that are associated with contemporary human societies. Art, personal adornment, long distance trade, and regional identity likely all have their roots in the MSA and were firmly established by the LSA (McBrearty 2013; McBrearty and Brooks 2000; Wadley 2015). These behaviours suggest that MSA peoples were similar to humans living today in terms of their capacity for emotion and intellect. Why these behaviours appeared in many parts of Africa during the MSA remains a question of importance to many paleoanthropologists and Stone Age archaeologists.

The LSA follows the MSA in many parts of Africa around 30-40 kya. In terms of lithic technology, the LSA is mainly characterized by a miniaturization of the tool-kit and an increased reliance on hafted tools. Many tools are referred to as backed pieces or microliths. Although there is debate over the use of these terms most archaeologists deploy them to discuss small tools that are intentionally blunted on one side to facilitate hafting (Pargeter and Brandt 2015). Bipolar technology also characterizes many LSA assemblages. The technique involves striking a core which has been stabilized on a stone anvil (Bradbury 2010; de la Peña 2015). The flakes produced in this way are not very predictable and bipolar technology is in some sense wasteful of materials. However, it likely allowed stone tool makers to work otherwise intractable materials and has the benefit of being expedient, involving little planning or skill. It is possible that this shift in blank production method may reflect an increased focus on perishable tool materials such as wood and bone.

1.1.2 THEORETICAL BACKGROUND - BEHAVIOURAL MODERNITY

The concept of behavioural modernity is highly contentious. It commonly refers to the sorts of behaviours exhibited by Upper Palaeolithic and later peoples, including the production of art and ornamentation, ritual treatment on the dead, etc (Clark 1992; Henshilwood and Marean 2003; Wadley 2001). These behaviours are thought to be the products of a fully modern brain, identical to those possessed by humans alive today, and hypothetically separate modern humans from archaic human species and other animals. Based largely on the archaeological record of Europe, it was initially believed that the onset of modern behaviour was relatively rapid and took place recently - within the last 40 to 50 kya (Bar-Yosef 2002; Fisher and Ridley 2013; Mellars and Stringer 1989). Our understanding of this process has since become more complex, including criticisms of the idea of modernity itself. The questions of when, where, how, and why these behaviours emerged remain open.

One of the main issues is that the sorts of behaviour that count as modern are debatable. Much of what might be considered modern behaviour, such as language use, does not leave a material signature. This fact leaves archaeologists dependent on a narrow range of non-perishable materials, most often stones and bones. Undue attention has thus potentially been placed on stone tool technologies such as the production of blades. For a long time lithic blades were understood to be a hallmark of modern cognition (Eren, Greenspan, and Sampson 2008). It was argued that they demonstrated an attempt to maximize both raw materials and available cutting surface. At the time, the evidence also seemed to show that only human populations within the last 50 thousand years made use of the technology. It has since been demonstrated that the actual emergence of blade technology is closer to half a million years ago in southern and eastern Africa (Wilkins and Chazan 2012). The same is true for evidence of bone technology, which is thought to have been developed relatively recently but has since been found to originate further back in time than initially thought (Yellen et al. 1995). A more promising distinction between modern and non-modern behaviour might be evidence for symbolically mediated behaviour (Burdukiewicz 2014; d'Errico and Henshilwood 2011; Henshilwood and Marean 2003). Symbols are simply things that stand for, or mean, something else, and their use is a persistent feature of modern human existence. Objects thought to encode symbolic meaning in the archaeological records are artifacts like beads, art objects, and ochre (Henshilwood, d'Errico, and Watts 2009; Miller and Willoughby 2014). The archaeological evidence clearly demonstrates that these sorts of artifacts became more common through time. However, the rate at which this transition occurred and its cause or causes is still debated.

Criticism has also been leveled at the use of the Upper Paleolithic record of Europe as the yardstick of modernity. A growing body of data from Africa and Asia documents a much older record of modernity (McBrearty and Brooks 2000). The sudden appearance of modern-looking artifacts in Europe is now increasingly understood to be the result of already modern human populations bringing these behaviours with them from elsewhere. Furthermore, this theory possibly conceals troubling assumptions about the innate superiority of Europeans relative to the people of Africa and Asia. On the other hand, several proposals have been put forward to mitigate some of the theoretical difficulties associated with concept of modernity. A main issue that has been identified is that modernity remains vaguely defined and difficult to test with archaeological data. One possible improvement is to consider behavioural variability instead

(Shea 2011). Shea defines variability as the cumulative breadth of human behaviours. He argues that variability can be quantified and thus more objectively studied. Despite the problematic concept of modernity, there is no clear standard that has emerged to replace it. Thus, many archaeologists continue to employ it, implicitly or otherwise.

1.2.1 GENETIC HYPOTHESIS

Despite conceptual issues with the idea of behavioural modernity, there are several hypotheses to explain how and why it might have emerged. The genetic hypothesis is mainly supported by Richard Klein who argues that modern behaviour emerged rapidly around 50 kya and is linked to a theorized change to the human brain (Klein 2009). On the basis of fossil crania it does not appear that an abrupt expansion in brain volume occurred within the vicinity of the last 50 thousand years ago, and thus the change must have occurred to the structure or organization of the brain. One possible genetic driver is the gene FOXP2, which is associated with the production of speech sounds (Lieberman 2009). Modern humans who possess a mutated form of the gene suffer from significant speech difficulties. However, it has since been proven that Neanderthals had the same form of FOXP2 which they, and modern humans, likely inherited from a shared ancestor that lived approximately 600 kya (Green et al. 2010). This hypothesis has mostly fallen out of favour given the difficulty testing it and the nature of the African archaeological record which shows a slower, more accretional pattern of change.

1.2.2 INTENSIFICATION HYPOTHESIS

Others have associated the emergence of modern behaviours to one or more periods of environmental deterioration in the late Pleistocene (Hetherington and Reid 2010; Maslin et al. 2014). Marine Isotope Stage 4, in particular, appears to coincide with the precocious records of southern Africa. MIS 4 was a period of increased aridity and cooler global temperatures. In many parts of Africa, this trend was marked by decreased rainfall, the expansion of savannah environments and the retreat of forests (Blome et al. 2012). If these changes were severe enough they may have placed pressure on human populations adapted to warmer and wetter conditions. It is argued that many MSA behaviours could be interpreted as a response to decreased resource availability, increasing home-range size and the establishment of distinct territories (Henshilwood and Marean 2003).

The primary challenge to the intensification hypothesis is the difficulty correlating continental and regional climate trends with particular cultural records. There is, for instance, debate as to whether Howisons Poort assemblages is South Africa date to periods of warm and wet or cold and dry climate (Chase 2010; Clarkson 2010). Furthermore, it is worth considering that human species have experienced periods of environmental stress before without demonstrating evidence of behavioural modernity. Based on this fact alone, it is likely that other factors are involved.

1.2.3 DEMOGRAPHIC HYPOTHESIS

Lastly, it is theorized that demographic increase in the last 100 thousand years may have accelerated the rate at which cultural innovations occurred. This trend may also have rendered groups less vulnerable to knowledge loss as a result of stochastic effects. This theory is largely based on mathematical modeling of the sort performed by Henrich (2004) and Powell et al. (2009). A demographic explanation potentially explains the pattern of first emergence for modern behaviour, which is characterized by periods of abandonment, hiatus, and rediscovery (Hovers and Belfer-Cohen 2006). Nevertheless, corroborating evidence of demographic increase remains difficult to prove.

It is also worth asking what might have caused demographic increase in the first place. Perhaps a period of relatively mild climate initiated a surge in the size of human groups until it reached a theoretical tipping point. One possible place where this demographic increase might have taken place is the coast of southern Africa where access to key resources like food and water is argued to have been relatively stable. The demographic hypothesis is thus also dependent on the quality and resolution of paleoenvironmental and paleoclimate data.

While there are still gaps in our knowledge of the Iringa Region, the Iringa record appears to encompass this critical window within the last 100 thousand years when modern behaviours were beginning to become fixed in the populations of Africa. Our preliminary analyses, and those of others, show a pattern which is distinct from the records of southern Africa. Most notably: a lack of precocious industries like the Still Bay or Howiesons Poort. The chapters that follow are particularly relevant to the study of the emergence of hafted hunting and projectile technology, which is often considered to be a residue of behavioural modernity. Chapter 2 addresses the intensification hypothesis in the context of Magubike Rockshelter.

1.1.3 THE MIDDLE STONE AGE ARCHAEOLOGY OF TANZANIA

Recent research suggests that eastern Africa played an important role in the anatomical and behavioural evolution of modern *Homo sapiens* (Clark 1988; Grine 2016; Lahr and Foley 2016; Tryon and Faith 2013). In particular, stable ecological conditions during the Pleistocene may have favoured long term habitation leading to demographic growth and socio-cultural innovations (Basell 2008; Blome et al. 2012). The archaeological signatures of MSA eastern Africa also differ considerably from places such as southern Africa. In particular, many precocious features of southern African assemblages, such as ochre-use, microlithic technology, and curated tool industries, are visibly absent, infrequent, or later in appearance in eastern Africa

(Tryon and Faith 2013). Explanations for these differences are likely to be found in the social and environmental context of the region. In Tanzania, specifically, there is evidence for significant habitat diversity, which is a likely driver for archaeological variation (Basell 2008; Mumbi et al. 2008).

Within Tanzania there are several well studied sequences that help to shed light on hunter-gatherer adaptation during the MSA. Of these sites, Olduvai Gorge is most well-known for its ESA material and fossil hominin localities, but the Upper Ndutu and Naisiusiu Beds contain MSA and LSA deposits. Although Mary Leakey engaged in a cursory survey of the beds, she was largely uninterested in the results (Tryon and Faith 2013). Follow-up survey and excavations by later researchers are more informative, despite being preliminary (Eren et al. 2014). Many of the MSA artifacts at Olduvai Gorge were produced from local volcanics, predominantly basalt and phonolite. Other materials include small amounts of quartz and chert. Raw materials were shaped using radial and Levallois flaking methods (Willoughby 2007) with little evidence of bipolar flaking (Eren et al. 2014). Very few retouched tools were found, a pattern which is consistent with other eastern Africa MSA assemblages. The LSA at Olduvai Gorge, found in the overlaying Naisiusiu Beds, includes backed blades and geometric microliths on obsidian and chert, as well as a greater reliance on bipolar flaking (Willoughby 2007).

Likely the most extensively studied MSA and LSA sites in Tanzania are located in the Lake Eyasi Basin. There are three main sites in the area including The Skull Site, Mumba Rockshelter and Nasera, which collectively have come to form the standard MSA/LSA cultural sequence for Tanzania. Like other eastern African MSA and LSA sites, the majority of tool blanks at Mumba and Nasera were produced by bipolar, radial and Levallois flaking. Tool retouch was minimal, although, the occupants occasionally modified blanks into points, scrapers and backed pieces (Mehlman 1989). The presence of “Heavy-duty”, or core, tools at these sites suggests the retention of ESA lithic templates. This notion is further supported by the large size of retouched pieces from Nasera (Tryon and Faith 2013). The transition from the MSA to the LSA at Mumba is characterized by an increased reliance on bipolar flaking to reduce small rounded pieces of quartz. The end products of this reduction chain were predominantly small backed pieces, which were likely affixed or inserted into a handle of wood or bone (Mehlman 1989).

In general, the archaeology of Tanzania is highly variable, with no single set of defining typological or technological features that are shared across all sites. This diversity may reflect adaptation to different local environments, or more subtle trends in demography, emerging cultural identities and migration. Tryon and Faith (2013), for instance, highlight the environmental diversity of eastern Africa as a possible cause. Several features are common, however. Radial and Levallois methods of flaking are typical of many MSA sequences, the products of which were transformed into scrapers and points. The size of end products declined in size between the early and late MSA, forming a continuum between the ESA and LSA. Backed pieces, beads, ochre and ground-stone artifacts also become more common towards the end of the MSA and beginning of the LSA (Tryon and Faith 2013).

1.1.4 MAGUBIKE ROCKSHELTER

Work at Magubike Rockshelter has largely focused on how the site fits into the broader picture of MSA culture in eastern Africa established by previous research (A map of the region can be found in chapter 2). Magubike Rockshelter is a large granite overhang located at 7º45.790’S, 35º28.399’E and was designated HxJf-01 using the Standardized African Site Enumeration

System (SASES). The initial survey of the site was undertaken by Dr. Pamela Willoughby in the summer of 2005 and 2006, which also revealed the existence of several nearby rockshelters within a few kilometers. Archaeological materials were observed on the modern ground surface in and around the site and included lithic, ceramic, and faunal remains, in addition to iron slag and ceramic fragments of an iron furnace.

Preliminary excavations at Magubike Rockshelter began in 2006, during which time three test-units were excavated within the shelter to establish the extent of the cultural presence at the site. Further excavations were conducted outside the shelter (Test Pits 4 and 5; Hxjf-03 Test Pits 1 to 3) in 2008 with the intention of determining the spatial limits of the site. Further field work at Magubike took place in 2012 under the continued direction of Dr. Pamela Willoughby. She was joined by Pastory Bushozi, Anne Skinner, and Frank Masele, as well as a number of undergraduate students from the University of Dar es Salaam. They were responsible for excavating seven new test-units (Test Pits 6 to 12) in the main shelter near Test Pits 2 and 3 from 2006. Due to the massive nature of the stratigraphy the site was excavated in arbitrary 10 cm levels using trowels, and the sediment was screened by hand in large basins. The artifacts were sorted, catalogued and made ready for export in the field. More detailed analyses occurred off-site at the University of Alberta, Canada. The lithic artifacts were classified according to Mehlman's (1989) typology for the sake of comparability with other Tanzanian assemblages.

The most recent excavation of the site was undertaken in 2016. The more limited scope of the work was mainly directed at the recovery of paleoenvironmental data rather than bulk sampling of lithic materials. These data are currently being analyzed. Nevertheless, archaeological materials were collected in the process of excavating 3 0.5 x 0.5 m test units under the overhang of the shelter. At the time of writing, these materials are being processed and stored at the University of Alberta.

Further survey was initiated in 2008 in an attempt to locate potential raw material sources local to the site. The results of the survey indicated that it is likely that a large percentage of the lithic materials were local, and were collected from nearby streambeds within 10 km of the site. However, sources of material such as chert, found at the site, were not able to be identified. Subsequent survey in 2016 by the author revealed several nodules of chert assessed to be located near to their original contexts. They occurred where overland run-off had cut down through the banks of larger streams as the water gained in energy. The water likely cut into bands of sediment containing chert nodules, thus dislodging them and sweeping them into the main channel.

1.1.5 CONCLUSION

While some of the basic questions of modern human origins seem to be resolved, new fossil and genetic evidence has opened up tantalizing new avenues of research and have contributed greatly to the scope of our understanding of this process. Archaeological finds from across Africa have also contributed substantially to our knowledge of how humans were changing behaviourally. The ancestors of modern humans began creating stone tools as much as 3.3 mya. These early artifacts were simple but grew in complexity over the period of the Oldowan and Acheulean. By the time *Homo sapiens* emerged, 200 kya, they were positioned to inherit a complex package of MSA behaviours. From then on the variability and sophistication of MSA and LSA material culture increased rapidly.

Needless to say, research into the archaeology of these early human populations is still ongoing. Considerable resources have been invested in the study of a select few sites such as those on the southern African coast. This trend has left other regions of Africa understudied or entirely unexplored. Efforts to correct for this tendency have included the Iringa Region Archaeology Project, which is focused the archaeological record of the Iringa Region of Tanzania. Survey and excavation conducted by IRAP over the last decade has revealed a high potential landscape with profuse evidence for Stone Age and more recent occupation.

The subsequent chapters deal with a portion of the stone artifacts recovered from the Magubike rockshelter site. The materials under study likely date to the critical period following the origin of modern humans, during which time the sophistication and variability of human behaviour began to increase rapidly. I also address issues related to the analysis of stone tools, particularly some new methods of functional analysis.

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CHAPTER 2: MIDDLE STONE AGE TECHNOLOGY AND CULTURAL EVOLUTION AT MAGUBIKE ROCKSHELTER, SOUTHERN TANZANIA

2.1 INTRODUCTION

Fossil and genetic evidence indicate an African origin for modern *Homo sapiens* during the Middle Stone Age (MSA), by 195,000 years ago (Cann et al. 1987; Fu et al. 2013; Grine 2016; McDougall et al. 2005; White et al. 2003). This speciation event occurred amidst a backdrop of significant behavioural change, which may have begun as early as ~500,000 years ago and became consolidated in the Later Stone Age (LSA) (Burdukiewicz 2014; Henshilwood 2007; McBrearty 2013; McBrearty and Brooks 2000; Shea 2011; Wilkins et al. 2015). During this time humans began to create sophisticated tools from both lithic and perishable materials such as wood and bone (Barham 2002; Leplongeon 2014; Wilkins et al. 2012; Wilkins and Chazan 2012; Yellen et al. 1995), to engage in long-distance exchange (Barut 1994; Mehlman 1989), to exploit a variety of ecosystems including marine coastlines (Arzarello et al. 2013; Barham 2002; Broadhurst et al. 2002; Drake et al. 2011; Jerardino and Marean 2010; Marean 2011; Marean et al. 2007; Walter et al. 2000), and to produce art and personal adornment (Bar-Yosef Mayer et al. 2009; D'Errico et al. 2005; Henshilwood et al. 2002, 2004, 2009; Hovers et al. 1997; Mackay and Welz 2008; Miller and Willoughby 2014; Willoughby 2007).

Many believe that these innovations were stimulated, at least in part, by changes in climate and environment during the Late and Middle Pleistocene (marine isotope stage 6 to 2) (Ambrose 1998; Basell 2008; Blome et al. 2012; Chase 2010; Drake et al. 2013; Larrasoaña et al. 2013; B. A. Stewart and Jones 2016). Amongst climate advocates, this view is often expressed in one of two ways. Some contend that repeated episodes of severe and unpredictable glacial climate encouraged the development of cultural buffering mechanisms as home ranges declined in productivity (Ambrose 1998; Clarkson 2013; Henshilwood and Marean 2003; J. R. Stewart and Stringer 2012). As such, new adaptive and social strategies became required to cope with changing patterns of resource availability and distribution, as well as greater exposure to non-kin. The increasingly patchy and unpredictable distribution of food and water resources in some areas may have caused a shift towards greater residential or logistical mobility and a preference for technologies such as microliths that made more efficient use of cores and blanks, and were potentially more portable (McCall 2007). A general trend towards exoticism in lithic raw material preference during the late MSA in many areas is also thought to support the notion that individual groups became more mobile or were increasingly embedded in far-reaching networks of exchange (Barut 1994; Clarkson 2013).

Alternately, others have proposed that stable conditions within refugia were necessary for risk free cultural experimentation (Jacobs et al. 2008; Ziegler et al. 2013). This version of the argument tends to draw on demographic models such as those of Powell et al. (2009) and Henrich (2004) that show that larger populations are more likely to innovate due to a greater pool of potential innovators. Large populations may also be more resistant to information loss as a result of stochastic effects because cultural knowledge is distributed across more members.

However, linking dynamic large-scale climate processes, such as those preserved in marine isotope stages, to site-specific material behaviours is difficult. As a result, many have called for paleoenvironmental work to be carried out on finer scales (Grine 2016; Roberts et al. 2016). With respect to the paleoenvironmental context of eastern Africa several high resolution climate records are available that indicate the existence of a variety of environments, which likely responded to climate change very differently (Faith et al. 2016; Lahr and Foley 2016). The unique conditions of these localized environments paired with relatively isolated populations may even be responsible for the significant behavioural diversity observed between eastern African sites during the MSA (Clark 1988; Douze and Delagnes 2016; McBrearty and Brooks 2000; Tryon and Faith 2013). Indeed, archaeologists have struggled to identify archaeological features that are common to all, or even many, eastern African MSA localities. Furthermore, a large proportion of eastern Africa sequences exhibit complex or indistinct patterns of temporal change that are for the most part typified by continuity in typological products through time (Douze and Delagnes 2016). For these reasons, several scholars have called for the creation of location-specific models of cultural change that can be aggregated to form a more coherent regional picture (Douze and Delagnes 2016; Mitchell 2008; B. A. Stewart et al. 2012; Tryon and Faith 2013).

One part of eastern Africa for which more data would be useful for completing this regional picture is southern Tanzania. Since the majority of archaeological survey and excavation has occurred at places such as Mumba and Nasera filling these gaps in the south of the country is vital for linking the MSA records of Zambia and Mozambique with those further north. Several newly discovered sites located in the highlands of southern Tanzania, containing comprehensive MSA sequences, may contribute valuable data to questions of local adaptation in this area (Miller and Willoughby 2014; Willoughby 2012). Early work on the lithic assemblage from the Magubike archaeological site in the Iringa region of southern Tanzania shows gradual, unidirectional change in lithic reduction intensity, artefact typology and raw material economy. This paper describes the available lithic evidence and explores possible reasons for the patterns, including broad-scale demographic and environmental factors active at that time.

2.2 THE MAGUBIKE ARCHAEOLOGICAL SITE

The Magubike archaeological site (Figs. 2.1, 2.2, 2.3) is a granite rockshelter situated in the Iringa province of southern Tanzania, near the town of the same name. It is located at latitude 7°45.790′S and longitude 35°28.399′E, at an elevation of 1541 m. It was assigned SASES number HxJf-1. The modern landscape consists of large granite kopjes and outcrops cut through by rivers and smaller ephemeral streams. As these kopjes eroded they left numerous shelters, which were the focus of late Pleistocene and Holocene human occupation in the area. Woodland and moist savannah plants form the dominant vegetation and dry montane forests are clustered on the hills and other high places. Climatologically the region is classified as dry to sub-humid or semiarid with a long, dry season and about 75–100 mm of annual rainfall.

The geology of Iringa is very old and is mainly comprised of Precambrian migmatites and granite that formed during the late Archean. Much of the subsequent geology of the area represents the reworking of these deposits. The sedimentology of the shelter consists mainly of unconsolidated aeolian silts interdigitated with disintegrated elements of the granite bedrock and shelter roof.

Initial exploration of the area around the village of Magubike was undertaken by Willoughby in 2005, and excavations of the site in 2006, '08 and '12 revealed substantial historic, Iron Age, Later Stone Age (LSA) and MSA deposits in three different locations (Willoughby 2012). Materials recovered from the Magubike site include lithics, faunal remains, a number of MSA hominin teeth (Willoughby et al. 2018.), ostrich eggshell beads dating to the MSA, LSA and Iron Age (Miller and Willoughby 2014), as well as evidence of pottery, iron smelting and blacksmithing (Willoughby 2012). A survey of the surrounding terrain was also undertaken in 2008 with the aid of topographic and geological maps to locate additional sites as well as potential lithic raw material sources.

Due to the massive nature of the deposits, the site was excavated using 1 m squares in arbitrary 10 cm levels. The stratigraphic profiles produced by the excavation were indistinct, and the artefacts were distributed throughout the sediment rather that clustered into what could be interpreted as discrete horizons or living floors. A patina of chemical precipitate on many of the artefacts suggests the movement of mineral rich water through the sediments, which implies a degree of disturbance. Nevertheless, there is no evidence of size-based sorting or preferential artefact orientation. Although we have chosen to approach the chronology of Magubike very conservatively until we have conducted the necessary geoarchaeological analyses, the deposits appear to be largely intact. A case for stratigraphic coherence is further supported by several sequential AMS radiocarbon and preliminary optically stimulated luminescence (OSL) dates (see below).

Artefacts were assigned to techno-cultural traditions based on a number of variables. Of these, the presence of discoidal and Levallois-like core technology in the deepest deposits of the main shelter suggest an MSA origin, as does the existence of Levallois flakes with dorsal shaping and facetted platforms. These flake and blade blanks were most often transformed into points and scrapers, or used without further modification (Ambrose 2001; Brantingham and Kuhn 2001; Tryon et al. 2005; Van Peer 1992). A higher diversity of lithic raw materials and a greater emphasis on metamorphic stones in what we have defined as MSA layers also indicates an important difference in raw material economy. The levels assigned to the LSA conversely, exhibit characteristics similar to other well-studied LSA sequences in Tanzania, such as those from Mumba and Nasera (Mehlman 1989; Prendergast et al. 2007). Namely, they show an almost exclusive reliance on vein and massive quartz for the production of small backed pieces, which some have referred to as microliths, although there is now debate as to the appropriateness of such a term (Pargeter and Brandt 2015). These levels are also free of Levallois cores or flakes, and generally show a decreased emphasis on radial flaking, with the majority of blanks achieved using bipolar methods. Finally, the Iron Age and historic/modern levels nearest to the surface contained lithic artefacts similar in material and typology to the LSA but are associated with pottery, iron, slag and ceramic furnace fragments. In two parts of Magubike, there are MSA occupations directly under LSA and Iron Age ones. However, in test pit 1, there was almost 40 cm of sediment between the end of the LSA at 70 cm below the surface and the start of a dense MSA deposit at 110 cm below the surface. In this 40 cm gap there were only a handful of stone artefacts with types characteristic of both periods. In test pit 5, which was excavated below the main shelter in 2008, a 2.5 m deep sequence was uncovered, which contained a historic level, then Iron Age, then an LSA dominated by small quartz artefacts, then a larger LSA, then a mixed LSA/MSA layer, and finally 90 cm of MSA artefacts. The small and large LSA sequence is similar to that excavated nearby at Mlambalasi rockshelter (SASES #HwJf-2) in 2006 (Willoughby 2012); the former LSA was dated to the Holocene, the latter to the late Pleistocene. It is only in the main shelter that organic materials are directly associated with Stone Age artefacts (Willoughby 2012). No chronometric dates are available yet except for those directly under the shelter, which includes Test Pits 2, 3, and 6 through 12.

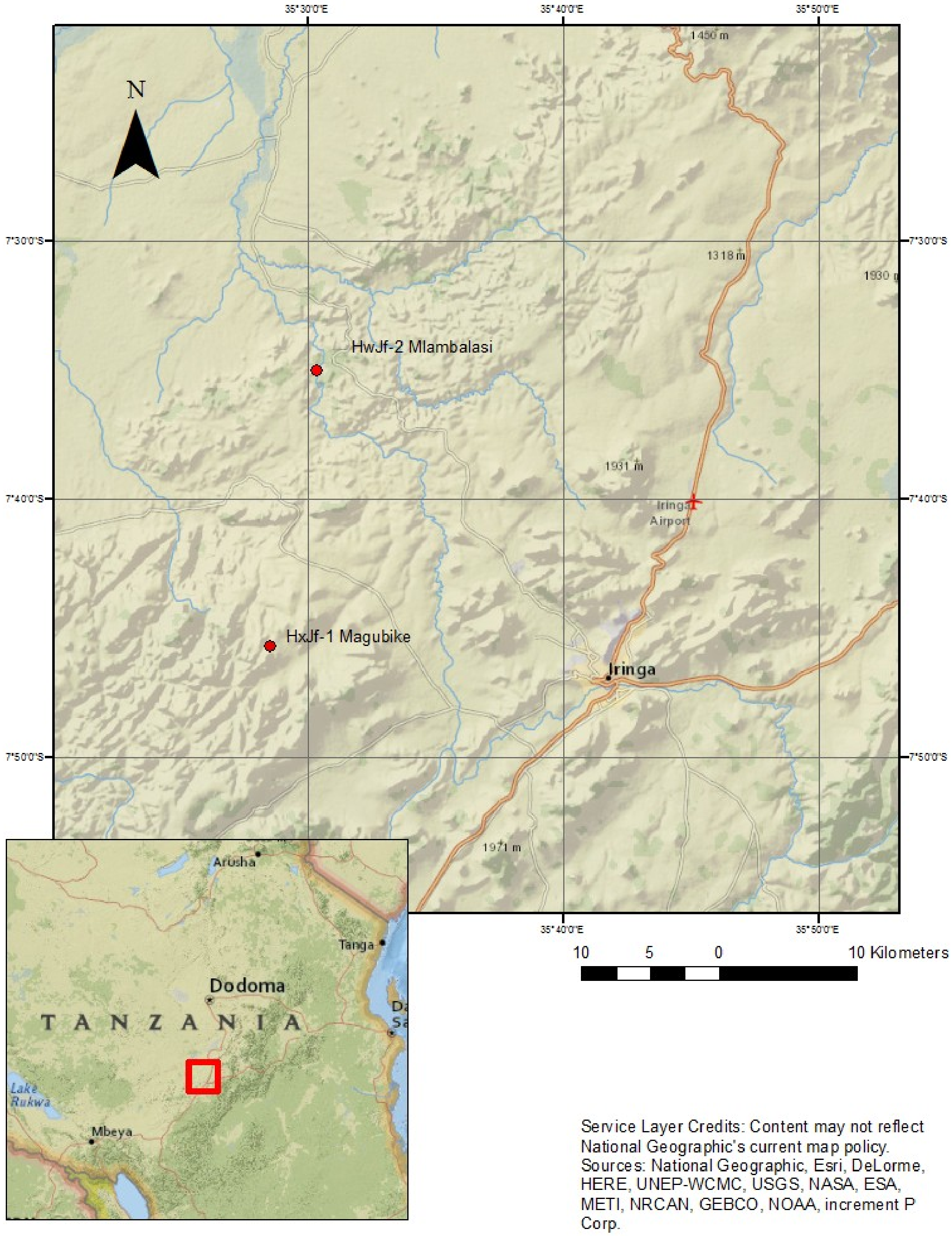

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Fig. 2.1. Map of Tanzania showing the Iringa Region and Magubike rockshelter.

Fig. 2.2. The Magubike rockshelter (photograph by Willoughby).

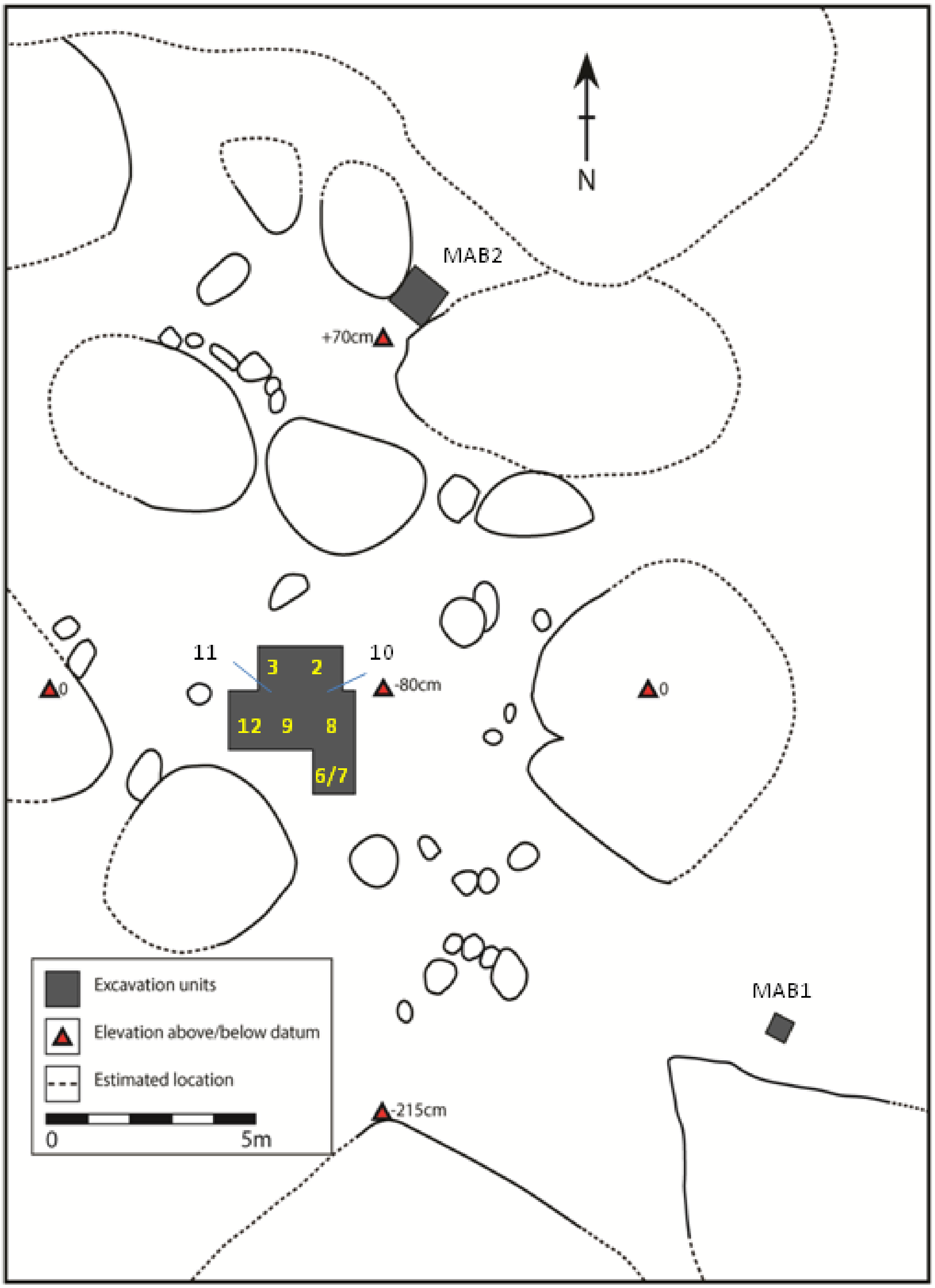


Fig. 2.3. Plan view of the site showing location of test pits.

2.2.1 THE CHRONOLOGY OF MAGUBIKE

Although the oldest deposits at the site are thought to date to the MSA primarily on the basis of lithic typology, several chronometric methods have been used at the Magubike site in order to establish the antiquity and continuity of the cultural sequence (Table 2.1). Three ostrich (*Struthio camelus*) eggshell (OES) beads from the MSA levels at Test pit 12 were directly dated using AMS radiocarbon to 47,750 ± 750 (OxA-27,626), 31,810 ± 180 (OxA-27,627) and 13,125 ± 50 (OxA27,625) years uncalibrated BP (Miller and Willoughby 2014). Levels 70–80 cm, 80–90 cm and 40–50 cm, from which the beads respectively derived, date to the established chronology of the LSA and late MSA (McBrearty and Brooks 2000). The dates are also consistent with the cultural materials found in these levels. However, the non-sequential dates of several of the beads suggest that they were likely vertically displaced in the sediment to some extent. Several more OES from adjoining test pits provide support for these dates (Table 2.1).

The second chronometric method that was attempted was electron spin resonance (ESR), which was performed on mammal teeth and giant land-snail shells (*Achatina*) found in association with archaeological materials. It became apparent early on that the dates obtained from this technique could not be meaningfully correlated with depth. Further testing by Dr. Anne Skinner also showed that ESR and radiocarbon dates obtained from the same samples were consistently and significantly different (up to a maximum difference of 90,000 years). The unusually high radiation level of Magubike's bedrock geology is thought to be a confounding factor. Until the substantial issues with the ESR dates can be resolved, we have chosen to ignore them for the purpose of interpreting the site's chronology.

Table 2.1 Radiocarbon dates from Magubike. Some dates have been previously published (Miller and Willoughby 2014; Willoughby et al. 2018).

Lab #	Test pit	Depth below surface (cm.)	Cultural period	Dated material	Age (BP)
OxA-27438	12	20 to 30 cm	Iron Age	Snail Shell (*Achatina* species)	4,477 ± 32
OxA-27625	12	40 to 50 cm	Iron Age / LSA?	Ostrich eggshell (*Struthio camelus*)	13,125 ± 50
OxA-27439	12	60 to 70 cm	MSA	Snail Shell (*Achatina* species)	49,200 ± 900
OxA-27626	12	70 to 80 cm	MSA	Ostrich eggshell (*Struthio camelus*)	47,750 ± 750
OxA-27627	12	80 to 90 cm	MSA	Ostrich eggshell (*Struthio camelus*)	31,810 ± 180
OxA-27440	12	90 to 110 cm	MSA	Snail Shell (*Achatina* species)	47,550 ± 750
OxA-27629	8	30 to 40	Iron Age / LSA?	Ostrich eggshell (*Struthio camelus*)	6,465 ± 33
OxA-27628	11	90 to 100 cm	MSA	Ostrich eggshell (*Struthio camelus*)	>50,100

The last dating method used at Magubike was optically stimulated luminescence (OSL) on associated sediments. Preliminary OSL dates show close agreement with those obtained with AMS radiocarbon on snail shells and OES beads and indicate that the Middle Stone Age deposits in the main site probably date to between 100,000 and 50,000 years ago (James Feathers, personal communications).

In summary, three independent chronometric methods have been used to date the site. AMS radiocarbon revealed a high-resolution record between ~4000 and 50,000 years ago. To date the materials from the site that surpass the radiocarbon limit ESR and OSL were used. The ESR dates do not accord well with those achieved with the radiocarbon ones, likely as a result of the highly radioactive sedimentary context. In contrast, preliminary OSL ages indicate the site was first occupied during the MSA by at least 64.8 ± 9.4 kya. On the basis of AMS and OSL it appears as though the MSA continued at Magubike until approximately 40,000 years ago, at which point there is a transition to LSA materials.

2.2.2 TEST PIT 12

The materials that are presented in this article originate from under the main overhang of the shelter (Test pit 12), which was excavated during the 2012 field season (Fig. 4). Test pit 12 measured 1.35 × 1.0 m and reached a depth of 180 cm, at which point the bedrock was contacted. It is immediately adjacent to Test pit 3, which yielded six hominin teeth in 2006 (Willoughby 2012). Included amongst the archaeological deposits were lithic artefacts, faunal remains, ostrich eggshell beads, iron slag, clay furnace fragments and potsherds. Everything below 50 cm from the modern surface of Test pit 12 belongs to the MSA, above which were 50 cm of historic and/or Iron Age materials (Fig. 2.4). At the west end of Test pit 12 was a depression with iron fragments and slag - possibly the remains of a furnace.

The abrupt transition between the MSA and the Iron Age levels, without an apparent intervening LSA, would seem to indicate a significant occupational hiatus. However, two ostrich eggshell beads directly dated with AMS radiocarbon point to a late LSA presence in this part of the site (Table 2.1). One is radiocarbon dated to 6,465 ± 33 BP (OxA-27,629), the other to 13,125 ± 50 BP (OxA27,625) (Miller and Willoughby 2014). Although the beads were found in what appear to be Iron Age deposits, their radiocarbon age places them within the known chronology of the LSA. A possible explanation for the apparent absence of the LSA in this part of the site is that it is mixed with, and occluded by, Iron Age materials that infiltrated down through the sediment. It is also conceivable that occupation of this part of the site during the LSA was minimal or that the beads were curated from elsewhere and reused during the Iron Age. Due to the similarity in the lithics of the LSA and Iron Age further geoarchaeological work is planned to differentiate these assemblages and provide deeper insight into the formation of the sequence.

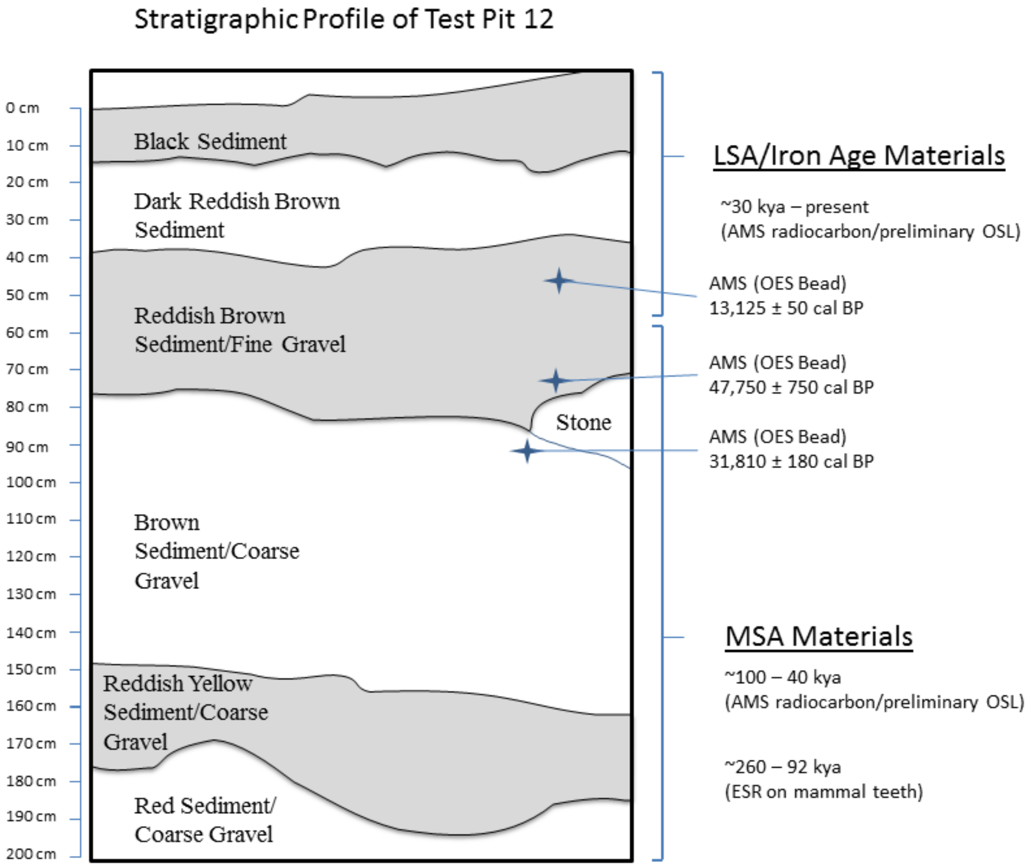


Fig. 2.4. Stratigraphic Profile of Test Pit 12.

2.3 PALEOCLIMATE OF EASTERN AFRICA

Determining the effects of climate change on the behavioural variability of MSA humans has become a major focus of research in modern human origins studies. Large-scale climatic trends are thought to have spurred considerable changes in regional economic and settlement systems in many parts of the continent, resulting in the emergence of a range of new material behaviours, including stone technology (Marean et al. 2007; McCall 2007). While climate and environmental change remains a plausible cause for technological change in eastern Africa, little direct supporting evidence has emerged (Blome et al. 2012; Douze and Delagnes 2016; Johnson et al. 2016; Tryon and Faith 2013).

On a coarse scale, eastern African climate appears to have become wetter after ~800,000 years ago, succeeding a long period of aridity, but was increasingly subject to longer and more severe periods of drought lasting tens of thousands of years (Lyons et al. 2015). The span of time between 145,000 and 60,000 years ago, in particular, shows evidence of extreme aridification, responsible for a decline in the level of Lake Malawi and Lake Victoria (Lyons et al. 2015; Scholz et al. 2011). However, a seasonal supply of monsoon rains from the Indian Ocean may have mitigated this, and other climatological upsets to a degree, as a range of environmental proxies indicate that eastern Africa experienced a relatively muted response to climate change, especially in comparison to northern and southern Africa (Ambrose 1998; Basell 2008; Blome et al. 2012). The comparable stability of the region is further supported by low variation in site frequency between 150,000 and 30,000 (Basell 2008; Blome et al. 2012). Based on this observation, some have argued that populations were able to moderate climate related factors by relocating to different altitudes, or that they were buffered to an extent in some other way (Basell 2008; Blome et al. 2012; Pickford 1995).

Nonetheless, it is important to recognize that large-scale climatic events had diverse local impacts, and different regions of eastern Africa experienced dissimilar and asynchronous climate regimes over their respective histories (Blome et al. 2012). The strategies adopted by human populations in response to climate change during the MSA are therefore likely to have been varied and highly dependent on existing local conditions. With respect to the timeline of Magubike, a multiproxy approach derived from continental and oceanic cores shows that during MIS 4 eastern Africa experienced a transition from a wet period to a dry one beginning around 65,000 years ago (Blome et al. 2012). This trend is supported by water level proxies from Lake Malawi, which show a similar decline in temperature and moisture between 71,000 to 61,000 years ago (Lyons et al. 2015; Scholz et al. 2011). Both of these records reveal a picture of cooling climate in eastern Africa at the time when Magubike was first occupied, approximately 65,000 BP.

More specific paleoenvironmental data for the Iringa Region is unfortunately limited. Lake cores from the Eastern Arc Mountains, ~40 km to the east of Magubike, show long-term climate stability dating back to at least ~48,000 BP, but do not necessarily imply climate stability further back in time (Finch et al. 2009; Mumbi et al. 2008). Environmental analysis of Magubike and its surrounding topography is planned for the near future to extend this sequence further back into the MSA and to test the environmental hypotheses explored in this article.

2.4 LITHIC ANALYSIS

The following is an analysis and discussion of lithic technology, typology and raw material variability in the MSA levels at Magubike. In general, human cultures are responsive to a diverse range of physical and social conditions, and frequently arrive at novel solutions to cope with them. One such set of consideration for Stone Age humans is the quality, abundance, availability and distribution of tool-stone in their home-range. In combination these factors are likely to inform not only immediate technological behaviours but also reflect broader patterns of land-use behaviour. Hunter-gatherer populations are also highly influenced by the distribution and predictability of food and water resources, and changes to these variables are often reflected in terms of stone technology as well. Thus, by incorporating knowledge of the lithic resources of the Iringa highlands with MSA technology from the site it is possible to better understand how biotic and abiotic environmental forces and stone technology were integrated at Magubike (Table 2.2).

The section below is a break-down of the lithic raw materials found at the site, contextualized within a geological understanding of the Iringa landscape. These observations factor into discussions of availability, land-use and procurement behaviour. A typological analysis is also presented, with an emphasis on how the representation of different artifact types in the sequence changed by level, and what this might reflect in terms of adaptive behaviour. A technological analysis of the artifacts was further used to trace specific reduction pathways and reinforce the conclusions concerning raw material economy. Lastly, a means of measuring reduction intensity was deployed to quantify the extent to which different materials were reduced, and how reduction intensity varied by level. These data are developed into a discussion of probable causes.

2.4.1 RAW MATERIALS

In Test Pit 12, small cobbles of quartz, and a range of metamorphic stones, formed the bulk of the lithic materials during the MSA (47.1%, n = 6311 and 43.6%, n = 5836 respectively) (Figs. 2.5 and 2.6). Vein quartz from decaying granites is ubiquitous on the modern surface around the rockshelter, and if the present distribution of quartz is at all similar to past conditions it would have been possible for MSA hominins to collect it in large quantities without expending much effort or time. However, local quartz is extant almost exclusively in the form of small rounded cobbles (between 3 and 6 cm in maximum dimension on average) and fractures unpredictably due to the common occurrence of internal fracture planes, which contribute to a high proportion of shatter. Its value may therefore have been diminished to some extent by its relative resistance to shaping (Biittner 2011).

The other major source of lithic material used by Magubike hominins was metamorphic rock. This category encompasses an assortment of macroscopically identical material types that are generally fine to course-grained, dark in colour, and found in larger pieces than the local quartz. Like quartz, no primary sources for metamorphic stones are evident, and it is likely that they were collected in the form of weathered cobbles from nearby stream-beds or other secondary contexts.

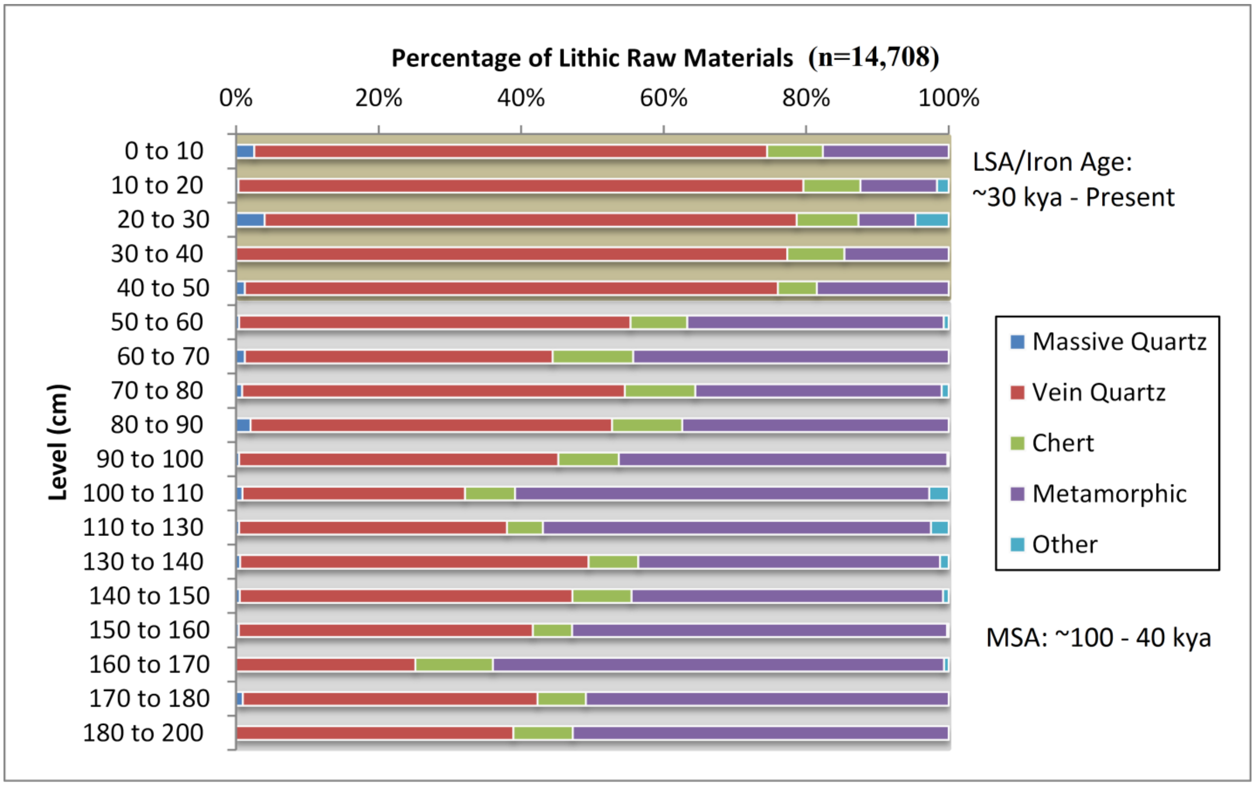


Fig. 2.5. Percentage of Lithic Raw Materials by Level.

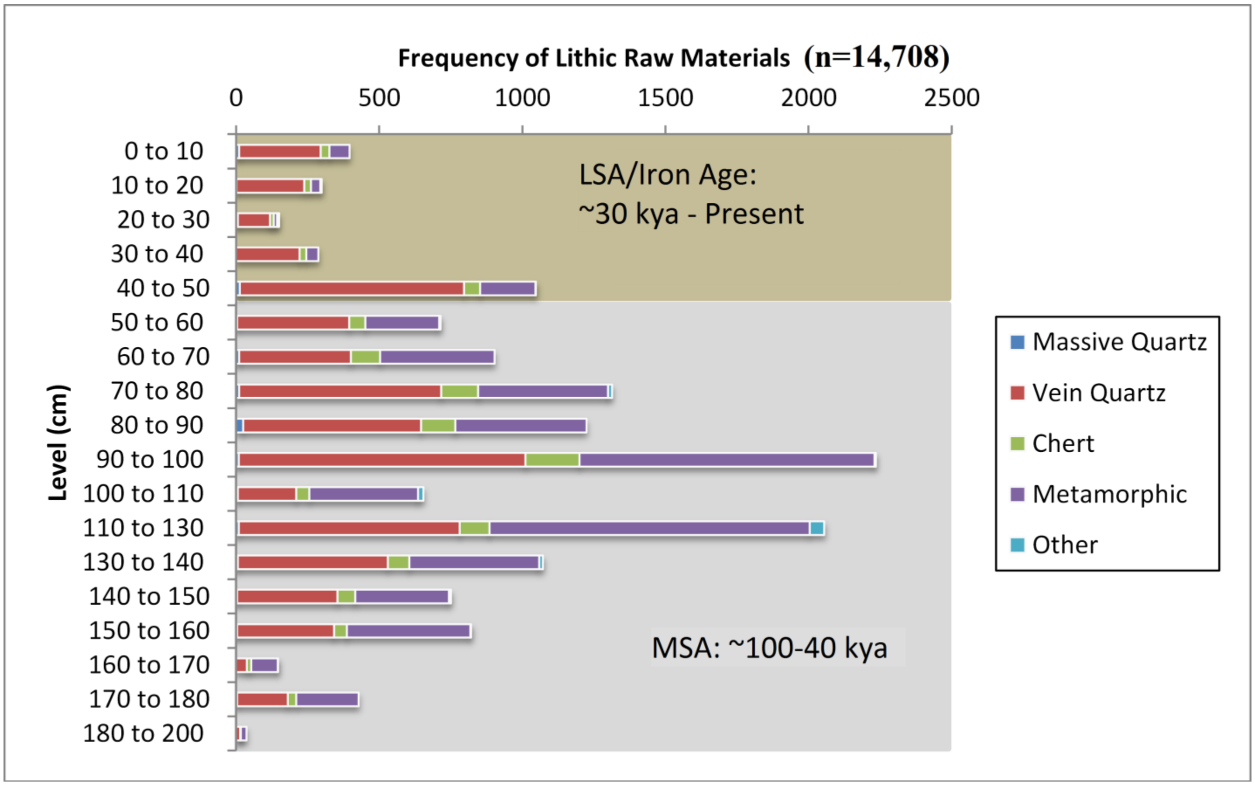


Fig. 2.6. Frequency of Lithic Raw Materials by Level.

Small quantities of chert were also present in the MSA assemblage (chert: 7.6%, n = 1119). Chert appears to have been present in the form of small weathered pebbles that likely eroded and were transported from their source locations. Although no chert sources are recorded on local geological maps, a study of the available information indicates that they may have derived from limestone deposits approximately 50 km from the Magubike site, and then been relocated by alluvial action. Further survey is planned to confirm these suspicions.

Despite the general pattern described above, the proportion with which these different materials were utilized during the MSA at Magubike shows evidence of change by level. While chert remained a consistently minor part of the assemblage, quartz increased in proportion at the expense of metamorphic stones. The change in raw material preference appears to have been gradual, taking place over several excavation levels, although a more dramatic, step-wise, increase in quartz is visible between levels 40–50 and 50–60 cm, potentially corresponding to the transition to the LSA (Figs. 2.5 and 2.6).

2.4.2 LITHIC TYPOLOGY AND TECHNOLOGICAL ORGANIZATION

For the sake of comparability, lithic artefacts were classified according to Mehlman's (1989) typology for Mumba and Nasera, which includes four general categories: trimmed (retouched) pieces, cores, debitage and non-flaked stone (see Table 2.3). For the purpose of calculating frequencies and proportions all collected pieces were tabulated. As at other MSA sites, very few trimmed pieces were recovered from the Magubike site (5.3%, n = 797) (Barham 2002; Schoville 2010). Those flakes that were retouched were generally lightly transformed into an assortment of scrapers, points and backed pieces. The degree of retouch intensity was, in most cases, very minor, and most pieces were not retouched beyond the margins of the tool. However, materials such as chert appear to have been selected for more intensive modification relative to more common and less workable materials like quartz.

It is likely that most tools were used expediently with little or no time invested in secondary modification, and edge damage, possibly attributable to utilization, was noted on many unretouched specimens (n = 415). While retouched tools remained a minor part of the MSA stone artefact assemblage, they did increase slightly in proportion and frequency through time (Figs. 2.7, 2.8). For the most part, this trend was generated by the frequency of backed pieces, which became increasingly common while points and scrapers were gradually phased out (Figs. 2.9, 2.10; Table 2.4). Unlike backed tools from later periods that are typically produced from blades and bladelets, most of the backed segments from the Magubike site appear to have been opportunistically created from large conveniently shaped flakes (Barham 2002). The backed pieces from Magubike also declined in size during the MSA, showing continuity with the smaller backed tools found in the subsequent LSA and Iron Age.

Scrapers from Magubike were predominantly created from quartz (n = 132, 54%) and metamorphic stones (n = 66, 30%). Although too few scrapers were recovered in each level to perform a statistical analysis they appear to show little variation over time. This trend is mirrored by points, which were uniformly made from quartz and metamorphic stones in each level (n = 29 and n = 30, respectively). Lastly, backed pieces were made almost exclusively using quartz (n = 205, 85%). This tendency does not seem to have changed with site level. For greater detail regarding artefact types and raw material see Table 2.2.

Core technology at the Magubike site was also relatively uniform chronologically. Bipolar cores comprised just over 85% (n = 489) of all cores in Test Pit 12. In this study bipolar cores are defined as having been reduced using the hammer-and-anvil technique in contrast to cores that were exploited from two opposing platforms. Many flakes also show evidence of having been produced using bipolar technology, such as battering on opposite ends in conjunction with overlapping step fractures and wedging initiations. It is clear that this method was deployed in response to the properties of local lithic materials, particularly quartz. Since Iringa quartz is found in the form of small round pieces, bipolar reduction may have been one of few viable strategies available to MSA hominins at the Magubike site. Most other cores appear to have been worked opportunistically from multiple platforms, or peripherally in a slightly more patterned manner. Although no classic Levallois cores were found, some flakes show evidence of Levallois-like core preparation, including multi-faceted platforms and radial or converging dorsal flake scars (Van Peer 1992). It is possible that Levallois cores were further worked using other methods, such as bipolar flaking, after they had been otherwise exhausted.

Middle Stone Age points at Magubike, in particular, seem to have been primarily produced using Levallois methods. These points were mostly made by removing flakes from adjacent platforms of the core, the scars of which converge to produce a triangular outline. Most points also showed evidence of platform preparation such as trimming and faceting, and some are characterized by modifications to the base subsequent to removal. These modifications take the form of flake removals from the dorsal and ventral surfaces, initiated from the platform, after the piece was struck from the core. Subsequent removals were presumably to facilitate hafting, although the precise function of MSA points from Magubike remains unknown.

The MSA occupants of the Magubike site also produced a large number of linear flakes that were classified as blades (n = 298). However, no blade cores have been found to date, and it is unclear if the behaviour was intentional (i.e., incidental to some other form of reduction) or if blades were transported to the site from elsewhere. Unlike trimmed pieces, which demonstrated differences in proportional representation through time, bipolar, multiple platform and peripheral/radial cores were randomly distributed throughout the sequence (Figs. 2.11, 2.12). We conclude that although the end products of the reduction sequence appear to have exhibited change over time, the methods of producing flake blanks remained relatively constant.

Nevertheless, raw material was significantly related to core type, suggesting the existence of different reduction pathways ($\chi2 = 42.254$ (df = 4), $p < 0.0001$). Specifically, quartz was the favoured material for bipolar and peripheral/radial cores while metamorphic stones were preferred for multi-platform and Levallois-like cores. Although chert cores were rare, they were most likely to be peripherally flaked. More detail on the raw material composition of cores by level is shown in Table 2.5.

As with most lithic assemblages, debitage formed the single largest category of stone artefacts (91.0%, n = 12,189). Most of this material was composed of flake fragments and angular shatter. However, a large number of whole flakes (n = 3165) and blades (n = 298) were also found. It is probable that many of these were used as expedient tools and then discarded shortly afterwards. As noted earlier, a total of 415 of these flakes and blades exhibited signs of utilization. The distribution of cortex on these flakes indicates that all stages of reduction were practiced in the rockshelter (Toth 1987). Given the profusion of stones readily available within a few kilometers of the shelter, the cost of transporting unmodified cobbles would have been relatively low, and extensive field processing may not have been required. Very few non-flaked stones were collected during excavation, many of which were not modified; they are therefore not described in any detail here (n = 4).

In summary, there appear to have been several different operational chains active at Magubike, which were somewhat material dependent. Few of the end-products of these sequences were comprehensively retouched, which is typical of other Tanzanian assemblages; although, pieces possibly bearing damage as a result of utilization suggest that the inhabitants of Magubike were manipulating different reduction sequences to produce varied blank or edge morphologies to use as tools. By far the most common chain involved the collection of small quartz cobbles and pebbles, abundant in the Iringa landscape, for transformation into expedient tools and backed pieces. Cortex on flakes and cores confirms that cobbles were brought to the site with little prior processing, and that the majority of reduction took place within the rockshelter. Most quartz cores were subsequently reduced using bipolar methods in order to achieve viable blanks, although a few of the larger quartz pieces were evidently selected for radial or opportunistic flaking. In a similar fashion, larger weathered cobbles of metamorphic materials were brought in a raw form to the site. From there they were transformed into blanks using either a casual, un-patterned approach or a more refined radial/Levallois method. Most metamorphic flakes were likely used expediently given a similar lack of formal tools. Conversely, some metamorphic blanks were transformed into scrapers and points with only a few used to create backed pieces (n = 9, 3.8%). Lastly, Iringa chert is found sporadically in the form of rounded cobbles no larger than 8–10 cm. These pieces were most often reduced bipolarly to produce sharp flakes and small tools, but were more likely than either quartz or metamorphic cores to show signs of meticulous radial flaking (17% compared to 5% for quartz and 4% for metamorphic stones). The majority of formal chert tools were scrapers and backed tools (37% and 30% respectively).

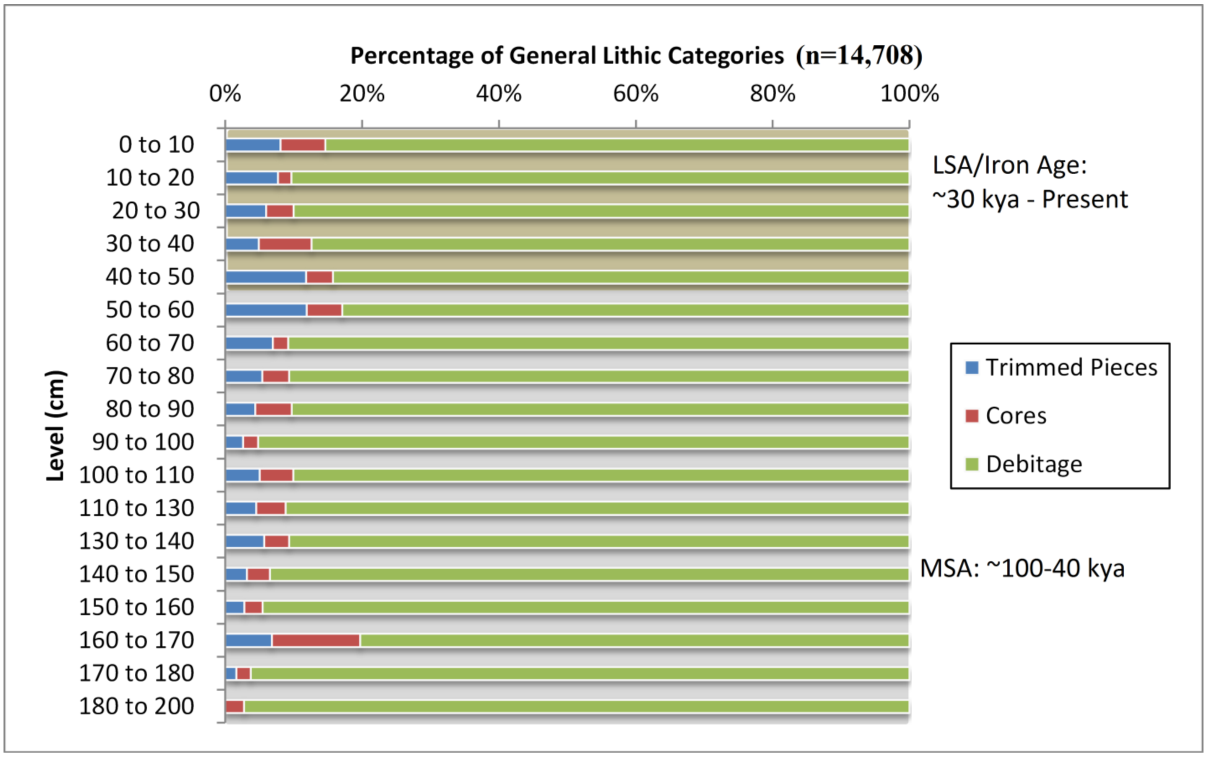


Fig. 2.7. Percentage of General Lithic Categories by Level (Angular fragments removed).

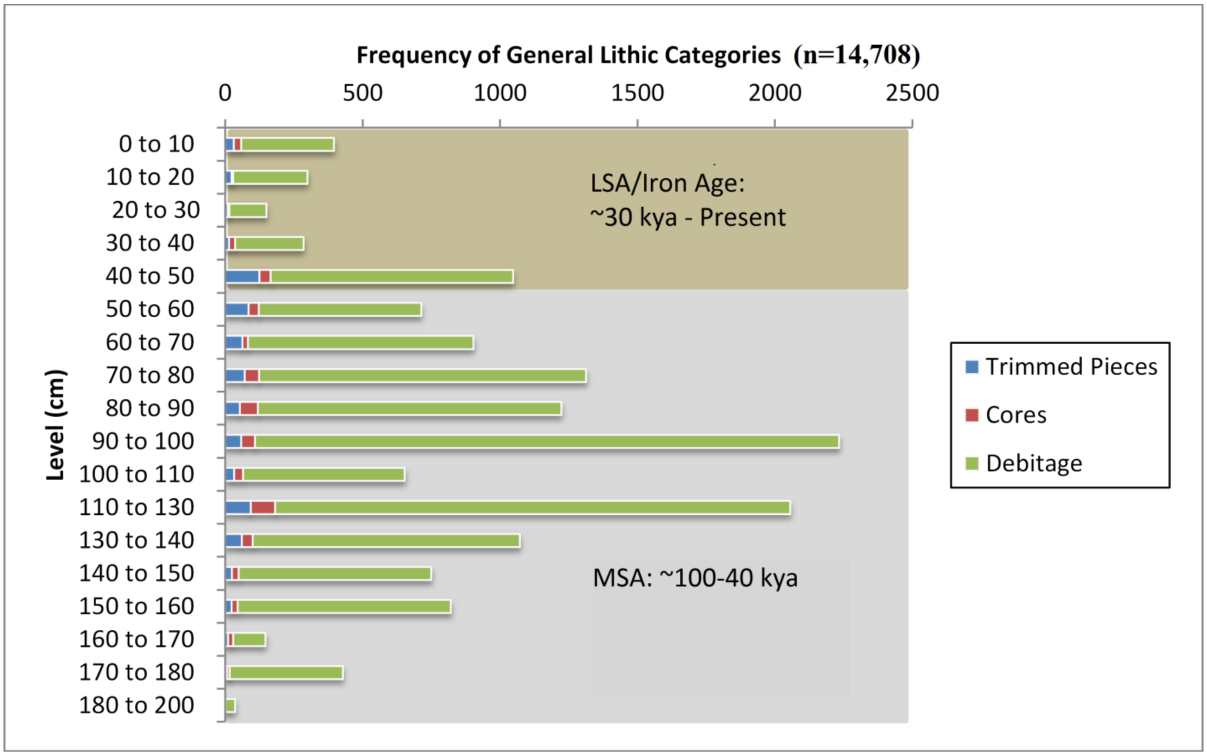


Fig. 2.8. Frequency of General Lithic Categories by Level (Angular fragments removed).

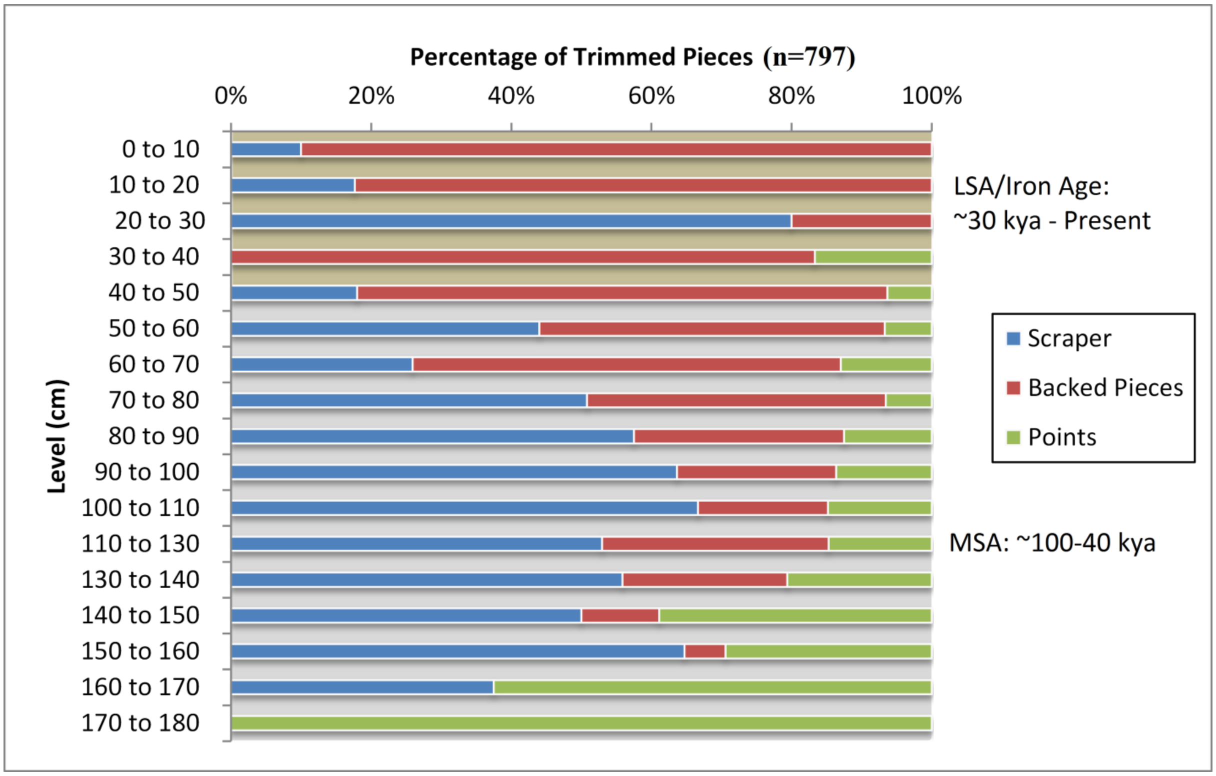


Fig. 2.9. Percentage of Trimmed Pieces by Level.

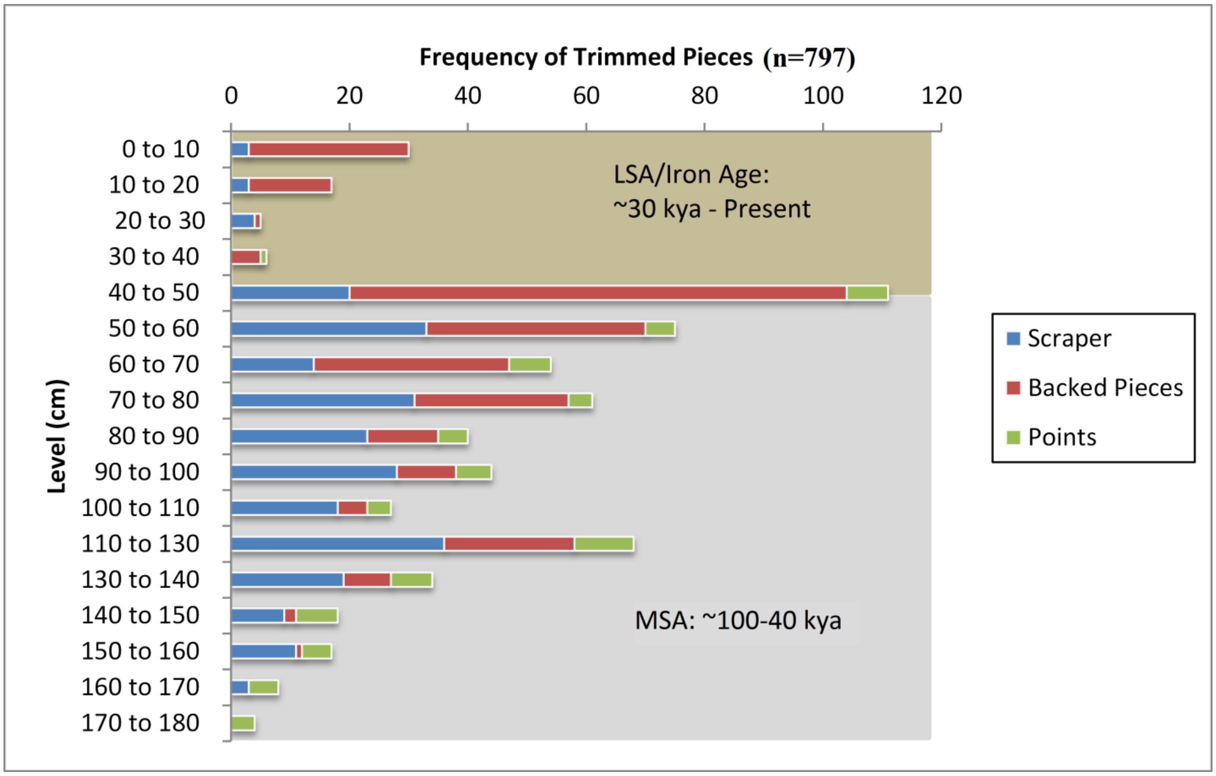
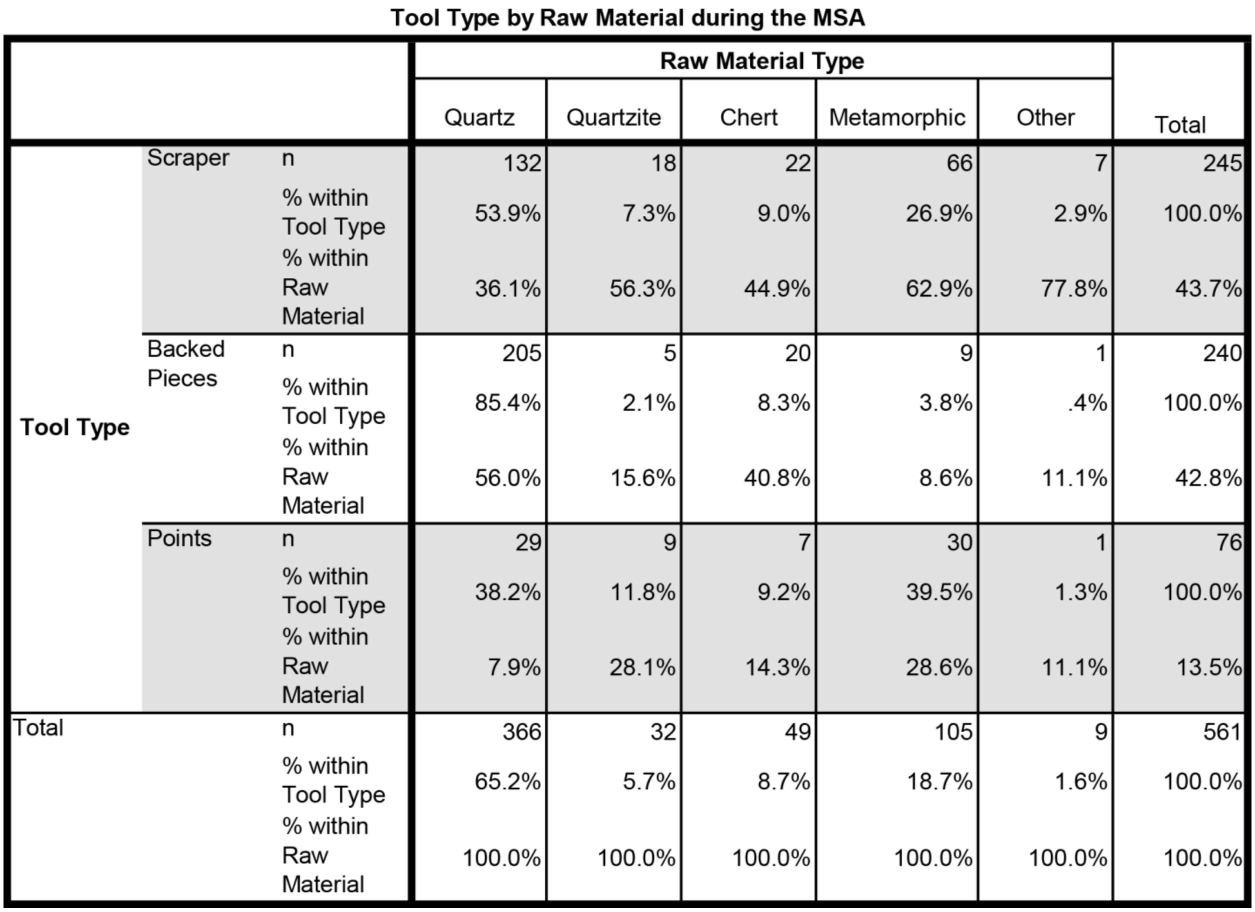


Fig. 2.10. Frequency of Trimmed Pieces by Level.

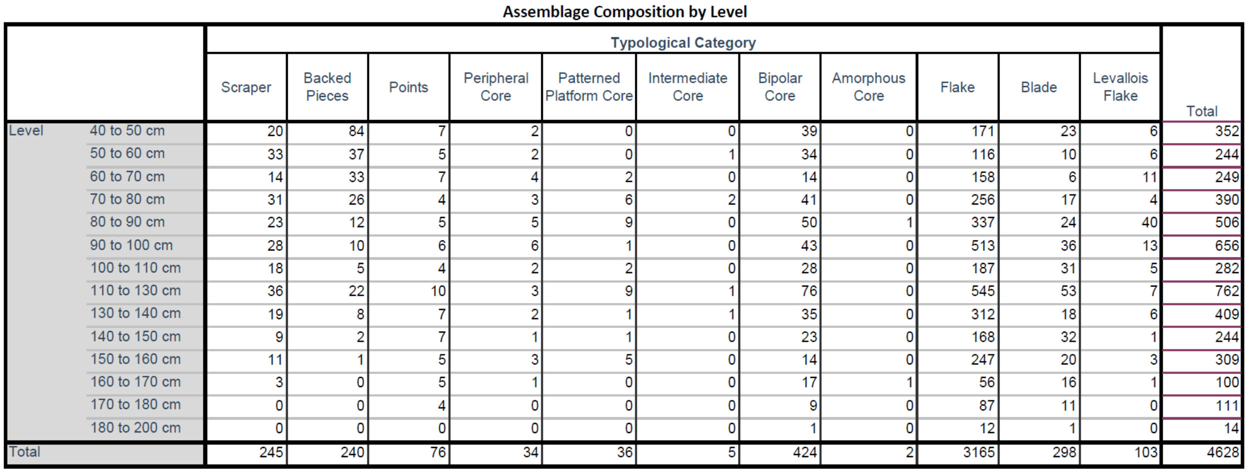
Table 2.2. Tool Type by Raw Material during the MSA.



Tool Type by Raw Material during the MSA

			Raw Material Type					
			Quartz	Quartzite	Chert	Metamorphic	Other	Total
Tool Type	Scraper	n	132	18	22	66	7	245
		% within Tool Type	53.9%	7.3%	9.0%	26.9%	2.9%	100.0%
		% within Raw Material	36.1%	56.3%	44.9%	62.9%	77.8%	43.7%
	Backed Pieces	n	205	5	20	9	1	240
		% within Tool Type	85.4%	2.1%	8.3%	3.8%	.4%	100.0%
		% within Raw Material	56.0%	15.6%	40.8%	8.6%	11.1%	42.8%
	Points	n	29	9	7	30	1	76
		% within Tool Type	38.2%	11.8%	9.2%	39.5%	1.3%	100.0%
		% within Raw Material	7.9%	28.1%	14.3%	28.6%	11.1%	13.5%
Total		n	366	32	49	105	9	561
		% within Tool Type	65.2%	5.7%	8.7%	18.7%	1.6%	100.0%
		% within Raw Material	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

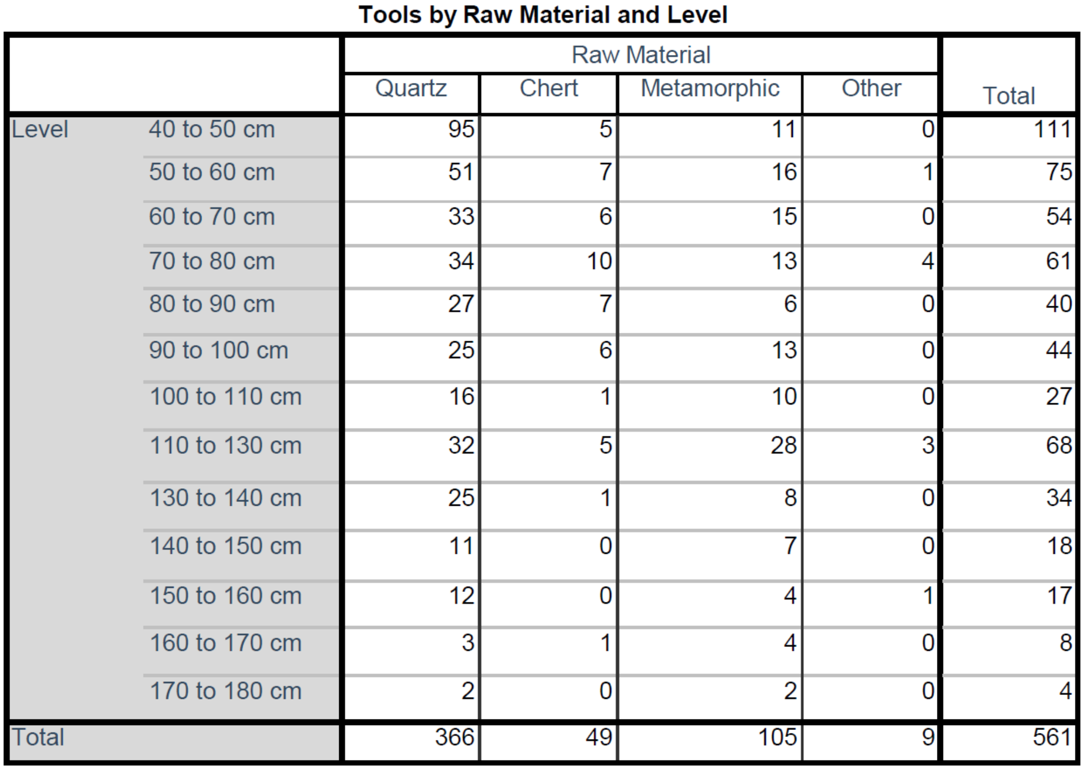
Table 2.3. Assemblage Composition by Level.



Assemblage Composition by Level

		Typological Category											
		Scraper	Backed Pieces	Points	Peripheral Core	Patterned Platform Core	Intermediate Core	Bipolar Core	Amorphous Core	Flake	Blade	Levallois Flake	Total
Level	40 to 50 cm	20	84	7	2	0	0	39	0	171	23	6	352
	50 to 60 cm	33	37	5	2	0	1	34	0	116	10	6	244
	60 to 70 cm	14	33	7	4	2	0	14	0	158	6	11	249
	70 to 80 cm	31	26	4	3	6	2	41	0	256	17	4	390
	80 to 90 cm	23	12	5	5	9	0	50	1	337	24	40	506
	90 to 100 cm	28	10	6	6	1	0	43	0	513	36	13	656
	100 to 110 cm	18	5	4	2	2	0	28	0	187	31	5	282
	110 to 130 cm	36	22	10	3	9	1	76	0	545	53	7	762
	130 to 140 cm	19	8	7	2	1	1	35	0	312	18	6	409
	140 to 150 cm	9	2	7	1	1	0	23	0	168	32	1	244
	150 to 160 cm	11	1	5	3	5	0	14	0	247	20	3	309
	160 to 170 cm	3	0	5	1	0	0	17	1	56	16	1	100
	170 to 180 cm	0	0	4	0	0	0	9	0	87	11	0	111
	180 to 200 cm	0	0	0	0	0	0	1	0	12	1	0	14
Total		245	240	76	34	36	5	424	2	3165	298	103	4628

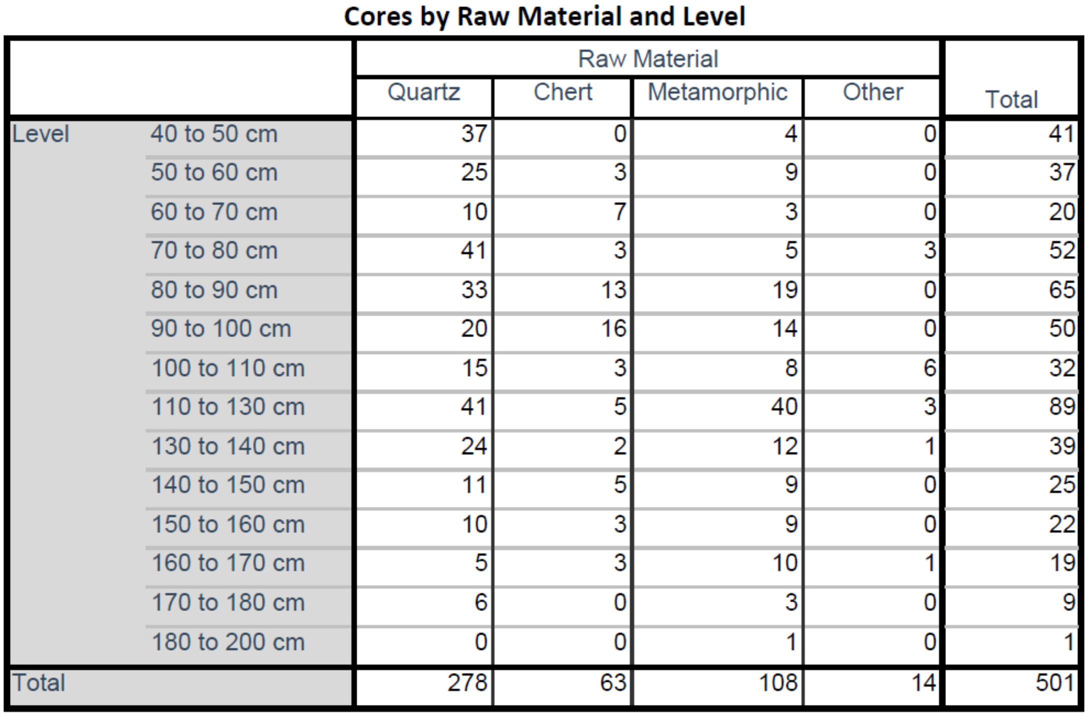
Table 2.4. Tools by Raw Material and Level.



Tools by Raw Material and Level

		Raw Material				Total
		Quartz	Chert	Metamorphic	Other	
Level	40 to 50 cm	95	5	11	0	111
	50 to 60 cm	51	7	16	1	75
	60 to 70 cm	33	6	15	0	54
	70 to 80 cm	34	10	13	4	61
	80 to 90 cm	27	7	6	0	40
	90 to 100 cm	25	6	13	0	44
	100 to 110 cm	16	1	10	0	27
	110 to 130 cm	32	5	28	3	68
	130 to 140 cm	25	1	8	0	34
	140 to 150 cm	11	0	7	0	18
	150 to 160 cm	12	0	4	1	17
	160 to 170 cm	3	1	4	0	8
	170 to 180 cm	2	0	2	0	4
Total		366	49	105	9	561

Table 2.5. Cores by Raw Material and Level.



Cores by Raw Material and Level

		Raw Material				Total
		Quartz	Chert	Metamorphic	Other	
Level	40 to 50 cm	37	0	4	0	41
	50 to 60 cm	25	3	9	0	37
	60 to 70 cm	10	7	3	0	20
	70 to 80 cm	41	3	5	3	52
	80 to 90 cm	33	13	19	0	65
	90 to 100 cm	20	16	14	0	50
	100 to 110 cm	15	3	8	6	32
	110 to 130 cm	41	5	40	3	89
	130 to 140 cm	24	2	12	1	39
	140 to 150 cm	11	5	9	0	25
	150 to 160 cm	10	3	9	0	22
	160 to 170 cm	5	3	10	1	19
	170 to 180 cm	6	0	3	0	9
	180 to 200 cm	0	0	1	0	1
Total		278	63	108	14	501

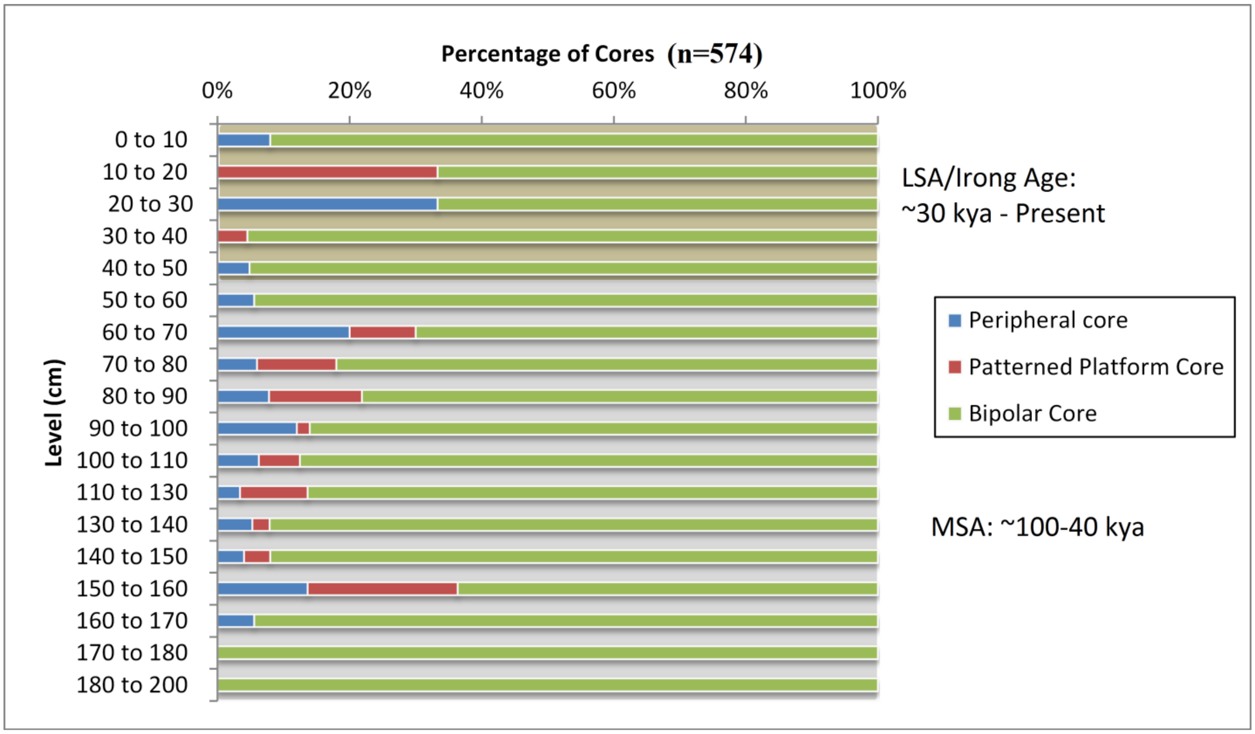


Fig. 2.11. Percentage of Cores by Level.

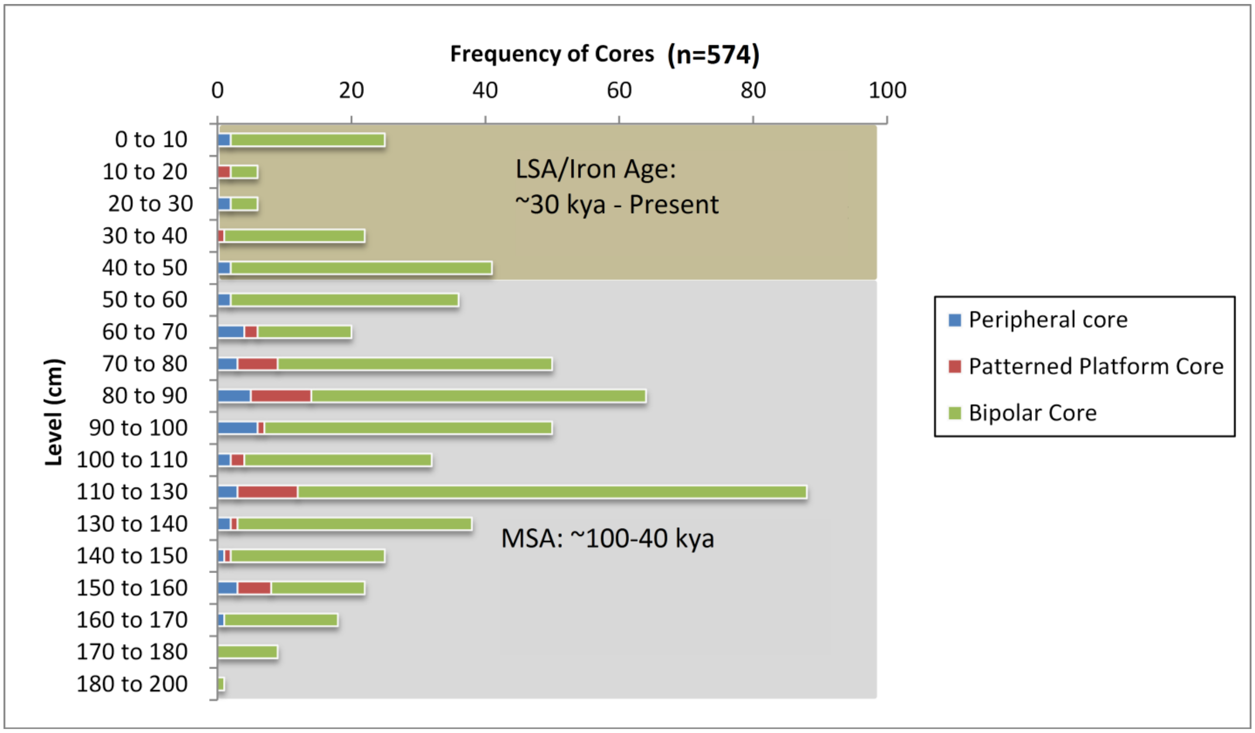


Fig. 2.12. Frequency of Cores by Level.

2.4.3 LITHIC REDUCTION INTENSITY

During the Late Pleistocene, fluctuations in environmental and demographic pressure appear to have had significant impacts on the settlement behaviour of MSA humans across Africa (Blome et al. 2012; Lane et al. 2013; McCall 2007). The cascading effects of these shifts likely transformed the ways in which early humans organized their subsistence strategies, social networks, and technology. If so, many of the adaptive choices made by MSA hominins would have been subsequently manifest in their use of lithic materials. In particular, the intensity with which materials were reduced is intimately linked to raw material requirements, availability and quality, and thus provides an effective means of recognizing changes in mobility, home-range size, trade, raw material preferences and transport (Barut 1994; Dibble et al. 2005; Marwick 2008).

Archaeological and ethnographic research has demonstrated that humans largely make cost-effective decisions about lithic raw material procurement (Andrefsky 2005; Bamforth 1986; Barut 1994; Bicho 2002; Gould and Saggers 1985; McCall 2007). This tendency usually results in the preferred use of local materials over those located more distantly, especially if raw material quality is held constant. Because of this relationship, higher procurement and transportation investments are frequently correlated with higher reduction intensity, as foragers implement practices to maximize high quality materials obtained at greater cost (Marks et al. 1991; Marwick 2008). Nevertheless, it is worth noting that the raw material quality requirements of certain technological approaches can significantly alter the relationship between procurement and mobility (Bamforth 1986; Gould and Saggers 1985). In the event that material requirements are not met locally, groups may move further in search of them or realign their reduction strategies to accommodate existing resources. On the other hand, if materials quality requirements are low, or raw materials are ubiquitous, evidence of a raw material selectivity may be minimal or non-existent (Barut 1994; Marks et al. 1991). Even so, variation in the distances to sources of under 2 km have been shown to have significant impacts on the raw material content of assemblages (Marks et al. 1991) and even minor differences in the way that raw materials are distributed can influence the manner and frequency with which they are collected, and how they are transformed within assemblages.

Raw material constraints are also associated with the adoption of different technological approaches. Levallois-like reduction strategies, for instance, are thought to be inhibited by regions where nodule size is small or low quality, and quantities of tool-stone are limited (Brantingham and Kuhn 2001; Sandgathe 2004; Van Peer 1992). The change to backed tool assemblages during the Howiesons Poort are also thought to be associated with a program of intensification in response to limits on material availability (Eren et al. 2008; Lombard 2005). However, rather than altering their technological approaches, prehistoric people may have simply opted to extend the use-life of cores by continuing the reduction process even after the core morphology was no longer ideal (Marks et al. 1991). In practice, both of these approaches may have been adopted to gain the most usable materials from a finite quantity of stones.

Because of its relevance to a number of common archaeological questions a series of different metrics have been developed and deployed to measure reduction intensity in stone tool assemblages (Blades 2003; Clarkson 2010; Clarkson and Hiscock 2008; Henry 1989; Hiscock and Clarkson 2005; Hiscock and Tabrett 2010; Marwick 2008). However, not all of these methods are applicable to all types of lithic assemblages. Techniques that focus on tool retouch, for instance, may be inappropriate for MSA artefacts, which often feature absent or minimal retouch. Due to a general lack of formal tools, approaches targeted at core rather than tool reduction may be more practicable. Conventional wisdom and experimentation show that as core reduction intensity increases core mass and the amount of cortex present generally decline (Henry 1989; Marks et al. 1991; Newcomer 1971). Simultaneously, as cores are reduced, the number of flake scars on their surface increases. Nevertheless, certain considerations prohibit these generalizations from being truly predictive. One important factor is nodule size, which significantly informs the size of the core at discard. In short, nodules that were small to begin with tend to be small when exhausted. Flake scar count is also somewhat dependent on variation in core size. In general, smaller cores will tend to have fewer flake scars, as a result of their reduced surface area. Finally, cortical surface is also sensitive to factors unrelated to reduction intensity, and some technological approaches, such as Levallois methods, may leave cortex until late in the reduction process (Van Peer 1992).

In an attempt to resolve some of these issues, Clarkson (2013) introduced a technique to measure core reduction in MSA assemblages using 3D scanning technology. His technique relies on the assumption that as core mass decreases, the ratio of flake scars to remaining surface area will increase. To quantify this relationship, flake scar count is standardized against core surface area to produce a new value called the Scar Density Index (SDI) represented by the number of flake scars per unit squared of surface area. Although Clarkson (2013) advocated the use of a 3D scanner to achieve the most accurate measurements of surface area, he noted a strong and significant correlation between scanner and caliper derived measurements ($r = 0.949$, $p = 0.0001$). Lin et al. (2010) also commented that although the error-range of non-scanning methods of surface area measurement can potentially be considerable for individual artefacts, this error was substantially mitigated as sample size increased. Furthermore, while 3D scanning results are undoubtedly more accurate, the cumulative time to scan individual artefacts can be prohibitive for very large samples. Here it is shown that a modified version of SDI, based on caliper measurements, can still effectively detect diachronic differences in reduction intensity as well as differences in reduction intensity between different raw material types.

2.4.4 FLAKE SCAR DENSITY INDEX (SDI) METHODS AND RESULTS

To measure relative reduction intensity, the SDI of 501 cores was calculated, as per Clarkson (2013). The geometric solid that produced the best approximation of surface area was a rectangular prism, the surface area of which is simple to calculate and requires only a few basic measurements that are commonly recorded by lithic analysts (length, width and thickness). Core length in this study was obtained by measuring the maximum dimension of the core. Core width was defined as the second longest dimension perpendicular to the length, and core thickness was defined as the third longest dimension perpendicular to the length (Andrefsky 2005). All cores were measured in this way and the data were entered into an IBM SPSS Statistics database for manipulation.

The compiled results (Figs. 2.13, 2.14) show that there was a significant difference in the way in which raw materials were reduced during the MSA at Magubike (ANOVA, df = 3, F = 8.713, p = 0.0001). Chert appears to have been most intensively conserved relative to other materials, despite forming only a small percentage of the MSA assemblage (Fig. 2.12). The next most reduced material was quartz, followed by metamorphic and other stones (Fig. 2.5). Quartz was significantly more reduced than metamorphic stones (t = 2.472, df = 419, p = 0.014), while metamorphic and other stones did not differ in the extent to which they were utilized (t = −.364, df = 118, p = 0.717). These differences suggest that a pronounced raw material economy existed during the MSA, which was responsive to factors such as lithic availability, abundance and quality.

Reduction intensity also varied by level during the MSA (Fig. 2.14). A significant increase in SDI for all materials was observed from the oldest layers through to the youngest (rs = − 0.253, df = 12, p = 0.0001). This trend suggests that the Magubike hominins were making more conservative use of stone resources at the end of the MSA relative to the beginning.

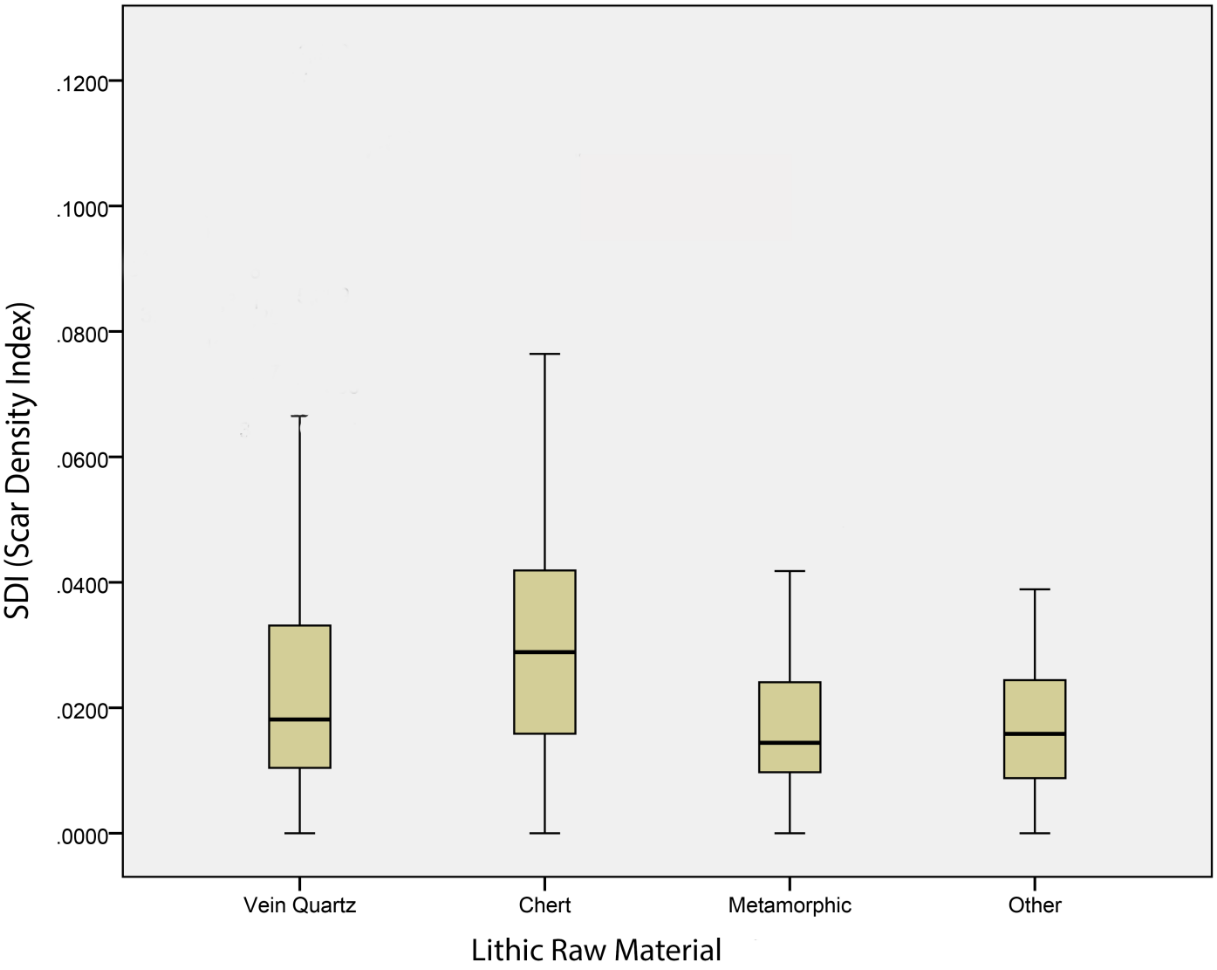


Fig. 2.13. Differences in SDI according to Raw Material.

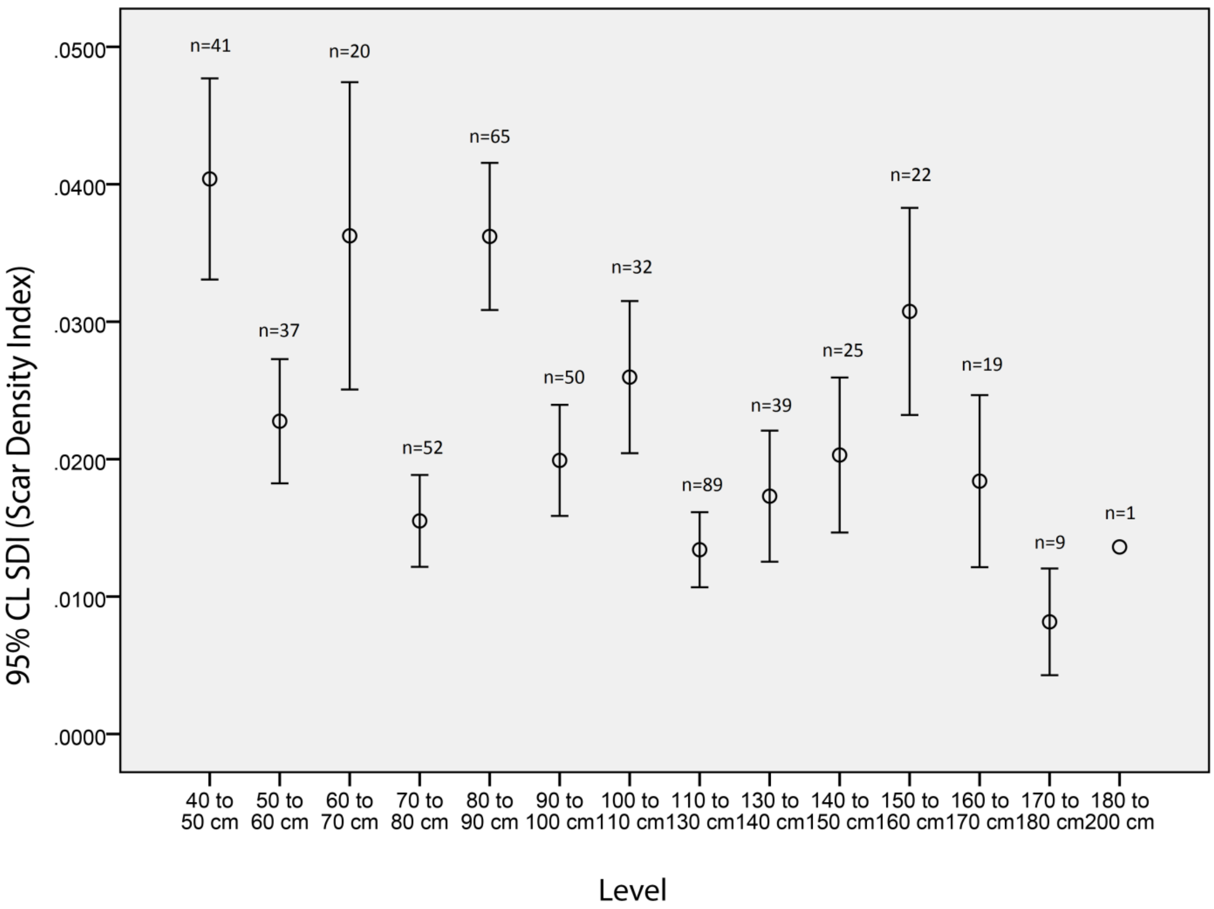


Fig. 2.14. Differences in SDI according to Level with 95% confidence level (CL) bars.

2.5 DISCUSSION

The analysis presented here is intended to contribute to the rapidly growing body of information available regarding the ways in which early human foragers met the demands of local environmental conditions during the MSA in eastern Africa. To date, the archaeological information available for eastern Africa indicates a general pattern of adaptation marked by gradual change, high diversity and a relative lack of clearly circumscribed industries such as the Howiesons Poort or Still Bay (Tryon and Faith 2013). This pattern is reinforced at Magubike, which exhibits a gradual unidirectional change in raw material preference, typology and reduction intensity. Here we explore several possible causes.

On the basis of SDI measurements, several conclusions can be drawn regarding raw material economy at Magubike during the MSA. Overall, chert was reduced much more intensely than other materials, suggesting that attempts were made to maximize this resource. Furthermore, it was far more likely to be flaked using economical strategies and modified by retouching. Despite an apparent preference for chert, its limited frequency in the MSA levels at Magubike is an indication that it was less abundant locally than other materials, or was more costly to access. Survey of the area is consistent with this assumption, and discrete chert sources have yet to be located in the area surrounding Magubike. Rather, chert in this region appears to be present as small isolated nodules, which likely formed as precipitates within a chalky matrix that was subsequently eroded. Given the unpredictable and patchy distribution of chert, it is probable that nodules of pebble chert were simply collected as they were encountered on the landscape during the course of other activities rather than targeted for acquisition. Early survey work shows that they may have been recoverable from stream beds and other catchments alongside other lithic materials. This theory of lithic access is further supported by water rounded cortex on chert flakes and cores.

Quartz, on the other hand, appears to have been a staple stone resource during the MSA and LSA. Like chert, non-centralized concentrations of quartz are scattered unpredictably across the Iringa landscape. It is therefore probable that this resource was also exploited as it was encountered. Unlike chert, however, quartz is much more abundant. It is likely for this reasons that quartz was reduced less intensively. Metamorphic and other stones, on the other hand, were the least intensively reduced materials at Magubike. The restricted degree to which metamorphic stones were reduced is likely due to their limited knapping quality, although they may have been preferred from some tasks requiring larger tools.

Reduction intensity during the MSA showed significant diachronic variation as indicated by an overall increase in SDI values between the first occupation of the site and the beginning of the LSA (estimated to be a minimum of 65,000 to 40,000 years). It is possible to speculate that this pattern parallels a transition from warm to cold climate observed during MIS 4 (Blome et al. 2012; Lyons et al. 2015; Scholz et al. 2011). It may even be that Magubike was first occupied by populations tracking steep gradients in altitude in order to exploit the intersections of the numerous and productive environments of Iringa (Ambrose 1998; Basell 2008). Although it is currently not possible to convincingly align the climate record of eastern Africa with the chronology of the site, we are working to clarify the paleoenvironmental context and age of cultural deposits at Magubike in order to test this hypothesis.

Meanwhile, patterns visible in the lithic record of Magubike demonstrate that a significant shift occurred during the MSA, which is consistent with adaptation to decreased environmental productivity (Clarkson 2013; McCall 2007). If the environment around Magubike became less dependable, foragers would have needed to travel larger distances in search of food and water. The rise in reduction intensity at Magubike in the MSA levels may thus be one symptom of the adoption of more mobile life-styles, and a greater reliance on projectile weapons, to track more widely distributed resources. Uncertain access to lithic materials as a result of larger home ranges would have encouraged conservation behaviour, reflected in a rising SDI.

A shift to more arid open landscapes during the Middle to Late Pleistocene is also commensurate with alterations to the tool-kit of MSA foragers at Magubike. Most types of retouched pieces were abandoned or phased out over time, resulting in a reliance on a fairly uniform selection of backed pieces, which presumably expanded to fill the roles of other tool types. The increased reliance on functionally generalized tools may indicate that the distribution of resources became less predictable and increasingly dispersed. Populations might therefore have adapted by creating tools that could be easily suited to a number of different extraction activities that could not be anticipated ahead of time. The increase in the proportion of backed pieces manufactured during the MSA may also reflect a more mobile life-style, as travel distances between resources patches increased, necessitating more portable tools, and the more careful conservation of stone resources.

A preference for backed tools is also associated with the gradual transition to quartz during the MSA levels ($\chi2 = 32.124$, df = 1, $p = 0.0001$). Although the small natural size of Iringa quartz limits its usefulness for manufacturing tools such as Levallois points or bifaces, it may have been conducive to the production of small backed segments. Replication experiments using Iringa quartz show a tendency for small cobbles to break into wedge-like slices when percussed on an anvil due to natural fracture planes within their structure (i.e., with a single cortical surface and two ventral surfaces that converge to a point). These pseudo-backed pieces appear in the Magubike assemblage with and without further retouching in great numbers (n = 240).

Finally, chert appears to have been used more flexibly than either quartz or metamorphic stones. Its superior flaking properties meant that it was equally well suited to the production of a number of different shapes, and was often transformed into scrapers and backed pieces. However, the small natural cobbles of Iringa chert are unsuitable for Levallois methods of reduction because of their size, and consequently, very few points were made using chert (n = 7).

There are also material signals that potentially contrast the notion that populations around Magubike were responding to deleterious changes to their environment. While the observed increase in reduction intensity and small backed tools indicates an escalation in residential or logistical mobility, a lack of retouched tools overall during the MSA at Magubike might point to the presence of a relatively sedentary population. As per Parry and Kelly (1987), mobile peoples are predicted to carry a small tool kit of carefully prepared tools to manage the risk of uncertain lithic availability and the high cost of tool-failure. Sedentary foragers on the other hand are generally more aware of nearby lithic sources and therefore invest comparatively little time producing highly refined tools, given that the cost of tool-failure and replacement is generally low.

Nevertheless, if local stones are of sufficient quality and abundance, both mobile and sedentary groups can exhibit a sedentary-like pattern of raw material usage, characterized by informal tools with little retouch (Gould 1980). The unpredictable access to lithic materials usually experienced by mobile groups may thus have been mitigated to a large extent by the ubiquity of quartz around Magubike, resulting in an assemblage more typical of sedentary groups. What is more, the frequency and proportion of retouched tools does appear to increase through time despite the possibility of mitigating factors. Alternately, the lack of retouched tools at Magubike may be related to a dearth of high-quality materials, such as chert, in the environment causing a realignment of technological approaches (Tryon and Faith 2013).

2.6 CONCLUSIONS

In order to understand the full spectrum of human adaptation during the MSA in eastern Africa it is important to reconstruct the behaviours of humans occupying a range of different places and environments. The purpose of this article is therefore to contribute to the expanding body of data available for Tanzania specifically and eastern Africa more generally. The most significant finding of this study is the existence of a long-term trend in reduction intensity, raw material selection, and artefact typology at Magubike. It is possible that this trend represents the gradual adjustment of MSA populations to a more mobile lifestyle during MIS 4, which likely included a generalist approach to lithic technology and a greater focus on raw material optimization. An exploration of the lithic data indicates behaviours consistent with adaptation to environmental deterioration possibly as a result of lower temperatures and rising aridity during MIS 4. Despite a suggestive pattern in the material culture, it is important to state that the chronology of Magubike cannot be precisely linked to the climate record of eastern Africa at this time, and this hypothesis is provisional awaiting further data. Planned field research, including paleoenvironmental and geoarchaeological analyses, will help to clarify the context in which MSA humans lived at Magubike, and why their approaches to stone resources changed over time.

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CHAPTER 3: BLIND-TESTING THE DAMAGE DISTRIBUTION USE-WEAR METHOD

3.1 INTRODUCTION

The emergence of hafted hunting weaponry, such as stone-tipped thrusting or hand-cast spears, and later the spear thrower and bow and arrow, marked a major transition in the resource procurement systems of early human foragers. Evidence suggests that the earliest forms of these weapons appeared in southern Africa during the transition from the Early Stone Age (ESA) to the Middle Stone Age (MSA) by at least 250 thousand years ago (kya) (Rots, 2013; Rots and Plisson, 2014), and possibly as early as 500 kya (Wilkins et al., 2012, 2015; for a review see Lombard, 2016). For the most part, these early hafted hunting weapons were composed of unretouched triangular flakes affixed to an organic handle using some combination of binding and/or mastic material. These artifacts are found at many sites across Africa and are often assumed to be spear armatures on the basis of morphological similarities with more recent projectile technology and existing functional research (Brooks et al., 2006; Donahue et al., 2004; Milo, 1998; Wilkins et al., 2012).

Nevertheless, we should be wary about assuming that all points shared a comparable function in light of contrasting studies, which show that points frequently had complex use-lives that may or may not have included a hunting function (Schoville, 2010; Van Gijn, 2009; Wendorf and Schild, 1993). Although use-wear analysis is theoretically well-positioned to provide insight on this topic, in practice, the analysis of MSA points has proven challenging for several reasons (Donahue et al., 2004; Shea, 2006). Prior to recovery, many MSA artifacts are exposed to significant levels of post-depositional damage which may act to erase or confuse use-wear and residue signatures. MSA tools manufactured from coarse grained materials are also often resistant to analysis, further limiting the pool of viable specimens (Conte et al., 2015; Shea, 2006). Lastly, diagnostic polishes do not always develop even on experimental hunting weapons, possibly because the period of use is so brief (Rots and Plisson, 2014).

On the other hand, some recognizable types of damage appear to be correlated with hunting (Fischer et al., 1984; Lombard, 2005; Odell and Cowan, 1986). These traces are referred to as diagnostic impact fractures, or DIFs. Although DIFs are one of the preferred ways of identifying hafted hunting weapons in the archaeological record they are not always present on experimental projectiles, and are sometimes found in low frequencies on tools as a result of manufacture or trampling (Pargeter, 2011). This ambiguity limits the utility of DIFs to some extent but may be overcome by analyzing assemblages of artifacts rather than individual specimens. Furthermore, a shared inventory of diagnostic fracture types and terminology has not fully coalesced, resulting in confusion in the reporting of findings (Coppe and Rots, 2017).

In the last decade another method of identifying hunting weapons has been developed and applied to MSA sites in southern Africa (Bird et al., 2007; Wilkins et al., 2012, 2015; Schoville and Brown, 2010; Schoville, 2010, 2014, 2016). The damage distribution method relies on plotting the distribution of edge damage using geographic information system (GIS) software at an assemblage scale, and has been shown to be effective at categorizing assemblages of points. The premise is that as stone tools are used they accrue the most damage on the portion of the edge that is in the most repeated or vigorous contact with the worked surface (Schoville, 2014, 2016). These aggregated damage profiles can then be compared to a reference collection of experimental tools using regression analysis to identify the primary manner with which they were used. For instance, at Pinnacle Point, South Africa, the method implied a scraping rather than hunting function for a series of points (Schoville, 2010; Schoville and Brown, 2010) whereas at Kathu Pan 1, South Africa, the results of the method were used to argue that an assemblage of points were used as spear armatures (Wilkins et al., 2012, 2015).

The technique has the potential to be particularly useful for classes of artifacts which are otherwise resistant to conventional use-wear analyses, such as heavily patinated or coarsely grained stones. It is also claimed to be more objective than conventional methods as it relies on statistical rather than visual comparison. Nevertheless, it is important to be aware that the damage profile of an individual specimen is unlikely to be informative about its function or the function of similar artifacts. Best practice dictates that the method be applied to assemblages of associated artifacts. It is also unlikely that specific contact materials could be identified in this way. For the time being, we make the conservative assertion that the method is best suited to distinguishing between two basic functional modes, which we term tip-dominant and marginal. Tip-dominant assemblages feature a large proportion of damage concentrated at the tips of the artifacts and are associated with uses like hunting, drilling, boring and piercing. Marginal assemblages, on the other hand, are correlated with a variety of cutting and scraping tasks, which causes damage to be dispersed across the lateral margins of the points. This assertion should be true regardless of the lithic type or the contact material.

Clearly, there is likely to be overlap between these use-modes; however, the distinctions that emerge at the level of the assemblage prove sufficient to test important archaeological hypotheses. In contrast, scholars like Rots and Plisson (2014) have raised important theoretical and methodological concerns and caution against the use of the technique. They remain skeptical that the damage distribution method is capable of extracting a coherent pattern from the “noise” introduced by post-depositional damage. This concern is supported by their observation that post-depositional damage is not randomly distributed across artifacts or assemblages, and thus cannot simply be subtracted. However, this claim is contradicted by experimental work that shows the opposite to be true (Asryan et al., 2014; Grosman et al., 2011; Schoville, 2014; Venditti et al., 2016; Wilkins and Schoville, 2016). The more pressing issue they advance is a lack of experimental validation, most notably a lack of blind-testing. We agree with this second point, and thus, the initial stage of our research was devoted to validating the damage distribution method using an experimental collection of points. Another possible confounder of this method is a failure to account for drilling/piercing/perforating as a use-mode. Although evidence for drilling technology during the MSA is surprisingly rare (Orton, 2008) it seems likely that drilling would result in a tip dominated damage profile similar to spear use. This possibility was approached in this study by creating and testing an experimental collection of drilling implements. Lastly, the damage distribution method was applied to a series of MSA points from Magubike Rockshelter, Tanzania. This is the first time that this method has been applied to an eastern African assemblage of prospective hunting weapons.

3.2 MATERIALS AND METHODS

3.2.1 EDGE DAMAGE DISTRIBUTION METHOD

To determine the function of the experimental and Magubike points the distribution of macroscopic damage on the margins of the tools was documented following a modified version of the method described in Schoville (2016). In this study an image analysis approach was integrated with the existing procedure to increase its objectivity, replicability and the speed at which it can be performed. Because the original technique has been presented in detail elsewhere only a brief overview is provided below.

To document the location of edge damage photographs of the artifacts were uploaded to ESRI ArcMap 10.3 and geo-referenced, allowing them to be measured by the in-suite tools. Photographs were captured using a DSC-W330 digital camera mounted on a tripod directly above the specimens. The artifacts and replica tools were photographed against a backdrop of a 1 cm by 1 cm grid for the purpose of geo-referencing. A polyline shapefile was created for each specimen that conformed to the silhouette of the point. The shapefiles were then split to indicate the damaged and undamaged sections of each margin. All observed pre-patination edge damage, regardless of hypothesized source, was documented in this way using ArcMap. Edge damage was identified with the unaided eye and verified at 40–50× magnification using a Dinolite pro digital microscope.

The data were then exported and a regression analysis was performed using IBM SPSS v24 to determine the likeliest source of damage for the Magubike points as well as the experimental assemblage consisting of scraping tools and spears (described in detail below). Potential damage sources (which were entered as predictor variables in SPSS) considered in this analysis were derived from the supplementary data in Schoville et al. (2016) as well as a series of experimental drills manufactured by the author (also described later in this section). Damage profiles from butchery implements and flakes used to field-dress carcasses (both from Schoville et al., 2016) feature high proportions of lateral wear and a result of either variable from the regression analysis was assumed to support a hypothesis of marginal use. Alternately, experimental spear-use (from Schoville et al., 2016) and drilling (this article) produce damage largely on the tips of the points and are thus consistent with tip-dominant usage. The third possibility is that the points were most significantly damaged by taphonomic sources unrelated to use which was tested for by including variables generated from a trampled assemblage and another that had been damaged in a rock tumbler (from Schoville et al., 2016). A result of either of these variables was taken to indicate that the flakes were too badly damaged to extract an interpretable functional signal.

The method described above was modified in this study by incorporating image analysis techniques in the creation of the shapefiles for each specimen. Image analysis refers to any process whereby information is extracted from digital imagery. It is often used for pattern identification and the quantification of image parameters. In the method outlined in Schoville (2010, 2016) the author traced the edges of points by hand in GIS to create the necessary point shapefiles (Schoville, personal communications). Although likely sufficient for the level of detail required this step represents a potential source of error and repeated tracings will almost certainly differ to some extent. To strengthen this aspect of the analysis tools available within ArcMap were used to automatically detect the edges of the point and transform the silhouette into a polyline shapefile. To better allow the program to accomplish this task the raster images were reclassified using the "reclassify" tool available in the "spatial analysis" toolbox. All the pixel values which corresponded to the background were reclassified as "0" while the range of pixel values corresponding to the foreground (the point) were reclassified as "1". Once the image is reclassified, the "raster to polyline" tool in the "conversion" toolbox can be used to transform the image into a shapefile. The "raster to polyline" tool operates by finding the limits of the point and creating a polyline that adheres to the margins of the artifact. The entire process takes only a few seconds, at which point a copy of the original image can be overlain back onto the new shapefile so that damage can be observed and plotted.

In addition to recording and analyzing edge damage using GIS software, evidence of damage diagnostic of hunting was also noted. Because of the continued confusion concerning

DIF terminology, we adopted the attribute based approach developed in Coppe and Rots (2017). These features are typically visible with the unaided eye but each point was also inspected using a Dinolite pro digital microscope (40-50x magnification) to confirm details such as fracture initiation and termination type.

3.2.2 THE EXPERIMENTAL ASSEMBLAGE

Thirty unretouched points were made by the author to test the ability of the damage distribution method to differentiate between tip-dominant and marginal use-modes. All points were made from obsidian using a quartzite hammer-stone and the use of the tools was carried out by two student volunteers (Fig. 3.1). This study employed a qualified double-blind approach, in that the students were not informed of the purpose of the experiment and were instructed only to use the tools in the manner which made the most sense to them. The analysis of the tools was subsequently carried out by the author without foreknowledge of how specific tools were used (although, I was aware of the three tasks for which the tools had been applied in a general sense).

Obsidian was chosen for this experiment because damage to its edges is easy to detect and record. Although the tool-stones used by Schoville et al. (2016) were quartzite and silcrete, we contend that this discrepancy is unlikely to have a significant effect on our results. Undoubtedly, the flaking properties of different materials impact the frequency with which damage is observed, but there is no reason to think that raw material differences would influence the location at which damage occurs.

Of the 30 points, ten were used to drill holes in fragments of ostrich eggshell. This task was accomplished by hafting the drill bits to a wooden dowel using a combination of mastic material and plant fiber (cotton) string. Each drill was then positioned above the shell and rotated rapidly by rolling the handle between the palms of the hands. Drilling was ceased when the drill had dulled to the point of being ineffective – usually after one to two minutes of direct contact. Although more precise measurements of use-duration (or strokes/passes) would be beneficial to future experimentation a naturalistic approach was adopted here to prevent the imposition of artificial restrictions on participants. Unsurprisingly, drilling produced a damage profile with a high frequency of tip damage. A small amount of sporadic damage also occurred along the margins of the tools. This secondary damage is likely related to the method used to haft the drills, which put the margins of the point in contact with the bindings and wood of the handle.

Another ten points were used to scrape bark from tree limbs. The student volunteers (both right handed) were provided with the points and asked to use them to remove the bark and plane the surface of the wood in whatever manner they found most effective. In general, the volunteers made use of the point margins in a pushing and pulling fashion with the dorsal face upwards. For the most part, the tip of the point was directed away from the body, though occasionally this grip was reversed. Both margins of the tools were utilized relatively equally, albeit, in succession as the primary margin dulled. The volunteers were encouraged to discard the tools after they felt they were no longer effective, which usually occurred after four to five minutes.

The remaining ten points were employed as hunting weapons. Most ballistic tests of Stone Age hunting weaponry use actual or simulated animal carcasses as targets (Lombard and Pargeter, 2008; Pargeter et al., 2016). However, assuming that at least some spears were used as projectiles a significant portion of the damage observed on archaeological points can be expected to have been generated from misses (contact with a material other than the intended target). To simulate this fact, and to push the capabilities of the damage distribution method (which was created using animal models), the points were tested by throwing them against a hard target, in this case, the trunk of a tree (*Populus tremuloides*).

Points were affixed to a wooden dowel using the same method described for drills and propelled by hand. Once thrown, points were inspected for damage. Points that had become damaged were carefully removed from the spear shaft and set aside to be photographed, while undamaged points were thrown again at the target. Points were used on average 1.7 times, to a maximum of three, before being recovered. Two of the points experienced catastrophic failure and had to be excluded from analysis.

3.3 THE MAGUBIKE ARCHAEOLOGICAL SITE

The archaeological materials in this study originate from Magubike Rockshelter, a granite overhang located in the highland Iringa region of southern Tanzania (Fig. 3.2). Test excavations conducted in the last decade have revealed sequential historic/Iron Age, Later Stone Age (LSA) and MSA deposits. These excavations uncovered numerous artifacts including ostrich eggshell beads, fossil human and faunal remains, pottery, evidence of iron smithing/smelting in the Iron Age levels and tens of thousands of lithic artifacts (Miller and Willoughby, 2014; Willoughby, 2007, 2012).

AMS radiocarbon and preliminary optically stimulated luminescence dating (OSL) suggest that the site was first occupied during MIS 4, probably sometime between ~100–50 kya. Magubike is located at 1541 m above sea level in an area which today receives approximately 750–1000 mm of annual rainfall. The modern environment of Iringa supports scattered woodland and moist savannah as well as dry montane forests clustered around highpoints in the landscape. The area around Magubike is further characterized by large granite hills intersected by rivers and smaller seasonal streams. As the hills eroded numerous caves and rockshelters were formed that would have been attractive living spaces for Stone Age foragers. Several surveys of the area in 2005, 2008 and 2016 confirm that many of the local rockshelters feature evidence of Stone Age occupation.

The geology of Iringa is exceedingly old. For the most part, the area is composed of Precambrian migmatites and granite that formed during the late Archeaen. The resulting geology represents the subsequent reworking of these deposits. At Magubike, unconsolidated wind-borne particles form the majority of deposits. Disintegrating elements of the granite bedrock are also present towards the base of the sequence. The massive nature of these deposits makes it difficult to delineate natural units which led to the decision to excavate in arbitrary 10 cm spits or levels.

The geology of Iringa also informs the type and availability of toolstone. For the most part, the lithic artifacts from Magubike were produced using three main raw material categories: vein quartz, metamorphic stones and chert. The most common tool-stone in the assemblage is vein quartz yielded by disintegrating local granites. Quartz is found in the form of small rounded and angular pebbles from secondary contexts, which are scattered liberally over the modern Iringa landscape and concentrated in desiccated streambeds. Despite its profusion, Iringa quartz commonly contains internal planes and faults that cause it to fracture unpredictably during shaping.

The second most numerous raw material category at Magubike is metamorphic stone. Although thin sectioning identified multiple varieties, all of the metamorphic stones procured from around the shelter share similar flaking properties, are medium to large grained and dark blue to grey in color. This category is made up of the following sub-types: quartzite, metadiorite, greenschist, metavolcanic and amphibolite (Biittner, 2011), all of which were grouped for analysis on the basis of their inherent similarity to one another and to improve sample size. As a group, unprocessed metamorphic stones are comparatively large (approximately 30 cm in maximum dimension) and rounded cortex visible on some cores suggests that metamorphic cobbles were predominantly collected from nearby high energy streams. Like quartz, metamorphic stones were likely present in large quantities near the site.

Lastly, several fine-grained types of chert may be found locally. These cherts tend to occur in the form of small water-rounded pebbles with thick cortex. There do not appear to be discrete primary sources of chert nearby. Rather, it was likely collected as it was encountered from secondary contexts, probably from the same streambeds that other materials were sourced.

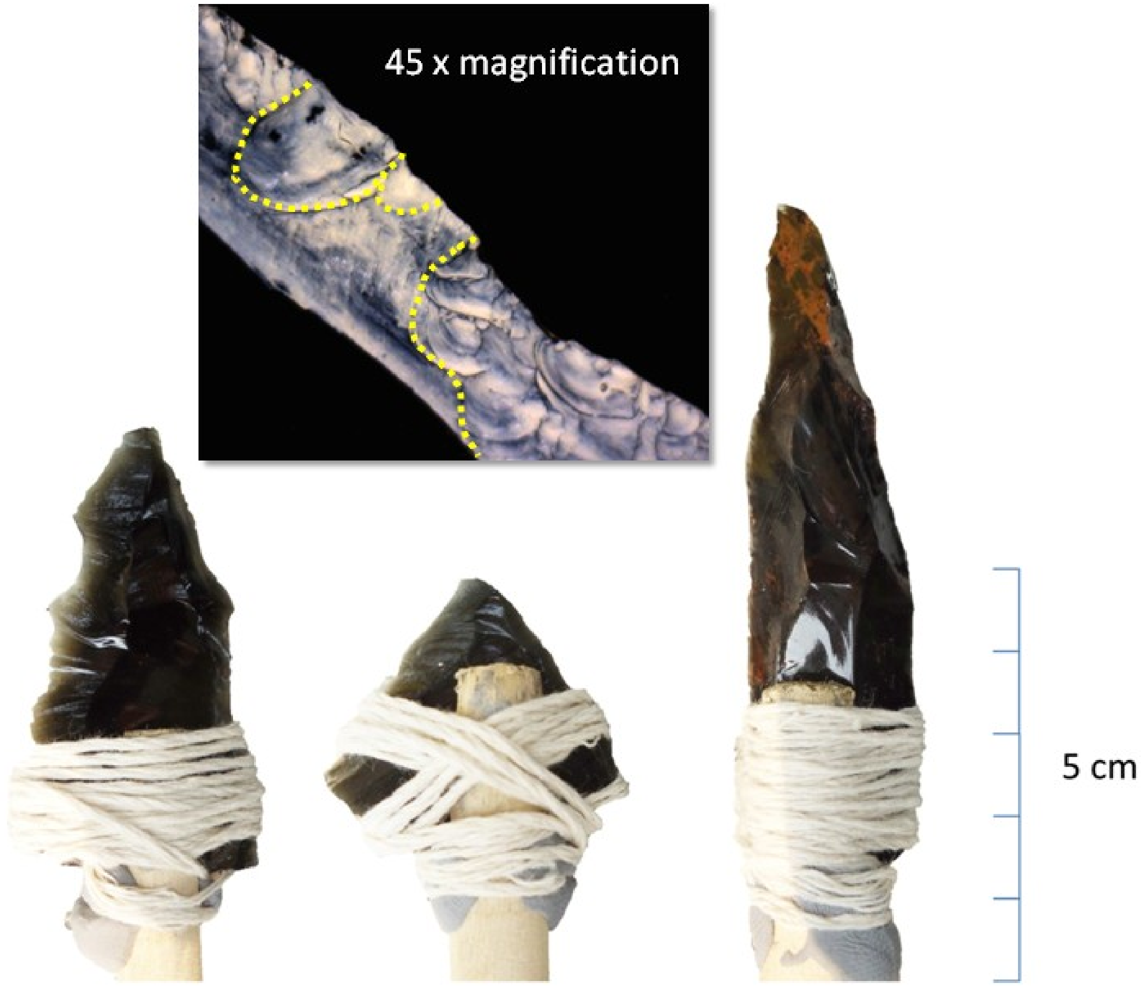

Figure 3.1. Experimental obsidian points hafted to wooden dowels using cotton string.

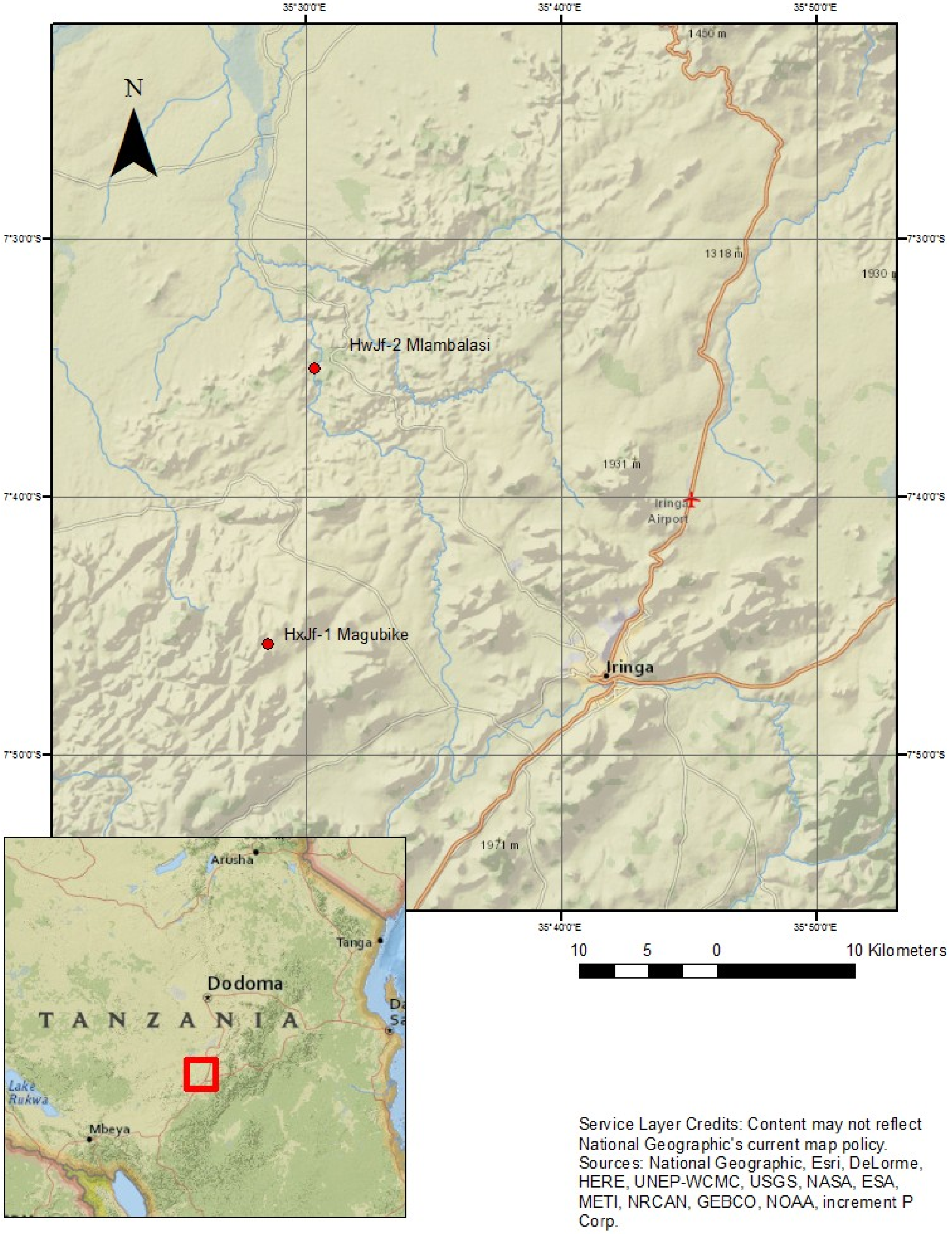

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Figure 3.2. Map of Iringa, Tanzania.

3.3.1 TEST PITS 9 AND 12

The Magubike points analyzed in this study come from the MSA levels of Test Pits 9 and 12. Test Pit 12 lies immediately to the west of Test Pit 9, both of which are under the main overhang of the shelter (Figs. 3.3 and 3.4). Test Pit 12 measured 1.35 m by 1.0 m and reached a depth of 180 cm at which point excavators reached the granitic bedrock. The artifacts recovered from the sequence were dispersed throughout the sediment and did not appear to be concentrated into what might be interpreted as living floors, although, significant changes in density were observed (Werner and Willoughby, 2017). It is almost certain that the material deposits have been time averaged to some extent.

Between 0 and 50 cm below the surface are the remnants of historic/Iron Age and possibly LSA habitation. These deposits include common Iron Age materials such as pottery fragments, and evidence of iron smelting in the form of slag and a furnace depression. Despite the presence of chronologically later materials, the lithic artifacts are typical of the LSA from northern Tanzania (such as Mumba and Nasera) as well as the Iron Age (Diez-Martín et al., 2009). Above 50 cm the formal tools are mainly composed of small backed tools made from quartz. Preliminary OSL dating in combination with radiocarbon dated ostrich eggshell also support the presence of an LSA component between 30 kya and 6 kya (Werner and Willoughby, 2017). One possibility is that Iron Age materials infiltrated downward through the sediment, obscuring the LSA signature. As it is, the similarity between early Iron Age and LSA lithics in other parts of the site make these two industries difficult to parse.

Below 50 cm there is no longer evidence of Iron Age material, and the lithics are suggested to be MSA in origin based on typological and technological traits such as a greater reliance on Levallois/radial flaking and a formal tool industry dominated by points and scrapers.

The MSA layers at Magubike are also characterized by greater raw material diversity and an increased focus on metamorphic stones. Preliminary OSL dating suggests a likely age of between ~100–50 kya for these levels.

Test Pit 9 measured 1 m by 1 m and also reached a depth of 180 cm before the bedrock was reached. The unit contained Iron Age materials such as pottery and iron slag in the upper 30 cm as well as lithic materials. Like Test Pit 12, it is possible that these artifacts are mixed with an LSA component, but since there are currently no dates from Test Pit 9 this argument is more difficult to support. Below 30 cm the assemblage is reminiscent of the MSA from Test Pit 12, featuring points and scrapers, as well as a small proportion of backed tools. In addition to Levallois and radial methods of flaking, bipolar technology is a major component of both test pits and is identifiable in every level. Finally, many of the artifacts were heavily patinated when recovered, likely as a result of mineral rich water percolating through the sediment. In order to remove adhering particles artifacts were bathed in vinegar followed by immersion in a sonic cleaner.

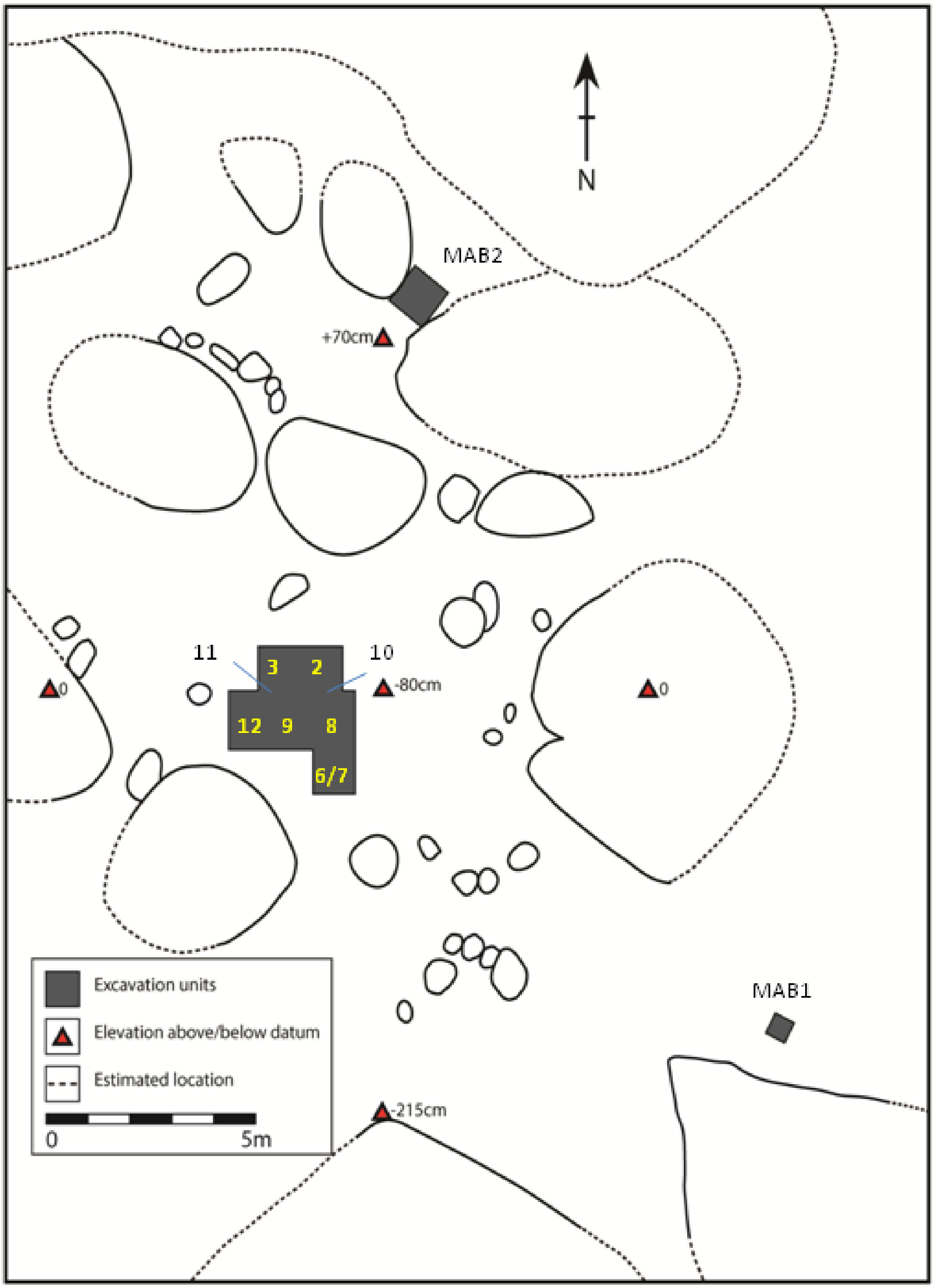

Figure 3.3. Site Plan of Magubike Rockshelter.

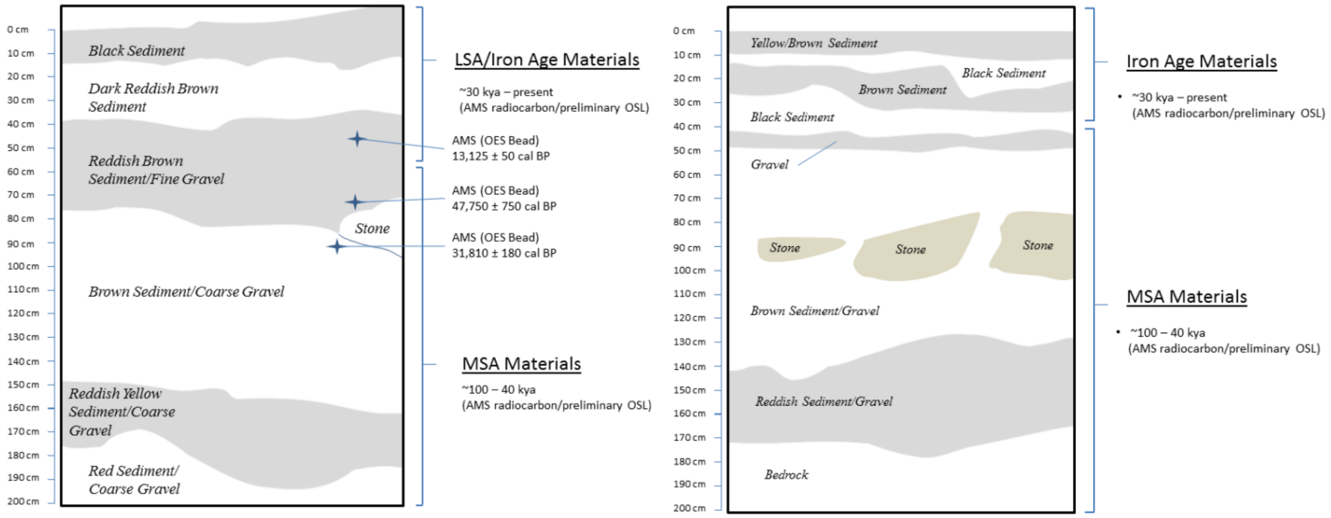

Figure 3.4. Stratigraphic Profiles of Test Pit 12 (left) and 9 (right).

3.3.2 POINT TECHNOLOGY AT MAGUBIKE

All intact MSA points from TP 9 (n=60) and 12 (n=38) were selected for inclusion in this study. The majority of the points that were studied were produced using metamorphic stones (n=65), although points were commonly made from quartz (n=18) and to a lesser extent chert (n=15) as well (Table 3.1).

A diacritical analysis revealed several common reduction pathways and strategies of point blank production at Magubike. Points were initially sorted based on the number of flaking directions apparent on their dorsal surfaces. Categories included unidirectional, bidirectional and multidirectional/radial (consisting of points with 3 or more visible flaking directions). The direction from which the point itself was removed was counted towards this total (Table 3.2). The technological process of creating unidirectional points was then secondarily classified as either parallel or convergent.

Unidirectional-parallel points were created by exploiting a single ridge perpendicular to the platform. Generally, this approach resulted in a straight dorsal arise dividing the point into two equal halves along its long axis. This technique also tended to create a thick triangular cross-section. Conversely, unidirectional-convergent points were created by establishing two or more intersecting ridges from a single extended platform. This approach often produced a distinctive triangular shaped scar originating from the proximal end as well as a trapezoidal cross-section. We found that the Magubike points were most commonly produced following a unidirectional-convergent flaking strategy, followed closely by unidirectional-parallel (Figure 3.5).

Points produced by a bidirectional strategy were also relatively common (n=27). For the most part bidirectional points were produced by exploiting the core face from opposing ends (bidirectional-opposite). Bidirectional-opposite points tended to feature a relatively more complex dorsal surface but frequently resulted in flake-scar configurations similar to those described for unidirectional-parallel and unidirectional-convergent points (i.e. a single dorsal ridge or two convergent ridges). Several bidirectional points were also described as bidirectional-orthogonal (n=5). These points were often flaked predominately from a single direction but featured corrective flakes from an adjacent, perpendicular platform, to maintain or establish suitable core morphology.

Finally, seven points showed evidence of multidirectional/radial flaking (flaking from 3 or more directions). An investigation of raw material showed that it did not influence the choice of reduction pathway or flaking strategy in any significant way (χ^2=3.542, df=2, p=0.170). In summary, a few dominant strategies were used to create triangular blank morphologies, although those which involved the preparation and exploitation of a single platform were the most common.

Table 3.1. Magubike Points – Descriptive statistics.

Raw Material	n	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)
Quartz	18	28.8	22.5	7.5	4.7
Metamorphic	65	43.4	33.2	10.1	12.6
Chert	15	40.2	25.3	7.7	7.1
Total	98	39.9	29.5	9.2	9.9

Table 3.2. Magubike Points – Summary of reduction pathways.

Reduction Pathway	total n	Quartz (n/%)	Meta. (n/%)	Chert (n/%)
Unidirectional Parallel	28	4(14)	18(63)	6(23)
Unidirectional Convergent	30	3(10)	21(70)	6(20)
Bidirectional-Opposite	22	5(23)	16(73)	1(4)
Bidirectional-Orthogonal	5	1(20)	4(80)	0(0)
Multidirectional/Radial	7	3(43)	4(57)	0(0)
Unknown	6	2(33)	2(33)	2(33)

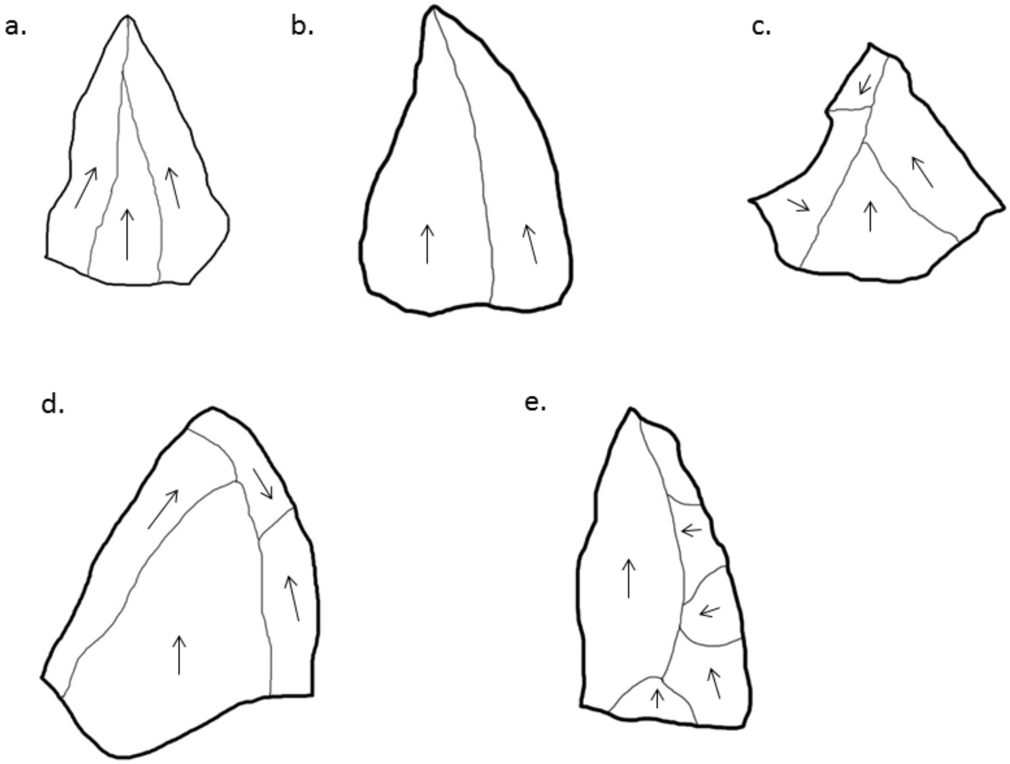

Figure 3.5. Point Reduction Pathways (arrows indicate direction of flaking): a) Unidirectional Convergent b) Unidirectional Parallel c) Multidirectional/Radial d) Bidirectional-Opposite e) Bidirectional-Orthogonal.

3.4 RESULTS

3.4.1 BLIND-TEST RESULTS

The regression analysis correctly identified the primary use-mode for the experimental wood scraping assemblage as marginal based on its statistical association with the field-dressing variable (Table 3.3). Damage is concentrated evenly across the margins of the tools and declines gradually towards the tips and the bases of the points. More damage occurs on the dorsal face of the tools ($t = 2.7247$, $df = 398$, $p = 0.007$) but is equally distributed between the left and right margins, unlike the ventral face for which damage was more frequent on the right margin ($t = 5.2495$, $df = 398$, $p < 0.001$) (Fig. 3.6).

Conversely, the assemblage of points used as throwing spears corresponds with a tip-dominant use-mode based on its association with the experimental spears variable (from the Schoville et al., 2016 Supplementary data). The strong and significant correlation of these variables suggests that the damage produced by impact with hard (tree trunk) and soft targets (animal carcass) is similar. The damage profile produced by this activity shows a concentration of damage around the tips of the pieces followed be a steep decline along the margins. There is also a secondary spike in damage that appears about a third of the way from the base on the right dorsal and right ventral sections where the bindings contacted the margin.

Lastly, the damage profile generated by drilling is strongly correlated with projectile use ($r = 0.914$, $p < 0.0001$). In particular, it features a high proportion of tip damage and relatively little marginal damage. Unlike the experimental spears, none of the drills exhibit conventional signs of impact.

3.4.2 MAGUBIKE POINT RESULTS

Chert points from Magubike were strongly associated with the “experimental spears” variable and nearly a third of chert points featured at least 1 DIF (Table 3.4 and Fig. 3.7). Damage is concentrated towards the tips of artifacts and declines towards the base.

The damage on the quartz points from Magubike, on the other hand, was found to be consistent with marginal use based on its association with the field-dressing variable. Furthermore, only 1 of 18 points showed diagnostic evidence of impact. The quartz damage profile shows high levels of tip damage on the dorsal face while the ventral face features extensive damage to the left and right margins.

The functional pattern derived from metamorphic points is less clear. Although the regression model yielded a tip-dominant result (experimental spears), only one of the 65 metamorphic points from Magubike exhibited possible evidence of impact. The damage profile also appears to be somewhat intermediate as it shows a high level of tip damage but also considerable damage on the margins as well.

Table 3.3. Regression Model Summaries and DIF statistics.

Samples	**DIFS (n/%)**	**R**	**R Squared**	**Associated Variable**
Magubike Metamorphic (n=65)	1 (2)	0.844	0.713	Tip-Dominant
Magubike Chert (n=15)	4 (27)	0.77	0.593	Tip-Dominant
Magubike Quartz (n=18)	1 (5)	0.759	0.577	Marginal
Experimental Scraping (n=10)	0 (0)	0.484	0.235	Marginal
Experimental Projectile (n=8)	6 (75)	0.891	0.794	Tip-Dominant

Table 3.4. Magubike Points – Summary description of DIFs.

ID #	**TP and Level**	**Raw Material**	**Location/Orientation**	Initiation		Termination	
				Type	**Location**	**Type**	**Location**
5	TP 12 (160-170)	Chert	Distal/Parallel	Bending	Ventral	Step	Dorsal
		-	Distal/Parallel	Bending	Ventral	Step	Dorsal
38	TP 12 (100-110)	Chert	Distal/Parallel	Bending	Ventral	Step	Dorsal
80	TP 9 (140-150)	Chert	Distal/Parallel	Bending	Dorsal	Hinge	Ventral
93	TP 9 (130-140)	Chert	Distal/Parallel	Unknown	Ventral	Step	L Margin
		-	Distal/Parallel	Bending	Ventral	Step	Dorsal
118	TP 9 (90-100)	Quartz	Distal/Parallel	Bending	Dorsal	Step	Ventral
		-	Proximal/Parallel	Bending	Dorsal	Step	Ventral
		-	Proximal/Parallel	Bending	Ventral	Feathered	Dorsal
128	TP 9 (80-90)	Metamorphic	Distal/Parallel	Unknown	Ventral	Step	Dorsal

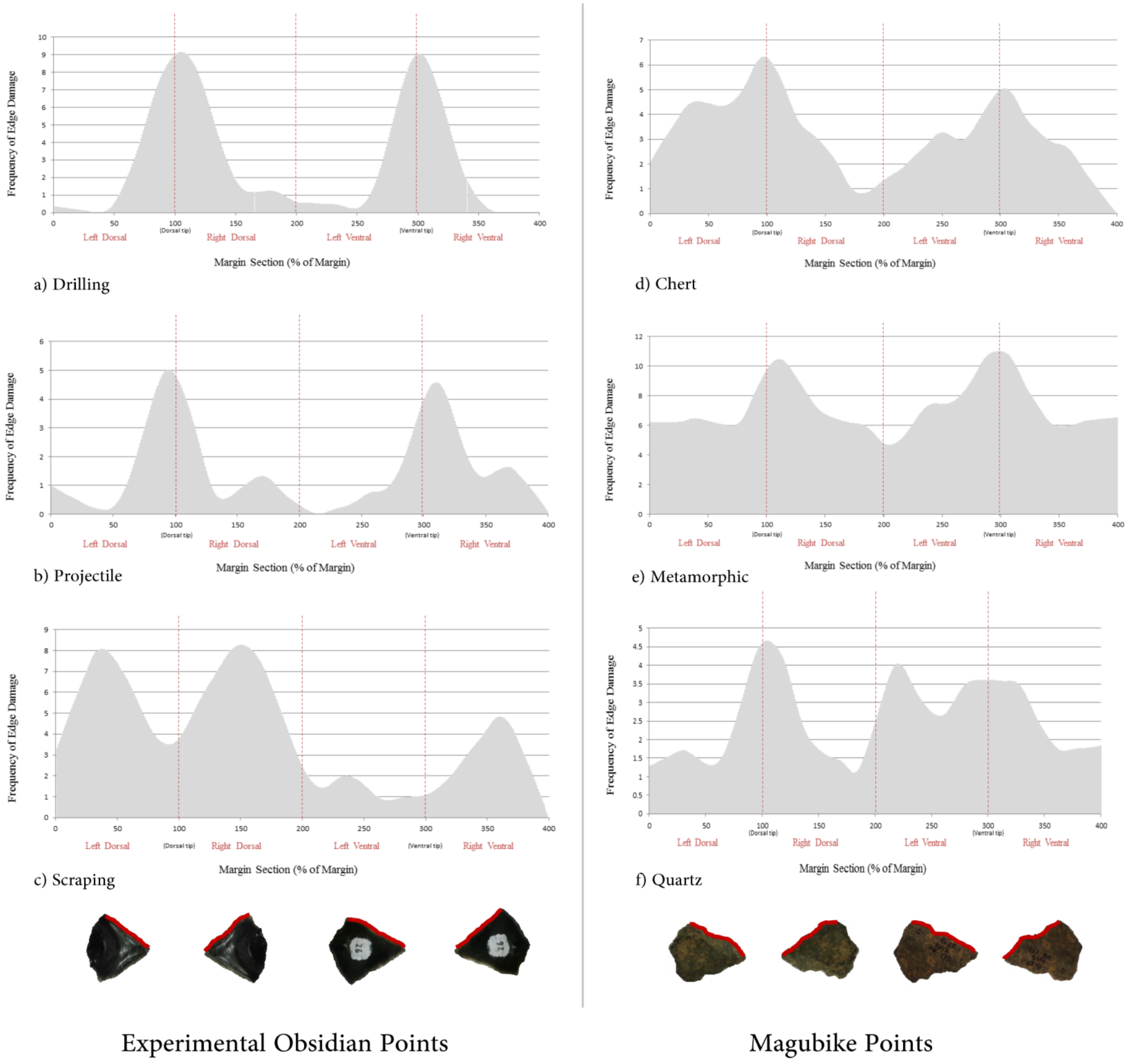

Figure 3.6. Edge damage profiles. Loess smoothing (locally weighted smoothing) was applied to each of the profiles to more clearly display trends in how damage was distributed. It operates by deriving a best-fit line without assuming a particular distribution type. The y-axis displays the frequency with which damage was recorded, while the x-axis shows the different marginal sections strung together as though they were a single continuous margin. For example, “0”

represents the base of the left dorsal margin while “200” represents the base of the right dorsal margin and the left ventral margin. Each section (divided by dotted red lines) corresponds to the margin highlighted on the points below.

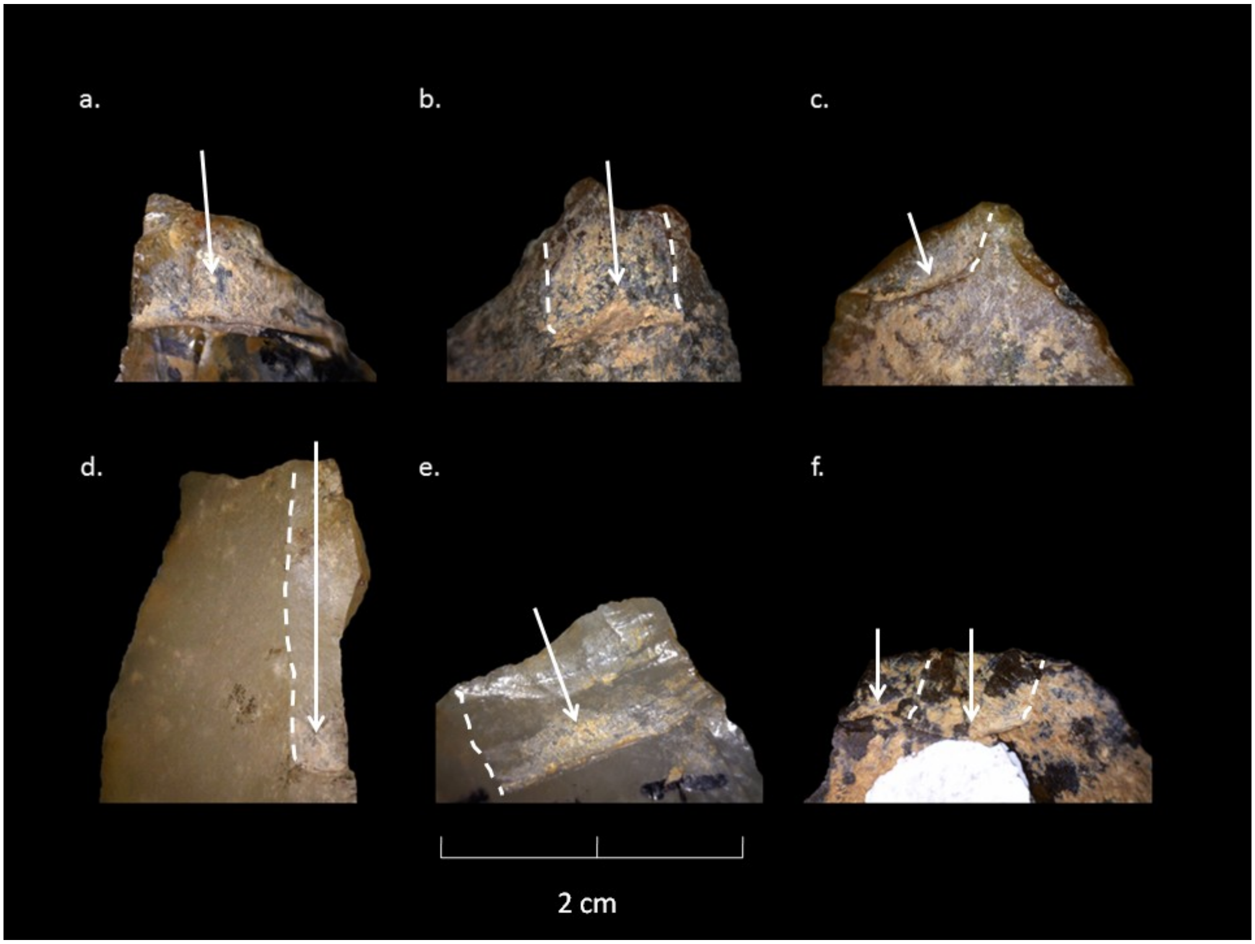

Figure 3.7. Examples of DIFS: a) (ID#118) Bending fracture initiated from the dorsal face/step termination on the ventral face, b) (ID#128) Bending fracture initiated from the ventral face/step termination on the dorsal face, c) (ID#80) Bending fracture initiated from the dorsal face/hinge termination on the ventral face, d) (ID#93) Unknown initiation type and location/propagation along the left margin/step termination on the left margin, e) (ID#38) Bending fracture initiated from the ventral face/step termination on the dorsal face, f) (ID#5) two parallel bending fractures initiated from the dorsal face/both step terminate on the ventral face.

3.5 DISCUSSION

Based on our blind-test findings we conclude that the damage distribution method is capable of distinguishing between tip-dominant and marginal functional modes. These results were achieved regardless of outstanding factors such as differences in contact material and lithic raw material. We therefore propose that the most important determinant of damage location is the manner of use. We believe that these results serve to validate existing research as well as the functional analysis of Magubike points conducted here. However, the analysis conducted as part of this study was in no way comprehensive, and we encourage others to continue to test this method under varying conditions and using alternate variables.

We also feel that our analysis of experimental drills contributes to existing knowledge of how and where damage forms on Stone Age drills. A critical finding is that the experimental drills were damaged in a way that is indistinguishable from projectiles using the damage distribution method - both activities produced high concentrations of tip damage and low levels of marginal damage. On the other hand, there is clear variation in the frequency with which DIFs were formed on these tools. None of the drills exhibited conventional signs of impact, likely because the compression force generated by drilling is not generally sufficient to produce the types of fractures observed on projectiles. This observation remains true even for extremely brittle materials like the obsidian used in this analysis.

Conversely, in his analysis of drills from the Neolithic site of Kumartepe, Turkey, Grace (1990) noted the presence of “fluting” and “burin type breaks” on tools that he suspected were used as punches or drills. Unfortunately, he does not give the number of drills that exhibited these features, stating only that a “few” of the 518 drills were broken in this way. Although we can't precisely define the rate at which DIFs formed on these drills based on Grace's description, we can be relatively confident that it is low. Even a charitable guess as to what “a few” refers to yields a result of < 1 or 2% of the assemblage. Therefore, we argue that the supplementation of the damage distribution method with impact fracture data is adequate to distinguish hunting from other activities which primarily employ the artifact tip.

With regard to the Magubike points, not only were we able to detect the presence of different functional modes amongst the assemblage, these modes appear to be organized according to lithic material type. In the case of chert points, a hunting function is strongly implied by a high percentage of DIFs (27%), which greatly exceeds the percentage expected from trampling or manufacture (~3%) (Pargeter, 2011). The hunting weapon hypothesis is further supported by the regression model which identified the use-mode as tip-dominant. Chert may have been a desirable material for this task because it is resistant to damage, easy to shape effectively and sharp. However, chert is also a rare commodity relative to other materials around Magubike, which might explain why so few chert points were found at Magubike and why so many of them feature impact damage. Specifically, we would expect intact chert points to be curated, and thus removed from the site, at a higher rate than other more accessible materials.

Alternately, quartz points were used in a way that resulted in a marginal damage profile, probably as a result of being used for cutting and/or scraping. A low proportion of DIFs also supports this hypothesis. The single quartz point that does not fit this pattern was made of crystalline rather than vein quartz and appears to have been used as a projectile armature. This prediction is made on the basis of three observed DIFs, consisting of a series of bending-type fractures. Crystalline quartz is harder than vein quartz and has a striking glass-like appearance, which might explain why it was earmarked for this purpose.

Metamorphic points reveal a less clear pattern of damage. Although the regression model yielded a tip-dominant result only a single DIF was recorded on a total of 65 points. The proportion of DIFs is well below what might be expected from a hunting assemblage and could conceivably be a byproduct of manufacture or trampling. On the other hand, the formation of DIFs (and indeed, most forms of use-wear) on course-gained lithic materials is not well studied and it may be that the proportion of DIFs we observed is well within the norm for metamorphic weapon tips (Conte et al., 2015). Further testing would need to be carried out to assess this possibility. Alternately, it may be more likely that metamorphic points were used as drills or piercers, used for multiple (or unknown) tasks, or that they were damaged beyond interpretability.

3.6 CONCLUSION

Based on our analysis we conclude that points at Magubike were utilized both as hunting weapons and cutting/scraping tools. Moreover, the distinction appears to have been mediated to some extent by raw material differences. These findings corroborate existing research which suggests that MSA points were not exclusively hunting weapons. The analysis of experimental tools conducted here also lends support to previous studies as well as our own. However, in doing so, we reveal that damage from drilling could potentially be misidentified as projectile use using the damage distribution method. Although outside evidence for drilling during the MSA is rare we reaffirm the recommendation made elsewhere that the damage distribution method be used in conjunction with other methods such as impact fracture survey to rule in or out this behaviour.

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CHAPTER 4: AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF POST-DEPOSITIONAL DAMAGE ON CURRENT QUANTITATIVE USE-WEAR METHODS

4.1 INTRODUCTION

Use-wear analysis presents archaeologists with a powerful tool with which to directly assess the function of artifacts without relying on morpho-functional arguments or by drawing analogies to modern tools. For the most part, these methods rely on a visual comparison of the damage formed by use on experimentally replicated tools and archaeological specimens. The origins of the field dates back to the 1960s, with interest among western archaeologists first peaking around 1980 (Keeley, 1980; Semenov, 1964; Stemp et al., 2016). Early on, however, researchers began to voice concerns. Critics claimed that findings were difficult to interpret, and that there was no standardized language with which to describe wear traces (Grace, 1996). Blind-testing also demonstrated that the success of conventional methods is heavily dependent on the training and experience of individual analysts, causing overall accuracy to vary widely across studies (Evans, 2014).

Although there has been significant progress since the 1960s, the field continues to struggle with four key issues (Evans and Donahue, 2008). First, the formation of use-wear is not yet completely understood, though detailed research by authors such as Stemp et al. (2015) and Ollé and Vergès (2014), among others, has been extremely helpful in this regard. Second, there has arguably been an overemphasis on the study of flint/chert assemblages leaving use-wear on non-flint tool-stones under-examined. This problem is also being approached by more comprehensive study of non-flint artifacts (Conte et al., 2015; Fernández-Marchena and Ollé, 2016). Third, many aspects of the burial environment are known to be capable of interfering with the interpretability of use-traces (Shea and Klenck, 1993; Venditti et al., 2016). Research suggests that natural transformations of stone artifacts may be mistaken for use-wear and can severely limit the information available from heavily altered pieces. The most common procedure for addressing the issue of post-depositional wear is to exclude artifacts or assemblages from analysis that are suspected to have been naturally damaged (Burroni et al., 2002). This practice remains an imperfect but potentially unavoidable solution. Lastly, and perhaps most challenging, the majority of use-wear analyses remain inherently subjective, difficult to reproduce, and independently verify.

Ideas vary as to how best to address this final challenge. Some researchers have proposed that analysts receive more intensive training within the framework of existing methods and argue for the creation of larger and more complete reference collections (Rots and Plisson, 2014). Alternately, others have looked to quantitative methods to improve accuracy and objectivity (Dumont, 1982; Evans and Donahue, 2008; González-Urquijo and Ibáñez-Estévez, 2003; Ibáñez et al., 2014; Macdonald, 2014; Macdonald and Evans, 2014; Stemp, 2014; Stemp et al., 2013, 2015, 2016). Use-wear quantification refers to a field of related techniques that seek to mathematically characterize and differentiate damage on stone tools. These approaches allow data to be statistically, rather than visually, compared to an experimental reference to determine the likely source, or sources of damage. While some scholars have focused on image analysis and damage distribution patterning (Bird et al., 2007; González-Urquijo and Ibáñez-Estévez, 2003; Schoville, 2010; Wilkins and Schoville, 2016), most recent emphasis has been on measuring the profile or areal roughness of stone tools using high-resolution scanning equipment borrowed from fields such as engineering and materials science (Evans and Donahue, 2008; Macdonald, 2014; Stemp, 2014; Stevens et al., 2010). One of the primary benefits of these approaches is that the results can be expressed probabilistically, allowing for better transparency and confidence in the reporting of findings.

Although use-wear quantification offers compelling advantages over conventional techniques, the field is still developing, and some of the problems inherent to conventional use-wear analysis are shared by both approaches. The purpose of this article is not to fully solve all of these problems, but to nudge quantitative methods closer to widespread adoption by studying the impacts of some of these issues. In particular, this experiment tests the sensitivity of measurements obtained with 3D scanning equipment to the distorting effects of post-depositional damage. Although the impact of the burial environment on artifacts of all kinds has been well studied (Lyman, 1994; Marreiros et al., 2015; McBride and Mercer, 2012; Shea and Klenck, 1993), the impact of trampling, patination, movement through the sediment, etc. on 3D scanning data has yet to be established through experimentation. Because of the precise nature of these measurements, it is conceivable that even minor amounts of post-depositional alteration could render these methods invalid. As a benchmark, Shea and Klenck (1993) observed that even short intervals of trampling (15 min) can significantly reduce the accuracy of conventional use-wear results. To investigate the effects of these processes on quantitative data the method detailed in this article was "stress-tested" by exposing the samples to increasing degrees of simulated post-depositional damage. The primary questions of interest were:

1. At what degree does post-depositional damage have a significant effect on the accuracy of scanning metrics?
2. Does additional damage correlate linearly with diminished quantitative use-wear accuracy?

3. Which types of use-wear are most likely to be obscured by damage introduced by post-depositional processes?
4. Is damage emulative of any particular use-traces?

4.2 METHOD

The methods used were loosely based on Shea and Klenck (1993), who investigated the effects of post-depositional damage on conventional use-wear interpretability. To test these effects, they assessed the ability of a skilled analyst (Shea) to provide accurate functional estimates for specimens that had been damaged by cumulative 15 min increments of trampling. For the purpose of the present experiment, an experimental assemblage of ten unretouched dacite flakes was manufactured. Dacite is a glassy, usually grey, volcanic stone that has similar flaking properties to obsidian (Fig. 4.1). All flakes in this study were produced using a quartzite hammer-stone by the author. With the exception of two unused control flakes, each tool was used in a sawing motion to process one of four materials for 40 min (two flakes per material type). The contact materials included in this experiment were wood (*Populus tremuloides*) covered in bark, dry antler (*Odocoileus hemionus*), dry hide (*Odocoileus hemionus*) and dry grass stems and leaves from native prairie grasses, collected near the University of Alberta campus.

Once the flakes were used, they were carefully cleaned to prevent the introduction of spurious use-wear traces. The experimental assemblage was washed by hand with a grit-free detergent, avoiding brushes or other abrasive materials (Stemp, 2014). They were then soaked in a dilute HCL solution and NaOH respectively for 10 min each to remove any lingering residues or particles (Evans and Macdonald, 2011). Because of its long working distance, worn sections of each piece were initially identified with a Nikon Eclipse LV150 optical microscope using the

20× and 50× objective lenses. These sections were marked with ink so they could be identified and re-scanned later. This preparatory step made it possible to directly trace the changes in surface roughness of a single segment of the tool. Three such areas were located on the ventral side of each piece, generally within 50–100 µm of the working margin. Polished areas were identified and measured although chipping, rounding, as well as series of striations sub-parallel to the direction of tool motion were also observed (Fig. 4.2). These wear signatures occurred most commonly on raised sections of the microtopography and are consistent with the sawing motion used by the experimenter. These locations were chosen randomly in the case of unused specimens.

After initial inspection, the specimens were scanned in the three places marked earlier using an Olympus laser-scanning confocal microscope (LSCM) (LEXT OLS3000) located in the chemical and material engineering department at the University of Alberta. The device reconstructs the surface of the tool using laser light reflected back from the specimen, collected at varying vertical increments. Its operation and anatomy are well described in Evans and Donahue (2008). A LSCM was chosen for this experiment for several reasons. Most importantly, its ability to differentiate contact materials has already been established by prior research (Evans and Donahue, 2008; Ibáñez et al., 2014; Macdonald and Evans, 2014). Furthermore, the instrument is capable of capturing areal as well as profile measurements and each scan can be acquired within a minute or two. The wavelength of the laser light used by this particular system is 408 nm, the horizontal resolution is 0.12 µm and the vertical resolution is 0.10 µm. Scans were taken using the 50× objective lens (NA = 0.95, WD = 0.3 mm), as recommended by the operator's manual, and each scan took under 2 min to complete. The “fine” setting was selected to enable the capture of detailed measurements. This setting prioritizes high fidelity data capture as opposed to speed. LEXT OLS4100 software was used to process the 3D renderings and to take measurements of their surfaces. The “surface correction” tool was used to remove differences in the inclination of the samples.

A filter was also used to separate the surface texture of the pieces into roughness and waviness data sets. Waviness refers to longer wave-length surface irregularities, while roughness refers to irregularities with a shorter wave-length and a greater frequency. The distinction between these data sets is based on several agreed upon cut-off points, including 8 µm, 12 µm, and 25 µm. In this case, a cut-off of 8 µm was chosen to isolate and quantify the roughness profiles of the flakes as per previous experimentation (Ibáñez et al., 2014). Measurements were taken at two different areas sizes as per Evans and Donahue (2008), specifically from 10 µm and 100 µm squares (Fig. 4.3). By varying the capture size of the measurements it is hypothetically possible to account for features of different sizes. Fifty measurements (from here on referred to as cases) were captured for each zone, totaling 150 cases for each specimen and 1500 cases overall. These capture areas were selected so that only visibly worn areas were contained within them.

Five different roughness parameters were captured for each case at two different scales. A roughness parameter is a mathematical formula that describes an aspect of the tool surface. Because of the complexity of lithic microtopography, it is unlikely that a single parameter is capable of fully describing a surface and it is currently not clear which parameter, or combination of parameters, are best suited to the task of discriminating between worn surfaces (but see Watson and Gleason (2016) for bone tools). Parameters that have proven effective, either individually or in combination, include the root square mean height of the surface (Sq), the arithmetic mean height of the surface (Sa), the maximum peak height (Sp), the maximum valley depth (Sv), the summed maximum peak height and valley depth (Sz), relative area: the ratio between the height of a material at a given threshold and the evaluation area (Sal) and the extreme peak height (Sdc). In this study, the parameters Sq, Sp, Sv, Sz and Sa (all the parameters available for measurement in the provided program) were used to create a multinomial logistic regression model in IBM SPSS v24.

Multinomial logistic regression is a statistical technique used to predict group membership from a set of continuous and/or categorical variables. In this way, it is similar to discriminant function analysis, but has fewer assumptions and can accommodate a greater variety of data types. All variables were log transformed to normalize the data and outliers were removed using the outlier labeling rule (g = 1.5). These extreme values most likely resulted from "noise", introduced when the laser is unable to reach a recessed area of the surface or strikes a reflective inclusion. This noise is typically manifest as high needle-like peaks or deep valleys that do not reproduce the actual surface. The variables were entered into the model using a forward step-wise method, for which the inclusion of variables is determined by an automatic process. The parameters included in the final model by the step-wise selection process were Sa10 μm2, Sq100 μm2, Sv100 μm2, Sz100 μm2, and Sa100 μm2.

Once entered, the regression model created a prediction for each individual case, resulting in 150 predictions per specimen. Not all of these 150 predictions were correct, but accurate contact material estimates were generated by tallying them and isolating the category with the most cases. It is also possible to measure the accuracy of the model for each contact material by observing the total percentage of cases that were correctly identified. These two means of assessing the model's accuracy are discussed more below. Once scanned for the first time, the specimens were subjected to simulated taphonomic processes. Unlike Shea and Klenck

(1993), the lithics were vigorously shaken in a sediment sieve shaker rather than trampled to better replicate processes such as the clearing of lithic debris from living spaces or abrasion from movement within the sediment (Fig. 4). The assemblage was shaken on full power in cumulative increments of 30 min (30, 60 and 90 min) on a 2 cm deep bed of sandy soil with rocky inclusions with their ventral faces downward. The soil type was kept consistent for all artifact sets, as soil type has been shown to generate significant difference in trampling experiments (McBrearty et al., 1998). The samples were buried with more sediment to a depth of 1–2 cm, and no attempt was made to prevent lithics from coming into contact with one another. Alternately, to prevent the lithics from contacting the metal walls of the shaker a paper insert was placed in the bottom of the shaker that sloped gently upwards around its edges. After each interval had elapsed, the artifacts were recovered, cleaned and scanned again in the same location.

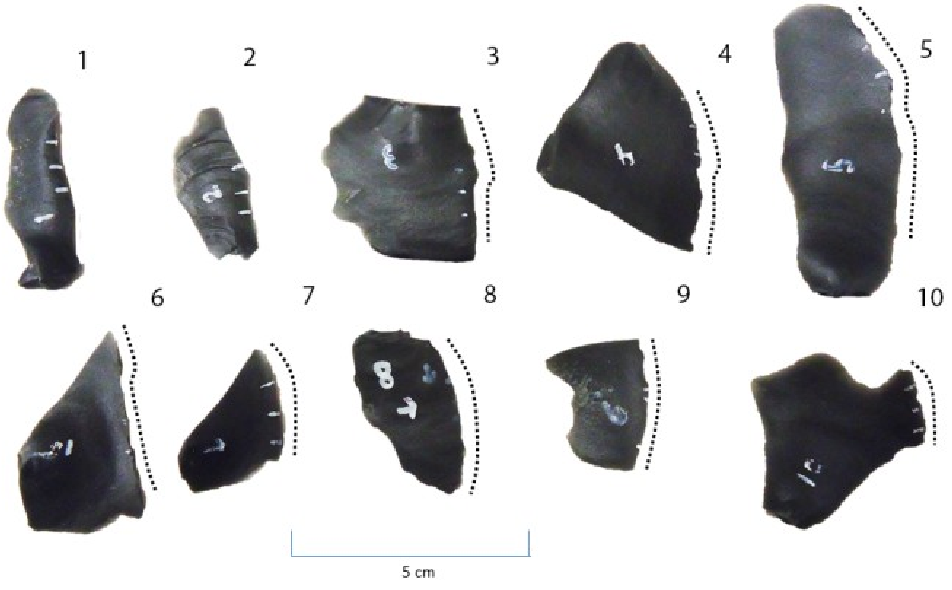


Fig. 4.1. Dacite Flakes. 1 and 2: unused, 3 and 4: wood, 5 and 6: antler, 7 and 8: hide, 9 and 10: grass. Dotted lines indicated the utilized margin, except for specimen 1 and 2 which were unused.

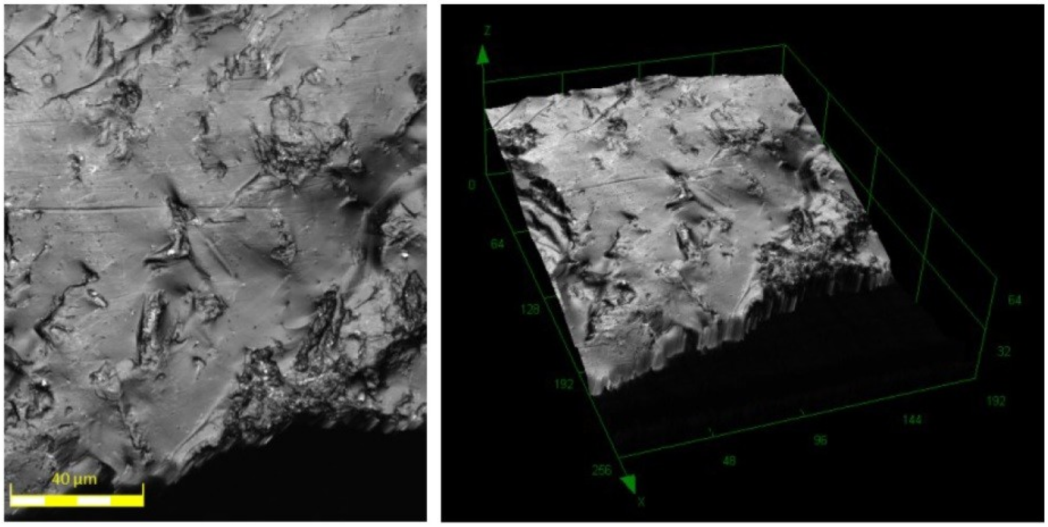


Fig. 4.2. An example of use-wear on a dacite flake as a result of wood-work. Damage appears as a series of sub-parallel striations and gouges. The image on the right is the same surface as the one on the left in 3D. The working edge of the piece is located at the bottom of both images.

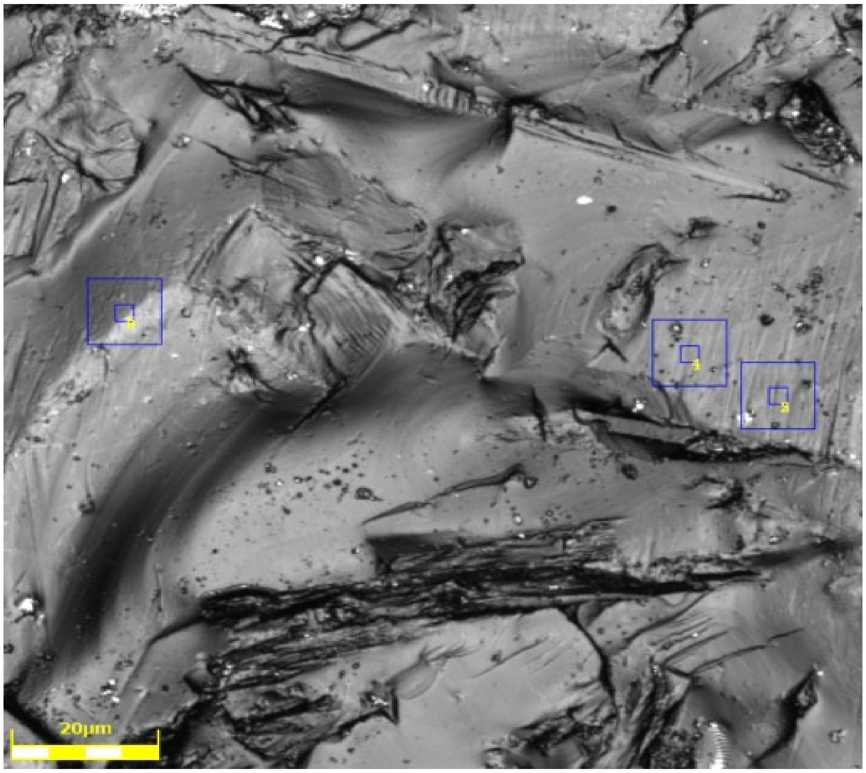


Fig. 4.3. Example of 10 μm^2 and 100 μm^2 capture areas nested within one another.

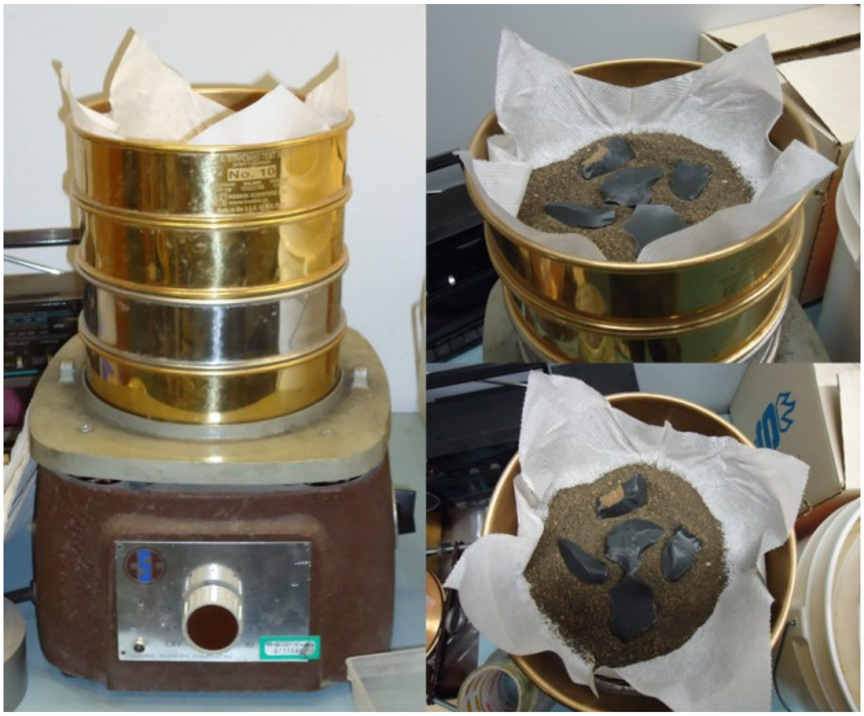


Fig. 4.4. The sediment sieve shaker used in this experiment and several dacite flakes.

4.3 RESULTS

Prior to shaking, the correct contact material was identified for 8 of the 10 specimens (Table 4.1). Specimen 7 (hide) was misidentified as unused while specimen 10 (grass) was considered to be misidentified because grass and hide were tied for the highest category at 42 cases each. The multinomial regression model generated a Nagelkerke's pseudo r-squared value of 0.497 indicating that it accounts for approximately 50% of the total variation. Overall, 45.5% of 1500 cases were correctly identified to contact material – 25.5% greater than chance. However, the accuracy of the model differed by material type (as shown in Table 4.2). Unused flakes and use-wear from hard materials (namely wood and antler) were easily distinguished, while grass and hide were less distinctive. Based on the part correlations generated by the regression model, Sa100 μm2 is the strongest predictor of contact material, which accords with the observations of Watson and Gleason (2016) for bone tools (Table 4.3).

After 30 min of shaking, the model was still able to correctly identify the contact material for 6 of the 10 specimens, down from 8 of 10. The total number of cases correct also declined from 45.5% to 34.7%. Specimens 5 and 6 (both antler) showed a significant divergence between the first and second scans (Fig. 5). As both specimens were also incorrectly classified it would appear that the damage produced by shaking had a disproportionally severe impact on the interpretability of antler wear signatures. Nevertheless, by either measure of accuracy, the model still functions well above chance on lightly damaged specimens.

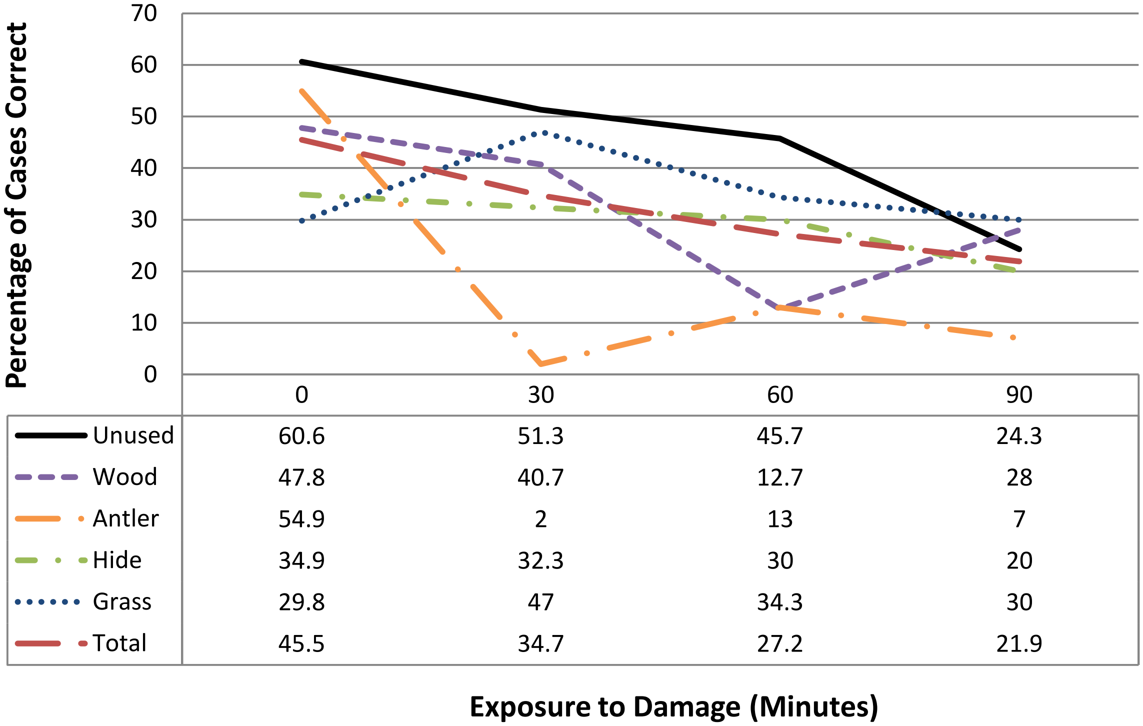
After 60 min of shaking, there was a further decline in the accuracy of the method. Only 4 of 10 specimens and 27.2% of cases were correctly identified. Similar to the first round, antler remained poorly characterized while the number of wood cases correctly classified also dropped. Interestingly, unused, hide and grass specimens appeared to be less impacted by the damage introduced by shaking. Although the method still predicted contact material at a greater rate than chance, its accuracy is substantially compromised after 60 min.

The experiment was terminated once the lithics had undergone 90 min of shaking. At that time the model was no longer able to predict contact material at a rate much greater than chance — only 3 of 10 specimens were correctly identified (21.9% of cases). Damage on many of the scan zones appeared as a chaotic series of striations with no clear patterning. Raised sections also bore additional evidence of gouging and roughing (Figs. 4.6 and 4.7).

Table 4.1. Model predictions. Incorrect estimates are shown in the cell.

	Exposure to Damage (Minutes)			
Specimen	0	30	60	90
Unused 1	-	Wood	-	-
Unused 2	-	-	-	Hide
Wood 3	-	-	Grass	-
Wood 4	-	-	Grass	Hide
Antler 5	-	Wood	Grass	Grass
Antler 6	-	Grass	Hide	Grass
Hide 7	Unused	Wood	Antler	Grass
Hide 8	-	-	-	Grass
Grass 9	-	-	Hide	-
Grass 10	Hide	-	-	Hide
n=correct	8	6	4	3

Table 4.2. The percentage of cases correctly identified by contact material.



	0	30	60	90
Unused	60.6	51.3	45.7	24.3
Wood	47.8	40.7	12.7	28
Antler	54.9	2	13	7
Hide	34.9	32.3	30	20
Grass	29.8	47	34.3	30
Total	45.5	34.7	27.2	21.9

Table 4.3. Summary statistics of the roughness parameters. Recall that values are log transformed with outliers removed.

	Material		Roughness Parameters in Model				
			Sa10	Sq100	Sv100	Sz100	Sa100
0 Minutes	**Unused**	mean	-3.71	-3.20	-1.29	-0.71	-3.60
		SD	0.49	0.30	0.51	0.46	0.29
	Wood	mean	-3.50	-3.06	-1.41	-0.79	-3.39
		SD	0.40	0.30	0.41	0.41	0.29
	Antler	mean	-3.04	-2.71	-1.10	-0.27	-3.07
		SD	0.35	0.29	0.36	0.47	0.26
	Hide	mean	-3.14	-2.78	-1.04	-0.40	-3.15
		SD	0.46	0.38	0.61	0.55	0.36
	Grass	mean	-3.23	-2.92	-1.24	-0.67	-3.27
		SD	0.46	0.38	0.49	0.44	0.38
30 Minutes	**Unused**	mean	-3.74	-3.34	-1.56	-1.00	-3.68
		SD	0.41	0.31	0.48	0.36	0.30
	Wood	mean	-3.56	-3.14	-1.49	-0.93	-3.49
		SD	0.45	0.37	0.49	0.44	0.35
	Antler	mean	-3.35	-3.07	-1.31	-0.82	-3.42
		SD	0.40	0.27	0.34	0.27	0.25
	Hide	mean	-2.79	-2.34	-0.61	0.12	-2.70
		SD	0.29	0.27	0.49	0.45	0.25
	Grass	mean	-3.23	-2.99	-1.33	-0.76	-3.35
		SD	0.37	0.34	0.43	0.38	0.32
60 Minutes	**Unused**	mean	-3.53	-3.16	-1.39	-0.80	-3.56
		SD	0.43	0.31	0.39	0.35	0.31
	Wood	mean	-3.09	-2.73	-1.15	-0.54	-3.07
		SD	0.38	0.27	0.39	0.34	0.27
	Antler	mean	-3.11	-2.76	-1.08	-0.48	-3.11
		SD	0.37	0.31	0.46	0.45	0.30
	Hide	mean	-3.09	-2.64	-0.83	-0.14	-3.02
		SD	0.44	0.33	0.45	0.52	0.32
	Grass	mean	-3.00	-2.71	-0.98	-0.42	-3.07
		SD	0.36	0.28	0.47	0.40	0.26
90 Minutes	**Unused**	mean	-3.32	-2.98	-1.34	-0.72	-3.34
		SD	0.51	0.45	0.61	0.52	0.43
	Wood	mean	-3.23	-2.92	-1.31	-0.71	-3.26
		SD	0.43	0.33	0.45	0.38	0.31
	Antler	mean	-3.13	-2.83	-1.23	-0.69	-3.17
		SD	0.39	0.34	0.40	0.33	0.31
	Hide	mean	-3.18	-2.70	-1.03	-0.53	-3.08
		SD	0.43	0.36	0.46	0.38	0.35
	Grass	mean	-3.10	-2.78	-1.05	-0.50	-3.15
		SD	0.42	0.36	0.53	0.47	0.35

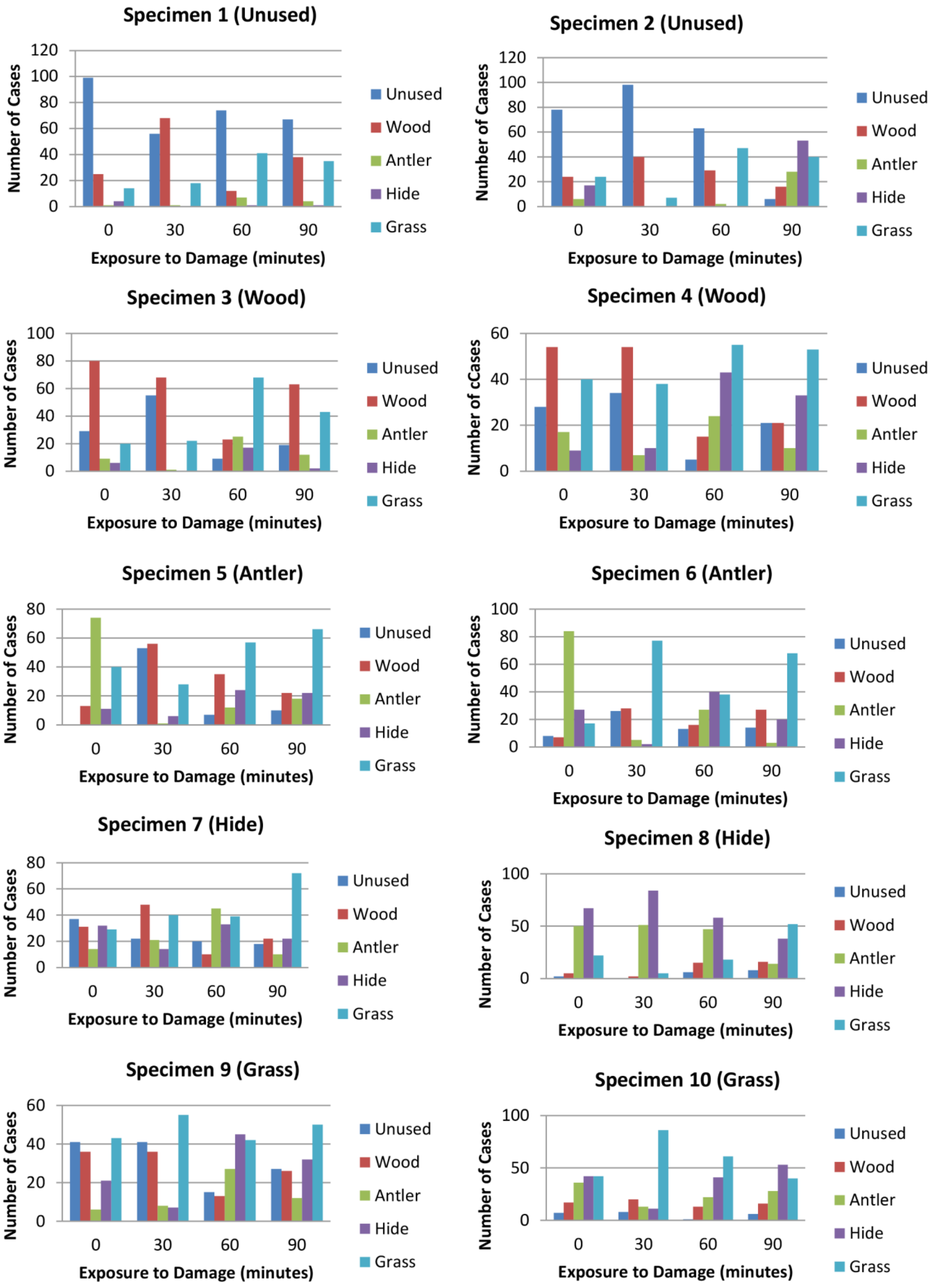


Fig. 4.5. Graphs showing how cases were assigned by the regression model.

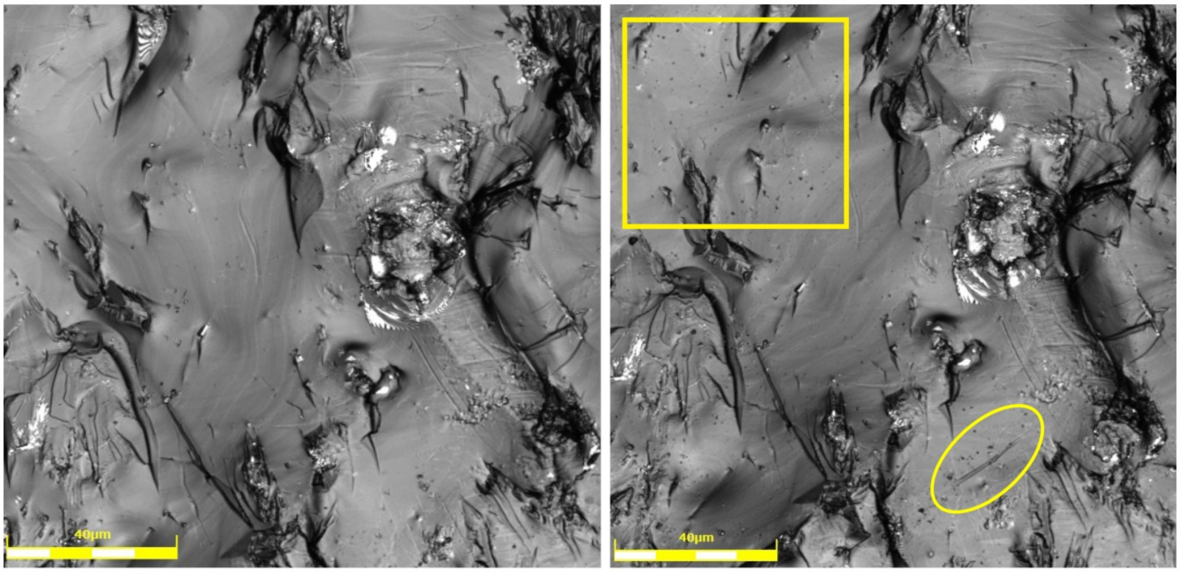


Fig. 4.6. The accumulation of damage between 30 minutes (left) and 60 minutes of shaking (right). Note the appearance striations and pitting highlighted in yellow.

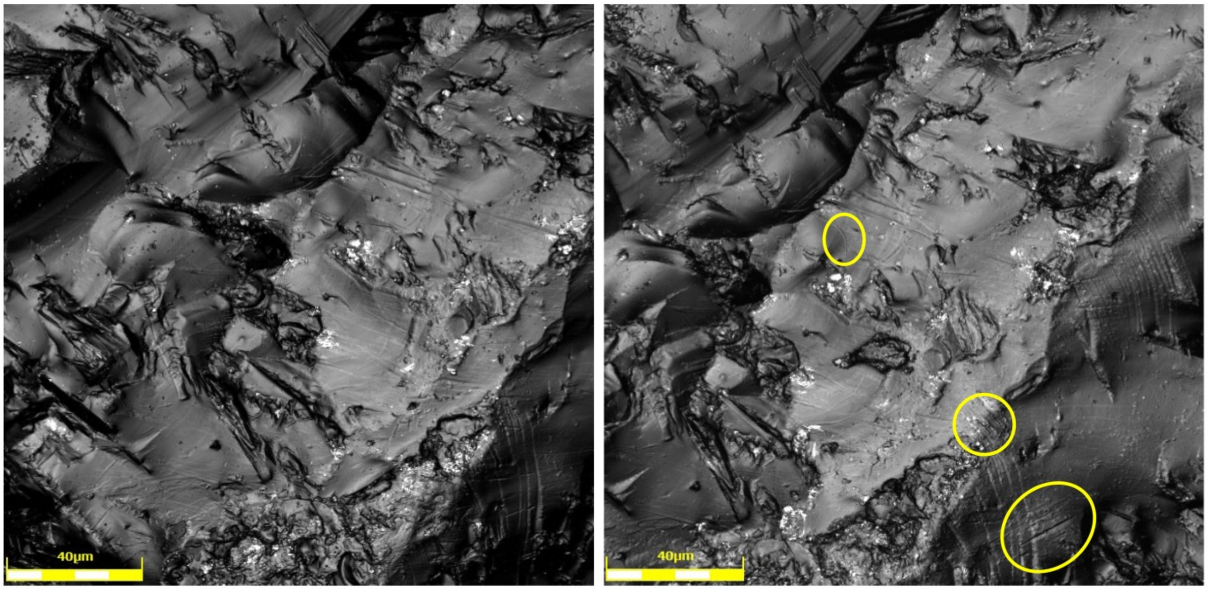


Fig. 4.7. The accumulation of damage between 30 minutes (left) and 60 minutes of shaking (right). Note the appearance striations and rounding highlighted in yellow.

4.4 DISCUSSION

The results of this analysis suggest that the method trialed here is capable of accurately predicting most contact materials for even lightly and moderately damaged specimens - antler was a clear exception, as antler-wear became unidentifiable after only light damage. Nevertheless, the LSCM was ineffective at predicting contact materials for extensively damaged specimens, which are defined as those exposed to 90 min of vigorous shaking with a sediment sieve shaker.

As with other forms of use-wear analysis, assemblage selection will continue to be important, but it appears that quantitative approaches employing a LSCM are no more vulnerable to post-depositional damage than conventional use-wear methods. Furthermore, this particular method performs comparably to, if not better than, most conventional use-wear programs that have been blind-tested (Evans, 2014). Of the lithic blind-testing that has occurred, the average success rate for contact materials is 49.5%. The method presented here ranks among the highest at 80% accuracy for undamaged specimens and 40–60% accuracy for lightly and moderately damaged pieces.

Secondly, the accuracy of the model and the degree of damage were nearly perfectly correlated. This finding is somewhat different from the results reported by Shea and Klenck (1993) who observed a steep decline in success after the first round, followed by a period of stability that continued through all successive rounds of the experiment. It is unclear what this distinction reflects, but it is likely due to a number of factors including, but not limited to differences in the manner in which damage was simulated (trampling vs shaking), differences in the sorts of wear studied (fractures vs polishes), differences in the lithic raw material of the experimental tools, differences in sedimentary substrate, and differences in the perceptive capabilities of a human observer and a LSCM. Given the discrepancy, it is probably valuable to combine qualitative and quantitative approaches.

Third, before being shaken, unused, wood and antler categories featured the most distinctive wear signatures. This trend is likely a product of the relatively unyielding nature of both antler and wood, which renders these materials more capable of inflicting wear. The unmodified surface of dacite also appears to be readily identifiable. However, as damage accumulated on the experimental collection, unused pieces as well as those used to process hide and grass continued to be interpretable while antler and wood quickly became unidentifiable. Interestingly, wear introduced by the shaker seems to be most similar to hide and grass, as these categories are disproportionally represented among the mistakes made by the model ($\chi^2 = 12$, df = 4, p = 0.017). This tendency potentially explains why the percentage of grass cases correctly identified rose from the first scan to the second; however, it is not immediately clear why the bias exists in the first place. It could be that the mechanism of wear formation for grass (sickle polish) is distinct from antler and wood, which makes grass polish more resistant/less vulnerable to damage. Some specimens, namely 1, 3 and 10, also alternate between correct and incorrect identification. This is likely because these specimens were correctly identified by a narrow margin to begin with and some degree of expected variation over repeated scans caused them to trend above and below the classification threshold.

In sum, the outcomes of this study are mainly consistent with Shea and Klenck (1993). They reported, for instance, that even 15 min of trampling can significantly increase the rate of interpretive errors using a conventional approach. This experiment also demonstrates that moderate to heavy damage (produced by 60–90 min of shaking) has a non-negligible effect on the performance of the statistical model used in this study. In concluding their article, Shea and

Klenck (1993) reaffirm the recommendation that use-wear analysis should be directed at undamaged artifacts and assemblages whenever possible. This sentiment is still accepted practice among contemporary use-wear analysts and remains valuable advice. However, it is also worth pointing out that there is almost certainly no such thing as a perfectly preserved assemblage, all artifacts having inevitably been exposed to at least low levels of post-depositional alteration. What is more, the exclusion criteria for worn assemblages are not necessarily obvious, and the process of exclusion itself involves a level of subjective judgement (Evans et al., 2014). The likely reality is that lightly and moderately damaged assemblages are analyzed routinely, either knowingly or unknowingly. Given the actuality of the situation, it is important that the use-wear methods we choose to employ are robust enough to function effectively despite confounders. The skill and experience of analysts is an obvious buffer against the confounding effects of post-depositional wear. Prior to this experiment, on the other hand, it was not experimentally known how well quantitative methods of the type demonstrated here would function under expected archaeological conditions. Fortunately, based on these outcomes, we can be reasonably confident of quantitative predictions, so long as already common precautionary measures are observed.

4.5 CONCLUSION

Despite methodological and technological advances in the field of lithic use-wear analysis it continues to be dogged by a poor understanding of wear formation processes (further complicated by differences in lithic raw material response) the impacts of the depositional environment and a lack of a quantitative foundation. As a means to correct some of these issues, several archaeologists have again begun to experiment with quantitative methods that rely on sophisticated measurements of tool surfaces. While many of these experiments have shown promise, the application of quantitative use-wear methods to archaeological materials has remained limited. Among the reasons for caution is the fact that the sensitivity of these techniques to damaging post-depositional effects is untested. This study not only develops a method of differentiating contact materials with the use of a LSCM, but demonstrates that it is capable of characterizing even lightly and moderately damaged specimens.

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CHAPTER 5: SUMMARY AND CONCLUSIONS

During the MSA the diversity of material behaviours evinced by the earliest *Homo sapiens* and their ancestors increased significantly. The appearance of these behaviours is now thought to be largely related to one or more episodes of extreme aridity that significantly altered the environments of Africa between MIS 6-2, potentially in combination with shifts in human demography. Nevertheless, these large-scale processes almost certainly varied in their regional expression. Eastern Africa, in particular, featured highly variable environments, which likely contributed to its diverse archaeological record. To properly characterize this diversity it is vital to excavate sites from a range of geographic and environmental contexts. In the case of Tanzania, the south of the country has remained largely unexplored by Stone Age archaeologists, resulting in significant gaps in our knowledge of the region. The research presented in this dissertation helps to fill the geographic gap between northern Tanzania and southern African archaeological sequences.

One of the primary contributions of this dissertation is a greater understanding of the economic use of stone resources at Magubike rockshelter. Based on my analysis, I conclude that local cherts were preferred materials for the manufacture of stone tools, and thus, flaked more intensively to gain the most usable products. This behaviour was likely further reinforced by the relative scarcity and unpredictability of chert in the Iringa landscape. Chert also seems to have been relied on for the manufacture of hunting weapons. Pointed flakes were created by manipulating the surface of the core prior to extraction such that the resulting piece did not require further modification. Numerous chert points featured evidence of impact, consistent with hunting. The manner in which aggregated damage was distributed on the margins of these flakes also indicates a hunting function. Other, less intensively reduced materials, such as quartz and metamorphic stones were more likely used as cutting or scraping tools based on a lack of impact fractures and the way in which damage was distributed on their edges.

The functional analysis of the points from Magubike in combination with other analyses carried out by IRAP members now allows us to make some tentative conclusions as to how the site was used during the MSA. It is noteworthy that the MSA levels contain lithic reduction debris, a few retouched tools and animal bones, some of which feature evidence of butchery. Clearly, the residents were involved in the processing of animal carcasses and the creation/maintenance of stone tools. The functional data also point to a hunting function for at least a portion of the artifacts. The picture that emerges is one of an impermanent camp and/or base of hunting activities, perhaps occupied on a seasonal basis. The area around the shelter (given current climatic trends) is characterized by ephemeral streams that dry-up completely during the dry season (although we did observe people digging for sub-surface water in dry stream beds). Water may thus have constituted a limiting resource for foraging groups, restricting intensive habitation of the area around Magubike to particular times of year. The shelter itself would also be more attractive during the wet season when rains are frequent and torrential. However, it is important to stress that Magubike rockshelter was probably closely integrated into a system of nearby shelters and other significant locations on the landscape. Surveys conducted by IRAP and others reveal numerous nearby shelters with evidence of Stone Age occupation, many within a few hundred meters from one another. We therefore, have no reason to suspect that the Magubike site was anchoring settlement in the area. Rather, any of the dozens of nearby sites, including Magubike, may have served as temporary shelters to get out of the rain, process game, and retool.

While usage patterns indicate a preference for chert, the intensity with which all materials were used at Magubike seems to have increased over time. This pattern is probably due to declining access to stone resources during the MSA occupation of the site. There are several possible scenarios to explain this observation, including changes in settlement strategy, the type and frequency of mobility practiced, and an increase in competition from other hominins. The ultimate cause of some or all of these organizational changes might be the drier and more unstable climate of the late Pleistocene. Scarcity of food and water due to climatic changes would likely have increased the size of foraging ranges and required hunter-gatherers to adopt a more mobile subsistence approach. The effects of increased mobility seem to be imprinted on the lithic record of Magubike. As human groups began to travel farther in search of resources, their access to fixed sources of tool-stone became more tenuous necessitating that they make more efficient use of the materials that they did have.

The appearance of ostrich eggshell beads in the Magubike sequence, around 50 kya, may be further related to climate forcing and a need for social technologies to mark group identity and mediate intergroup interaction. In particular, these objects became necessary as shrinking habitable areas brought unrelated populations of humans into contact with one another with growing frequency. These interactions would have to be carefully handled to avoid conflict and mediate territorial boundaries. The construction of social networks was also vital to early hunter-gatherers who could not always rely on their local environments to consistently provide for their subsistence needs, particularly during periods of climate flux. Good relationships with neighbors provided mutual insurance against localized shortages as well as other social benefits, including the exchange of marriage partners.

While the analysis of the stone tools from Magubike shows statistically significant trends, the above interpretation needs to be heavily qualified. As it is, the chronology of Magubike is not well integrated into regional sequences and therefore cannot be convincingly aligned with the climate record of eastern Africa or other archaeological sites. For now, local climate data and a better understanding of the formation of the site (both of which are underway) are required to test this idea. A more thorough chronology is also necessary to begin to assess the rate at which these changes occurred.

The complementary focus of this dissertation is quantitative use-wear methodology. The mathematical description and comparison of use-wear signatures represents a major step in understanding the economic systems of Stone Age hunter-gatherers. However, forward progress has been slow. As part of my investigation of point function at Magubike I provide experimental validation of the damage distribution method developed by Bird and later refined by Schoville and others. This work serves to reinforce the findings of previous studies as well as the research presented in this dissertation. Furthermore, I developed and tested a method of use-wear analysis that relies of 3D data generated with a LSCM. Because both of these methods rely on statistical rather than visual comparisons there are arguably more objective and transparent than conventional methods currently in use.

5.1 FUTURE DIRECTIONS

In future, I hope that efforts will be made to better situate the data from Magubike into a broader regional framework. The last time this type of comparative work was attempted was in 2011 and a great deal has been added to our understanding of Magubike since then. Furthermore, there are many remaining questions that hinge upon the establishment of a firm site chronology.

To the extent that it is possible given the problematic stratigraphy, secure dates would be a considerable asset to future research and interpretation. Related to the issue of dating is that of paleoenvironmental reconstruction. I hypothesized in Chapter 2 that the pattern of tool-stone usage is consistent with a backdrop of deteriorating environmental conditions. However, a comprehensive understanding of the paleoenvironmental history of the site will also be necessary to test this idea.

Comparative work involving the points from Magubike would also be interesting. By the standards of the finely-made Aterian and Stillbay points of northern and southern Africa, respectively, the points from Magubike are crude. Although we have good reason to suspect that at least some of these objects were used as hunting equipment they do not all exhibit equal levels of energy investment or care. One possibility is that artifacts such as Stillbay points were imbued with greater symbolic significance, and/or were markers of individual skill. On the other hand, similar symbols may have been encoded in different media at places like Magubike. In an eastern African context, hunting tools may have been viewed in more utilitarian terms.

I also think that there are many possible ways to build on the use-wear method that I developed in Chapter 4. As a proof of concept, I think that the results are very promising and future avenues might include programs testing a greater variety of both contact and lithic materials. I also think that it may be possible to modify the method to flag post-depositionally worn specimens so as to exclude them from further analysis.

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