CHANGE IN LITHIC TECHNOLOGICAL ORGANIZATION STRATEGIES DURING THE MIDDLE AND LATER STONE AGES IN EAST AFRICA

BY

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DISSERTATION

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ABSTRACT

This dissertation reports on archaeological research carried out in Kenya's central Rift Valley. The primary research objective was to investigate differences in lithic technological organization strategies among archaeological sites dating to the Middle (MSA) and Later (LSA) Stone Ages. The motivation for the project was to better understand how the development of cooperative social networks by modern humans during the late MSA enabled more effective planning of tool use during the LSA.

To accomplish the research objective I analyzed six flaked stone artifact assemblages from three different archaeological sites located in the Lake Naivasha basin. Three MSA assemblages from Marmonet Drift are dated >110 ka, 110-94 ka, and <94 ka; two early LSA assemblages from Enkapune Ya Muto date from >40 to 36 ka; and one LSA assemblage from Ol Tepesi dates to 19 ka. Assemblages were analyzed in four ways: 1) typological composition; 2) artifact morphometrics; 3) tool production techniques; and 4) artifact curation strategies, including use-wear analysis and retouch patterns. These assemblages provided an exceptional opportunity to examine long-term changes in human technological organization with great control over raw material quality and availability.

Results of my analysis show dramatic change in lithic technological organization strategies between the MSA and LSA in terms of artifact size, shape, morphological standardization, production techniques, use, and curation. Large and heavily retouched stone artifacts, including unifacial points, scrapers, and knives, dominate MSA assemblages. Most of these tools accumulated high frequencies of use-wear traces and, along with large numbers of soft hammer retouch flakes in assemblages, indicate long artifact use-lives. These data suggest a

technological organization strategy of curating large, transformable, morphologically flexible, and functionally versatile tools that had the potential to perform a wide range of unplanned tool-using activities. Conversely, smaller, thinner backed microliths with low frequencies of use-wear traces dominate LSA assemblages. End scrapers made on blades and their associated steep-edged retouch flakes represent the only major curated tool class. These data suggest that LSA technological organization strategies were geared toward the production of disposable, replaceable, and morphologically standardized tools organized in anticipation of more planned tool-using activities.

The results of this research project are significant for our understanding of the evolution of human technological planning. It appears that MSA humans reacted to foraging opportunities they encountered in their environments by relying on flexible and transformable toolkits while LSA humans appear to have anticipated and strategically planned for tool-using activities with specialized toolkits. The development of cooperative social networks during the late MSA likely enhanced the ability of modern humans to plan resource acquisition strategies using mechanically efficient and standardized tool designs.

This dissertation is dedicated to my parents,

Susan and Mitchell Slater,

Thank you for all that you do.

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Finally, I have come from humble beginnings to accomplish great things and without the constant support and encouragement from my family this project would never have been seen through to completion. My Mom and my Dad taught me at a young age to work hard and never to be satisfied with average work, my work ethic and this dissertation is a testament to their faith in me. My two brothers, Sam and Marty, did so much more than put up with my (sometimes) hard-handed rule as big brother. Sam was a constant companion throughout my childhood, a couple of Dashin' Desperados we were, and to this day is still the most difficult videogame foe I have ever faced. Marty taught me responsibility and patience, I would not be the man I am today without him. I am lucky to have been able to spend so much time with my grandparents, both when I was young and to this day. Pop Bobby, along with my father, taught me how to fish and drive a boat, skills I one day hope to pass on to my own children. Mimi taught me how to play cards, honk the car horn (beep-beep, Grandma's driving), and always had time to throw me a ball as I jumped in the pool. I hope I have lived up the label of #1 grandson. Grandma Gerry taught me the value of family and that there is always time for brunch or a phone call. Grandpa Lester always provided me with love, support and kind words to carry me on.

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Chapter 1

Introduction

Fundamental questions concerning the timing, context, and nature of the emergence of our species, *Homo sapiens*, have dominated paleoanthropological research over the past 25 years (Mellars and Stringer, 1989; McBrearty and Brooks, 2000; Bar-Yosef, 2002; Mellars et al., 2007). As archaeologists discover more sites, more fossils, more artifacts, more evidence for complex technological and symbolic behaviors, and refine chronological sequences around the world, it has become clear that the African Middle Stone Age (MSA), the period of time from about 300 to 50 thousand years ago (ka), is crucial for understanding the origins of anatomically and behaviorally modern humans. The period following, the Later Stone Age (LSA), dates from 50 ka to the Iron Age in the mid-late Holocene and is characterized by the amalgamation of the full suite of modern human behaviors that appeared at different times and in different places during the MSA. Human evolution during the African MSA and LSA includes dramatic changes in their biology (Cieri et al., 2014), cognition (Barham, 2010), socio-territorial organization (Ambrose and Lorenz, 1990), and technology (McBrearty and Brooks, 2000). In this dissertation I will focus on the technological aspects of behavioral change between these two periods.

The East African Rift Valley is an ideal location to investigate the evolution of modern human behavior. The same volcanic and tectonic activities that were responsible for the original formation of this Rift Valley also did an exceptional job of preserving millions of years of faunal and archaeological remains, as well as creating the stratified volcanic materials suitable for the dating of many of those deposits (WoldeGabriel et al., 2000). The earliest anatomically modern *Homo sapiens* fossils appear in the eastern Rift Valley just after 200 ka in the Omo Kibish

Formation (McDougall et al., 2005) and this region was likely an important source area for modern human populations that dispersed out of Africa to the Levant and Arabian Peninsula during the last interglacial and spread across the world after 60 ka (Shea, 2010; Lachance et al., 2012; Veeramah and Hammer, 2014). All materials that I will analyze in this dissertation are derived from MSA and LSA archaeological sites in Kenya's central Rift Valley.

Different paleoanthropologists emphasize different aspects of behavioral change as most significant for the transition from 'archaic' to 'modern' species of *Homo sapiens* (table 1.1). Depending on the specific archaeological finds of their field sites, different social, cognitive, or technological innovations are given priority. Modern humans as a species, however, are characterized by an extreme adaptability of resource exploitation (Klein, 2001, 2009; Weaver et al., 2011; Thompson and Henshilwood, 2014), social (Ambrose and Lorenz, 1990; Gamble, 1998; Ambrose, 2002, 2010), symbolic (Henshilwood et al., 2011; Texier et al., 2013), and technological (Yellen et al., 1995; Ambrose, 2001a; Conard et al., 2012; Scerri, 2013) behaviors that manifest themselves in different ways depending on climatic or environmental conditions such as rainfall, temperature, ecology, and landscape topography. Therefore, it should be expected that Stone Age humans at different times, places, and climates across Africa had different cultural behaviors, used different technologies and relied on different social and subsistence strategies for survival. It is the wide range of behavioral capability, in addition to some uniquely modern human behaviors such as symbolism and cooperative social networks, which characterize our species. The evidence for this diversity and adaptability is well documented in southern and northern Africa, and it is now emerging in the archaeological record of the East African MSA and LSA as well.

Table 1.1. List of modern human behaviors and their first appearance dates in Africa

Behavior	Date	Evidence or Location
Painted images	28 ka	Apollo 11, Namibia (Wendt, 1976)
Resource exploitation scheduling	40 ka	Seal hunting seasonality (Klein et al., 1999)
Poison armatures	40 ka	Border Cave (d'Errico et al., 2012)
Boats	50 ka	Australia (Davidson, 2010)
Backed microliths	≤55 ka	Enkapune Ya Muto (Ambrose, 1998a) and Mumba (Mehlman, 1989);
	71 ka	Howiesons Poort (Brown et al., 2012)
Fishing	60-70 ka	Barbed bone points: Katanda (Yellen et al., 1995; Feathers and Migliorini, 2001)
Enhanced technological planning	75-60 ka	Stillbay, Howiesons Poort (Wurz, 2013)
Incised objects	75 ka	Ochre and ostrich eggshell: Blombos (Henshilwood et al., 2009), Diepkloof (Texier et al., 2013), Apollo 11 (Vogelsang et al., 2010)
Bone tools	85 ka	Blombos (Henshilwood et al., 2001), Klasies River Mouth (d'Errico and Henshilwood, 2007), Sibudu (Backwell et al., 2008)
Long distance exchange	100 ka	Obsidian (Merrick and Brown, 1984a, 1984b; Merrick et al., 1994)
Beads	50-45 ka	Ostrich eggshell; Kenya (Ambrose, 1998a) and Tanzania (Miller and Willoughby, 2014)
	90-120 ka	Marine shells; Levant (Vanhaeren et al., 2006), North (Bouzouggar et al., 2007) and South Africa (Vanhaeren et al., 2013)
Human burials	90-120 ka	Skhul and Qafzeh Caves, Israel (Klein, 2009; Shea, 2010)
Regional artifact styles	150 ka	Africa (Clark, 1992; McBrearty, 2013)
Heat treatment of stone	160 ka	Pinnacle Point 13B (Brown et al., 2009)
Shellfishing	160 ka	Pinnacle Point 13B (Marean et al., 2007)

Table 1.1 continued. List of modern human behaviors and their first appearance dates in Africa

Pigment processing		≥280 ka	Kapthurin Formation, Kenya (McBrearty, 2001), Twin Rivers, Zambia (Barham, 2002a)
Blades		≥280 ka	Kapthurin Formation, Kenya (Johnson and McBrearty, 2010, 2012)
Hafting	Backed pieces	61-65 ka	Sibudu Howiesons Poort (Lombard, 2011)
	Points	≥284 ka	Kapthurin Form. (Tryon and McBrearty, 2002)
	Oldest (tentative)	500 ka	Kathu Pan1, South Africa (Wilkins et al., 2012)

Note that chapter 2 provides an in-depth discussion of these behaviors and their associated archaeological evidence

Because of the great diversity in the MSA and LSA archaeological record across Africa there is still no consensus among paleoanthropologists on how modern human behavior should be defined (see chapter 2 for a review). Rather than attempting to measure whether any single behavior was more significant to the evolution of modern humans than another, I will examine one aspect of the 'archaic' to 'modern' human behavioral transition in detail, the change in lithic technological organization strategies from the MSA to the LSA. This dimension of modern human behavior has been examined in South Africa (Bousman, 2005; Porraz et al., 2013;), North Africa (Scerri, 2013), and East Africa (Eren et al., 2013), but rarely been explicitly theorized (Binford, 1989; Ambrose, 2002, 2010; McCall, 2007).

Theoretical Framework and Research Objective

Binford (1989: 19) originally proposed that that the relationship between lithic technology and the behavioral consequences of planning, "…is among the most productive avenues of research…" for understanding the transition from 'archaic' to 'modern' human behavior. Ambrose and Lorenz (1990; Ambrose, 2002, 2010) extended this proposition by suggesting that the development of cooperative information-sharing social networks among interacting hunter-gatherer local groups during the late MSA, after ~100 ka during the early last glacial maximum, would have enhanced planning by providing information regarding current environmental conditions and food resources. This strategy of knowledge pooling would have reduced the risk of foraging failure and permitted enhanced technological planning whereby people could make task-specific tools in advance of anticipated tool-using activities. They proposed that improved planning during the late MSA and LSA, evinced by the transition to blade-based microlithic tool industries and seasonal scheduling of food resource exploitation, was an important component of the transition to fully modern human behavior.

The act of making stone tools generates a large amount of flaking debris that represents a direct record of Stone Age human behavior. This debris (debitage) is composed of retouched tools, flakes, broken chunks, cores, and the occasional hammer stone. All are byproducts of the tool production sequence and offer clues as to what types of tools were made, and how they were produced, maintained, and used. Lithic technological organization (TO) is a theoretical framework that explains the strategic decisions people make regarding tool production (i.e. planning) as a way to buffer against the risk of failure (Nelson, 1991; Bamforth and Bleed, 1997). These strategic decisions include balancing the goals of time (Torrence, 1983; Eren et al., 2013), weight (Kuhn, 1994; Morrow, 1996), and risk (Bousman, 2005; McCall, 2007) minimization. For example, in some situations it may be better to make a small number of large versatile tools that can accomplish several different tasks and be quickly resharpened or reshaped to accomplish different tasks, whereas in other situations it may be better to have many small, but differently shaped, tools designed to accomplish specific tasks. Lithic TO theory includes all aspects of the tool production sequence from raw material collection, use, and conservation to artifact production, maintenance, and discard (Nelson, 1991; Andrefsky, 1994; Shott, 1996).

Observing similarities and differences in tool manufacturing processes between MSA and LSA industries is extremely useful for making inferences about long-term diachronic changes in TO strategies (Bradbury and Carr, 2014).

The ultimate objective of this dissertation is to investigate how the development of cooperative social communication networks by modern humans during the late MSA enabled more effective planning of tool use during the LSA. To do this I will quantify changes in lithic TO strategies spanning the MSA/LSA technological transition, and specifically, the shift from MSA flake-based to LSA blade-based toolkits. Many explicit hypotheses concerning differences in patterns of artifact morphology, size, production, maintenance, and discard were set forth prior to the study and will be presented and tested in the following chapters. These hypotheses are encompassed within two research questions:

1. How do lithic TO strategies change from the MSA to LSA?
2. Do LSA TO strategies represent enhanced technological planning relative to the preceding MSA?

To answer these research questions I will analyze artifact assemblages from three archaeological sites spanning ~100,000 years from the central Rift Valley in Kenya. The oldest site, Marmonet Drift (GtJi15), contains three MSA archaeological horizons that are dated to >110 – 94 ka. The intermediately aged site, Enkapune Ya Muto (GtJi12), contains two early LSA horizons that are dated to between 55 – 35 ka. And the youngest site, Ol Tepesi (GsJi53), has one LSA horizon that is dated to ~19 ka. These three sites represent key temporal points (the mid-late MSA, early LSA, and mid-late LSA) that will allow me to assess long-term diachronic change in lithic TO strategies spanning the MSA/LSA technological transition. To assess change in lithic TO strategies I will analyze artifact assemblages from each site in four ways: 1) typological composition; 2) artifact morphometrics; 3) tool production techniques; and 4) artifact curation strategies, including use-wear analysis and retouch patterns. The concept of technological planning is qualitative, multifaceted, and complex, encompassing aspects of toolkit composition, production, standardization, use, and curation. My methods of analysis have been specifically selected to measure these different aspects and test expectations derived from TO theory and other temporally relevant archaeological assemblages.

By answering these two research questions I will provide valuable insight into the evolution of modern human cognition and behavior during a critical period in our species' history. In particular I will show how humans used available information to better plan and organize their use of technology so that they reduce the risk of failure during tool-using activities. The development of this enhanced level of technological planning would have been crucial for enhancing the survivability of modern human populations in the unpredictable and unstable environments of the last ice age. Ultimately, this behavior likely facilitated the dispersal of our species out of Africa after ~60 ka and the subsequent replacement of archaic human species across the globe. Therefore, the results of this dissertation will be significant for understanding how communication and technology, two behaviors that modern humans excel at, shaped the evolutionary history of our species.

Outline

Accomplishing the research objective of this dissertation first requires a contextual background for the project. Chapter two presents the climatic, fossil, genetic, and archaeological evidence for the timing, nature, and variability of modern humans and their behavior, including the MSA/LSA technological transition and lithic TO theory. Chapter three presents the archaeological materials used in this project and their associated methods of analysis. Chapters four through six each present in-depth analysis of lithic artifact assemblages from individual archaeological sites in Kenya, one MSA and two LSA, which will serve as the basis for higher-level theoretical interpretations of TO strategies. Collectively, these single site analyses will serve as the foundation for chapter seven in which I will present a comparative and diachronic analysis of TO strategies. Finally, chapter eight provides a summary of the project's results and conclusions, and discusses the broader implications of this study for the evolution of technological planning across the MSA/LSA transition and modern human behavior in general.

Chapter 2

Modern Human Origins and Lithic Technological Organization Theory

This chapter reviews the evidence for modern human origins and the role of lithic technological organization within human evolutionary history. I begin with a summary of the Earth's climatic record over the last 300,000 years. Because variability in rainfall and temperature (among other factors) affect the distribution of plant and water resources in the short (daily and monthly) and long (year, decade, millennial, etc.) term, climate (and climate change) has significant effects on the variability of subsistence, mobility, settlement, and social behaviors of humans and animals. This background is important for understanding behavioral choices that modern humans would have made for surviving in the Stone Age. Next I will present the biological evidence for the emergence of anatomically modern humans (i.e. *Homo sapiens* or *H. sapiens*). Fossil and genetic data show that *H. sapiens* first appeared in East Africa sometime in the last 200,000-150,000 years but it was only within the last 60,000 years that modern humans spread outside of Africa and replaced archaic hominin species across the world (Cavalli-Sforza and Feldman, 2003; Klein, 2008; Fu et al., 2014). This background discussion validates my selection of the East African Middle Stone Age (MSA) and Later Stone Age (LSA) periods as the most relevant time and place to investigate the evolution of modern human technological planning. In the second part of the chapter I review the archaeological evidence for the evolution of modern human behavior during the MSA and LSA and the two main competing models explaining its emergence. I discuss the origin and development of regional cultural sequences in the MSA, including variation of new technologies, symbolic behaviors, long-distance exchange networks, and socio-territorial organization. Understanding the range of behavioral variability for modern humans across Africa is paramount for generating testable predictions regarding differences in levels of technological planning spanning the MSA/LSA technological transition. Finally, I frame my investigation of the evolution of planning within the theoretical framework of lithic technological organization and present the specific hypotheses that will be tested in the later chapters of this dissertation.

Paleoclimate of the Late Pleistocene

Deep-ocean sediment cores provide the longest record of Earth's environmental history, including its paleoclimate. These cores contain a chronological record of environment and climate-induced variation in mineral grain size, terrestrial dust, microfossils, molecular biomarkers, and various other types of detritus that fall to the ocean floor. These microfossils, and measurements of oxygen isotope ratios (expressed as $\delta^{18}O$‰ values) in calcium carbonate foraminifera shells in particular, can tell us a great deal about the history of the ocean's chemistry, temperature, and ice cover. Emiliani (1955) originally examined deep-ocean sediment cores and interpreted variation in oxygen isotope ratios as reflecting the ocean's temperature. However, it was later found that the isotopic variation actually reflects global ice volume, and thus a record of ice ages and sea levels (Aitken and Stokes, 1997). The observed variability over time illustrated a clear picture of climatic change in Earth's recent history. Emiliani (1955) identified 13 warm and cold phases that he termed 'Marine Isotope Stages' (hereafter MIS). This MIS sequence was later reaffirmed, and expanded, to over 100 stages back to almost 6 million years ago (Shackleton and Opdyke, 1973, 1976; Shackleton et al., 2000; Lisiecki and Raymo, 2005). Martinson et al. (1987) combined oxygen isotope data from deep-ocean cores with the concept of 'orbital tuning' (variation in Earth's orbital geometry) and defined the chronological boundaries of MIS stages over the past 300,000 years. Orbital tuning enhances the precision and accuracy of these boundaries. However the rates of climate change across boundaries is poorly resolved in marine cores due to vertical mixing of sediments, which limits resolution to several centuries at best (Martin, 1993; Kidwell and Flessa, 1995; Roy et al., 1996). Ice core records show that the MIS 5-4 boundary, at 74 ka spans two stadial-interstadial events between 74 and 70 ka, and should be redefined to 70 ka (fig. 2.1).

Higher resolution data for understanding Earth's recent climate and atmospheric conditions is available from ice cores in Greenland (North Greenland Ice Project Members, 2004). Snow that accumulates each year on continental ice sheets captures dust, volcanic ash, aerosol chemicals, atmospheric gases (as bubbles), and even human pollutants. These materials can be analyzed at annual resolution with chemical and isotopic methods to reconstruct global environmental conditions such as temperature, precipitation, ice volume, sea level, atmospheric CO_2 and methane levels, atmospheric dust, solar insolation variability, cosmogenic nuclide production and magnetic field strength variation, and events such as volcanic eruptions. Oxygen isotope ratios from the Greenland ice cores show that between 128 ka and 12 ka Earth's temperature and precipitation shifted 25 times, often abruptly in a few decades between warm/wet and cold/dry periods. These quick shifts of 8-16°C, called Dansgaard-Oeschger (D-O) events (Dansgaard et al., 1996) or Greenland Stadial (GS = cold) and Interstadial (GI = warm) events, are invisible in the lower-resolution deep-ocean cores. Despite lower chronological resolution, direct dates and oxygen isotope records from cave speleothems in China (Cheng et al., 2009) and the Levant (Bar-Matthews et al., 2003) confirm that the Greenland climate record is also present in the tropics and mid-latitudes.

In summary, MIS stages 8 – 1 encompass the last 300,000 years. Odd numbered stages are generally characterized as warm and wet interglacial periods while even numbered stages reflect more cold and dry periods (Aitken and Stokes, 1997). The duration of numbered MIS stages (table 2.1) is shorter for the last 128,000 years (MIS 5 to MIS 1) because Emiliani labeled them before the pattern of 100,000-year-long cycles with shorter subcycles was recognized. Based on the combination of oxygen isotope data from deep-ocean sediment cores, Greenland ice cores, and stalagmites (speleothems) a series of alternating warm/wet and cold/dry climatic periods is observed. Figure 2.1 shows the $\delta^{18}O$‰ record of the Greenland Summit ice core for the last 123,000 years labeled with the five most recent MIS stages, 25 Dansgaard-Oeschger events, and the Toba super-volcano event (discussed below).

Table 2.1. List of marine isotope stages, their ages, and climate. Dates according to Martinson et al. (1987: Table 2).

Stage #	**Age**	**Climate**
MIS 1	13 – 0 ka	Warm and wet – Holocene.
MIS 2	29 – 13 ka	Consistently cold and dry - Last Glacial Maximum.
MIS 3	59 – 29 ka	Highly variable between glacial and sub-glacial.
MIS 4	74 – 59 ka	Consistently very cold and dry glacial. Toba erupts at 74 ka.
MIS 5a	90 – 74 ka	Generally warm and wet interglacial but with alternating sub-stages. Stages 5a, 5c, and 5e are warmer while 5b and 5d are cooler intervening periods. 5e was warmer than analogous MIS-1 (see figure 2.1).
MIS 5b	96 – 90 ka	
MIS 5c	107 – 96 ka	
MIS 5d	116 – 107 ka	
MIS 5e	128 – 116 ka	
MIS 6	191 – 128 ka	Cold and dry. Possible East African megadroughts.
MIS 7	243 – 191 ka	Warmer and wetter.
MIS 8	300 – 243 ka	Cooler and drier.

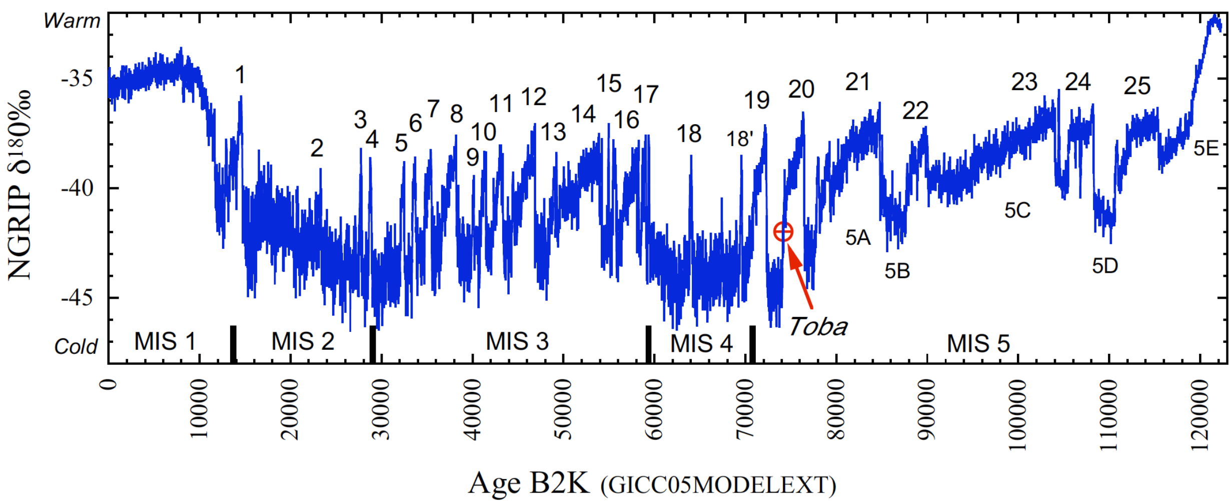


Figure 2.1. North Greenland ice core oxygen isotope values from 0-123 ka, plotted as 20-year averages (NGRIP Members, 2004) in years before 2000 AD (B2K), using the Greenland Ice Core Chronology extended age model (GICC05Modelextend) (Wolff et al., 2010; Obrochta et al. 2014; Data downloaded from www.iceandclimate.nbi.ku.dk/data/). Marine Isotope Stages (MIS) and substages are indicated below the plot line; Dansgaard-Oeschger interstadial warm events are numbered above. MIS age boundaries follow Obrochta et al. (2014, figure 1, except for the MIS 4/3 boundary). The circle at 74.16 ka marks the position of the large volcanic sulfate spike at 2547.98-2548.03 m below the core surface that is correlated with the Toba eruption (Abbot et al., 2012; Svensson et al., 2013). Although Martinson et al., 1987 date the MIS 5/4 boundary to 74 ka, MIS 4 appears to begin around 70 ka, after interstadial 19. Figure used with permission from Stanley Ambrose.

Additional evidence for East Africa's recent climatic record comes via sediment cores from Lake Malawi. These lake core deposits preserve finely laminated, high-resolution records of East African terrestrial climate variability including a series of 'megadroughts', with short intervals of higher rainfall, before 130 ka during late MIS 6 (Scholz et al., 2007; see Lane et al., 2013 for the revised and updated chronology). These megadroughts were characterized by dramatically lowered water levels in some of East Africa's largest lakes, reflecting intense, extended dry seasons and less intense, shorter rainy seasons (Scholz et al., 2007; Cohen et al., 2007). Terrestrial and aquatic ecosystems would have also been affected, with plant and animal species shifting habitation zones in response to variation in local weather patterns.

One specific event, the volcanic super-eruption of Mt. Toba in Sumatra ~74 ka near the end of MIS 5, as defined by Martinson (1987), may have been a particularly important catalyst for global climatic change (Storey et al., 2013). The crater lake that remains behind today hints at the scale of the explosion that occurred; the lake is about 90 km long, 35 km wide, and over 500 m deep. Estimates of the blast volume suggest that Toba was the largest known explosive volcanic eruption in Earth's last 27 million years (Ambrose, 1998b). Obviously, within the physical blast radius the environmental destruction would have been immediate and enormous (Robock et al., 2009; Williams et al., 2009). However, it is the more widespread and long-term effects of dust, ash and sulfur ejected into the atmosphere that would have been most damaging to human populations in Asia, Middle East, Europe, and Africa. Evidence of the immense dispersal of dust and ash from the Toba eruption is observed in the Indian Ocean, Arabian Sea and East China Sea with a widespread 10+ cm layer of volcanic ash (Pattan et al., 1999; Song et al., 2000; Bühring et al., 2000; Liu et al., 2006; Williams et al., 2009).

High levels of volcanic sulfate from Toba have been found in the Summit, Greenland ice core, over 13,000 km away. The sulfate spike spans six years of ice accumulation within the interstadial to stadial 20 transition (Zielinski et al., 1996). It is followed by about 1750 years of the ice core's lowest oxygen isotope ratios (i.e. cold and dry conditions) of the last 123,000 years (figure 2.1) (North Greenland Ice Project Members, 2004). Oxygen isotope ratios from tropical speleothems indicate that this intense cold period occurred at lower latitudes as well (Cheng et al., 2009). Together, these data support a rapid and extreme global cooling event (i.e. six-year volcanic winter), followed by 1750 years of low temperatures and high aridity that was more intense than that of the Last Glacial Maximum (LGM) around 20 ka (Ambrose, 1998b; Rampino and Ambrose, 2000).

Climate models run by Robock et al. (2009) of Toba's impact on atmospheric aerosol chemistry and on vegetation cover support dramatic global cooling and increased aridity in the immediate aftermath of the eruption. Robock et al. (2009) concluded that the volcanic winter simulated in two different models would have had devastating consequences for human populations as well as global ecosystems. Paleosol carbon isotopes in three sites spanning >450 km in central India stratified above and below the Toba ash support this vegetation impact model. Soils beneath the ash supported C_3 plants and were likely forested; soils formed on and above the ash supported C_4 grassy vegetation, demonstrating that central India was deforested following the Toba eruption (Williams et al., 2009). To conclude, the Toba eruption was massive in scale and had both immediate and long-term effects on worldwide climate, though the more specific effects on East Africa's climate, ecosystems, and modern human populations are not yet fully agreed upon (Williams, 2012).

Earth's climate during the remainder of MIS 4, during Greenland stadials 19-18, about 70 to 59 ka, with only two brief interstadials (18 and 18', fig 2.1), was consistently colder and drier than any other period in Greenland ice core records. Such a climate regime would have reduced closed forests, expanded grasslands, and created a scattered and unpredictable resource structure that was spread out across large and open environments (Ambrose and Lorenz, 1990). It is notable, though, that there was regional variation in environmental change, with some regions, such as equatorial and southern Africa, experiencing less change than others (Blome et al., 2012). MIS 3 was relatively warmer and wetter, but with more variability than MIS 4. Distributions of animals, plants and water resources would have shifted considerably with the seasons, and changing rainfall patterns would have required flexibility in adaptation to new localized conditions. For example, shallow eastern African Rift lakes would have had frequent fluctuations in depth and shoreline margins while forests and grasslands would have expanded and retracted as rainfall and temperatures fluctuated (Hamilton, 1982). Additionally, depending on water influx and depth, many lakes may have changed from fresh to alkaline conditions, which would affect the types of animal and plant species that lived in and around them (Bergner et al., 2009; Gasse et al., 2008).

Finally, MIS 2 encompasses the LGM, the period in Earth's recent history when polar ice and glaciers in North America, Europe, and Asia were at their thickest and the sea levels at their lowest. Relative to the present-day, continental and polar ice sheets incorporated enough water to lower sea levels around the world by 130 to 160 m (Klein, 2009). This exposed large tracts of land along continental shelves and, in some cases, connected previously isolated landmasses, allowing humans and other animals to inhabit new areas. These ice sheets profoundly impacted Earth's climate, causing drought, desertification, and erosion. In equatorial regions, the LGM caused forests to recede, and grasslands and deserts to expand (Maitima, 1991). These glacial conditions persisted until about 15,000 years ago when conditions gradually became warmer and wetter up through the Holocene.

Overall, the picture that emerges of Earth’s climate over the last three glacial-interglacial cycles (300 ka), is one of intermittent swings between warm/wet and cold/dry conditions, some of which are on a precessional scale of approximately 11,000 years, but others are on a millennial scale (1000-4500 years), particularly during the last 75,000 years (North Greenland Ice Project Members, 2004). East Africa also faced multiple 'megadroughts' before ~130 ka that would have dramatically affected the composition of terrestrial ecosystems, requiring rapid adaptation by modern humans to novel environmental conditions and resource structures. The Toba super-eruption at ~74 ka may have caused a six-year volcanic winter during the transition to an 1750-year-long period of intense cold and aridity (GS 20) (Rampino and Ambrose, 2000) that was followed 2000 years later with the consistently extremely cold and dry MIS 4. MIS 3 returned to a generally variable warm and wet, but still glacial climate, before the arrival of the extremely cold and dry MIS 2 (the LGM). Climate models run by Blome et al. (2012) for the entire 150 – 30 ka time period suggest that, at a continental scale, changes in temperature and rainfall were significant, but asynchronous, and likely created opportunities for migration among adjacent regions by humans exploiting fluctuating resource bases. Finally, Ziegler et al. (2013) have proposed that many of the social and technological innovations of the MSA (discussed below) can be directly linked to the 'climatic seesaw' of the last 100,000 years as modern humans adapted to adapted to consistently changing, rather than stable, environmental conditions.

Fossil Evidence for Modern Human Origins

Current data suggest that anatomically modern humans evolved from archaic human forms within East Africa after 200 ka. The oldest fossil remains attributed to *H. sapiens* date to ~195 ka and were found in the Omo Kibish Formation in Ethiopia (McDougall et al., 2005; Shea et al., 2007). These fossils were classified as *H. sapiens* based on the presence of a rounded brain case and somewhat projecting chin, among other features that distinguished them from

Neanderthals. Another cranium, found in Herto, Ethiopia, dates to ~160 ka and also has a rounded brain case, though it retained relatively large and projecting brow ridges (White et al., 2003). These and other early *H. sapiens* fossils older than MIS 4 in Africa and the Levant are now considered ‘almost-modern’ (see discussion below) (Klein, 2009; Cieri et al., 2014). Other fossils dated to younger than ~120 ka have been found at Border Cave (Butzer et al., 1978; Grün and Beaumont, 2001; Grün et al., 2003) and Klasies River Mouth in South Africa (Singer and Wymer, 1982; Grine et al., 1998; Rightmire and Deacon, 2001).

The oldest fossils outside of Africa that have been classified as *H. sapiens* were found in Israel, at the Skhul and Qafzeh caves, and date to MIS 5 between approximately 125 – 90 ka (Bar-Yosef, 1998; Shea, 2007). These skulls display a mix of archaic (robust brow ridges and projecting face) and modern (rounded and large brain case) traits. It was originally thought that they might represent a transitional species between Neanderthals and *H. sapiens* (Vandermeersch, 2002). More recently, it has been hypothesized that the Skhul/Qafzeh fossils represent the first migration out of Africa by early modern humans around 125,000 years ago, along with the onset of a warmer and wetter climate in early MIS 5 (Stringer, 2003; Shea and Bar-Yosef, 2005). This population appears to have died out in the Levant by ~80 ka ago due to foraging competition with Neanderthals and/or a trend toward cooler and drier conditions near the end of MIS 5 (Shea, 2008). The next oldest evidence for *H. sapiens* outside of Africa is not until ~60 ka when molecular genetic dating suggests that they again expanded out of Africa during the warm/wet conditions of early MIS 3. This time they eventually made their way throughout northern Eurasia by 45 ka (Trinkaus et al., 2003; Higham et al., 2011; Benazzi et al., 2011; Fu et al., 2014), Southeast Asia before 50 ka (Demeter et al., 2012) and Australia by 50 ka (Bowler et al., 2003).

Despite all of these fossils being attributed to the species *H. sapiens* there are notable differences in facial robusticity that separate humans older than ~80 ka from those that are younger (Klein, 2009). Cieri et al. (2014) quantified such craniofacial changes within *H. sapiens* fossils from the Middle to Late Pleistocene, specifically focusing on the size and projection of brow ridges and facial length. The authors found a clear reduction trend for these features over this time period and concluded that humans older than ~80 ka (a.k.a. 'almost-modern', including Skhul/Qafzeh specimens) were craniofacially more robust than younger ones (a.k.a. 'fully-modern'). Cieri et al. (2014: 430) suggested that this physical distinction reflected different levels of the androgen hormone testosterone (T) between 'almost-modern' (higher T levels) and 'fully-modern' (lower T levels) *H. sapiens*. They characterize this change as craniofacial feminization, and draw analogies with changes in cranial morphology from wild to domesticated mammals. Such a reduction in testosterone for 'fully-modern' humans would have had social consequences as well, reducing interpersonal aggression and promoting greater social tolerance (Cieri et al., 2014). Ambrose (2010) has proposed a similar argument for reduction in testosterone and increases in pro-social hormones in increasing social cooperation in post-Toba (<74 ka) human populations in Africa due to strong selection for cooperation in small populations during the 1750-year-long GS-20. This distinction between 'almost-modern' and 'fully-modern' *H. sapiens* suggests that the transition to fully modern behavior likely included subtle, but significant, physiological and hormonal changes.

Genetic evidence for Modern Human Origins

Genetic evidence also supports a recent African origin for modern humans (Hedges et al., 1992; Endicott et al., 2010; Blum et al., 2011). Studies of mitochondrial DNA (mtDNA) in present-day populations from around the world indicate that overall genetic diversity in modern humans is small, but that sub-Saharan Africans have the highest levels of within and among-group genetic variation (Cann et al., 1987; Stoneking et al., 1992; Gagneux et al., 1999; Lachance et al., 2012). This suggests that African populations have evolved longer than non-African ones, because they had the longest time to accumulate genetic differences (Jorde et al., 1998; Jorde et al., 2000). More recent analyses of modern day mtDNA by Behar et al. (2008) and nuclear DNA (Veeramah and Hammer, 2014) have confirmed the 200 ka date for 'Mitochondrial Eve'. Harpending et al. (1993), also looking at mtDNA, found that that the effective long-term population size was very small, around only 10,000 breeding females, or perhaps 50,000 individuals, and that populations expanded during early MIS 3. Taken together, this is strong genetic evidence for a recent African origin from a single small population.

Harpending et al. (1993) also found that modern humans had previously suffered a major population crash, or bottleneck, at some point between 100 ka and 50 ka. This proposed bottleneck has since been supported by other genetic studies that narrowed the date of the bottleneck down to ~70 ka, and reinforced (or even lowered) the low population size estimate (Sherry et al., 1994; Takahata et al., 1995; Jorde et al., 1998; Jorde et al., 2000; Forster, 2004; Fu et al., 2014). Ambrose (1998b; Rampino and Ambrose, 2000; Williams et al., 2009), in particular, has championed this hypothesized bottleneck as coinciding with the Toba super-eruption plus GI stadial 20 and MIS 4, and proposed that modern humans differentiated regionally within Africa during GS-20 and MIS 4, primarily due to small population size, founder effects, and genetic drift. These small groups rebounded in size, likely in tropical Africa during the early last glacial period, particularly after 60 ka, during warmer MIS 3. Finally, fully modern humans appear to have expanded from Africa in two major waves beginning around 60 ka and spread across the world replacing archaic hominins, including Eurasian Neanderthals and Asian *Homo erectus*, outside of Africa in the process (Cavalli-Sforza and Feldman, 2003; Forster, 2004; Fagundes et al., 2007; Fu et al., 2014; Veeramah and Hammer, 2014).

A Question of 'Modern Behavior'

In contrast to the broad consensus of modern human biological origins, questions regarding human behavioral modernity are still the subject of intense debate (e.g. McBrearty and Brooks, 2000; Henshilwood and Marean, 2003; Conard, 2010; Shea, 2011; McBrearty, 2013; Villa and Roebroeks, 2014). The concept of 'modern human behavior' (hereafter MHB) was initially focused on differences between Neanderthals in Europe and modern humans in Africa, but genetic and fossil revelations (discussed above) have shifted this focus to African hominins and the MSA. Ultimately, although there is some agreement regarding what types of archaeological evidence indicate MHB, there is considerable debate about whether there is a distinct sequence, when it occurred, and whether it was gradual or abrupt (Ambrose, 2002, 2010; Henshilwood and Marean, 2003; Conard, 2005; Hiscock and O'Connor, 2006; Belfer-Cohen and Hovers, 2010; Brown et al., 2012). Definitions of MHB vary considerably in scope and criteria, but typically include: cooperative social networks with long distance exchange (Ambrose, 2002), symbolic behavior, including ornamentation and pigments (Ambrose, 1998a; Wadley, 2001; Barham, 2002a; Henshilwood et al., 2009; Henshilwood et al., 2011), syntactical language (Ambrose 2001a, 2010), blade and microlithic technology (Mellars, 1989; Foley and Lahr, 1997; Barham, 2002b, 2013), hafting, bone tools (Brooks et al., 1995; Henshilwood et al., 2001; d'Errico et al., 2012), regional artifact styles (Clark, 1988; McBrearty and Brooks, 2000), sophisticated pyro-technologies (Brown et al., 2009), effective hunting and gathering techniques

(Thompson and Henshilwood, 2014), and seasonally scheduled site use (Klein, 2001, 2009; Weaver et al., 2011).

Several competing models have been proposed by paleoanthropologists to explain the composition, timing, and tempo of the emergence of MHB. Henshilwood and Marean (2003) succinctly summarized the various models, of which two are particularly prominent, and will be compared and contrasted here. The first is termed the *Later Upper Pleistocene* (*LUP*) model, and proposes that *H. sapiens* attained biological modernity around 200 ka, followed by a long period of stasis before abrupt changes in behavior, possibly due to a genetic mutation at ~50 ka (Klein, 1995, 2008). Correspondingly, proponents of this model distinguish anatomically modern humans (~200 – 50 ka) from behaviorally modern humans (after 50 ka). Note that this distinction is not coupled to the slightly earlier transition from 'almost modern' to 'completely modern' self-domesticated cranial robusticity discussed above (Cieri et al., 2014). It was this sudden change in behavior, encompassed within the MHB package, which facilitated the spread of modern humans out of Africa immediately thereafter.

In this context, the origin of MHB is seen as a punctuated event where specific traits (most of which are listed above) first appeared together, as a package, due to a sudden genetic mutation involving language, or change in human cognition (Klein, 2008, 2009). This 'revolution' was most clearly observed in differences between the archaeological records of the Middle Paleolithic (MP) and Upper Paleolithic (UP) of western Eurasia. Proponents of the *LUP* model argue that the lithic technology of the European MP (made by Neanderthals) and African MSA are quite similar, exhibiting a steady record of generalized and homogenous toolkits that were used to exploit non-dangerous prey species. Consistent evidence for symbolic behavior, such as personal ornamentation, artwork or non-utilitarian ochre use, was said to be absent

(Henshilwood and Marean, 2003). Finally, because MHB is said to appear all at once, early traces of individual advanced behaviors at African MSA sites are discounted as anomalies.

The *LUP* model contrasts with by the *Gradualist* model, or what McBrearty and Brooks (2000) so eloquently named *The Revolution That Wasn't* (*TRTW*). *TRTW* posits that the modern human biological and behavioral transition occurred as a gradual and cumulative process in Africa during the MSA between ~250 – 60 ka. 'Modern' behaviors are considered to have emerged piecemeal, at different times and in different places, rather than as a complete package at a single point in time. Evidence for an increase in the behavioral variability of modern humans during the MSA is observed both in the rate of appearance of new features, and diversity of those features within and between different regions. This collection of behaviors (described in more detail below) is what many paleoanthropologists define as MHB.

Notably, both the *LUP* and *TRTW* models of MHB are based on a similar trait-list of behaviors that are required at a particular site before it is considered to be representative of fully modern human behavior. The notion of a particular list of traits for identifying MHB in the archaeological record is somewhat problematic, but still useful. Because many of the traits are actually derived from the European UP archaeological record rather than the African archaeological record, certain behavioral adaptations should not actually be expected in such vastly different environmental contexts. For example, the exploitation of difficult to acquire food resources in the UP, such as fish or fowl, may be more parsimoniously explained in terms of optimal foraging theory and/or population pressure causing an expansion of diet breadth, rather than as evidence for MHB (Klein et al., 2000; Thompson, 2008). Rather than using prey-specific hunting behaviors as evidence for MHB, which will vary widely based on environment, it is more useful to focus on universal behaviors of modern human populations such as communication and symbolism (Henshilwood and Marean, 2003; Adler et al., 2006).

Second, the African archaeological record is simply not on the same scale as that of Western Europe. This is problematic because so many MHB traits were originally derived from the much better documented European archaeological record. Considering the smaller African archaeological record the level of variability appears to be higher in the Africa MSA than in the non-African MP. Over the past 10-15 years, research programs focusing on the African MSA, especially in South Africa, have begun to narrow this disparity and illuminate the true behavioral variability in the African MSA. As more and more sites are excavated and dated in Africa, the European UP archaeological record does not seem to be as much of a 'revolution' (see Mellars and Stringer, 1989) as it once did. In fact, consistent with TRTW, many of the features of the UP that comprise the MHB trait list developed earlier in the African MSA and support an expansion of behaviorally modern humans out of Africa after 60 ka. In other words, the archaeologically identifiable behaviors that are used to define modernity in the European Upper Paleolithic, were developed earlier in the African MSA, and were part of the behavioral repertoire of the people who left Africa 50-60 ka.

Dating and identifying the Middle and Later Stone Ages. The MSA was first defined by Goodwin and Van Riet Lowe (1929) and had both temporal and geographic components; it existed as the period in prehistory between the Early (ESA) and Later Stone Ages (LSA) and occurred in sub-Saharan Africa. The ESA was characterized by Mode 1 and 2 technologies (Clark, 1969) including choppers, flakes and handaxes, and presumed to be only about four thousand years old. The LSA was characterized by Mode 4 and 5 technologies, blade production and microliths, and presumed to be only about two thousand years old. The MSA, therefore, connected these two periods temporally (4-2 ka) and technologically with Mode 3 technologies, which are similar to the western Eurasian Middle Paleolithic with Levallois prepared-cores and formal flake tools. Hints of variability in the MSA were present even then, with a number of regional industries (e.g. Pietersburg, Mossel Bay, Stillbay, Howiesons Poort) identified by Goodwin during his fieldwork in South Africa (Deacon and Deacon, 1999).

We now know that the MSA is much older. It lasted for at least 250,000 years, from ~300 ka to <50 ka (Klein, 2009). However, dating the MSA remains extremely challenging because traditional techniques, such as radiocarbon and K/Ar, are not effective for that time period. Recent innovations in optical stimulated luminescence (OSL), electron spin resonance (ESR), amino acid racemization (AAR), $^{40}Ar/^{39}Ar$, and uranium (U)-series dating techniques have greatly improved our understanding of the age and duration of the MSA, but, with the exception of U-series on speleothems (Bar-Mathews et al., 2010) they remain relatively imprecise and inaccurate. Unfortunately, dates from MSA archaeological sites excavated before the development of current methods must be regarded with skepticism (McBrearty, 2013), so combining materials from those older excavated sites with newly excavated ones can be problematic. Despite this issue, ongoing research continues to indicate that most of the supposed MHB traits first appear in the African MSA, long before the LSA and European UP. Dating the MSA/LSA transition and the LSA (after ~50 ka) is less problematic because of the effectiveness of radiocarbon. What has become apparent, as more sites are found in Africa that date to less than 50 ka, is that the MSA/LSA transition was anything but uniform across time and space.

Technologically, the MSA is characterized by the presence of prepared-cores and triangular flakes that were retouched into points, knives, and scrapers. As in the Middle

Paleolithic of Europe (Bordes, 1961), unretouched convergent triangular flakes and flake-blades, particularly from prepared (Levallois), radial, and discoidal cores are also generally classified as points. Points are considered the *fossiles directeurs* of the MSA (Brooks et al., 2006; McBrearty, 2013). The invention of prepared-core techniques, such as the classic Levallois, fundamentally changed how MSA humans organized their technology, allowing them to plan, shape, and remove a 'target' flake of anticipated size and shape. The degree to which these flake products are predetermined, or planned, especially in the earlier MSA (≥200 ka), is contested (e.g. Boëda, 1995; Schlanger, 1996; Bar-Yosef and Van Peer, 2009), but the fact that purposeful effort is clearly involved to prepare the core by removing many smaller flakes before a single larger flake is removed unequivocally indicates some level of control and anticipation by the toolmaker that was not present in the preceding ESA (White et al., 2011).

The transition from Early Stone Age (ESA) large cutting tools to MSA points and other smaller flake-based is a significant technological development because points signify the replacement of single-component handheld artifacts by hafted, multi-component or composite tools (Clark, 1988; McBrearty and Brooks, 2000; Ambrose, 2001a, 2010; Barham, 2010, 2013; Haidle, 2010; Lombard and Haidle, 2012). The replacement of a reductive technology (shaping a single component tool by removal of material, for example flaking a handaxe or whittling a wooden spear point) with an additive one (combining different materials collected at different times and in different places to make a composite tool such as a stone-tipped spear) has been argued by Ambrose (2001a: 1751) to "…represent an order-of-magnitude increase in technological complexity that may be analogous to the difference between primate vocalizations and human speech." The analogy of additive MSA technology and syntactical human speech is a valid one because each involves assembling multiple components (stone point, wooden shaft, and binding/adhesive vs. sounds and words) to produce either a functional tool or meaningful sentence. To further this analogy, changing the order of words changes meaning and changing the way in which the same components are assembled changes tool function. If this proposed coevolution of composite tool manufacture and grammatical language is correct, then the technological transition from the ESA to MSA was also accompanied by the development of complex speech and language (Ambrose, 2001a, 2010; Barham, 2010).

Goodwin and Van Riet Lowe (1929) also recognized the significance of the transition to composite tools and identified it as the primary defining feature of MSA technologies. The oldest points (and evidence for hafting) found in Africa come from the Kathu Pan site in South Africa and are tentatively dated by OSL and U-series to the Early Stone Age (ESA), almost 500 ka (Porat et al., 2010; Wilkins et al., 2012). Notably, there is some disagreement among the dates acquired from the two methods and the antiquity of these artifacts should be regarded as provisional; they may be younger. In the Kapthurin Formation of central Kenya MSA points, Levallois cores, and blades that are dated to ≥284 ka have been found interstratified with characteristic Acheulean elements such as handaxes and large flakes (McBrearty and Tryon, 2006). This sequence is important because it shows that the ESA/MSA transition was not an instantaneous or unidirectional process.

The site of Gademotta in central Ethiopia has a long, well-dated, and stratified sequence (Wendorf and Schild, 1974) that was recently re-dated to >276-105 ka (Sahle et al., 2013a). It has one of the earliest true MSA assemblages in East Africa because it contains no Acheulean elements, unlike assemblages of the Kapthurin Formation. Points, which were apparently hafted, and scrapers made on obsidian flakes from Levallois-prepared cores are the dominant retouched tool forms at Gademotta (Wendorf and Schild, 1974). Many of the points exhibit basal thinning and a burin-like 'tranchet' scar near the tip that has been interpreted as either an intentional blow by a knapper to straighten and resharpen the cutting edge (Wendorf and Schild, 1993; Douze, 2014) or as an impact fracture from use as a spear tip (Sahle et al., 2013b). Regardless of their function, these tools were clearly hafted and provide some of the earliest evidence for the use of composite technology in the MSA. Ultimately, points of different forms and materials persisted throughout the MSA attesting to their technological effectiveness and reliability. Especially after ~100 ka points used in the production of multiple-component projectile armatures began to show regional diversity in morphology, which suggests the development of distinct cultural traditions supported by syntactical human speech (Clark, 1988; McBrearty and Brooks, 2000; Ambrose, 2010; McBrearty, 2013).

Points, and other tools, were also made on bone during the later MSA in Africa after 100 ka. The use of bone tools in any form was traditionally thought to be a defining feature of the European UP, but elaborately carved barbed bone points have been dated to the MSA (70-60 ka) at Katanda in the Democratic Republic of Congo (Brooks et al., 1995; Yellen, 1995; Feathers and Migliorini, 2001). In South Africa, bone points and other implements have been recorded at Blombos Cave (Henshilwood et al., 2001), Klasies River Mouth (d'Errico and Henshilwood, 2007), and Sibudu Cave (Backwell et al., 2008; d'Errico et al., 2012) among other sites. All date to the late MSA, between 85 ka and 65 ka.

A traditional hallmark of the LSA (and European UP) is the production of blades and, in particular, backed (dulled or blunted on one edge) blade segments called microliths (Bar-Yosef and Kuhn, 1999). Blades are conventionally defined as flakes with lengths twice as large as their widths, elongated and parallel negative flake scars on the dorsal face, and having more or less parallel edges. Blade production involves the preparation of a core face and platform(s) in such a way that long and thin flakes (i.e. blades) of a relatively similar size can be removed sequentially, with little re-preparation between removals (Bar-Yosef and Kuhn, 1999). While blade production certainly become more systematic and refined during the LSA and UP, blades are found in MSA sites with large cutting tools such as handaxes as far back as 500 ka at Kathu Pan (Porat et al., 2010; Wilkins and Chazon, 2012) and the Kapthurin Formation (Johnson and McBrearty, 2010, 2012). Other early MSA/MP (≥250 ka) industries with blades and handaxes include the Fauresmith in South Africa (Volman, 1984; Herries, 2011) and the Mugharan in the Levant (Jelinek, 1990; Weinstein-Evron et al., 1999). Blades become a somewhat more common component of the later MSA industries after ~128 ka, however, point-based flake industries remain a technological mainstay across Africa until at least ~60 ka. In short, blades appear significantly earlier than the MSA/LSA transition and are not necessarily tied to the production of microliths or considered a significant marker of MHB (Bar-Yosef and Kuhn, 1999; Belfer-Cohen and Hovers, 2010).

Whereas blades have deep roots in the MSA/MP, occurrences of the definitive LSA/UP stone tool, microliths, within MSA assemblages across Africa are generally rare. Early examples of backed blades at Kalambo Falls (Tanzania) and Twin Rivers (Zambia) have been dated to ~260 ka, however the context and dating of those finds is rather uncertain (Barham, 2002b; McBrearty, 2013). The first true microlithic industry, the Howiesons Poort (HP), is found across southern Africa and is dated to the MSA at ~71-59 ka (Brown et al., 2012). The production of small blades and backed microliths in association with bone tools, shell beads, and incised ochre pieces suggests this may be an early LSA industry, however, the HP is replaced at 59 ka by traditional MSA flake-based industries that persist in this region for the next 30,000 years. This long gap means that true LSA industries are not identified in South Africa until after ~25 ka with the Robberg (Deacon, 1984) and that the HP should not be considered transitional between the MSA and LSA. In eastern Africa LSA microlithic industries first appear at Mumba (Mehlman, 1989) and Enkapune Ya Muto (Ambrose, 1998a) after 55 ka. These industries are considered transitional because microliths do not completely disappear in the region after these first appearances. Similar to the ESA/MSA transition described above, the adoption of LSA microlithic technology and thus the MSA/LSA transition was not uniform or instantaneous across Africa.

Regional diversity of the MSA and MSA/LSA transition. This section will go into greater detail on the different regional chronological sequences of the MSA and MSA/LSA transition in Africa from north to south. The two major regional MSA industries across northern Africa are the Nubian Mousterian and Aterian. The Nubian Mousterian industries occur during MIS 5-4 (~128-59 ka) in northeast Africa, particularly in the Nile Valley and eastern Sahara (Van Peer and Vermeersch, 2007). They are characterized by a distinct method of preferential Levallois reduction, where cores are prepared from the distal (Type 1) or lateral (Type 2) edges to create a convergent flake that results in a Nubian Levallois point. This technique is different from nearby Levantine Middle Paleolithic sites, which are broadly characterized by preferential unidirectional-convergent or centripetal core reduction strategies (Rose et al., 2011). Notably, the Nubian also occurs in the Arabian Peninsula and provides evidence for the presence of an African MSA industry outside of Africa during MIS 5 (Rose et al., 2011; Usik et al. 2013).

The Aterian is contemporaneous with the Nubian Mousterian but covers a wide geographical range from the western rim of the Nile Valley in Egypt, across the Sahara, and northwest to Morocco (Scerri, 2013). Dates of sites across this area are encompassed within a

~70,000 year period, between about 120 and 50 ka (Barton et al., 2009; Jacobs et al., 2012). Based on recent OSL dates from sites in Morocco, Jacobs et al. (2012) have proposed two phases for this long-running industry, an early stage during MIS 5e-b and a later stage in MIS 5a-4. Both Aterian stages are characterized by tanged and/or foliate points made from radial or Nubian Type I cores (Clark, 2008; Foley et al., 2013; Scerri, 2013) and worked bone tools (Bouzouggar and Barton, 2012), as well as symbolic elements such as pigments and perforated shell beads (Bouzouggar et al., 2007; d'Errico et al., 2009). Notably, the Aterian industry is absent within and east of the Nile and there appears to have been a cultural boundary with the Nubian Mousterian Complex. Based on this division Van Peer (2001) has suggested that the Aterian may represent a technological adaptation of Nubian groups as they dispersed into the drier Saharan environments. However, it is also possible that the Aterian represents populations with technologically similar foliates and tanged artifacts that expanded from central Africa during the last interglacial (Clark, 1993; Kleindienst, 2001; Garcea, 2004; Clark et al., 2008).

Moving south to Ethiopia is a collection of sites within the Aduma region of the Middle Awash valley that are loosely dated to ~100-75 ka (MIS 5) with U-Series and OSL methods. Yellen et al. (2005) reported a distinctive range of flake-based point, scraper, perforator/bec (pointed pieces), and Levallois core types as characterizing this sequence. Blade production is absent until the youngest assemblage (site A-5) and no backed microliths were recovered, although retouched blades were used as informal tools. The small "microlithic" size of cores and retouched points and scrapers in the younger assemblages is striking (Yellen et al., 2005: 59), and represents an increased emphasis on smaller and more elongated (i.e. blade-like), though still typologically MSA, tools over time.

At Porc Epic cave in Dire Dawa late MSA occupations with a blade component are dated to 77-61 ka using obsidian hydration (Michels and Marean, 1984). Retouched artifact types include points, scrapers, burins, and casually retouched flakes typical of the MSA along with small numbers of retouched blades and backed microliths (Clark and Williamson, 1984). Notably, the production of blades and microliths does not appear to have been a major technological goal of knappers and the typological classification of the microliths has recently been called into question (Leplongeon, 2014).

At the Mochena Borago rockshelter in Ethiopia's southwest highlands three major horizons were excavated and dated to between 53-38 ka with AMS radiocarbon (Brandt et al., 2012). The oldest horizon contains typical retouched MSA points, scrapers, and burins made on end-struck flakes from tabular, discoidal, and Levallois cores. Backed microliths first appear in the middle horizon, <45 ka, and increase in frequency over time through the overlying horizon while points and scrapers decrease. Bipolar cores are added to the toolkit for the first time in the youngest horizon, which is dated to <40 ka. Brandt et al. (2012) argue that there is evidence for strong technological continuity within the sequence and that the MSA/LSA transition in this region was long and gradual. Notably, the base of the deposits in the cave was not reached and so the sequence may extend even further back in time.

Other examples of MIS 3 and early MIS 2 sites in Ethiopia include Goda Buticha (Pleurdeau et al., 2014) and two sites along the Bulbula River (Menard et al., 2014). Deposits at Goda Buticha are dated to 43-31 ka with two main horizons. The older horizon contains an MSA Levallois flake-based production sequence with unifacial and bifacial points, relatively large debitage, and rare LSA components (microliths). In contrast, the younger horizon is microblade-based and dominated by microliths, with retouched MSA tools being more rare (Pleurdeau et al., 2014). Two sites (B1s3 and DW1) along the Bulbula River are dated to 35-28 ka with AMS radiocarbon. Both assemblages are exclusively oriented towards the production of blades from single or double (opposed) platform cores with extensive platform preparation. Notably, shaped formal tools are extremely rare at both sites, with only a few scrapers and retouched MSA-like points. Blade tools, including microliths, are absent, despite their overwhelming presence in production (Menard et al., 2014).

In central Kenya the extensive sequence at Marmonet Drift contains five major horizons encompassed with ~150,000 years from 244-94 ka (Ambrose et al., 2002). In the oldest horizons scrapers and denticulates with marginal or semi-invasive retouch made on flakes with thick, wide platforms are the most common types. Points, scrapers, and burins characterize younger horizons. Invasive flaking is common on many thinner artifacts in the youngest two horizons, including some blades with diffuse platforms and bulbs of percussion. This technique of shallow invasive retouch represents an innovative strategy for extending artifact use-life by retaining volume (i.e. conserving raw material) while still producing thin, sharp edges. A more in-depth description of the three youngest horizons is presented in Chapter 4 of this dissertation.

The nearby Enkapune Ya Muto (EYM) rockshelter contains three major Pleistocene horizons. The oldest is a flake-based MSA industry, the Endingi, and is dated to >55 ka (Ambrose, 1998a). Its blank production technique is considered typical MSA; flakes have faceted platforms and radial dorsal scar patterns, and radial and convergent cores are common. Tool types are comprised of outils écaillés and scrapers, with rare points and burins, and very rare backed microliths. The overlying Nasampolai is dated to between 55-40 ka and contains large (>5cm) geometric microliths associated with a blade technology. The youngest industry in the Pleistocene part of the EYM sequence, the Sakutiek Industry (40-35 ka), is still considered to be LSA but actually contains fewer microliths than the Nasampolai and greater numbers of thin, parti-bifacial shallow invasive flaked knives, discoidal cores, and faceted platform flakes, features that are more typical of the MSA (Ambrose, 1998a, 2002). The Sakutiek Industry is distinctly LSA because the most abundant tool types are outils écaillés, convex end scrapers (thumbnail scrapers) and backed microliths, along with ostrich eggshell beads.

At Prospect Farm four high-density MSA horizons were excavated by Barbara Anthony (1978) and reanalyzed by Merrick (1975). The youngest is dated to 53-46 ka with obsidian hydration, a minimum estimate due to cooler temperatures and a reduced hydration rate during MIS 3-2 (Michels et al., 1983). Retouched scrapers, points, and becs of highly variable size and shape are the most common types, and there are no blade-based cores, debitage, or backed pieces. The nearby site Prolonged Drift contains an MSA industry dated to >35 ka (Merrick, 1975). Retouched scrapers, parti-bifacial points, and bifacial pieces produced from triangular Levallois-like cores dominate the toolkit. There is no blade production or backed pieces.

Lukenya Hill, which is located outside of the Rift Valley, is represented by a series of sites that include both MSA and LSA artifact-bearing deposits. One location, GvJm22, was originally excavated by Gramly (1976) but recently re-analyzed by Tryon et al. (2015). The base of the sequence is tentatively dated to >46 ka and shows a gradual shift from flake production by Levallois methods to blade manufacture from single and opposed platform cores. This production shift over time is accompanied by an increase in the number of microliths and a corresponding decrease in the number of retouched points and scrapers. Tryon et al. (2015) note that, though this industry features a combination of MSA and LSA components, they cannot conclude with 100% certainty that, in their original context, these assemblages were not exclusively MSA or LSA and only became mixed during excavation.

Sites located on the eastern edge of the Loita Plains near the western margin of the southern Kenya Rift Valley provide important evidence for the MSA/LSA transition. Ntumot (GvJh11, Ntuka River 3) contains three relevant horizons (Ambrose, 2002). The oldest horizon, in strata 15-16, lies 5 meters below a radiocarbon date on ostrich eggshell of 30 ka and directly beneath a carbonate nodule that formed within a volcanic ash bed (Stratum 14) dated by U-series to 56 ka (C. Lundstrom, A. Raddatz, and S. Ambrose, unpublished data). This 'transitional MSA/LSA industry' is characterized by small bifacial points, radial cores and backed microliths. The overlying horizon, in strata 8.1-10.5, lies below the radiocarbon date of 30 ka and has a U-series date of 35 ka on a carbonate nodule in Stratum 9. While microlithic in size, this industry is comprised mainly of small flakes and bipolar cores rather than blades. Although artifact densities are high, backed tools and other formal shaped tools are rare. The youngest horizon, in upper Stratum 8 is associated with the 30 ka radiocarbon date, includes tiny microblades and microcores with burins and outils écaillés but, again, no microliths. Finally, Norikiushin (GvJh12, Ntuka River 4), located 1.3 km downstream from Ntumot, contains a large blade industry dominated by large long blades with faceted platforms and large backed blades and geometric microliths, plus a few points (Ambrose, 2002). Although it was described as being similar to the Mumba Industry in Tanzania (Ambrose, 2002: 16), it most closely resembles the earliest LSA Nasampolai Industry at Enkapune Ya Muto (Ambrose, 1998a).

Continuing further south into Tanzania, Mumba rockshelter contains the earliest backed microlith industry (Bed V, Mumba Industry) in East Africa at 65-55 ka (Mehlman, 1989, 1991; Prendergast et al., 2007; Gliganic et al., 2012). Mehlman (1989) initially classified the Bed V Mumba industry as transitional between the MSA and LSA based on the mixed presence of points, Levallois cores, blade production, and backed microliths, and the overlying Bed III

Nasera industry (~36 ka; Bed IV is sterile) as LSA despite having fewer backed tools than the older Mumba industry. Recent re-excavations by Diez-Martin et al. (2009) paint a different picture, with a reduction in the number of radial-style MSA cores and retouched scrapers and points, and an increase in the number of blades, microliths, and bipolar reduction from Bed V to Bed III. This discrepancy may be the result of Mehlman's partial analysis of materials collected in the 1930's, which were biased in terms of large artifact size collection. That the more recent excavations uncovered abundant small backed microliths in Bed III, along with many OES beads and fragments, supports this. Notably, the Mumba sequence is similar to that of EYM in Kenya because it evinces an abrupt appearance of LSA microlithic technology around 55 ka.

In southern Africa there are only a limited number of dated assemblages from MIS 5 (Wurz, 2013). These are collectively included within the MSA 1, MSA 2, and Stillbay industries, which are dated ~115-90 ka, ~100-80 ka, and ~76-71 ka, respectively (Wurz, 2002; Brown et al., 2012; Jacobs, et al., 2013; Lombard et al., 2012; Mackay et al., 2014). The site of Klasies River Mouth includes over 10 m of deposits that date to 115-80 ka and include both the MSA 1 and 2 phases (Wurz, 2002). At Klasies River Mouth the MSA 1 horizon is characterized by the production of large and relatively thick blades, many of which were retouched into denticulate knife forms. Knappers in the MSA 2 industry were more focused on producing convergent flakes with thick faceted platforms from radial and Levallois-prepared cores. Such tool blanks were typically retouched into points that were probably hafted as spear tips (Wurz, 2013; Mackay et al., 2014).

The Stillbay Industry is one of the most widely known anywhere in Africa due to its wide distribution and beautifully made large, long, and thin bifacial foliate points (Henshilwood and DuBreuil, 2011). Points went though two general stages of production, including 1) making of the initial flake blank from a large radial core, and 2) thinning and shaping, probably with a soft hammer such as wood or bone (Wurz, 2013). There is some variability in the point forms; for example, Lombard et al. (2010) report bifacial serrated points in Stillbay levels at Umhlatuzana rockshelter. Notably, cores are rare and small, possibly as a result of the maintainable design of the large bifacial points (McCall and Thomas, 2012).

In southern Africa microliths first appear around 71 ka with the HP industry (Jacobs et al., 2008; Brown et al., 2012). The HP microliths at Pinnacle Point sites 5-6 are especially notable because they are made on heat-treated silcrete, which would have also required sophisticated control and knowledge and of fire, and its effects on the physical properties of stone (Brown et al., 2009; Brown et al., 2012). HP microliths from several South African sites also retain evidence for hafting residues (Lombard, 2007; Charrié-Duhaut et al., 2013) and use-wear damage on tips that has been interpreted as impact fractures from their use as projectiles (Villa et al., 2010; Lombard, 2011) or hafted knives (Igreja and Porraz, 2013). Several microliths from the Nasampolai Industry at EYM in Kenya retain ochre on their backed edges, which suggests they were also used as components of hafted tools (Ambrose, 1998a). Notably, the microlithic HP disappeared quickly around 59 ka at the end of the extremely cold and dry MIS 4, and was replaced by a series of more typical MSA flake-based industries, including the recently named Sibudan (~58 ka; Conard, 2012), that persisted until ~25 ka, through MIS 3 and into MIS 2. Because of the long disappearance of blade-based microlithic industries across southern Africa the HP is not considered transitional to the LSA (Soriano et al., 2007). This is unlike the earliest microlithic industries in East Africa, which are considered transitional, because microliths do not completely disappear from sites after their first appearance (Ambrose, 2002).

Post-HP industries of southern Africa were often ignored, at least in terms of relative research focus, in favor of the more technologically striking Stillbay and HP. For example, the "lower case naming" of many these industries as post-HP, late MSA, or final MSA by Wadley and Jacobs (2006: 15–16) was significant and deliberate, because it showed that the names were not accorded a formal industrial status. However, as Conard (2012: 181) notes, "…this informal terminology is untenable, because it implies that material cultural remains can be characterized by what they are not, rather than by…" what they are. To combat this informality Conard formally defined and named the first post-HP industry at 58 ka the Sibudan based on an assemblage from Sibudu (Conard, 2012), which contained two distinct tool types: Tongati knives and Ndwedwe points. More in-depth analysis of early post-HP assemblages from other sites in the region will be necessary to determine how widespread this specific industry may have been. Beyond the Sibudan most post-HP assemblages are conventional flake-based MSA composed of triangular retouched points, knives, denticulates, and scrapers made on flakes from radial and Levallois-prepared cores. Blades and bladelets continued to be manufactured in small numbers, but they are relatively minor components of assemblages. Artifacts are also generally larger in size than those of the HP and more similar to that of the Stillbay, which is unsurprising considering that backed microliths were replaced with retouched flake points and other tools (Klein, 2009; Mackay, 2011; Conard, 2012).

The first widely recognized microlithic LSA industry in South Africa is the Robberg, originally named by Deacon (1984) after the type-site Nelson Bay Cave on the Robberg Peninsula. It is now collectively dated from many sites across the region to <25-12 ka and is characterized by the production of true micro-blades or bladelets, often less than 20 mm in length, from small pyramidal cores (Cochrane, 2008). These bladelets were typically unretouched (not backed) and used as unmodified inserts in a haft; use-wear evidence suggests they were used for cutting or sawing soft organic materials such as plants and hides (Binneman, 1997; Binneman and Mitchell, 1997). Other formal shaped tools, such as scrapers, are very rare. Other LSA industries in southern Africa, including the Albany and Wilton, are all dated to the Holocene. Though they are all considered microlithic, the relative amount of backed microliths in each industry varies widely, possibly as a response to environmental changes related to the middle-Holocene dry period (Ambrose and Lorenz, 1990).

Based on this review it is clear is that there is a substantial inter and intra-regional variability in the timing and adoption of microlithic industries (and the LSA) across Africa. MSA flake-based industries persist at some sites until after 30 ka, while fully LSA microlithic industries appear at other sites as early as 55 ka. Many of these early LSA industries also contain MSA elements, suggesting that the MSA/LSA technological transition was not marked simply by a linear replacement of types and techniques characteristic of the MSA (points, knives, radial and Levallois cores, side scrapers), with those of the LSA (backed microliths, burins, end scrapers, bipolar flaking).

Symbolic behavior. Making artifacts with symbolic meanings, such as art or ornamentation, requires the ability to create, understand, and manipulate arbitrary symbols (Wadley 2001; d'Errico et al., 2003; Henshilwood and Marean, 2003). These symbols may represent physical objects, places, social relationships, or other abstract concepts that are maintained and reinforced through cultural traditions. The use of red ochre as a coloring agent, applied to human skin, tools, or clothing for example, has been argued to represent health, strength, and vigor (McBrearty, 2013). While a primarily utilitarian function for ochre, such as an additive for preparing hides or hafting adhesives has also been proposed (Lombard, 2007), Marean et al. (2007) and Watts (2010) note that at Pinnacle Point the consistent selection by humans of the more vivid reds from the various available shades suggests ochre must have had at least some symbolic function.

Currently, the oldest archaeological ochre find is from the GnJh15 site in the Kapthurin formation of Kenya, which has been dated to ≥284 ka (McBrearty, 2001). Specularite, another variety of naturally occurring pigment, has been tentatively dated to ~266 ka at the Twin Rivers site in Zambia (Barham, 2002a) while red ochre from Pinnacle Point 13b has been dated to as old as ~164 ka. More rare yellow ochre was found in the early MSA Sangoan horizon at Sai Island, dated to between 220 and 150 ka (Van Peer et al., 2003). Red ochre chunks and a hammer stone with red staining on one rounded tip were recovered during the 2013 field season at Marmonet Drift stratified above a ~94 ka volcanic ash (see chapter 4). Abraded ochre lumps and stained artifacts dating to ~92 ka have been found at Qafzeh and Skhul in levels associated with the 'almost-modern' human fossils (Hovers et al., 2003; d'Errico et al., 2010). Robust evidence for ochre processing has recently been found at Blombos Cave in South Africa, where a ochre-rich mixture was mixed within two abalone (*Haliotis*) shells in levels dating to ~100 ka (Henshilwood et al., 2011). A stone slab (probable grindstone) with adhering ochre and a long bone stained with ochre (possible mixer and/or applicator) were found in direct association with the shells. These finds are clear evidence for ochre processing and, in some cases, for its use as a symbolic coloring agent during the MSA.

Another way that modern humans created symbols was by incising or engraving materials with abstract designs. At Blombos, partially abraded ochre chunks with clear crosshatched incisions are dated to between 100 and 75 ka. These appear to be designed templates that may have been reproduced on other materials such as human skin, wood, or stone (Henshilwood et al., 2002; Henshilwood et al., 2009). Several distinct patterns of incised decoration have also been found on ostrich eggshell (OES) fragments from Diepkloof (Texier et al., 2013) and Klipdrift rockshelters in South Africa (Henshilwood et al., 2014) dated 65-60 ka. Many of the OES fragments from Diepkloof were refit, and one egg has a large intentionally shaped round perforation similar in size to that found on modern OES water bottles; the authors concluded that the eggshells were decorated water bottles. Similarly engraved OES fragments have also been found at Apollo 11 in Namibia, dating to ~63 ka (Vogelsang, 1998; Vogelsang et al., 2010).

Perhaps the most clear-cut evidence for symbolism in the MSA is the use of personal ornaments, particularly beads. Humans all around the world today express their social and economic status, and individual and group identity through visual clues such as clothing and jewelry (McBrearty, 2013). Ethnographic research of modern hunter-gatherer tribes shows that beadwork is worn to enhance personal appearance and social status, as well as to express both group and individual identity (Wiessner, 1977, 1982, 1994). Archaeological evidence for bead production extends back to at least 100 ka at Skhul (Vanhaeren et al., 2006), and ~92 ka at Qafzeh (Bar-Yosef Mayer et al., 2009). Both of these finds are, again, associated with the 'almost-modern' human fossils. Notably, at Qafzeh the shells would have had to travel at least 35 km inland from the Mediterranean Sea, indicating that the site occupants collected and brought them to the site. Other early marine shell beads were found at Grotte des Pigeons in Morocco and dated by luminescence and uranium-series techniques to ~82 ka (Bouzouggar et al., 2007). A date of ~75 ka for marine shell beads at Blombos in South Africa (Henshilwood et al., 2004; Vanhaeren et al., 2013) confirm the wide geographic spread of this tradition.

The marine shell beads described above were perforated (punctured) rather than drilled. Late MSA beads were also made with ostrich eggshell (OES) and may represent the earliest drilled artifacts anywhere in the world. Complete OES beads in MSA and early LSA levels at Magubike Rockshelter in Tanzania have been directly dated via radiocarbon (calibrated) to between >50 ka and 30 ka (Miller and Willoughby, 2014). Two beads at Boomplaas in South Africa are dated ~42 ka (uncalibrated) (Deacon, 1995). OES beadwork is much more common in LSA sites across Africa. Hundreds of OES fragments, ~20 drilled fragments and preforms and 14 complete beads, were recovered from Enkapune Ya Muto in Kenya, in early LSA levels dated by radiocarbon (uncalibrated) to 36-40 ka (Ambrose, 1998a). OES beads (n=14) were also recovered from early LSA levels of the same age in Border Cave, South Africa (d'Errico et al., 2012). At Mumba in Tanzania, layers with OES beads (Mehlman, 1989) have been dated by OSL to between 63 and 57 ka (Gliganic et al., 2012). Direct radiocarbon dates on these beads have yet to be published and they may be much younger. OES beads have also been found in early LSA contexts at Nasera Rockshelter, Kisese II, Naisiusiu in Olduvai Gorge (Mehlman, 1989), Lukenya Hill in Kenya (Tryon et al., 2015), and White Paintings Rockshelter in Botswana (Robbins, 1999; Robbins et al., 2000). Together, evidence for ochre processing, engraved ochre and OES, marine shell beads, and OES beads satisfy the criteria for symbolic expression of both group and individual identity, and show unambiguously that African MSA people lived in a world characterized by symbolically mediated social and cultural relationships (Conard, 2010; McBrearty, 2013).

Long distance exchange. The development of long-distance material exchange networks is considered one of the hallmarks of modern human social and economic complexity (Klein, 2009). The ability to create and maintain social relationships over long distance requires trust and cooperation between individuals from different social groups that do not seen each other very often. Once established, such relationships can be maintained by the exchange of material goods that benefit both parties. Materials such as beadwork ivory, marine shells, amber, and lithic raw material (or finished tools) that were transported more than ~45 km, the largest modern hunter-gatherer home range sizes in arid environments (Gamble 1993; Gould and Saggers, 1985; Whallon, 2006), are considered to represent long-distance exchange (Ambrose, 2002, 2012).

In the African MSA, the earliest and most secure archaeological evidence for long-distance exchange networks is the quantity of lithic artifacts made from exotic raw material sources, primarily obsidian. Analysis of the geochemical composition of obsidian artifacts, using electron microprobe (EMP), X-ray fluorescence (XRF), and neutron activation analysis (NAA) techniques, at archaeological sites allows matching with the composition of sampled obsidian sources around a landscape, enabling researchers to determine the source of stone used for tool manufacture, and the distance between collection and discard.

Pioneering geochemical sourcing of obsidian by Merrick and Brown (1984a, 1984b; Merrick et al., 1994) in East Africa shows that during the earlier MSA (≥100 ka) only small percentages of obsidian artifact assemblages (<5%) were transported greater than 50 km. Notable examples come from the MSA levels at Muguruk, Kenya and Mumba, Tanzania, where artifacts were found to have come from sources over 230 km and 320 km away, respectively, in the central Kenya Rift Valley (Merrick and Brown, 1984b). At later MSA and LSA sites (≤100 ka) Merrick and Brown found higher percentages of artifacts made on obsidian sources from >50 km away. At Lukenya Hill (GvJm16) >50% of MSA obsidian artifacts came from Rift Valley sources 65-135 km away while in the youngest (>35 ka) MSA horizon at Prolonged Drift

(GrJi11) ~50% came from >50 km away, despite the fact that obsidian sources that were exploited in older MSA levels were available within 30 km of the site (Merrick and Brown, 1984b; Merrick et al., 1994; Ambrose, 2001b, 2002).

The question then becomes how these people were obtaining the exotic material. If the stones were obtained directly during their normal foraging rounds, then they must have had very large home ranges that would have required extensive knowledge of geographic landmarks and resources over a vast territory. Alternatively, or additionally, the stone could have been obtained through contact, interaction, and exchange with other social groups. This would imply formalized social relationships with a shared economic system (McBrearty, 2013). That close sources of obsidian (≤30 km) were passed over in favor of more distant ones (≥50 km) during the late MSA at Prolonged Drift suggests that proximity or quality of stone sources did not factor into the procurement patterns of people living there, and that social factors, such as exchange networks may have been a significant source of lithic procurement (Ambrose, 2002, 2006, 2012). In conclusion, evidence for the long distance movement material objects in the MSA before ~100 ka is rare and suggests that the social skills necessary to create and maintain relationships with infrequently visited people or groups did not develop until later. Thus, the modern human behavioral transition appears to have included enhanced capacities for communication and social skills, such as trust and diplomacy, when initiating contact with distant and unfamiliar groups (Gamble, 1998; Ambrose, 2010).

Socio-territorial organization. The combination of diverse regional artifact styles and increased long-distance movement of lithic raw materials after ~100 ka indicate fundamental changes in modern human social and territorial (a.k.a. socio-territorial) organization relative to the earlier MSA. If we accept the inference of social interaction and networks from long distance transport of lithics, then it seems reasonable to extrapolate those networks to open and cooperative territorial organization among distinct social groups (Ambrose, 2010). Such network organization is commonplace among modern day semi-mobile forager groups in harsh and unpredictable arid environments, including the Kalahari Desert of Botswana and Namibia (Wiessner, 1977, 1982, 1994), and Australia's Northern Territory (McAllister et al., 2008). This makes sense because, in situations where resources are scattered and unpredictable, social coordination and cooperation should reduce the risk of starvation (Dyson-Hudson and Smith, 1978). For example, the Kalahari social networks, called *hxaro*, can span up to 200 km and are composed of regularly occurring social interactions among individuals acting as nodes in a larger network (Wiessner, 1982). The *hxaro* system is predicated on a balanced and delayed reciprocal gift exchange system where partners must be willing to offer assistance to each other based on future rather than immediate needs. Assistance typically includes providing reciprocal rights of access to neighboring territories for water and food resources (Barnard, 1992). This strategy acts as a social safety net that reduces risk and increase survivability for the entire population (i.e. both groups) in times of resource scarcity (Whallon, 2006, 2011).

The development of extended social landscapes during the late MSA would have transformed local territorial bands into a large-scale web of interacting tribes and marked a fundamental change in the way human groups socially and territorially organized themselves across a landscape (Gamble, 1998; Ambrose, 2002; Whallon, 2006, 2011). This new cooperative social strategy may have been especially crucial for modern human survival in degraded environments immediately after the Toba super-eruption and during the consistently cold and dry MIS 4 (Ambrose, 2002, 2006). The HP industry of South Africa, with its age, abrupt appearance, backed microlithic industry, and use of exotic raw materials, was proposed by Ambrose and Lorenz (1990) to represent just such an example. They argued that the onset of colder, more arid, and unpredictable MIS 4 environments (compared to MIS 5 and MIS 3) reduced resource abundance and predictability, necessitating an increased foraging range and the development of cooperative and information sharing social networks to exploit a novel resource structure. Because group mobility increased socially linked populations would have then had greater potential to transmit beneficial social or technological innovations over very far distances (Davies, 2012). Coupled with possible population bottlenecks at ~74-72 (after Toba eruption) and 70-60 ka during MIS 4 (Ambrose, 1998b), which would have forced people into smaller and more isolated groups, there would have been a strong selective force for the evolution of trust, reciprocity, and cooperation within and between modern human groups (Fehr and Henrich, 2003; Richerson et al., 2003; Ambrose, 1998b, 2010).

Summary. There is overwhelming evidence for significant biological, technological, and social evolution in *H. sapiens* over the past 200,000 years. Various technological, symbolic, and social inventions are collectively referred to as MHB. These appeared piecemeal, at different times and in different places (*TRTW* model) rather than as a single 'revolutionary' package at one point in time (*LUP* model). The observed temporal and spatial variability in the African MSA/LSA archaeological record should be expected considering the scope of time and physical size of the continent as well as the relatively rapid pace of climatic fluctuation within this time period. That the full suite of MHB is observed as an almost instantaneous event in the European UP record further lends support to the *TRTW* model of modern human origins (McBrearty and Brooks, 2000; McBrearty, 2013). Such an abrupt chronological boundary between 'archaic' and ‘modern’ human behavior may occur with population replacement, as is the case for the UP, however, fossil and genetic evidence for population continuity in Africa indicates an in-situ behavioral evolution rather than revolution.

The features that characterize MHB do not occur in every MSA site, and some periods, such as the late MSA of southern Africa, appear to have fewer features (Lombard, 2012). Rather than defining the concept of MHB as a rigid checklist of required traits and associated dates it may be more useful to appreciate the mosaic of temporal and geographic variability that characterizes our species (Belfer-Cohen and Hovers, 2010; Lombard, 2012). A research agenda examining the context and possible causes of different traits within the MHB complex should help paleoanthropologists to better understand the processes that contributed to the modern human state. In this dissertation I will focus on one aspect of the ’modern’ human behavioral transition in detail, the MSA/LSA technological transition and the shift from MSA flake-based point industries to LSA blade-based microlithic industries.

Lithic Technological Organization Theory and the MSA/LSA Transition

The development of extended social networks during the late MSA, after ~100 ka is considered a crucial stage in the evolution of MHB (Ambrose and Lorenz, 1990; McBrearty and Brooks, 2000; Ambrose, 2002, 2010; Klein, 2009). Regional artifact styles and increased long distance transport of stone tool raw materials provide strong evidence for social and material exchange networks among distinct cultural groups (Ambrose and Lorenz, 1990; Gamble, 1998). Integrating local groups into extended social landscapes (Gamble, 1998) would have allowed information regarding current environmental conditions and resources to be shared among cooperative, but dispersed hunter-gatherer groups (Wiessner, 1982, 1994; Whallon, 2006, 2011).

Such timely information would facilitate strategic planning of tool-using activities with task-specific toolkits (Binford, 1979, 1989; Ambrose, 2002, 2010; McCall, 2007; McCall and Thomas, 2012). Extensive information sharing networks and strategic toolkits would have been particularly important strategies for minimizing risk in degraded environments after the Toba super-eruption, and during the early last glacial era (MIS 4) after ~75 ka (Ambrose, 1998b, 2006, 2010; Whallon, 2006).

The theoretical framework of TO, and thus the analyses in this dissertation, encompasses aspects of human mobility (Kelly, 1988; Kuhn, 1992a, 1994; Eren et al., 2013), stone tool maintenance, curation (Binford, 1977, 1979; Bamforth, 1986; Shott, 1986, 1996; Kelly, 1988), reduction (Dibble, 1987, 1995; Kuhn, 1991), discard (Kuhn, 1989), reliability (Bleed, 1986), maintainability, flexibility, versatility (Shott, 1989; Nelson, 1991), and raw material availability (Bamforth, 1990; Andrefsky, 1994; Sahle et al., 2012) to explain strategic decisions made by humans regarding the production and use of their stone tools. Because foragers can only carry a limited toolkit in their daily travels they must decide which tools they will most likely need. Therefore, time, toolkit size and weight, and risk minimization are critical factors for formulating effective TO strategies (Torrence, 1983, 1989; Nelson, 1991; Kuhn, 1992a, 1994; Bamforth and Bleed, 1997; Carr and Bradbury, 2011; Eren et al., 2013).

Information about resource availability, predictability, and distribution obtained in social networks also influences choices in TO strategies (Binford, 1979; Bamforth, 1986; Bleed, 1986; Shott, 1986; Kelly, 1988; Kuhn, 1991, 1992; Andrefsky, 1994; Ambrose, 2002; McCall and Thomas, 2012). In situations lacking up-to-date information, planning of tool use would be based primarily on personal experiences, direct observation, and on information about opportunities within their home range shared within a group. This may suffice for survival in stable, predictable, and resource-rich environments. However, past experience is an imperfect predictor of future prospects, particularly in the unpredictable environments that characterized the early last glacial period, when survival may have required exploiting larger home ranges.

Planning a TO strategy for unpredictable environments without current information requires a versatile toolkit with large tools that can be modified quickly for several, as yet unknown, contingencies (Nelson, 1991; Morrow, 1996; Hiscock, 2006). Eren et al. (2008) have shown that the lateral edges of large, wide and thick flakes can be retouched many times compared to narrow, thin blades. Large flakes and retouched tools thus have intrinsically higher potential for maintenance and transformation (i.e. curation) for a diversity of potential tasks, which makes them morphologically flexible and functionally versatile (Kelly, 1988; Shott, 1989; Kuhn, 1992a; Dibble, 1995; Morrow, 1996; Hiscock, 2006; Dibble and McPherron, 2006). Shott's (1996: 267) extensive review of the concept of curation explicitly defined it as the relationship between potential and achieved utility in a tool. Because utility is tied to the maintenance and recycling of tools, it is extremely relevant to investigations of artifact use-lives and TO strategies (Binford, 1977, 1979; Kelly, 1988; Shott, 1989). For example, although one larger tool may weigh more than several small ones, it may better maximize the ratio of tool utility/mass (Morrow, 1996). Therefore, a few large tools can accomplish the same volume of work as many smaller tools, with lower replacement and transport costs (Eren et al., 2008). In situations of opportunistic foraging large thick flakes and bifaces provide the greatest adaptability because they can be resharpened and reshaped, and even provide small flakes to suit expedient tasks (Kelly, 1988; Morrow, 1996).

MSA and MP lithic assemblages are typically characterized by a low number of curated, heavily retouched artifacts made on flakes with large, thick platforms. Thick platforms, and thick tools overall, indicate large blank sizes (Kuhn, 1992b; Roth and Dibble, 1998; Shott et al., 2000). Small retouch flakes are also more abundant, in MSA than in LSA assemblages (Merrick, 1975; Ambrose, 1984), reflecting the maintenance and transformation of larger long-lived, curated tools (Carr and Bradbury, 2011). Because tool reduction is an ongoing process, artifacts continuously change morphology and, therefore, typology (the Frison Effect) (Dibble, 1995). Heavily reduced MSA/MP artifacts do not fit easily into named 'types' because they represent arbitrary points along a continuum of variation, rather than discrete morphological designs (Dibble, 1987, 1995; Clarkson, 2005; Hiscock, 2006). A discarded artifact may reflect only the final stage of its use-life history (Dibble, 1995; Shott, 2010) despite having gone through several phases of use, maintenance, resharpening, and shape modification (Jelinek, 1976; Rolland and Dibble, 1990). Ultimately, typical Eurasian MP (Neanderthal) and African MSA (*H. sapiens*) toolkits suggest a TO strategy of planning for uncertain futures by curating large, flexible, and versatile tools (Nelson, 1991; Kuhn, 1992a, 2011; Dibble, 1995; Ambrose, 2002; McCall, 2007).

Conversely, tools made for anticipated and planned activities can be specially designed for specific tasks (Torrence, 1983; Bleed, 1986). The most mechanically efficient stone tool edges are thin and sharp blades such as those on microliths, however, because they are fragile and inherently not resharpenable (Eren et al., 2008), replacement microlithic components must be produced and carried in anticipation of breakage or loss (Ambrose, 2002; Hiscock, 2006). The point being that, rather than resharpening thin-edged blade tools, it is more effective to discard and replace them. Such small and thin blade tools, particularly microliths, are the most common artifact type in most African LSA and European UP lithic industries, while curated tool forms are rare. Thicker blade tool classes, such as burins or end scrapers, are important exceptions, though, because they can be resharpened along the long flaking axis of a blade while maintaining the same width and thickness for the utilized bit (Shott and Weedman, 2007).

There are two major technological consequences of the small size of backed microliths. As mentioned above, because they are so fragile they should be produced in large quantities ahead of time. This necessary 'mass-production' was accomplished by a reorganization of tool blank production from cores that accompanied the transition from flake to blade-based toolkits. The transition has been described as moving from a 'surficial' Levallois approach to a 'volumetric' blade approach of core reduction, and one that enabled a more efficient exploitation of the initial volume of the raw nodule or block (Belfer-Cohen and Hovers, 2010). This conceptual refinement can be understood more as a modification of the underlying concepts associated with MP/MSA tool production rather than a revolutionary conceptual change (Davidzon and Goring-Morris, 2003). By using a single platform (or two opposed) and core face for blade removals there is little wasted volume or time, and consistently sized and shaped tool blanks (i.e. standardized) can be produced at a much faster rate than with MSA Levallois or radial cores (Bleed, 1986; Bar-Yosef and Kuhn, 1999).

Second, microliths cannot be substantially reshaped through retouch and so they must be made in the "right" shape from the outset. The "right" shape would be determined by the upcoming task, and what the most efficient edge angle and shape was to complete that task. Therefore, LSA knappers would have needed several different sizes and shapes of microliths to complete various tasks that they engaged in, something that is reflected in the generally high typological diversity and number of formal tools in LSA industries compared to those of the MSA (Nelson, 1973; Merrick, 1975; Mehlman, 1989). This TO strategy is most effective when people have specific knowledge of upcoming tasks. Otherwise they must produce and carry a large diversity of tool forms for all possible tasks, which is an unrealistic expectation. That backed microliths are the dominant tool class of LSA industries suggests that LSA humans had greater knowledge of upcoming tasks and the associated toolkit requirements than MSA humans who utilized larger, morphologically flexible and functionally versatile toolkits (planning for the unknown). Such knowledge was likely acquired through cooperative social networks would have allowed LSA humans to strategically plan tool-using activities with mechanically efficient tool forms (Ambrose, 2002, 2010; McCall, 2007).

Research Objective and Hypotheses

The ultimate objective of this dissertation is to investigate how the development of cooperative social communication networks by modern humans during the late MSA enabled more effective planning of tool use during the LSA. More specifically, I will quantify changes in lithic TO strategies spanning the MSA/LSA technological transition, including the shift from MSA flake-based to LSA blade-based toolkits. The primary research questions that I will investigate are:

1. How do lithic TO strategies change from the MSA to LSA?
2. Do LSA TO strategies represent enhanced technological planning relative to the preceding MSA?

Based on reviews of the MSA/LSA technological transition and TO theory I have generated three major hypotheses along with testable predictions regarding differences in patterns of artifact morphology, size, production, use, maintenance, and discard between MSA and LSA industries. These hypotheses will be tested using data collected on lithic artifact assemblages from three sites in central Kenya: Marmonet Drift (MSA, Chapter 4), Enkapune Ya Muto (early LSA, Chapter 5), and Ol Tepesi (LSA, Chapter 6).

The first hypothesis focuses on the size and shape (i.e. morphometrics) of artifacts: if LSA industries used information sharing networks to better plan their TO strategies with mechanically efficient tool designs while MSA TO strategies relied upon versatile and flexible tools then I expect artifact (debitage and tools) size to be smaller in the LSA. This hypothesis includes three test predictions:

1. MSA debitage will have significantly larger overall size than LSA debitage;
2. MSA debitage will have significantly larger average platform sizes than LSA debitage; and
3. MSA formal tools will have significantly larger average sizes than LSA types.

The second hypothesis focuses on tool production: if LSA industries utilized a technological system with a variety of specialized and replaceable mass-produced microlithic tool components while MSA industries produced larger and more morphologically flexible tools individually, then I expect there to be an increase in the diversity of tool types and the degree of tool standardization in the LSA. This hypothesis includes two test predictions:

1. LSA assemblages will have greater formal tool diversity, determined using Simpson's Index of Diversity, than MSA assemblages; and
2. Primary debitage and formal tools from LSA assemblages will be more standardized, meaning less variable in size, than those of MSA assemblages.

Simpson's Index of Diversity (SID) will be used to quantify the typological diversity of formal tools in artifact assemblages. SID takes into account the number of types present (richness), as well as the relative abundance (evenness) of each type. The more unique types present in an assemblage the richer, and more diverse, it is. The more even the counts of those different types, the more diverse the assemblage is.

As a conceptual tool, standardization is based on the notion that a particular product, in this case Stone Age tool industries, have low variability in the physical characteristics that define them (Marks et al., 2001). Some of the specific characteristics that define stone tool industries are qualitative, and include: the preparation of core platforms and crests, the technique(s) of tool blank production, and the manner in which blanks are shaped. Other characteristics are quantitative and include: the types and numbers of artifacts produced, the location, angle, and shape of retouch on tools, and the size and shape of artifacts. For the purpose of measuring standardization in this dissertation I will focus on artifact size, and specifically artifact size variability as determined the coefficient of variation (CV). Because the CV is calculated as a ratio of the SD/mean it is critical for comparing variability in samples with different means.

The third hypothesis focuses on formal tool maintenance and discard (i.e. curation): if MSA industries are more highly curated than LSA industries, then I expect less tools, more retouch flakes, and tools with longer use-lives in MSA assemblages, while LSA assemblages should have the contrast. This hypothesis includes three test predictions:

1. MSA assemblages will have fewer formal tools than LSA assemblages;
2. MSA assemblages will have higher ratios of retouch debitage to tools than LSA assemblages; and
3. MSA formal tools will have greater intensity (multiple use sessions) and diversity (multiple functions) of use-wear traces than LSA formal tools.

Together, these hypotheses and associated tests will enable me to evaluate long-term changes in lithic TO strategies and levels of planning in East African MSA and LSA industries.

In the following chapter I will describe the specific lithic assemblages and various analytical methods I will use to collect the necessary data for testing these hypotheses.

Chapter 3

Materials and Methods

The purpose of this chapter is to describe the archaeological materials analyzed in this dissertation and the methods of analysis that I used to produce data for testing my hypotheses. Methods included field techniques for the Marmonet Drift excavation, lithic artifact type-attribute classification, artifact metrical measurements, statistical analyses, artifact illustrations, and use-wear analysis. Excavation at the Marmonet Drift site was essential for this project because existing sample sizes from all horizons were inadequate for analyses of technological organization (TO). One additional goal of excavation was search for stratified datable deposits and archaeological horizons above the youngest MSA horizon analyzed that could provide evidence for the Late MSA and Early LSA.

Artifact typological classification was necessary for understanding assemblage composition (tool, core and debris types), and to facilitate comparisons amongst the three sites as well as to other sites/industries in this region and beyond. Typological data will be used to test predictions from hypotheses two and three (Chapter 2). Artifact illustrations emphasize specific technical features that are often difficult to see in photographs. Artifact dimension measurements were necessary for understanding 1) the size and shape of debitage, cores, and tools, and 2) the degree of morphological standardization in assemblages. Hypotheses one and two both contain predictions that are tested using data derived from this method. Statistical analyses provided assessments of the significance of mean differences in artifact class size and shape, counts of specific types, and degrees of morphological standardization and typological diversity. Finally, artifact use-wear analysis was necessary for producing data to test hypothesis three regarding predictions on the intensity and diversity of use-lives for different artifact classes. I first discuss how use-wear analysis can test predictions of TO, and then summarize my own functional experiments with obsidian tools and the patterns of use-wear associated with different tasks. Ultimately, each method of lithic analysis in this dissertation was selected to evaluate different predictions derived from TO theory to test hypotheses of differences in organization strategies of MSA and LSA artifact assemblages.

Archaeological Sites and Lithic Assemblages

This dissertation presents a comprehensive analysis and comparison of lithic artifact assemblages from three archaeological sites located on the western and northern margins of the Lake Naivasha basin in Kenya's central Rift Valley (figure 3.1). All sites are well preserved, stratigraphically sound, and all have several distinct occupation horizons. All three sites are located within 20 km of each other. Assemblages analyzed from these sites range in age from from >110 ka to 19 ka, and include three MSA and three LSA artifact assemblages that I analyzed for this research.

The oldest site, Marmonet Drift (MD; GtJi15), is an open-air site with a thick sequence of deposits exposed by erosion on the west side of the Marmonet River Valley at an elevation of ~2080-2105 m. This sequence contains five MSA archaeological horizons interstratified with five dated volcanic ashes. MD was excavated in 2001, 2007, 2010 and 2013 under the direction of Stanley H. Ambrose. I participated in excavation during the 2010 season and directed excavation in the 2013 season, with guidance by Ambrose on matching stratigraphic levels with previous excavations and layout of new trenches. In this dissertation I report only on the excavation and artifact assemblages from the 2013 field season. A total of 8551 artifacts from three horizons (H2, H4, and H5, numbered from older to younger) were analyzed as part of this project. H2 is ~11 m above the basal tuff dated to 244 ka, and about 2.5 m above a tuff with a preliminary date of ~205 ka. An undatable welded tuff with a deeply eroded upper surface seals H2. A tuff 5-6 m higher in this sequence has dates of 104 and 110 ka. H2 is thus likely to date closer to 200 ka, and thus within MIS 6 in the Martinson et al. (1987) chronology (table 2.1). H4 is bracketed by two volcanic ashes dated between ~110 and 94 ka, and most likely dates to MIS 5d or early 5c. H5, the youngest assemblage analyzed, lies conformably above the 94 ka ash, and likely dates to late MIS 5b.

The second site, Enkapune Ya Muto (EYM; GtJi12), is a large rockshelter on the Mau Escarpment at 2400 m. It contains seven major archaeological horizons spanning >50,000 years, from the latest MSA through the Iron Age (Ambrose, 1984, 1998a, 2001b). The earliest stratum (RBL4) contains an MSA horizon with several typological features of the LSA. The second stratum (GG1) contains the earliest microlithic LSA industry known anywhere in Africa. The LSA industry in the third stratum (DBL1) is contemporary with the earliest LSA industries elsewhere in Africa. The second and third strata are the focus of analysis in this project. I sampled a total of 3173 artifacts for analysis from the DBL1 and GG1 horizons. DBL1 has three uncalibrated radiocarbon dates on charcoal between 35,000 and 40,000 BP and one temperature corrected obsidian hydration date of ~36,000 BP. GG1 has one temperature-corrected obsidian hydration date of ~46,000 BP; the underlying RBL4 horizon has an uncalibrated radiocarbon date on charcoal of 41,000 BP. If radiocarbon dates were calibrated, then DBL1 would likely date to 45 to >35 ka and GG1 would date to ~55-45 ka, both firmly within MIS 3. Although there are issues with dating accuracy near the maximum age limits of the radiocarbon and obsidian hydration dating techniques, these deposits are stratified so their relative ages are indisputable.

The third site, Ol Tepesi (OT; GsJi53), is a very large rockshelter on the lower slopes of Mt. Eburu at an elevation of 2160 m. It has at least five major archaeological horizons with charcoal radiocarbon dates from ~19,000 to 1,350 cal BP. The base of this sequence was reached at 6.2 m below datum on the steeply sloping floor of the excavation, but deposits likely extend further back in time in areas closer to the dripline. Ambrose excavated OT twice, in 1991 and 2002. All of the artifacts that I analyzed for this project came from his 2002 excavations, which are stored in the National Museum in Nairobi. I sampled a total of 3696 artifacts from one square in the lowest horizon, 5.15-5.54 m below the datum (spit 17). This level has one calibrated radiocarbon date on charcoal of ~19,000 cal BP.

There is a ~300-meter difference in elevation between MD (2105 m), Ol Tepesi (2175), and EYM (2400 m), but all are relatively similar in terms of habitat, temperature, and precipitation. All are now or were historically located within or close to the lower margin of the modern montane forest where it grades into woodland and wooded grassland. Most importantly for the purposes of this research project, the closest available sources of high quality lithic raw materials, all obsidian, are located within 9-11 km of each site (figure 3.1). This provides significant control over raw material quality, mechanical properties and accessibility because all sites would have had similar access to large quantities of high-quality stone for making tools. Indeed, more than 99.5% of recovered stone artifacts from all horizons at all three sites are made on obsidian. Control over raw material variation is extremely important in comparative lithic studies because it does not confound variation due to differences in knapping techniques and technological organization strategies of different lithic industries.

Field Excavation Techniques and Field Catalog at Marmonet Drift (GtJi15)

All trenches were laid out in 1-meter squares and excavated separately. Excavation was primarily carried out using natural stratigraphic levels as a guide, serving as boundaries for excavation levels. All depths were recorded as ‘cm below the trench datum’, beginning with the unexcavated ground surface before excavation, and for each corner of each square after completion of each level. Measurement of depth at each corner is used to calculate excavated sediment volume and artifact densities. Arbitrary levels were used to subdivide layers in trenches where thicknesses of natural units exceeded 30 cm. For trenches 1a and 4, great efforts were made to match level thicknesses to those in adjacent squares from previous excavations in order to maintain stratigraphic integrity and contemporaneity of artifact assemblages from different excavation seasons. Trenches 5 and 6 are new excavations in higher levels of the sequence that were not excavated in previous field seasons. Photos and a map of the site, including all of the trenches, are presented in Chapter 4.

Excavation tools included full sized picks, pointed pick tips of geological hammers, shovels and trowels for levels with low artifact density, as well as small wooden picks, brushes and dental tools where appropriate. Many soil layers were extremely dense and compacted. In levels with high artifact density we used geological hammer pick tips, brushes and trowels. In order to minimize damage to artifacts by contact with excavation tools, large chunks (25-30 cm in diameter) were excavated with geological picks and full-sized picks and disaggregated for screening by pounding with wood clubs and the flat sides of geological hammers. Dental picks and other small tools were used to remove in-situ artifacts from the soil chunks. All soil was collected in baskets and sieved through 5 mm mesh screens. In layers with high densities of micro-debitage (e.g. levels 5 and 6) a screen with 2.5 mm mesh was used as well. All flaked stone artifacts and faunal remains were bagged by square and level. Artifacts broken during excavation that were identified in-situ were bagged separately to facilitate repair. After completing excavation the stratigraphic profiles were photographed and drawn (also presented in Chapter 4), and Munsell soil colors were recorded. Ambrose used similar techniques during the excavations at Enkapune Ya Muto (GtJi12) and Ol Tepesi (GsJi53); however, picks and pounders were unnecessary in these softer rockshelter deposits.

The excavation team included Philip A. Slater (U. Illinois), Stanley H. Ambrose (U. Illinois), John Marigi Munyiri (National Museum of Kenya), Emily C. Zimmermann (Sheffield U.), Cleophas Mukenga Kyule, Samuel, Henry and George Ole Kamamia (local assistants, sons of the primary land owner), and three undergraduate archaeology students from the University of Nairobi; Joshua Abungu, Moses Kiplangat and Njuguna Kageche. Muli Kiiti and Samuel Mutuku Wa Mbua washed all excavated artifacts with water and tooth brushes in the field camp. Slater, Ambrose, Kyule, Muli and Mutuku combined to count and weigh all artifacts after the conclusion of the field season at the National Museum in Nairobi. All finds were sorted into raw material types (obsidian, lava, chert, quartz, other stone, pigments, bone, tooth), and assigned bulk catalog numbers. Identifiable faunal remains, ground stone and otherwise rare items were given individual catalog numbers. Mutuku and Kyule assisted in gluing broken artifacts. Slater entered all data into the master site catalog, including all artifact classes, sorted by raw material in each level and each grid square, including ground stone and pigment, faunal remains and geological samples.

Lithic Artifact Type-Attribute Classification System

The foundation of any comparative analysis of flaked stone artifacts is a well-defined system of description, classification, and measurement of technological attributes and types. It is important that such systems, called typologies, are relatively consistent among different researchers so that diverse sets of stone artifacts can be compared directly. They are frameworks for classifying stone tools in standardized categories related to their morphology, retouch attributes, assumed function, time period or geographic location (Monnier, 2006). Typologies are essential for comparative analyses. In this section I will present a short review of the history of lithic artifact typologies and the origin of the typology I used in this dissertation.

Gabriel de Mortillet (1869) first used typologies for classifying lithic artifacts in order to identify temporal and spatial boundaries of prehistoric culture groups in Europe. Typological analysis systems for identifying later Pleistocene cultures continued to be refined through the mid 1900's (de Sonneville-Bordes and Perrot, 1953; Bordes, 1961; Tixier, 1963). A problem with this approach was the proliferation of types and subtypes that *could* be named by analysts as they made their way down the typological rabbit hole and got entangled in what Charles Nelson (1973: 134) termed '*reductio ad absurdum'*. For example, François Bordes (1961) developed one of the most well-known and explicit typological systems for European Middle Paleolithic (MP) artifacts in which he recognized 63 discrete types of tools, including multiple subtypes of points, knives, denticulates, scrapers, burins and other tool classes. Upper Paleolithic typologies often included many more types and subtypes (de Sonneville-Bordes and Perrot, 1953; Tixier, 1963, 1974).

Bordes's (1961) typology identified five different repeated patterns of artifact type frequency distributions in archaeological sites across southwest France. He explained these patterns as representing assemblages of artifact types made by five synchronic cultural groups that alternated their occupation of rock shelter sites. In other words, the percentages of different types were culturally determined. Moreover, he assumed, though perhaps not explicitly, that the form in which a tool was discarded was the same as that when it was initially manufactured, in other words the artifact shape was made to conform to a preconceived style.

Lewis and Sally Binford (1966; Binford, 1968) largely accepted this teleological (predetermined discrete types) interpretation of types, but asserted that the different frequencies of types reflected discrete toolkits for different tasks that were manufactured by a single cultural group, rather than five separate ones. The Binfords suggested that these different tasks were being carried out at different localities (sites) and at different times (stratigraphically interspersed). Shortly thereafter, Bordes (Bordes and de Sonneville-Bordes, 1970; Bordes, 1973: 221) reiterated his stance that the five major industrial variants of the Mousterian demonstrated "a mosaic of different cultures and different cultural variants, more or less contemporary" with each other.

Mellars (1970) attempted to evaluate these competing claims of culture *versus* function. He showed that there were actually fewer discrete types of assemblages, and that they usually occurred in the same stratigraphic position in different sequences. For example, the Mousterian of Acheulean Tradition (MAT) was always stratified above the Quina Mousterian. He concluded that a chronological model of Mousterian variability was the most plausible explanation. Binford (1973: 231) accepted this evidence for a temporal sequence but did not necessarily agree with "an exclusive sequential arrangement of all the variability."

George Frison (1968) later challenged Bordes's assumption of fixed predetermined types. Frison demonstrated that resharpened stone tools could change shape and function considerably throughout their use-life. This phenomenon was named the 'Frison Effect' by Arthur Jelinek (1976). A significant implication of this argument is that the 21 types of scrapers that Bordes identified in his 1961 MP typology might not represent distinct tool designs, but rather a single tool typewith a variable morphology that depended on the duration of its use-life history and resharpening potential, both of which correlated with artifact size and thickness.

Harold Dibble (1987, 1995) investigated whether the 'Frison Effect' could account for some of the typological variation Bordes saw in MP scrapers. Based on experimental and archaeological research he showed that scraper types formed a continuum rather than discrete categories. Dibble found, for example, that several bouts of resharpening (i.e. reduction) of a blank with scraper retouch on one lateral margin could transform it from a single side scraper into a transverse scraper; several rounds of retouch on two lateral margins would transform the tool from a double side scraper to a convergent scraper. Dibble thereby demonstrated that artifacts at different stages of the resharpening reduction continuum could encompass several of Bordes's scraper types. The reduction continuum is a more parsimonious and logical explanation for the morphological variation observed in MP retouched artifact assemblages (and many other lithic industries around the world) because it does not assume that artifacts are recovered in their final intended form. Rather, artifacts have use-life history trajectories that can transform them through a series of what Bordes considered to be discrete types. Dibble thus effectively exposed the *reductio ad absurdum* of typological systems based on the assumption of discrete types.

Ian Davidson and William Noble (1993; Davidson, 2002) have proposed a similar argument, the 'Finished Artifact Fallacy', to explain morphological patterns of Acheulean handaxes that some researchers (Leakey and Roe, 1994; Wynn, 1995; *contra* Ashton and McNabb, 1994; White, 1998; McNabb et al., 2004) say were shaped intentionally and indicate the emergence of artifact style and language-based communication during the Early Stone Age. Davidson and Noble's proposition states that it is "…a fallacy to assume that the form in which a stone artifact is found is a product of an intention to produce that form” (Davidson, 2002: 182). They advocate that archaeologists should exercise restraint when proposing cultural or mental explanations of lithic artifact morphological variability, which can often be accounted for by variation in raw material flaking characteristics (but see Eren et al., 2014) or the intensity of use and maintenance.

Despite the potential problems with lithic typologies they are useful for organizing artifact assemblages and have helped to standardize categories and terminology in discussions of regional variations of lithic industries (Debénath and Dibble, 1994). In order to make sure that the typological analysis that I carried out in this study will be accessible and useful for future researchers it is necessary to use well established and widely used definitions for typological categories that are flexible enough to incorporate available data. Appendix A contains a complete list of typological definitions used in this study. These typological categories are based on combinations of discrete retouched edge attributes. Attributes include retouch position (end, side, combinations), edge shape in plan form (notch, concave, straight, convex, etc.), direction (normal, inverse or longitudinal [burin blow]), edge angle (acute, steep, vertical/abrupt) invasiveness (marginal to fully invasive across the dorsal and/or ventral surface), continuity (partial), and regularity (continuous, discontinuous, denticulate).

Repeated attribute combinations define artifact types and subtypes, including combination tools, and tools transformed from one type to another. For example, the tool type “scraper” is universally defined as a flake, flake fragment or chunk with a retouched edge with an angle of greater than ~60° and less than 90°, formed by retouch that removes a continuous line of small flakes struck from a platform formed by the ventral or flat surface, and removes the edge of the dorsal side of a flake blank. This is termed the 'normal' retouch direction, and creates a plano-clinal edge. These retouch flake removals are generally not invasive enough to reduce the original thickness of the blank. The type named scraper represents a shorthand summary of this combination of attributes. Adding modifiers for position (end) and edge shape (convex) defines a more specific type in the class of plano-clinal retouched edge class, in this example a convex end scraper. This conceptually simple system allows for direct comparisons of type counts to be made between assemblages from widely different contexts.

However, a type name for a constellation of covarying attributes only provides so much information to the lithic analyst. A convex end scraper may be smaller than my thumbnail or larger than my thumb. A bifacial point may be as small as an arrowhead or as large as a spearhead (Shea, 2006; Brooks et al., 2006; Shea and Sisk, 2010; Sisk and Shea, 2011), and can have all of the same technical retouch and shape attributes as an Acheulean handaxe. Therefore a combination of attribute-based description and metrical measurement such as that used in this dissertation is best for comparing the typological composition and morphometric variation of different lithic industries.

The typology and attribute descriptions that I used in this analysis were derived primarily from Charles Nelson's (1973) dissertation on East African LSA technology, in which he did an admirable job combining formal attribute-based typology systems from exceptional scholars including de Sonneville-Bordes and Perrot (1953), Tixier (1963), J. Desmond Clark (Clark and Kleindienst, 1974) and Mary Leaky (1971). Nelson (1980; Ambrose, 1985) also defined features of blade technologies that had been overlooked in previous African lithic technology and typology systems. Appendix A provides the full names and descriptions of all artifact classes, types, attributes, and morphometrics that I recorded in this analysis.

Because all of the artifacts that I analyzed were made on obsidian, their attributes can almost always be clearly observed and described accurately, and the order of modifications can be determined, facilitating reconstruction of artifact shape and type transformations resulting from reduction. However, some artifacts have unique combinations of attributes that defy unambiguous type classification, while others have previously unknown combinations of attributes for MSA artifacts that are nearly identical on several different pieces. When several examples share the same novel combination, they warrant the naming of a new type (see Conard et al., 2012). Two novel MSA types were encountered in the 2013 excavation at Marmonet Drift: the Helwan backed knife and oval scraper. These are described in Appendix A and Chapter 4.

A higher level of artifact assemblage classification involves the naming of local lithic industries, and their regional and temporal variants (phases and facies) within broader techno-complexes such as the Acheulean, MSA and LSA. Recommendations for defining lithic industries were developed at the 29th Wenner-Gren Symposium on "Systematic Investigation of the African Later Tertiary and Quaternary" in 1965 (Clark et al., 1966). Different industries may share many of the same formal classificatory shaped tool types and even the same percentages of each type. However, the sizes, shapes and other attributes of shaped stone artifacts (morphometric styles), and techniques of blank production, including core platform preparation, may differ significantly among industries. For example, flakes and blades with proportionately wide, thick, multifaceted platforms, and generally long and narrow backed microliths characterize the Kenyan LSA Eburran Industry. Conversely, the overlying Elmenteitan Industry, even in the same sites, is characterized by proportionately small plain, abraded blade platforms, and short, wide backed microliths (Ambrose, 2002). Conard's (2012) analysis of the post-Howiesons Poort industry at Sibudu rockshelter, which he named the Sibudan, exemplifies the procedure for formally defining a distinct lithic industry on the basis of new, clearly defined types and flaking techniques. Some of lithic assemblages analyzed in this dissertation, including one from Ol Tepesi and two from Marmonet Drift, have distinct combinations of technological, typological and/or morphometric features that have not been observed in other assemblages. Thus, I will present formal industry names for them.

Lithic Artifact Measurements and Statistical Analyses

I measured all artifacts in this dissertation at the Kenya National Museum in Nairobi using a single set of digital calipers and recorded the data in Microsoft Excel files. Except in some cases of formal artifact types, measurements for platform width (PW), platform thickness (PT), length (L), width (W) and thickness (Th) were taken using the flaking axis of the artifact (from platform to distal end). Lengths of points and scrapers, for example, were taken relative to the tool axis of the piece, from base to tip.

Data were recorded in Excel spreadsheets and imported into SPSS (version 21 for Mac) software for statistical analyses. All statistical comparisons, unless otherwise noted, are among complete whole (unbroken) artifacts. Size dimensions and ratios (PT/PW, PW/W, PT/Th, W/L, W/Th, L/Th) were compared within different types and classes of tools within and across sites for evidence of size reduction over time and degrees of morphological standardization. For example, primary debitage size dimensions were compared across horizons at Marmonet Drift and across all three sites analyzed in this dissertation. Independent groups t-tests were used when analyses were limited to two groups for comparison and a one-way ANOVA was used for comparisons among three or more groups.

For many analyses, multiple dimensions are analyzed simultaneously using either the t-test or ANOVA, which inflates type-I error rates, known as a family-wise error rate. Family-wise error rates are a statistical measure of the risk that any one null hypothesis will be rejected from a family of null hypotheses tested simultaneously, when in fact it should it not be. This means that it would be inappropriate for me to compare the results of one hypothesis test in a family of tests to the standard alpha (α) value of 0.05. Therefore I used the Bonferroni procedure to control for the family-wise error rate. The Bonferroni procedure controls family-wise error rate by dividing α/m where $\alpha = 0.05$ and m = the number of hypotheses tested at one time (Agresti and Franklin, 2009). For example, if I were comparing length, width and thickness of one tool type in two different horizons, I would be conducting three tests at once. Rather than compare the result of each of those tests to an α value of 0.05, I divide 0.05 by 3 (0.05 / 3 = 0.017). The result of each test is compared to this adjusted α value rather than 0.05, thereby controlling the risk that I would reject the null for any one hypothesis when in fact it is true. For ANOVA analyses, SPSS calculates this value automatically. For t-tests, this value is calculated manually and reported when t-tests are reported. This increases my confidence that when statistically significant comparisons are found, they are likely due to their group membership in any one horizon or site, rather than random chance.

Chi-square (χ^2) tests were run to determine whether there were significant differences between the expected and observed frequencies of certain artifact types for different horizons within a single site or among different sites. The purpose of these tests was to ascertain whether differences between observed and expected were the result of random chance (the null hypothesis), or due to other factors such as the technological organization strategies of different site occupants.

Coefficients of variation (CV) were used for assessing the degree of morphological standardization (or variability) within artifact assemblages. They were calculated for various tool dimensions using the formula (SD/mean)*100. The CV calculates the standard deviation (SD) as a percentage of the mean. This is critical for evaluating samples with different means because, all else being equal, a larger mean has a proportionately higher SD than a smaller mean. The CV is a more reliable indicator of the degree of variability within a population than the SD alone because it is independent of the unit in which the measurement was taken; therefore it is a dimensionless number. For example, an assemblage with mean length of 20 ± 4 mm has a CV of 20%, while one with a mean of 40 ± 5 mm has a CV of 8%. In this example the assemblage with the smaller mean and SD actually has much greater variability.

Finally, Simpson's Index of Diversity (SID) was used to quantify the typological diversity of formal tools in artifact assemblages. SID accounts for the number of types present (richness), as well as the relative abundance (evenness) of each type. The greater the number of unique types and the more even the counts of those different types are the more diverse an assemblage is. Note that combination tools were counted as single pieces so as to maintain consistency between the total number of each tool type listed in the typologies and SID calculations. Consider the formal tool samples from two different hypothetical assemblages (table 3.1). They both have the same richness because they each have three types present, however, assemblage B has a more even distribution of counts and, therefore, has greater evenness and is more diverse than assemblage A. In order to quantify this I used the formula $1-(\Sigma n(n-1)/N(N-1))$, where n = the total number of artifacts of a particular type and N = the total number of artifacts for all types combined. The value of SID ranges between 0 and 1 and a higher number indicates greater sample diversity. In the example above the SID of assemblage A is 0.51 and assemblage B is 0.73, confirming that assemblage B has a greater diversity of formal tools than assemblage A.

Table 3.1. Example tool assemblages for calculating Simpson's Index of Diversity

Tool Type	**Assemblage A**		**Assemblage B**	
	Count	**n(n-1)**	**Count**	**n(n-1)**
Point	7	7(6) = 42	0	0(0) = 0
Scraper	1	1(0) = 0	3	3(2) = 6
Burin	2	2(1) = 2	3	3(2) = 6
Backed microlith	0	0(0) = 0	4	4(3) = 12
Total (N)	10	10(9) = 90	10	10(9) = 90
1-(Σn(n-1)/N(N-1))	1 – ((42+0+2+0) / 90)		1 – ((0+6+6+12) / 90)	
SID Value	0.51		0.73	

Lithic Artifact Illustrations

"If a clear sentence is better than a vague generic term, an accurate technical drawing can usefully replace a vague description" (Inizan et al., 1999: 17).

I drew all artifact illustrations at actual size with a 0.3 mm pencil and digitally scanned them using an HP Deskjet F380. Similar to orientation for measurement analysis, artifacts were drawn using the flaking axis of the artifact with the platform at the bottom of the drawing. Retouched tool drawings were oriented using the tool axis or axis of symmetry where appropriate. These drawing emphasize the technical features of flaked stone artifacts that are often difficult to see in photographs. These drawings will allow independent evaluation of my description of attributes and classification of individual artifacts.

Lithic Artifact Use-Wear Analysis for Reconstructing Technological Organization

Researchers have long been interested in identifying and understanding stone tool function in order to answer the question "What were these tools being used for?" Microscopic use-wear analysis provides direct evidence of stone tool function through the identification of damage on edges and surfaces that results from contact between the tool and worked material. Some of the types of information that can be gleaned from use-wear analysis include: whether or not a stone tool was actually used vs. being trampled or broken naturally, the kinematics or use-action (the angle of contact of a tool and direction of movement on a material), what kinds of materials were contacted during use, and if it was hafted. Use-wear analysis is a powerful analytical tool for archaeologists because it can be used to test hypotheses related to:

1. Artifact function, such as those implied by the functional names of some typological categories, including scraper, knife or point.
2. Theoretical predictions of TO for artifact use, maintenance, reuse, and discard.

The relationship between stone tool function and morphology is hypothesized to vary with differences in TO strategies (Kelly, 1988; Nelson, 1991; Shott and Nelson, 2008; Eren et al., 2013). Ambrose (2002: 21) has applied the concepts articulated by Kelly (1988) in his paper titled "Three sides of a biface", to the African MSA and LSA. Ambrose proposed a distinction between what he calls MSA "Jack-of-All-Trades (but Master-of-None)" toolkits (i.e. functionally flexible and morphologically transformable tools), *versus* LSA task-specific toolkits composed of the "Right Tool[s] for the Job" (i.e. single function tool classes).

The first toolkit comprises larger, thicker flake-based MSA tools that were used for a variety of tasks, and resharpened and reshaped multiple times (curated) for use for different kinds of activities involving contact with different materials, resulting in artifacts with long and complex use lives. Shott (1986) and Torrence (1983) have shown that high mobility foragers often maintain limited tool inventories, which include large, curated multi-purpose tools typical of the MSA. Such artifacts can go through several phases of use and maintenance, with each 'phase' having a different function or a single repeated function (Jelinek, 1976; Shott, 1986;

Rolland and Dibble, 1990). Functional shifts may be accompanied by changes in artifact morphology, which can also alter the resulting typological classification.

Nelson (1991:70) identified two types of multi-purpose tools. 1) 'Flexible', where edges are reshaped to suit particular functions and 2) 'Versatile', where tool edges can serve multiple functions without reshaping. Use-wear analysis, combined with artifact refitting, could help to distinguish these types. Versatile tools would have several kinds of microwear traces on the same edge, while flexible tools may have only one kind of microwear trace per edge, but show different kinds of microwear traces on different edges or at different stages of resharpening. Small retouch flakes produced during maintenance sessions may also retain use-wear traces on their platforms and proximal dorsal edges. Ultimately, tools with long and multi-functional use-lives should have a high intensity and large diversity of use-wear traces.

The second toolkit includes predominantly smaller artifacts that are the "Right Tools for the Job". For example microliths made on thinner, narrower standardized blades, which, in contrast to generalized MSA tools, are produced in anticipation of a planned tool-using task. Ambrose (2002) proposed that microliths are mass-produced in standardized, but diverse, forms and designed to be single-use or disposable components in hafted composite tools. They are thin, sharp, and efficient at a specific task, with different forms (e.g. long and narrow vs. short and wide) being designed for different functions. Notably, because they are so thin they are also very fragile and have little, if any, potential for resharpening and transformation. Therefore, these disposable and task-specific tools should have a low diversity and low intensity of use-wear traces. The distinction between curated MSA tools and disposable LSA microliths represents the third test prediction of hypothesis 3, of which I will test with use-wear analysis. This is in part supported by experimental research by Eren et al (2008) who showed that large, thick wide flakes have greater potential for resharpening than thinner narrower blades.

Obsidian Use-Wear Analysis Imaging

Obsidian is a volcanic glass formed on the edges of silicic lava flows where it cools quickly, without a crystalline structure (Dietrich and Skinner, 1979). It is a hard, brittle, non-crystalline and homogeneous material that fractures uniformly in all directions (isotropic) producing extremely sharp edges. These features made it a highly desirable lithic raw material during all periods of Stone Age prehistory (Ambrose, 2012). Use-wear analyses are traditionally performed on flint and chert tools (e.g. Curwen, 1930, 1935, 1936; Semenov, 1964; Tringham et al., 1974; Keeley, 1980; Kamminga, 1982; Hardy, 2004; Hardy et al., 2008; Rots, 2010; Rots and Plisson, 2013) because they acquire diverse distinctive wear and polish patterns when used to work different materials. Other raw materials such as quartz do not acquire such a wide range of distinctive wear patterns (Sussman, 1985; Rots and Van Peer 2006; Rots et al., 2011).

Use-wear analyses on obsidian were rarely performed and reported before about 2005 (but see Fedje, 1979; Lewenstein, 1981; Hurcombe, 1992; Aoyama, 1995) for three primary reasons. First, obsidian use-wear traces differ from those on flint, so analysts needed to develop specific criteria for observing and interpreting function on obsidian tools. Case in point, in the seminal edited volume *Lithic Use-Wear Analysis*, Ahler (1979: 301) titled a chapter “Functional Analysis of Non-Obsidian Chipped Stone Artifacts: Terms, Variables, and Quantification.” Second, conventional use-wear studies most often use direct-incidence reflected light microscopes, which allows identification of characteristic types of polish. However, direct incident lighting creates a glaring reflection on obsidian’s reflective surface, which obscures use-wear features. Third, the smooth reflective surface of obsidian is already perfectly polished, and does not readily acquire functionally diagnostic types of dulling (Hurcombe, 1992).

In the last 10 years there have been major improvements in microscope light control, most specifically the ability to control the degree of light polarization, that have enabled analysts to obtain clearer images of obsidian artifact edges with traditional reflected light microscopes (see Kononenko, 2007, 2011; Beyin, 2010; Setzer, 2012). There are still limitations due to reflection, but given time with the newer and more advanced hardware, analysts have been able to produce images of obsidian edge damage with reflected light microscopes comparable to those of chert or flint (figure 3.2; see also Kononenko, 2011). A microscope that excels in this role is a line of compact (~4 inches long) digital microscopes from Dino-Lite™, which connect through USB ports to any computer and have manual controls for magnification, focus, and polarization.

A Scanning Electron Microscope (SEM) also negates the issue of light reflection on a material's surface by scanning it with a high-energy beam of electrons (Pollard and Herron, 2008). Because no light source is used to 'see' the surface, there is no reflection. Images up to ~500x magnification are focused and clear, with a great depth of field. Digital images can be viewed on the computer screen and saved for further analysis. The disadvantages of an SEM are 1) access to an instrument, 2) expense of operation, and 3) becoming proficient in its operation. Primarily for these reasons the SEM has been used in only a few use-wear studies (Fedje, 1979; Del Bene, 1979; Kamminga, 1982; Anderson-Gerfaud, 1990; Hurcombe, 1992; Iovino et al., 2008). The University of Illinois Materials Research Laboratory (http://mrl.illinois.edu) is a central facility for high-end analytical instruments, including several SEM models available for use by students and faculty. Low hourly rates and opportunities for hands-on training with full-time technicians negated the disadvantages mentioned above. The SEM model best suited for lithic use-wear analysis was a JEOL 6060LV (figure 3.3), which has a large main chamber with a relatively quick sample introduction procedure and does not require any special sample preparation for imaging at magnifications ≤1000x.

For conventional imaging in an SEM, a sample must be electrically conductive and grounded in order to prevent the accumulation of electrostatic charge at the surface. Therefore, samples are usually coated with an electrically conducting material such as gold or carbon. The LV (low vacuum) mode on the JEOL 6060 model allows samples to be viewed without coating by keeping the sample under a relatively high atmospheric pressure (partial vacuum) with a short working distance between the electron gun and sample.

Before each artifact imaging session the SEM filament and electron gun are aligned and the microscope lens is focused. To do this accurately I used a glass slide coated in epoxy with small embedded obsidian chips rather than an uneven stone tool. This surface was smoothed with 400 grit superfine sandpaper, carbon coated and loaded into the SEM with the HV (high vacuum) mode activated. Setting up the imaging parameters in HV mode with a perfectly flat surface at 10,000x magnification also optimized lens focus and astigmatism (none) in LV mode.

I cleaned and prepared all stone tools for SEM observation by hand washing with Alconox soap powder dissolved in water. No brushes were used to avoid scratching surfaces or chipping edges; instead, fingers were used to gently rub tool surfaces clean. If necessary, tools were soaked for fifteen minutes in a bath of potassium hydroxide (KOH) to dissolve any organic residues or materials adhering to the edge. Tools were immersed in distilled water for ten minutes in an ultrasonic water bath and dried on lint-free Kimtech™ wipes in a fume hood. Tools were bagged separately in polythene bags to prevent post-experiment edge damage, and handled with powder-free disposable latex gloves to prevent transfer of residues from my hands.

Clean stone artifacts were mounted rigidly on a specimen holder using carbon tape. Carbon tape also grounds the artifact, which minimizes image-obscuring charge buildup on the artifact's surface. For best results, the edge to be imaged must be kept flat. The sample holder could be tilted up to 45° within the chamber to present angled edges to the detector. Artifacts as large as 6 cm maximum dimension were mounted effectively. Instrument imaging conditions were the same for all artifacts: the vacuum was set to 10 Pa, electron gun accelerating voltage was set to ~20 kv, with a spot size (the cross sectional diameter of the beam at the surface of the specimen) of 38 nanometers. All images were saved as *.tiff* files with the magnification and metric scale embedded.

Obsidian Experiments: Kinematics and Use-Wear Traces

As noted above, analysts cannot simply apply the same system of use-wear traces that have been developed for non-obsidian raw materials. The types and formation rates of use-wear traces on obsidian are distinct from those of chert, flint, basalt, or any other fine-grained raw material and so it requires its own reference set of experimental tools. Obsidian lacks visible surface roughness, even at magnifications of 1500x (figure 3.4), and so its unused surface has a natural polish that acquires unique patterns of abrasion, dulling, scratches, and micro-fractures during dynamic contact with materials (Hurcombe, 1992; Kononenko, 2011).

I created an experimental assemblage of obsidian tools in order to develop criteria for understanding the formation of and visually identifying different types of use-wear traces on obsidian. Experiments were designed to test various kinematic motions and worked materials. Kinematics has two major variables: edge orientation and the type of use-action. Edge orientation describes the angle of the tool edge relative to the worked material. This can be anywhere from 0° (very low) to >90° (very high). The three main types of use-actions are transverse (scraping and whittling), longitudinal (slicing, sawing and grooving), and rotary (drilling or boring) (Keeley, 1980). For transverse use-actions the tool edge is perpendicular to the worked material. For longitudinal use-actions the tool edge is parallel with the worked material. And for rotary use-actions the tool tip (rather than a sharp edge) is pointed at the worked material and twisted in the hand.

In order to identify stone tool function analysts use the physical traces (i.e. damage) left on tool edges and surfaces by worked materials during use. These use-wear traces include: negative microflake scars, bending fractures (half-moon breaks) and edge snaps, striations and scratches, edge rounding, dulling, polish, and residues (Keeley, 1980; Tringham et al., 1974). Microflake scars are typically the most visible use-wear trace because lithic raw materials are often brittle, particularly obsidian, and tend to chip away as they are used, regardless of the hardness of the worked material. Negative microflake scars on tool edges have four primary attributes: density, angle of scar relative to tool edge, flake termination type, and length or invasiveness. Density is the number and distribution of scars per length of edge. Angle refers to orientation of the flaking axis of the negative flake scars to the edge, as determined by the orientation of arêtes and ripples relative to the position of the negative bulb. Termination type refers to feather, hinge or step at the distal end of the negative flake scar (Cotterell and Kamminga, 1987). Negative flake scar length is measured from the tool edge to the distal termination.

Other kinds of edge microfractures include bending fractures, which are characterized by a near-vertical scar origination lacking a distinct negative bulb of percussion with a fracture surface that curves over the dorsal or ventral side of the artifact. This fracture type creates a smooth concavity in the plan form outline of the fracture edge that is conventionally described as a "half-moon break". Bending fractures grade into true edge snaps, which are characterized by a near-vertical snap facet.

Striations are scratches or grooves on a tool's surface that result from a hard material contact point or grit that slides along the surface of the tool during its use. Attributes of striations include orientation to the tool edge, length, width, depth and density. "Grit" can include particles of soil, fragments or edge of the worked material or microflakes removed from the stone tool itself. Fedje (1979) termed this phenomenon autostriation. There also appears to be a continuum in striation form, both ends of which are visible in figure 3.5; the first being what Lawn and Marshall (1979: 72) identify as partial Hertzian cracks that do not remove surface material (figure 3.6) and the second being grooves or gouges into the glass. Hertzian crack striations are linear tracks of nested C-shaped partial ring cracks. The trail of partial cracks indicates the direction that the indenter moved across the surface of the piece, with the partial cracks opening *toward* the direction of movement (Ben Abdelounis et al., 2009).

Edge rounding is where the edge becomes smoothed from rubbing on the worked material. Dulling on obsidian is quite similar to polish, or a shiny "lustre", which is one of the earliest use-wear traces to be recognized on chert and flint tools (Curwen, 1930, 1935, 1936). Because obsidian is a naturally smooth glass it does not form "polishes" in the same way as the surface of microcrystalline flint or chert (Lewenstein, 1984; Bamforth, 2010). Instead, rubbing alters the surface of obsidian, and it acquires a subtle "dulled" contrast between the fresh and rubbed areas (Hurcombe, 1992). The attributes for rounding and dulling are the size of the affected spot(s), and their distribution and location on the tool surface or edge.

Finally, residues are traces of non-lithic materials that adhere to the tool surface such as ochre, adhesive gums or plant phytoliths. All use-wear traces and their associated attributes vary depending on a tool's use-action, edge orientation, the intensity and duration of use and the softness or hardness of the worked material. All of my experiments with obsidian tools were designed to observe and understand the variability of use-traces that result from different functions in order to help identify these functions in archaeological assemblages.

Experimental Design

Obsidian was purchased through an online lithics dealer (www.neolithics.com) because it was not feasible to export large blocks from Kenya. The obsidian came from a quarry in Oregon in two varieties; the first was black and semi-clear in thin-section, while the other was reddish-brown and 100% opaque. The black obsidian was noticeably heavier and slightly more brittle than the red-brown. Both produced extremely sharp flakes and usable edges with each obsidian type forming about half the experimental assemblage of tools. I produced flakes with direct percussion of hand-held cores using a combination of hard (water-rounded beach cobbles) and soft (roe deer and moose antler) hammers.

I used a total of 101 obsidian flakes and edge fragments for experiments. Each piece was assigned a unique identifier (PAS-#) and labeled with a Dremel electric diamond tipped engraving scribe. Tools were used for six use-actions, including slicing, sawing, whittling, scraping, boring, and butchery (defleshing raw meat from bones). All experiments were performed using hand-held tools; none were hafted. Materials worked with these use-actions included dry leather hides, wood (hard and soft), grasses, soft tubers (raw potatoes and carrots), raw meat on bone, and cooked meat scraps on bone. Controls were also established for six conditions: unused fresh edges, hard hammer retouch, hard hammer abraded, soft hammer retouch, trampling (on two different backyard footpaths) and edge rubbing on fresh flakes from being carried around in a small bag. Table 3.2 lists all experimental artifacts with information on their use context, kinematics, duration of use, worked material, and use-wear results.

Because the goal of the experiments was to understand the formation and variation of use-wear traces for specific functions, all but two of the experimental tool edges were used for only a single activity in order to identify their distinct use-wear traces. Some tools were retouched before use to obtain a desired edge shape (e.g. straighten a curved edge for more uniform slicing), but no tools were retouched during or after use. Tools were used for either a timed period (usually 20-25 minutes) or until a specific task had been completed with the available materials; one example being to cut 20 thin strips from a large square leather sheet. After each experiment, notes were recorded on use-action, edge orientation, worked material, duration of use, and any visible macroscopic damage.

Task	Sample ID	Worked Material (Hardness)	Duration (min)	Microflaking Direction	Microflaking Termination Type	Microflaking Invasiveness	Striations	Striation Direction	Rounding	Dulling
Control	PAS-068a	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-069	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-070	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-071	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-105	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-106	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-107	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-108	Unused edge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-067	Unused burin bit	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Control	PAS-068b	Hard hammer retouched	n/a	Perpendicular	Feather	Semi-invasive	None	n/a	None	None
Control	PAS-072	Hard hammer retouched	n/a	Perpendicular	Feather	Semi-invasive	None	n/a	None	None
Control	PAS-154a	Hard hammer abraded	n/a	Perpendicular and oblique	Feather and stepped	Marginal	None	n/a	None	None
Control	PAS-154b	Soft hammer retouched	n/a	Perpendicular	Feather	Invasive	None	n/a	None	None
Control	PAS-109	Trampled on footpath	2 weeks	Highly variable	Feather with edge snaps	Marginal	Rare	Random	None	None
Control	PAS-110	Trampled on footpath	2 weeks	Highly variable	Feather with edge snaps	Marginal	None	n/a	None	None
Control	PAS-111	Trampled on footpath	2 weeks	Highly variable	Feather with edge snaps	Semi-invasive	None	n/a	None	None
Control	PAS-112	Trampled on footpath	2 weeks	Highly variable	Feather with edge snaps	Marginal	Rare	Random	None	None
Control	PAS-113	Trampled on footpath	2 weeks	Highly variable	Feather with edge snaps	Semi-invasive	None	n/a	None	None
Control	PAS-114	Carried in bag - edge rubbing	2 weeks	Highly variable	Feather	Marginal	None	n/a	None	None
Control	PAS-115	Carried in bag - edge rubbing	2 weeks	Highly variable	Feather	Marginal	None	n/a	None	None
Control	PAS-116	Carried in bag - edge rubbing	2 weeks	Highly variable	Feather	Marginal	Rare	Random	None	None
Control	PAS-098	Test for surface etching with KOH	20	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Slicing	PAS-005	Dry hide (soft)	20	Oblique away	Feather	Semi-invasive	None	n/a	None	None
Slicing	PAS-033	Dry hide (soft)	25	Oblique away	Feather	Marginal	Rare	Sub-parallel	Rare	None
Slicing	PAS-006	Dry hide (soft)	15	Rare, oblique away	Feather	Semi-invasive	None	n/a	Rare	Rare
Slicing	PAS-133	Fresh grasses (soft)	25	Rare, oblique away	Feather	Marginal	None	n/a	None	Rare
Slicing	PAS-134	Fresh grasses (soft)	25	Rare, oblique away	Feather	Marginal	None	n/a	None	Rare
Slicing	PAS-135	Raw tubers (soft)	25	Rare, oblique away	Feather	Marginal	None	n/a	None	None
Slicing	PAS-136	Raw tubers (soft)	20	Rare, oblique away	Feather	Marginal	None	n/a	None	None
Slicing	PAS-014	Cooked meat on bone (soft/hard)	20	Oblique away	Feather and stepped with edge snaps	Semi-invasive	Rare	Parallel	None	Some grease
Slicing	PAS-038	Cooked meat on bone (soft/hard)	15	Oblique away	Feather and stepped	Marginal	None	n/a	None	None
Slicing	PAS-039	Cooked meat on bone (soft/hard)	20	Perpendicular and oblique away	Feather and stepped with edge snaps	Marginal	Rare	Parallel	None	Some grease
Slicing	PAS-073	Cooked meat on bone (soft/hard)	20	Oblique away	Feather and stepped	Marginal	None	n/a	None	None
Slicing	PAS-074	Cooked meat on bone (soft/hard)	20	Perpendicular and oblique away	Feather and stepped with edge snaps	Semi-invasive	Present	Parallel	None	None
Slicing	PAS-075	Cooked meat on bone (soft/hard)	15	Perpendicular and oblique away	Feather and stepped with edge snaps	Marginal	Present	Parallel	None	Some grease

Table 3.2. Experimental artifacts with information on function and use-wear.

Task	Sample ID	Worked Material (Hardness)	Duration (min)	Microflaking Direction	Microflaking Termination Type	Microflaking Invasiveness	Striations	Striation Direction	Rounding	Dulling
Slicing	PAS-076	Cooked meat on bone (soft/hard)	15	Oblique away	Feather and stepped	Semi-invasive	None	n/a	None	Some grease
Slicing	PAS-077	Cooked meat on bone (soft/hard)	20	Perpendicular and oblique away	Feather and stepped	Semi-invasive	None	n/a	None	Some grease
Slicing	PAS-090	Fresh bone with meat scraps (soft/hard)	20	Oblique away	Feather and stepped	Semi-invasive	Rare	Parallel	None	None
Slicing	PAS-095	Raw meat on bone (soft/hard)	20	Oblique away	Feather and stepped with edge snaps	Semi-invasive	Present	Parallel	None	Some grease
Sawing	PAS-078	Wood (soft)	25	Oblique	Feather with rare edge snaps	Marginal	Rare	Sub-parallel	None	None
Sawing	PAS-079	Wood (soft)	25	Oblique	Feather with rare edge snaps	Semi-invasive	Present	Parallel	None	None
Sawing	PAS-080	Wood (soft)	25	Oblique	Feather and stepped with rare edge snaps	Marginal	Rare	Parallel	None	Possible
Sawing	PAS-081a	Wood (soft)	25	Perpendicular and oblique	Feather with rare edge snaps	Marginal	None	n/a	None	None
Sawing	PAS-081b	Wood (soft)	25	Oblique	Feather and stepped with rare edge snaps	Marginal	Present	Sub-parallel	None	None
Sawing	PAS-022	Wood (medium)	20	Oblique	Feather and stepped with edge snaps	Marginal	None	n/a	None	None
Sawing	PAS-023	Wood (medium)	20	Oblique	Feather with edge snaps	Semi-invasive	None	n/a	None	None
Sawing	PAS-032	Wood (medium)	25	Oblique	Feather and stepped with edge snaps	Marginal	Present	Parallel	None	Possible
Sawing	PAS-085	Wood (medium)	25	Perpendicular and oblique	Feather with edge snaps	Marginal	None	n/a	None	None
Sawing	PAS-086	Wood (medium)	25	Oblique	Feather and stepped with edge snaps	Marginal	Rare	Sub-parallel	None	None
Sawing	PAS-087	Wood (medium)	25	Oblique	Feather and stepped with edge snaps	Marginal	None	n/a	None	None
Sawing	PAS-140	Wood (medium)	25	Perpendicular and oblique	Feather with edge snaps	Marginal	Rare	Parallel	None	None
Sawing	PAS-156	Wood (medium)	25	Oblique	Feather with edge snaps	Marginal	Present	Sub-parallel	None	None
Sawing	PAS-082	Wood (hard)	25	Perpendicular and oblique	Feather and stepped with edge snaps	Semi-invasive	Rare	Parallel	None	Possible
Sawing	PAS-083	Wood (hard)	25	Perpendicular and oblique	Feather and stepped with edge snaps	Marginal	None	n/a	None	None
Sawing	PAS-084	Wood (hard)	25	Oblique	Feather and stepped with edge snaps	Marginal	Present	Parallel	None	None
Whittling	PAS-034	Wood (medium)	25	Perpendicular	Stepped with edge snaps	Marginal	Present	Perpendicular	None	None
Whittling	PAS-035	Wood (medium)	20	Perpendicular	Stepped	Marginal	Present	Perpendicular	None	None
Whittling	PAS-036	Wood (medium)	20	Perpendicular	Feather and stepped	Semi-invasive	None	n/a	None	None
Whittling	PAS-155	Wood (medium)	25	Perpendicular and oblique	Feather and stepped	Semi-invasive	Present	Perpendicular	None	None
Whittling	PAS-158	Wood (medium)	25	Perpendicular	Stepped with edge snaps	Marginal	Present	Perpendicular	None	None
Whittling	PAS-160	Wood (medium)	25	Perpendicular	Stepped	Marginal	None	n/a	None	None
Scraping	PAS-009	Dry hide (soft)	25	Perpendicular	Feather	Marginal	Present	Perpendicular	Rare	Yes
Scraping	PAS-011	Dry hide (soft)	20	Perpendicular	Feather	Marginal	None	n/a	None	None
Scraping	PAS-019	Dry hide (soft)	25	Perpendicular	Feather	Semi-invasive	Rare	Perpendicular	Rare	Yes
Scraping	PAS-037	Dry hide (soft)	20	Perpendicular and oblique	Feather	Marginal	None	n/a	Rare	Rare
Scraping	PAS-010	Dry hide (soft)	25	Perpendicular	Feather	Marginal	None	n/a	None	Rare
Scraping	PAS-020	Dry hide (soft)	25	Perpendicular	Feather	Marginal	Rare	Perpendicular	None	None
Scraping	PAS-099	Dry hide (soft)	25	Perpendicular and oblique	Feather	Semi-invasive	None	n/a	None	Rare
Scraping	PAS-100	Dry hide (soft)	25	Perpendicular	Feather	Semi-invasive	Present	Perpendicular	Rare	None
Scraping	PAS-101	Dry hide (soft)	25	Perpendicular	Feather	Marginal	None	n/a	None	Yes

Table 3.2 continued.

Task	Sample ID	Worked Material (Hardness)	Duration (min)	Microflaking Direction	Microflaking Termination Type	Microflaking Invasiveness	Striations	Striation Direction	Rounding	Dulling
Scraping	PAS-050	Wood (soft)	25	Perpendicular	Feather	Semi-invasive	Present	Perpendicular	None	None
Scraping	PAS-051	Wood (soft)	25	Perpendicular and oblique	Feather and stepped	Semi-invasive	None	n/a	None	None
Scraping	PAS-052	Wood (soft)	25	Perpendicular	Feather and stepped	Semi-invasive	Present	Perpendicular	None	None
Scraping	PAS-053a	Wood (soft)	25	Perpendicular	Feather	Semi-invasive	Present	Perpendicular	None	None
Scraping	PAS-053b	Wood (soft)	25	Perpendicular	Feather and stepped	Marginal	Rare	Perpendicular	None	Rare
Scraping	PAS-054	Wood (soft)	25	Perpendicular	Feather and stepped	Semi-invasive	None	n/a	None	None
Scraping	PAS-055a	Wood (medium)	25	Perpendicular and oblique	Feather and stepped	Semi-invasive	None	n/a	None	None
Scraping	PAS-055b	Wood (medium)	25	Perpendicular	Feather and stepped	Invasive	Rare	Perpendicular	Rare	None
Scraping	PAS-056a	Wood (medium)	25	Perpendicular	Feather and stepped	Semi-invasive	None	n/a	None	None
Scraping	PAS-056b	Wood (medium)	25	Perpendicular	Feather and stepped	Invasive	Rare	Perpendicular	None	Rare
Scraping	PAS-057a	Wood (hard)	25	Perpendicular	Stepped	Invasive	Present	Perpendicular	None	None
Scraping	PAS-057b	Wood (hard)	25	Perpendicular	Feather and stepped	Invasive	None	n/a	Rare	None
Scraping	PAS-058	Wood (hard)	25	Perpendicular	Stepped	Semi-invasive	Rare	Perpendicular	None	None
Scraping	PAS-059	Wood (hard)	25	Perpendicular and oblique	Feather and stepped	Invasive	Rare	Perpendicular	None	None
Scraping	PAS-060	Wood (hard)	25	Perpendicular	Stepped	Marginal	None	n/a	None	None
Scraping	PAS-091	Fresh bone with meat scraps (soft/hard)	20	Perpendicular	Feather and stepped	Semi-invasive	None	n/a	None	Some grease
Scraping	PAS-092	Fresh bone with meat scraps (soft/hard)	20	Perpendicular	Feather and stepped	Invasive	Present	Perpendicular	None	None
Scraping	PAS-096	Raw meat on bone (soft/hard)	25	Perpendicular	Feather and stepped	Invasive	Rare	Perpendicular	None	Some grease
Scraping	PAS-097	Raw meat on bone (soft/hard)	20	Perpendicular	Stepped	Marginal	None	n/a	None	Some grease
Boring	PAS-061	Dry hide (soft)	20	Perpendicular and oblique	Stepped	Marginal	None	n/a	Rare	None
Boring	PAS-062	Dry hide (soft)	20	Oblique	Feather and stepped	Semi-invasive	Rare	Sub-parallel	Rare	Yes
Boring	PAS-063	Dry hide (soft)	20	Oblique	Stepped with edge snaps	Marginal	None	n/a	None	Rare
Boring	PAS-064a	Dry hide (soft)	20	Perpendicular and oblique	Feather and stepped	Semi-invasive	Rare	Oblique	None	None
Boring	PAS-064b	Dry hide (soft)	20	Oblique	Stepped	Marginal	None	n/a	Rare	Yes
Boring	PAS-065	Dry hide (soft)	20	Oblique	Stepped	Marginal	None	n/a	None	None
Grooving	PAS-066	Wood (soft)	15	Perpendicular	Stepped	Marginal	None	n/a	None	None
Defleshing	PAS-088	Raw meat on bone (soft/hard)	20	Perpendicular and oblique	Feather and stepped	Marginal	None	n/a	None	None
Defleshing	PAS-089	Raw meat on bone (soft/hard)	20	Perpendicular and oblique	Feather and stepped	Semi-invasive	Rare	Parallel	None	None
Defleshing	PAS-093	Raw meat on bone (soft/hard)	20	Oblique	Feather and stepped	Semi-invasive	None	n/a	None	None
Defleshing	PAS-094	Raw meat on bone (soft/hard)	20	Perpendicular and oblique	Feather and stepped	Semi-invasive	None	n/a	None	None
Sawing and Scraping	PAS-159	Wood (medium)	20	Perpendicular and oblique	Feather and stepped with edge snaps	Invasive	Present	Perpendicular	None	None

Table 3.2 continued.

Experimental Results

Results of experimental artifact use-wear patterns are summarized in table 3.3.

Table 3.2	*Control 1*	*Control 2*	*Control 3*	*Control 4*	*Control 5*	*Control 6*	*Slicing*	*Sawing*	*Scraping*	*Whittling*	*Boring*	*Defleshing*	*Grooving*
Use-Action	Unused edge	Hard hammer retouched	Hard hammer abraded	Soft hammer retouched	Trampled in footpath	Carried in bag of flakes	Longitudinal	Longitudinal	Transverse	Transverse	Longitudinal	Transverse and Longitudinal	Longitudinal
Edge Orientation	n/a	n/a	n/a	n/a	n/a	n/a	Vertical, 90°	Vertical, 90°	High, ~80°	Acute, 30°	Vertical, 90°	Variable	Acute, 30°
Use Direction	n/a	n/a	n/a	n/a	n/a	n/a	Unidirectional	Bidirectional	Unidirectional	Unidirectional	Twisting	Bidirectional	Unidirectional
Edge Wear Symmetry	n/a	Symmetrical	Asymmetrical	Symmetrical	Asymmetrical	Asymmetrical	Symmetrical	Symmetrical	Asymmetrical	Symmetrical	Symmetrical	Asymmetrical	Symmetrical
Microflaking Direction	n/a	Perpendicular	Perpendicular and oblique	Perpendicular	Highly variable	Highly variable	Oblique	Oblique	Perpendicular	Perpendicular	Oblique	Perpendicular and oblique	Perpendicular
Microflaking Termination Type	n/a	Feather	Feather and stepped	Feather	Feather with edge snaps	Feather	Feather	Feather with edge snaps	Feather and stepped	Stepped	Stepped	Feather and stepped	Stepped
Microflaking Invasiveness	n/a	Semi-invasive	Marginal	Invasive	Semi-invasive	Marginal	Marginal to semi-invasive	Semi-invasive	Semi-invasive	Marginal	Marginal	Semi-invasive	Marginal
Striations	n/a	None	None	None	Rare	Rare	Rare	Present	Present	Rare	Rare	Very rare	None
Striation Direction	n/a	n/a	n/a	n/a	Random	Random	Parallel	Parallel	Perpendicular	Perpendicular	Sub-parallel	Parallel	n/a
Rounding	n/a	None	None	None	None	None	None	None	Present	None	Present	None	None
Dulling	n/a	None	None	None	None	None	None	None	Yes	None	Rare	None	None

Table 3.3. Summary of use-wear traces categorized by functional task.

Controls. It was first necessary to establish a control baseline of images of unused flaked piece edges. The first control group was a set of fresh flakes without any edge modification. These surfaces and edges are sharp and pristine (figure 3.4) except for longitudinal fissures associated with conchoidal fracture from percussion during normal flake production (figure 3.7). Mineral inclusions are sometimes visible on the surface but are easily distinguished from any use-wear feature or residue because they are fully embedded within the obsidian (figure 3.8).

The second control group comprised pieces retouched with hard and soft hammers. Flake edges that were retouched with a hard hammer stone are characterized by marginal to semi-invasive microflake scars with wide feather terminations and robust negative bulbs of percussion (figure 3.9). Edges that were retouched with a soft hammer are characterized by invasive microflake scars with feather terminations and weakly developed negative bulbs of percussion (figure 3.10). Robustness of bulbs and invasiveness of flake scars best distinguish these hammer types. For edges that were abraded with the stone hammer, microflake scars are uniformly shallow with stepped terminations and are denser than either of the retouched edges. Trampled artifacts represent a more random assortment of damage types, including large edge snaps, half-moon breaks, notches, marginal to semi-invasive microflake scars with terminations bidirectionally angled from the tool edge, and a pseudo-denticulate edge shape where multiple snaps formed along a single edge. Striations formed rarely, but in random positions and orientations. The flakes that were carried around in a bag were characterized by edge damage consisting of marginal feather flake terminations with rare striations in random directions. No control group formed edge rounding, dulling, polish, or residues.

Scraping experiments. Scraping is a transverse use-action where the tool edge is held at a high angle (80°-90°) and the artifact is pulled toward the user. Wear traces are concentrated on the edge and upper face of the tool. Microflakes are removed perpendicular to the edge as they are driven off the tool opposite to the direction of the use-action. Microflake morphology changes during use. First, invasive microflake scars with feather terminations form; second, shallow overlapping stepped terminations at the edge of the tool. Sometimes these overlapping stepped scars are so dense that they can actually appear as rounded edges (figure 3.11). Striations are oriented perpendicular to the worked edge. These form primarily on the face that is pulled toward the worked material. In other words, if the tool is held with the ventral side facing the user, and is drawn toward the user while in contact with the worked material, striations form on the ventral face. This is significant because it shows that, for scraping, use-wear traces may form asymmetrically on different tool faces due to unequal contact with the worked material.

Microflake and striation attributes of scraping tools differ according to raw material hardness. Tools used to scrape hard materials, such as wood or bone, generated more invasive feather microflake scars, more robust striations, and little edge rounding. Tools used to scrape soft materials, such as dry leather hides, produced fewer and more marginal to semi-invasive microflakes with feather terminations, and fewer edge snaps and striations. Hide scraping also left a noticeable dulling on the tool edge, which was not present on tools used to work hard materials (figure 3.12).

Whittling experiments. Whittling is a transverse use-action where the tool edge is held at a low angle (≤45°) to the worked material and the artifact is pushed away from the user. Wear traces most often form perpendicular to the tool edge, and are distributed evenly on the upper and lower faces of the tool. Microflake scars are marginal, with stepped terminations; invasive feather scars are rare. Edge rounding may form after prolonged use as stepped terminations overlap. Striations are most common on the tool face that is closer to the worked material.

Slicing experiments. Slicing is a longitudinal use-action with a high (typically 90°) edge orientation where the tool is pushed or pulled in a single-direction. Wear traces are distributed equally on both tool faces. Microflake scars are produced at oblique angles to the tool edge and opposite of the direction the tool is being pulled (figure 3.13). Lawrence (1979: 118) observed a similar microflake orientation pattern in slicing experiments with chert on bone and hide. Striations tend to form marginally and are oriented parallel to the tool edge. Edges tend to remain sharp with little edge rounding or dulling or jagged where small snaps and half-moon breaks are present. Slicing hard materials typically generates short microflakes with deep negative bulbs of percussion, stepped terminations, edge snaps and striations. Soft materials produce fewer use-wear traces, with longer more invasive scars, and feather terminations

Sawing experiments. Sawing is a longitudinal use-action with a high (typically 90°) edge orientation where the tool is alternatively pushed and pulled while in contact with the material. This is a bi-directional action, in contrast to only the single direction of slicing. Similar to slicing, though, wear traces are distributed equally on both faces of the tool. Microflake scars are produced at oblique angles to the tool edge in two directions, matching the use-action. Hertzian cracks and striations also follow this bidirectional pattern. Sawing produces higher frequencies of edge snaps and stepped terminations compared to unidirectional slicing, as well as more short, marginal, stepped terminating flakes, rather than a long invasive ones (figure 3.14).

Snaps may be more common because edges are thinner due to more negative flake scars, and because there may be more lateral pressure (wobbling) when reversing direction. An interesting feature of tool edges after sawing is the macroscopic appearance of a pseudo-denticulate edge, which results from nearly continuous overlapping snaps and half-moon breaks along the edge. Harder materials produce more pronounced snaps, stepped terminations, and much higher frequencies of striations. High frequencies of striations may be due to trapping of microflake and snap debris in the sawn groove of the worked material (autostriation).

Boring experiments. Boring is a rotating use-action with a high (typically 90°) edge orientation where a tool tip or bit (rather than a sharp edge) is pointed at the worked material and the tool is twisted in the hand. Microflake scars were typically marginal, with stepped terminations at oblique angles (25° - 65°) to the bit edge. Striations formed rarely, but were most often sub-parallel or oblique to the bit. Edge rounding and traces of dulling sometimes formed on the lateral margins of the bit.

Butchery experiments. Butchery of cooked or raw meat on bones produced the most variable pattern of use-wear, most likely due to the diversity of use-actions involved, including slicing, sawing, scraping, twisting, and prying. As may be expected, the overall pattern of damage was one of mixed results with 'heavy-duty' types of wear, such as half-moon breaks (on thin edges), striations, and marginal microflake scars with deep negative bulbs of percussion and hinged terminations (figure 3.15). Use-wear traces were predominantly marginal to semi-invasive with perpendicular and oblique use directions.

Blind Test Experimental Design and Results

I observed a total of ten blind test artifact edges to evaluate the effectiveness of functional interpretations based on the experiential assemblage. Forty-five unretouched whole obsidian flakes were provided to Stanley Ambrose to be used in any manner that he saw fit. All flakes were made on either the same red-brown or black obsidians used in previous experiments. Some workable materials were also provided, including dry leather hide, fresh hardwood sticks with bark (*Maclura pomifera*) and meaty beef bones, though it was not required that they be used. Ambrose selected seven flakes to use, three of which had two separately used edges and added two materials for processing: slicing fresh cornhusk leaves and slicing fresh kernels off of the cob. Ambrose provided no information to myself on the nature of their use. Artifacts were photographed together with their worked materials before and after the tasks, including the products generated by tool use.

Flakes provided for the blind test had two main forms; sharp, acute edges, mainly suitable for slicing, and thicker flakes with more robust edges. The tester preferred flakes with thicker edges, particularly for working the harder materials. All parameters concerning use were left to the tester, including the worked material, use-action, edge orientation, use duration and used edges. All tools were used, then cleaned with dilute dishwashing detergent, ammonia and bleach by Ambrose, and returned to me for observation and interpretation. Table 3.4 lists each blind test artifact, the actual use, and my blind interpretation.

I correctly interpreted six of the ten artifacts for both use action and worked material. Two artifacts were interpreted correctly for either worked material or the use action, but not both. Finally, two were incorrectly interpreted; one for both use-action and worked material and the other was thought to be too minimally damaged to have been used. Considering that each tool had two possible correct ‘points’ (one for worked material and one for use-action) then I scored a total of 14/20 (70%) points in this blind analysis.

Results of blind tests confirm that unique combinations of use-wear traces are produced on obsidian tool edges during different use-actions. Tools used to work cornhusks and cobs were incorrectly identified as unused due to a low density of use-wear traces, something that a short use-duration would also suggest. There was also some overlap of traces for certain use-actions. For example, sawing produced bifacial edge damage features similar to whittling, particularly microflake and striation patterns, though these features were distinguishable by their different orientations. This overlap was not entirely unexpected, as experiments showed that there is limited variation in the morphology of use-wear features and seemingly different use-actions may have still similar contact zones between the tool edges and worked materials forming similar use-wear traces.

Table 3.4. Summary of blind test artifacts with actual uses and my interpretations based on use-wear. Adapted from Slater (2011).

Sample ID	Context	Use Action	Worked Material	Result
PAS-016 Left	Actual	Scraping	Bone	Correct
	Interpreted	Scraping	Bone	
PAS-016 Right	Actual	Defleshing	Meat, tendons and bone	Correct
	Interpreted	Sawing/Slicing	Meat	
PAS-018 Left	Actual	Scraping	Hide	Correct
	Interpreted	Scraping	Hide	
PAS-018 Right	Actual	Slicing	Hide	Correct
	Interpreted	Slicing	Hide	
PAS-109	Actual	Whittling	Hard Wood	50% Correct
	Interpreted	Sawing	Hard Wood	
PAS-118	Actual	Slicing/Sawing	Hard Wood	Correct
	Interpreted	Sawing	Hard Wood	
PAS-123 Left	Actual	Scraping	Hard Wood	Correct
	Interpreted	Scraping	Hard Wood	
PAS-123 Distal	Actual	Scraping	Hard Wood	Incorrect
	Interpreted	Boring	Bone	
PAS-125	Actual	Slicing	Corn Husks	50% Correct
	Interpreted	Slicing	Soft material – meat?	
PAS-126	Actual	Slicing	Corn kernels from cob	Incorrect
	Interpreted	Unused	Unused	

Experimental Discussion and Conclusions

There are five overarching discussion points that these experiments on obsidian bring to light. First, it can be difficult to identify tools that were either used for either short durations or on very soft materials. For example, flakes used to cut grasses and tubers generated very limited traces of wear, even after 20+ minutes of use. This finding could be significant in archaeological contexts where excavated tools were used expediently and then discarded because analysts may not be able to identify that the tools were even used. This is much less of an issue with hard worked materials simply because those use-wear traces are more robust. Ultimately, this could lead analysts to underestimate the number of tools used for cutting grass or soft plant foods relative to wood working at a site. On a related note, sticky residues were often present on tools used to work plant materials. This was also the case for butchery tools, which were typically covered in grease, meat or periosteum. In both cases, the KOH cleaning bath was usually, but not always sufficient to remove these residues. In the case of fatty residues, additional treatment with organic solvents such as methanol, chloroform or ether may be necessary.

Second, the morphology and attributes of microflake scars and striations were found to be the two most important features for distinguishing among tool functions. As shown in the blind tests, different use-actions can produce scar and striation patterns that mirror each other and must be considered during interpretation. For microflake scars, termination types and directionality were the most informative attributes. The angle of scars relative to the worked edge had a very direct relationship to tool use-action because microflakes were removed opposite to the direction of tool use. Perpendicular (~90°) orientation indicates transverse kinematics while oblique orientation, consistently higher and/or lower than 90°, indicates longitudinal kinematics. A unidirectional action is indicated if all scars have the same direction of deviation from 90°, whereas a bidirectional action is indicated if flake scar deviations are removed obliquely in two directions (e.g. 60±20° and 120±20°). Termination type was most informative for material hardness; with harder materials creating more stepped or hinged terminations as well as edge snaps. For striations, the orientation relative to the tool edge often provided supporting evidence for microflake scars on the use-action of a tool while their size provided evidence regarding the characteristics of the worked material. Not surprisingly, harder materials tended to produce larger and wider striations.

Both of these findings are consistent with previous experiments on obsidian use-wear. As a natural glass, obsidian may be more susceptible to surface abrasion and therefore, "striations may act as a more effective criterion to distinguish patterns of wear" than for flint or chert (Tringham et al., 1974: 179; Bamforth, 2010). Lewenstein (1981) analyzed an assemblage of Mesoamerican blades and found that there was a correlation between microflake termination type (e.g. feather, hinge, snaps) and use-actions such as sawing and scraping. Hurcombe (1992) corroborated these results in a study of obsidian lunate tools from a Bronze Age Sardinian site, and also suggested that the invasiveness and length of microflake scars could be helpful in determining the hardness of worked materials.

Third, not all use-actions produce symmetrical use-wear between the two different tool faces. Analysts must be aware that there may, literally, be two sides to the functional history of a tool (see scraping vs. sawing). In order to confidently identify artifact functions, both sides should be observed.

Fourth, a tool edge used for a single task that involves more than one use-action (e.g. butchery) cannot be easily differentiated from an edge used for two different use-actions at different times. For example, a tool used for alternating kinematic actions (i.e. transverse scraping and then longitudinal sawing) may have oblique microflake scars that partially or completely remove previous striations and perpendicular scars. If it is possible to determine such an order of use-wear features then it may provide evidence for more than one use-action. However, this does not necessarily demonstrate diverse kinematics in a single activity. One possible way around this problem is if the edge was retouched between uses, and trimming flakes were recovered that refit to the piece. These trimming flakes may then retain previous use-wear traces on their platforms or dorsal face that could expand the known functional history of the piece (Cahen et al., 1979).

Fifth, trampling can mask 'previous' traces of use-wear. This is especially the case for obsidian, particularly on thin, acute edges. Because the raw material is so brittle, it chips easily and a few steps on a tool can mask or remove the subtler traces that result from use. Overall, the damage patterns that result from trampling are random and intense, and could be mistaken for hard hammer retouch or sawing on a hard material. These findings echo those of McBrearty et al. (1998) who carried out experiments on tramping with flakes of various raw material types, including obsidian. They concluded that trampling could transform unused flakes into classifiable pseudo-tools, especially notched and denticulate types. This is a point of concern for any use-wear analyst and one that needs to be accounted for before any conclusions are reached. Luckily, not all Stone Age lithic assemblages are extensively trampled and broken, and in some cases, including at Marmonet Drift and Ol Tepesi Rockshelter, artifact preservation can be pristine with minimal or no trampling damage.

Archaeological Application

Stone Age artifacts were flagged for use-wear analysis during sorting and classification at the National Museum. Flagged artifacts included pieces with visible use-wear traces, including informal and formal shaped tools, as well as some artifacts with no visible damage. During the classification stage artifacts were observed with a 10x eye loop or under low magnification (≤50x) with a Dino-Lite Pro digital microscope (model AM-413ZTAS). The Dino-Lite proved to be an invaluable tool in helping to quickly discern prehistoric use-wear traces from modern excavation damage. Clear, non-reflecting, digital images of notable features were taken quickly using the adjustable light-polarizing feature allowing me to return at a later time with the SEM and observe those features more closely. I used the same sample preparation methods and JEOL 6060LV SEM for archaeological specimens as I did for experimental pieces. The results on archaeological artifacts are described in the next three chapters.

Figures

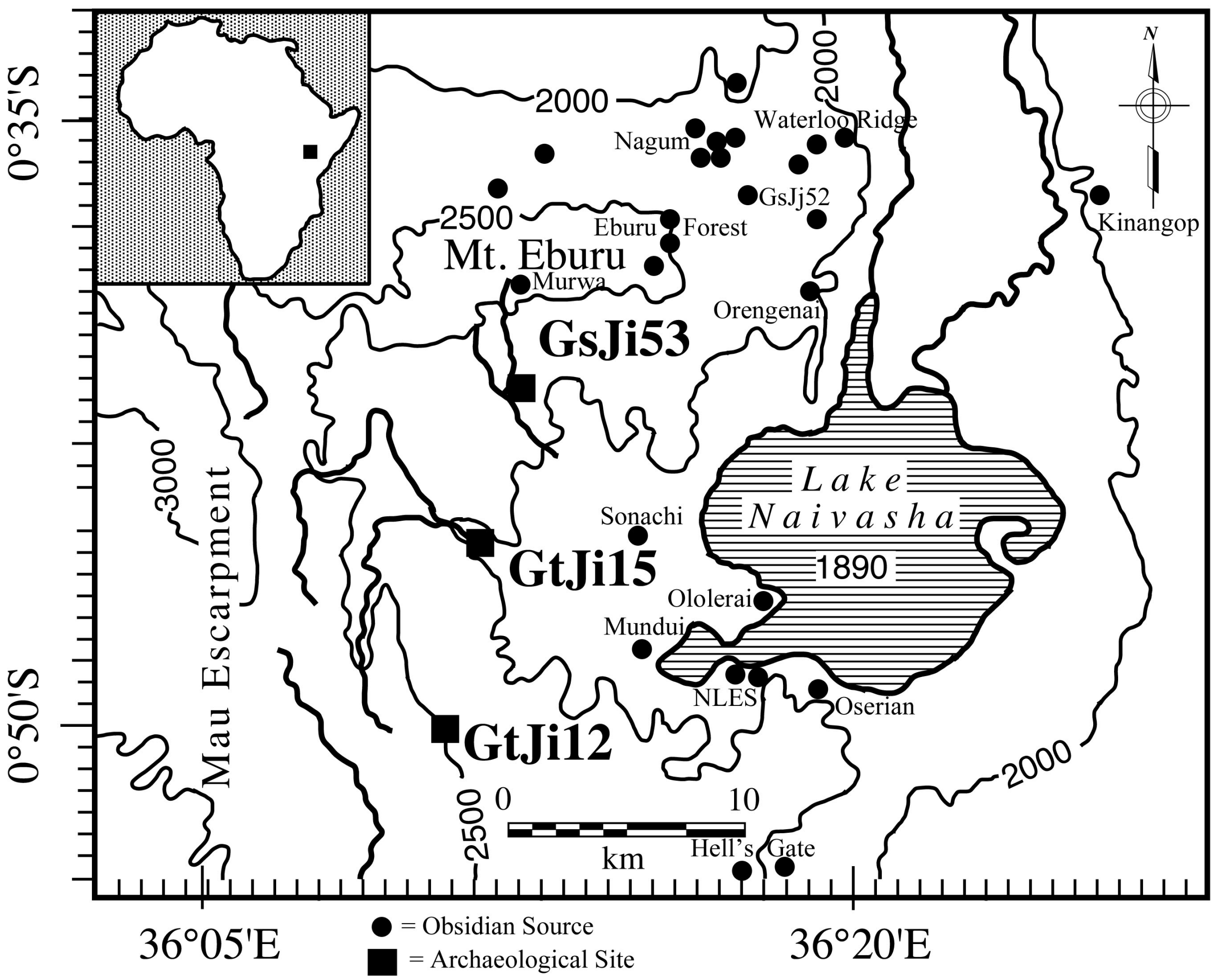


Figure 3.1. Location of archaeological sites analyzed in this dissertation. GtJi15 is Marmonet Drift, GtJi12 is Enkapune Ya Muto, and GsJi53 is Ol Tepesi. Locations of the largest and highest quality obsidian sources are also labeled. Many other small outcrops within the lake basin are not labeled, but would have provided valuable raw material sources as well. All obsidian sources were either found during fieldwork from 2008-2010 (Slater et al., 2012) or relocated based on previous research (Merrick and Brown, 1984; Merrick et al., 1994) and all were sampled or resampled for geochemical fingerprinting for reconstructing procurement and exchange patterns.

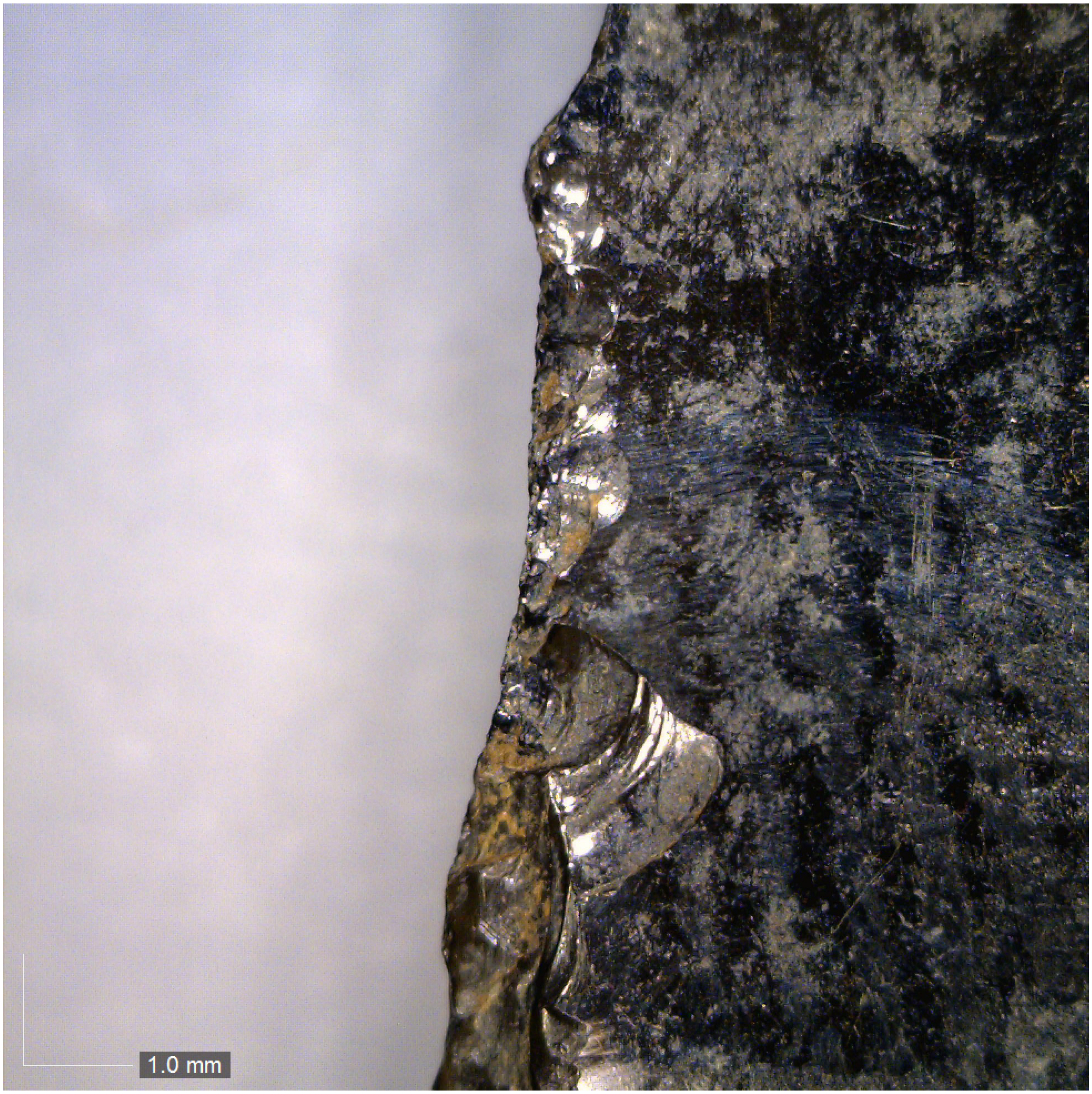


Figure 3.2. Obsidian edge use-wear taken with the Dino-Lite reflected light microscope. Image is of inverse casual retouch on a unifacial point (#2728) from Marmonet Drift H5.

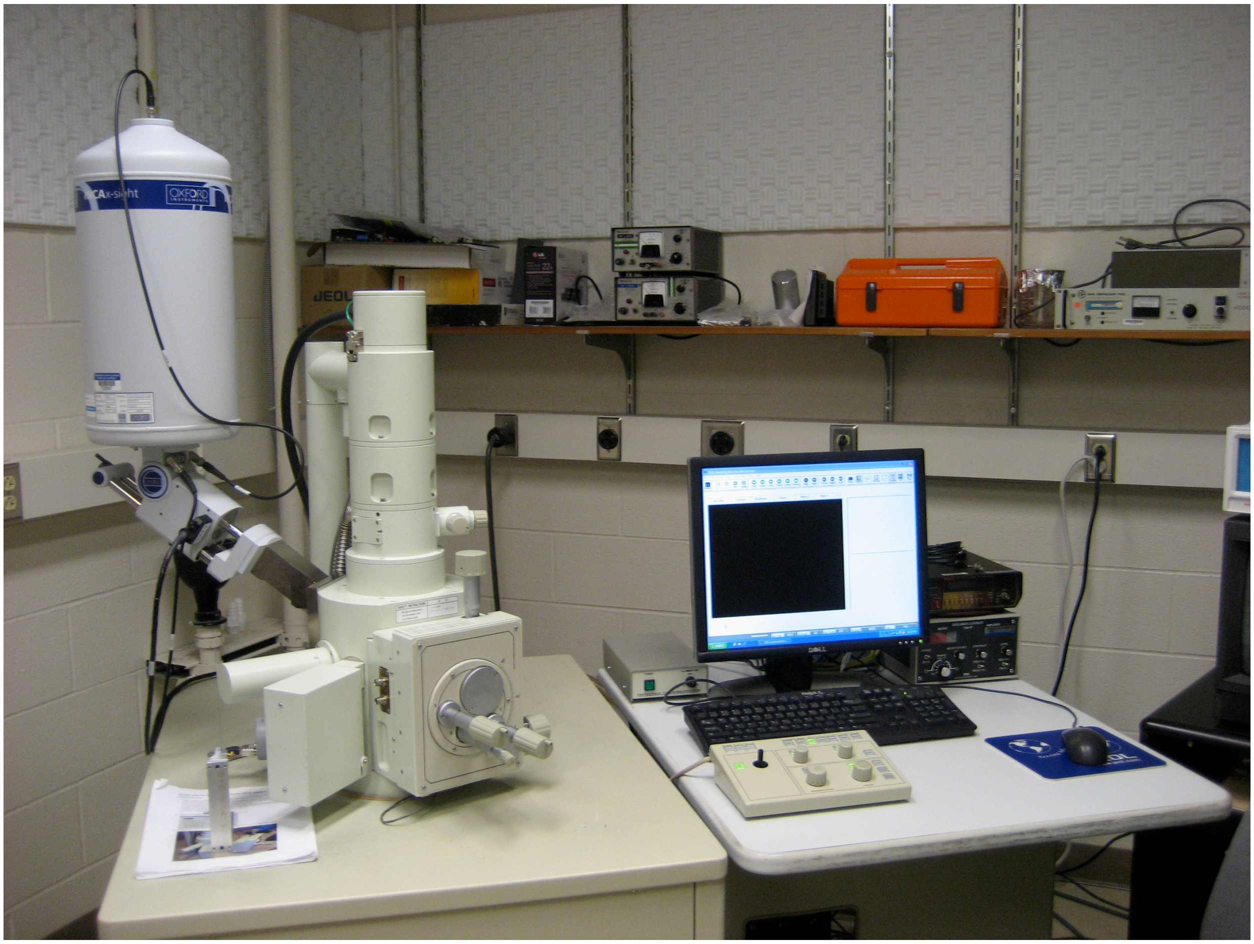


Figure 3.3. The JEOL 6060LV SEM used in this study. It is located at the University of Illinois's Materials Research Laboratory.

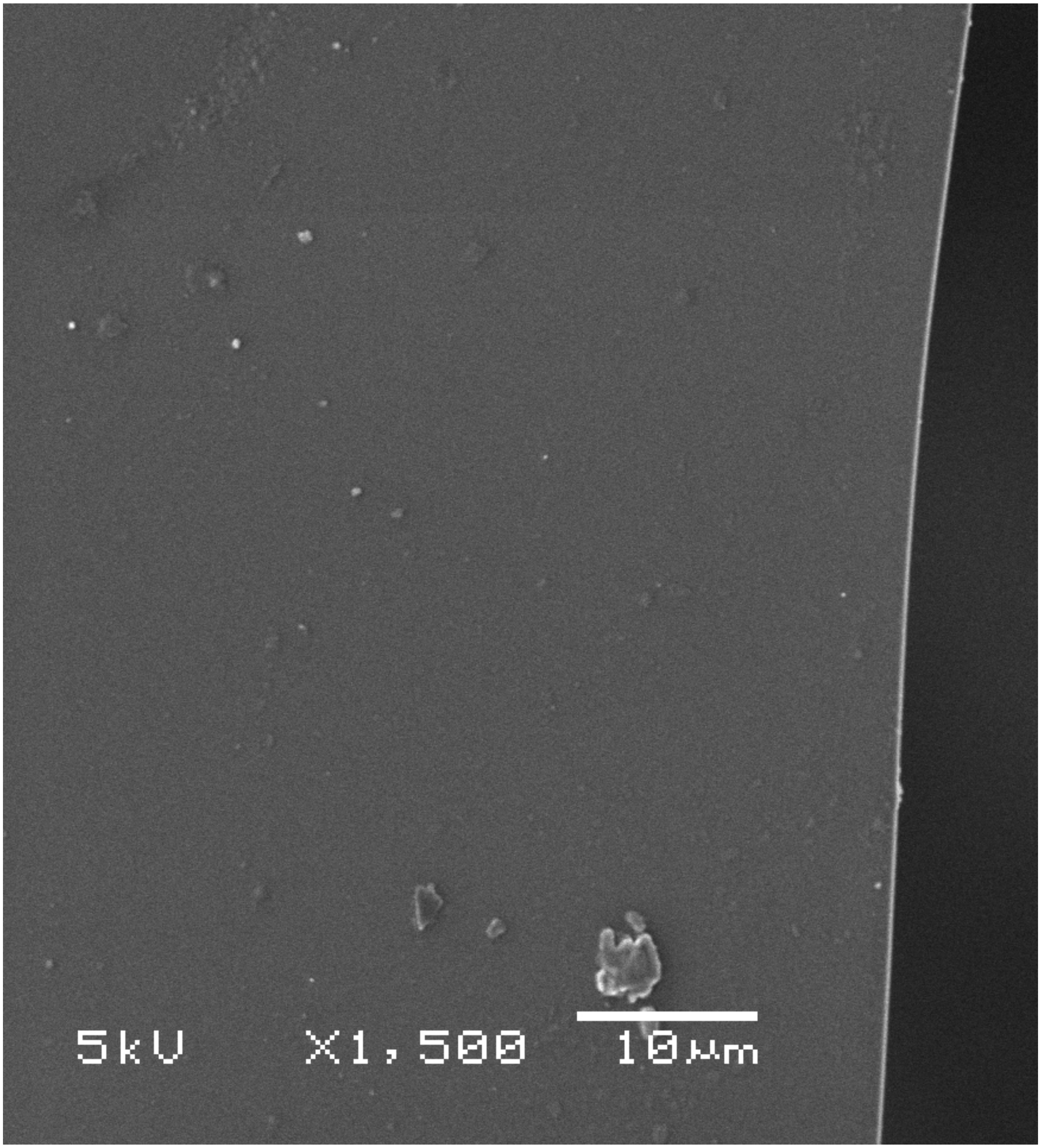


Figure 3.4. An experimental (PAS-069) unused obsidian flake edge at 1500x magnification.

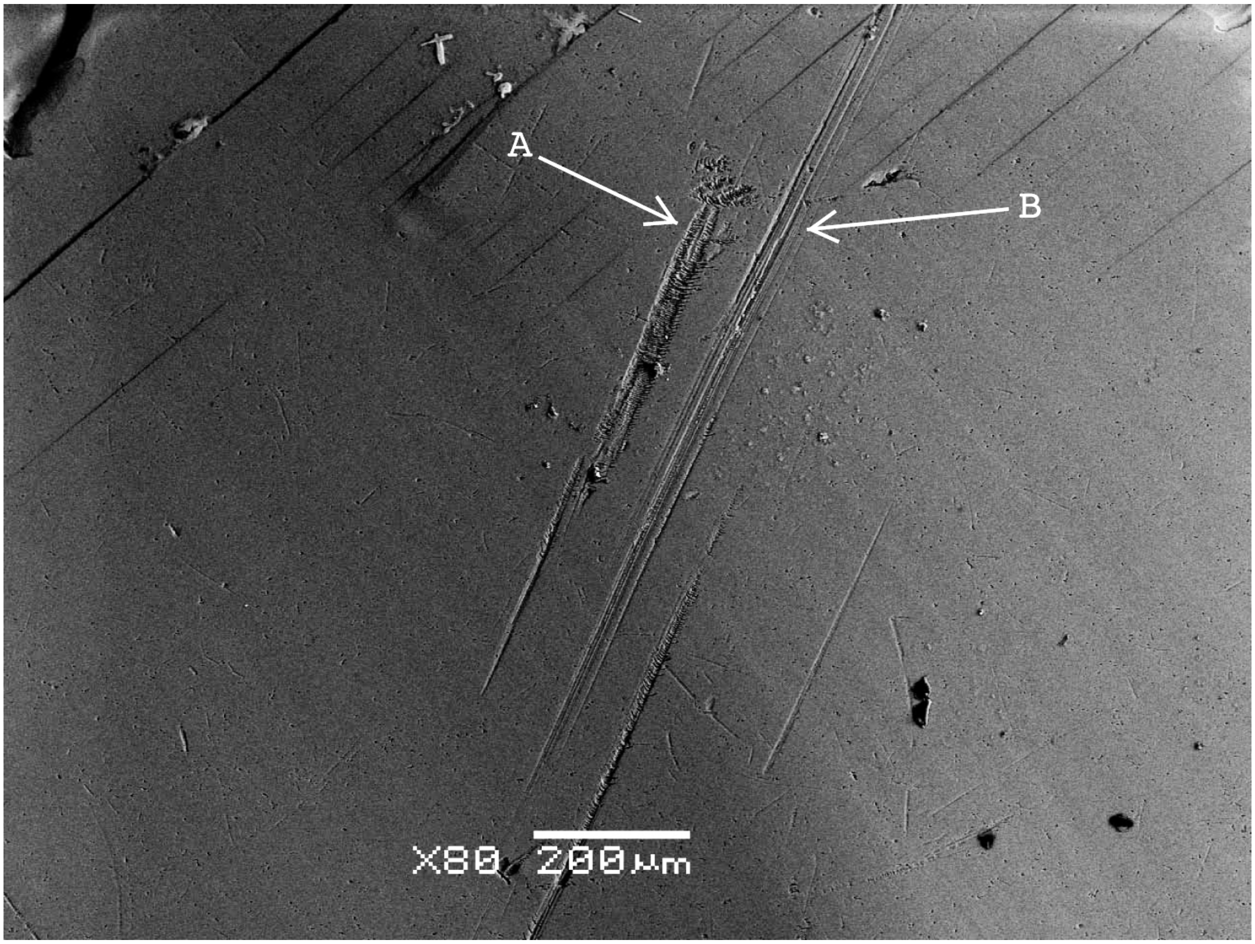


Figure 3.5. Two types of striations that form on obsidian from use. (A) partial Hertzian cracks on the surface; and (B) grooves or gouges into the glass. Also visible (unlabeled) are oblique parallel fissures from the top right to bottom left. These are not use-wear features, they are created naturally on a flake's release surface perpendicular to the ripples when the flake is struck from a core. This image is of bifacial point (#2219) from Marmonet Drift H5.

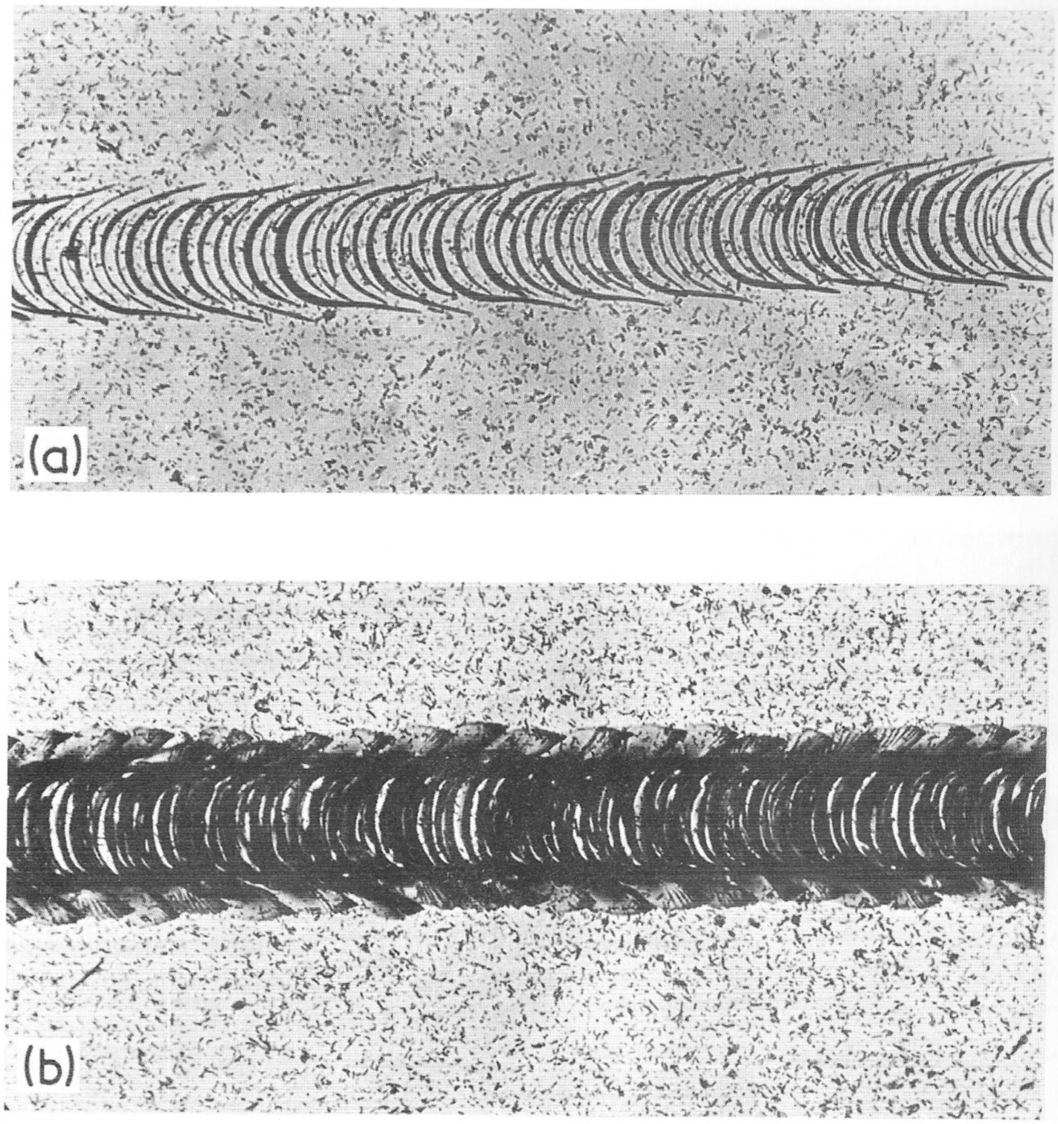


Fig. 6 Partial Hertzian cracks on glass surfaces, using 1.5 mm diam. tungsten carbide sphere, in (a) *n*-decanol, giving coefficient friction 0.12, and (b) water, giving coefficient friction 0.44. Surfaces etched; note flaws. Direction of sliding, left to right. (Optical micrographs in transmitted light, width of field 1.25 mm, normal load 10 N; after Crimes 1973.)

Figure 3.6. Experimental scratches on glass from Lawn and Marshall (1979: 72). Note the orientation of the cracks in relation to the movement direction of the indenter (left to right).

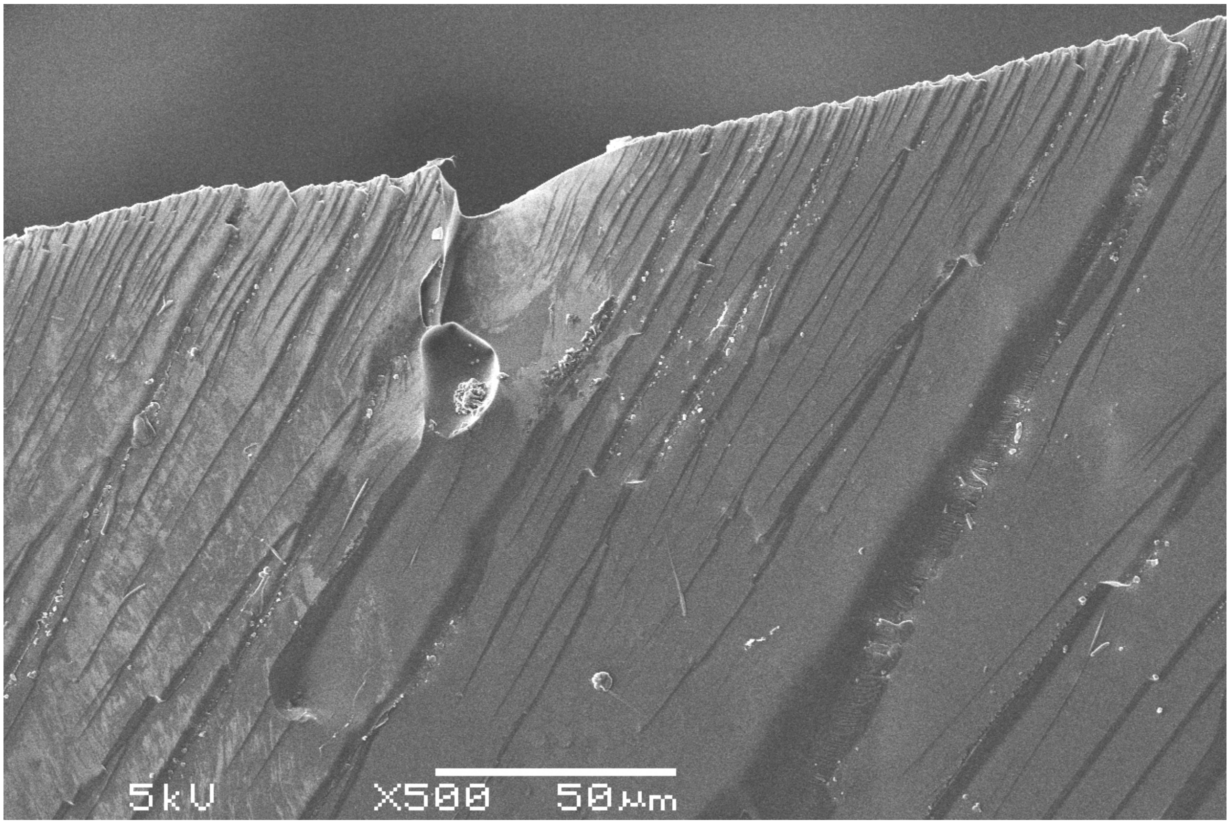


Figure 3.7. Unused edge of an obsidian flake (experimental piece PAS-105). Note the natural fissures formed during flake production.

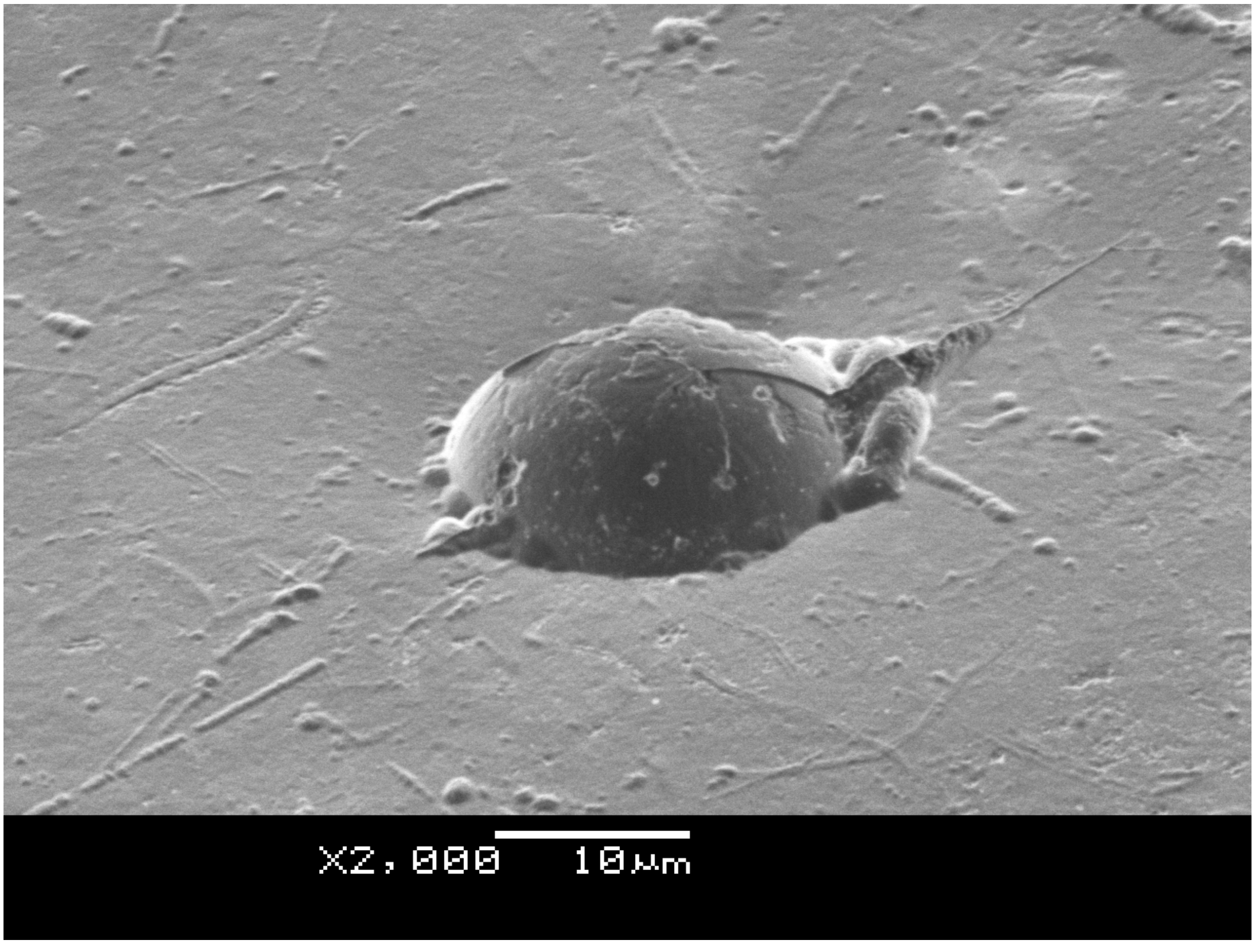


Figure 3.8. A globular/pisolithic mineral inclusion embedded within the obsidian surface. These are common in some outcrops of the obsidian source at Lake Sonachi and Mudui Farm, which is the closest source (figure 3.1) in the upper MSA levels at Marmonet Drift. Image is of artifact #337 (utilized proximal flake fragment) from Marmonet Drift H2.

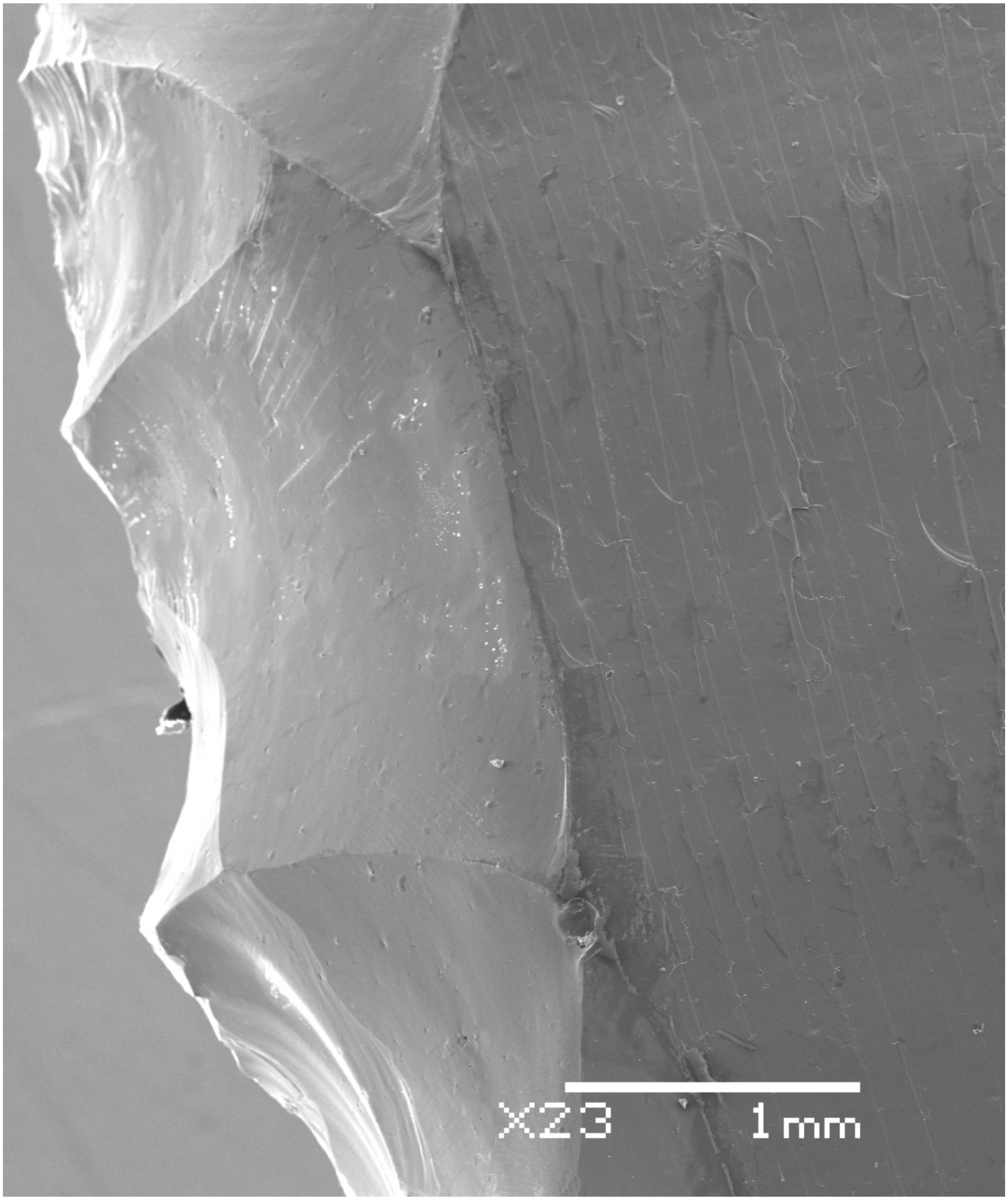


Figure 3.9. Experimental (PAS-072) artifact edge retouched with a hard hammerstone. Note the robust negative bulbs of percussion, marginal invasiveness, and wide feather terminations.

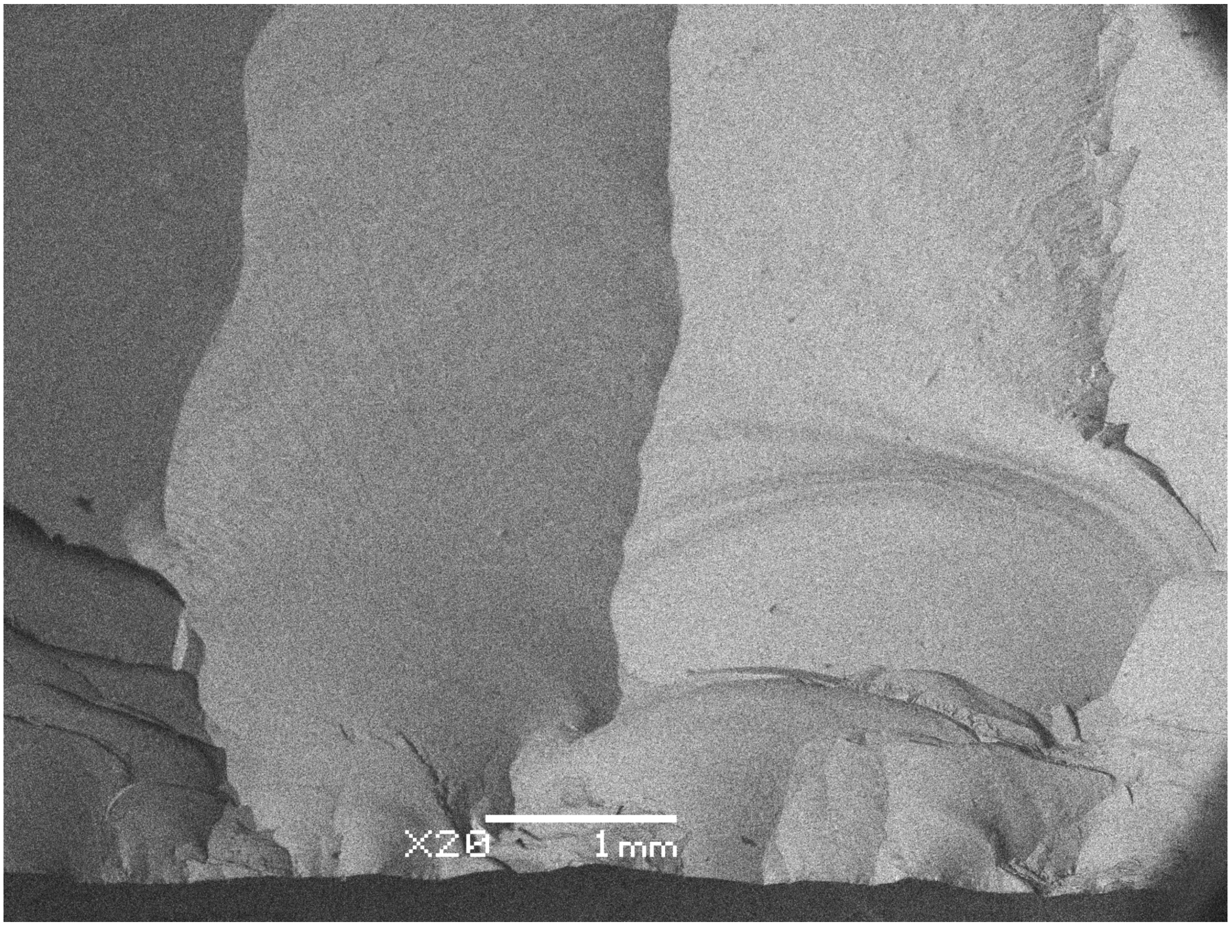


Figure 3.10. Experimental (PAS-154b) artifact edge retouched with a soft hammer (antler). Note the weakly developed negative bulbs of percussion and invasive microflake scars.

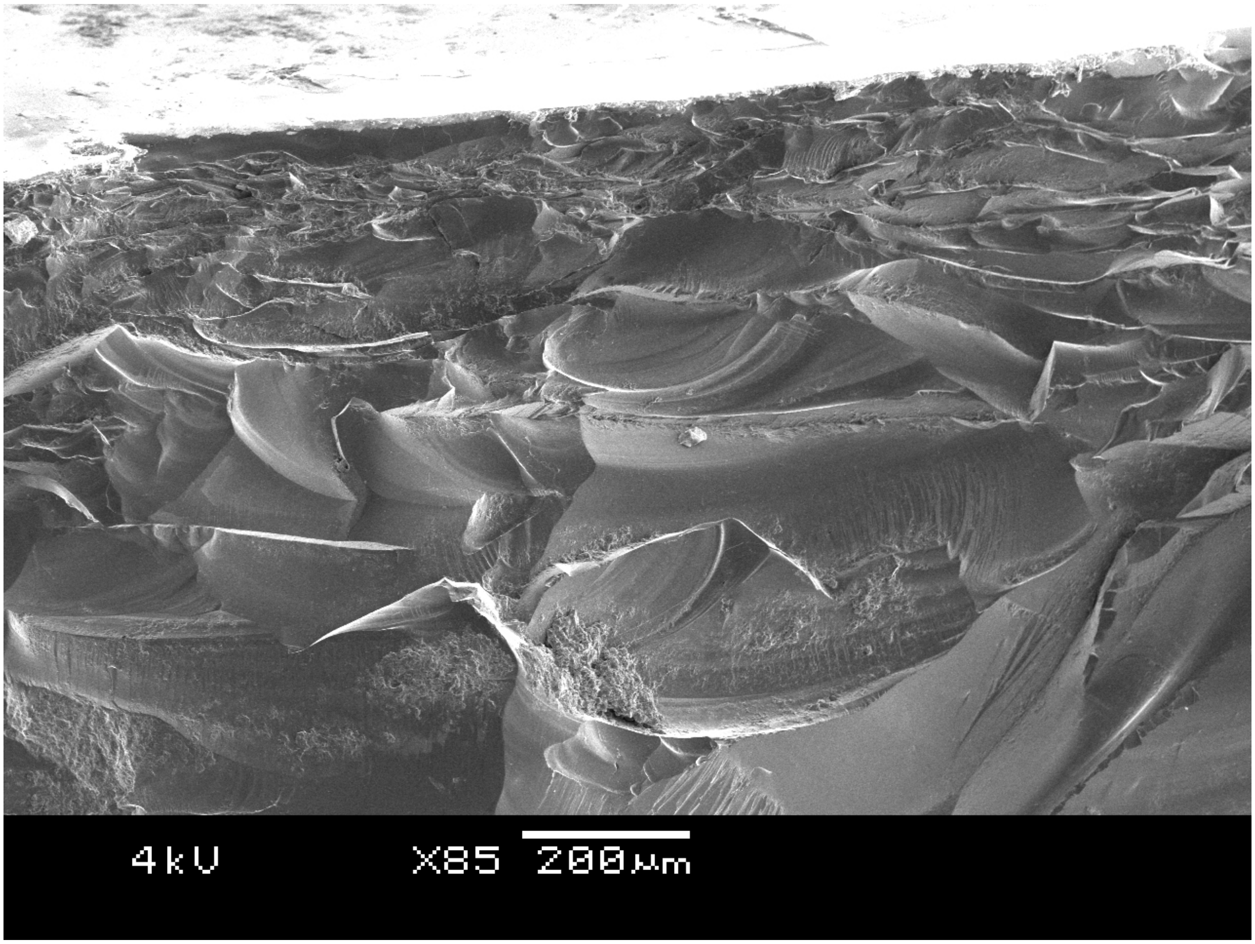


Figure 3.11. Edge on view of experimental (PAS-052) artifact edge used for scraping wood. Invasive microflake scars with feather terminations form first, and are overlain by shallow overlapping stepped terminations. Note the unidirectional removal of microflakes down and away from the flat ventral face, in line with the direction that the tool was pulled.

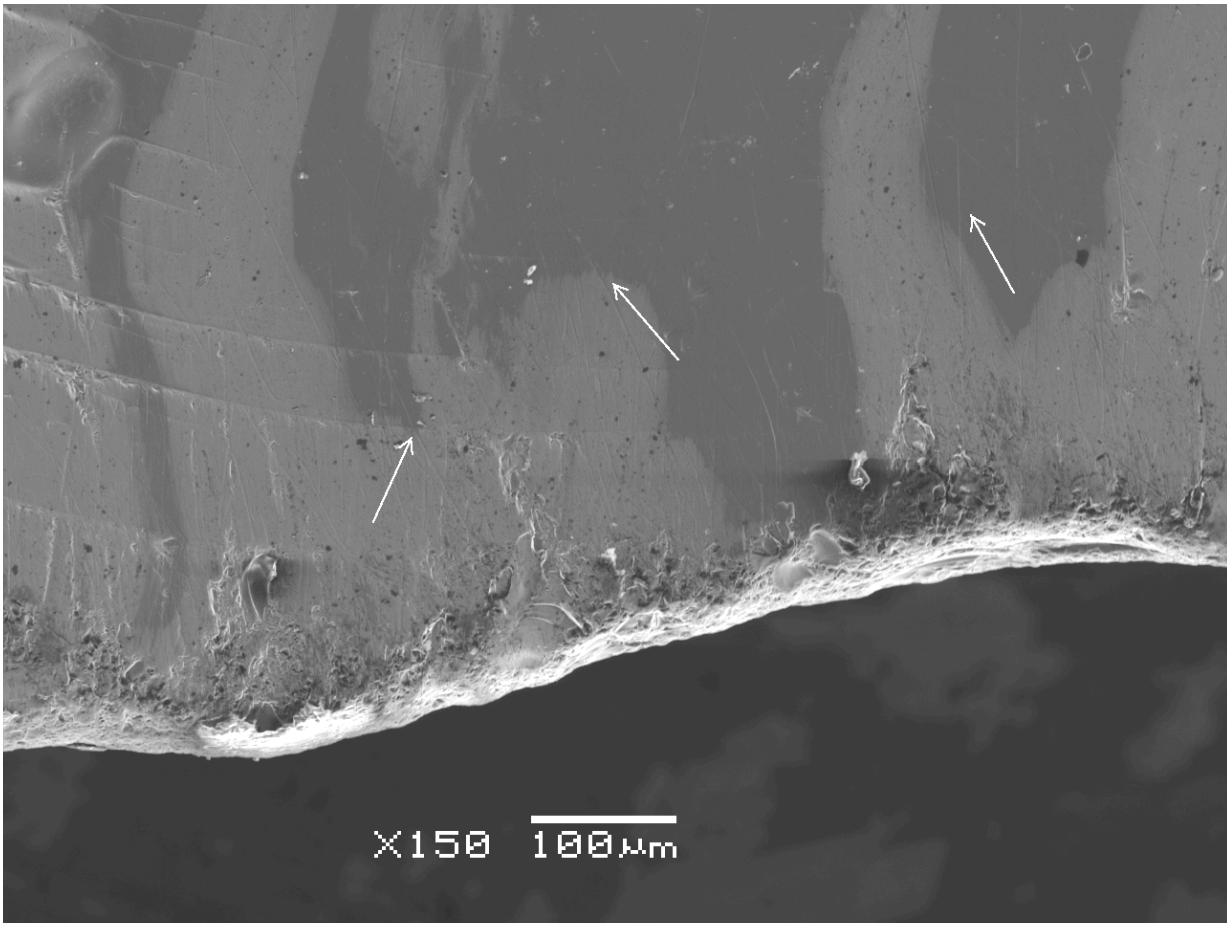


Figure 3.12. Experimental artifact (PAS-101) edge used for scraping dry leather hide. Note the rounded edge and perpendicular striations (arrows indicate three of the larger examples).

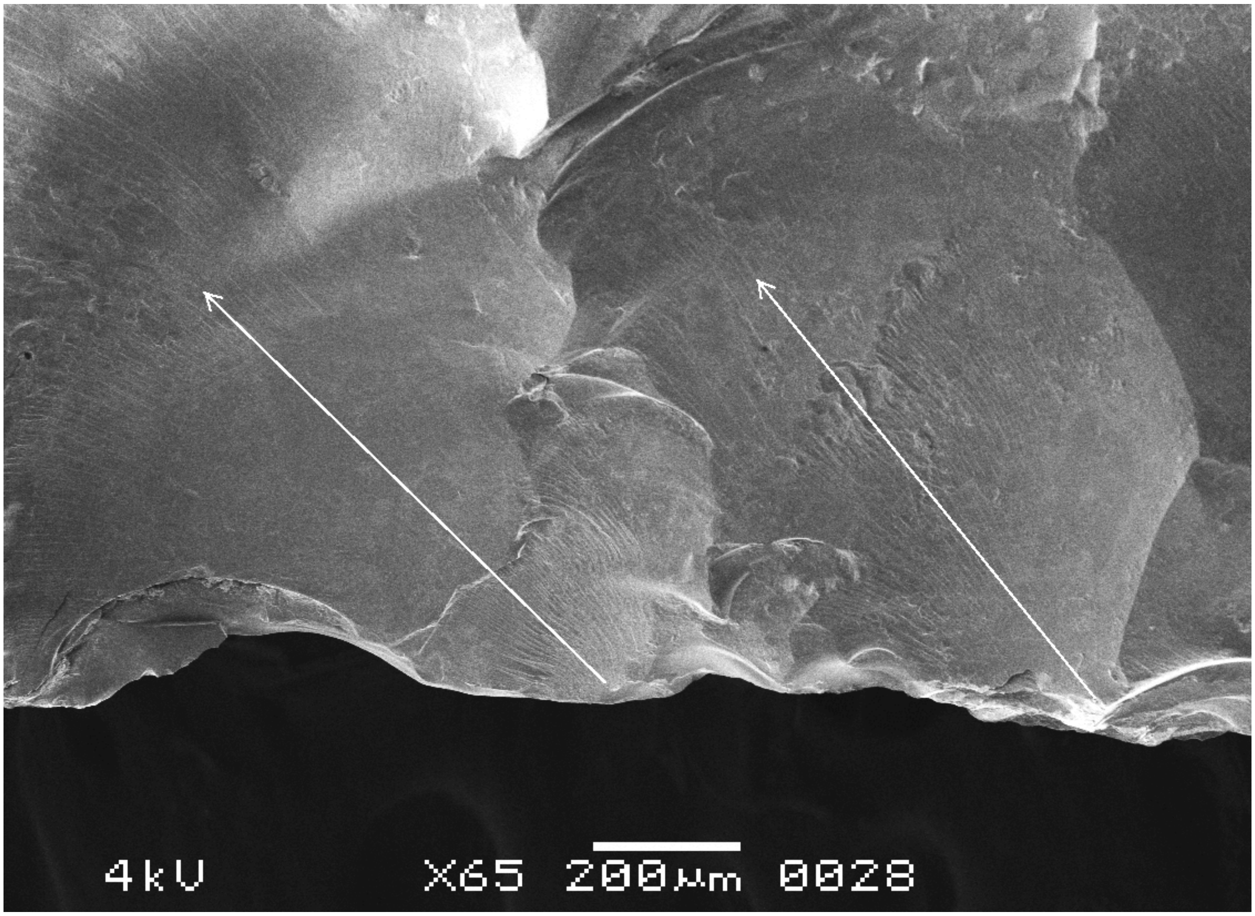


Figure 3.13. Experimental artifact (PAS-033) edge used for slicing dry leather hide. Microflake scar terminations are orientated at oblique angles to the tool edge and ‘point’ opposite the direction the tool is being pulled (indicated by the arrows).

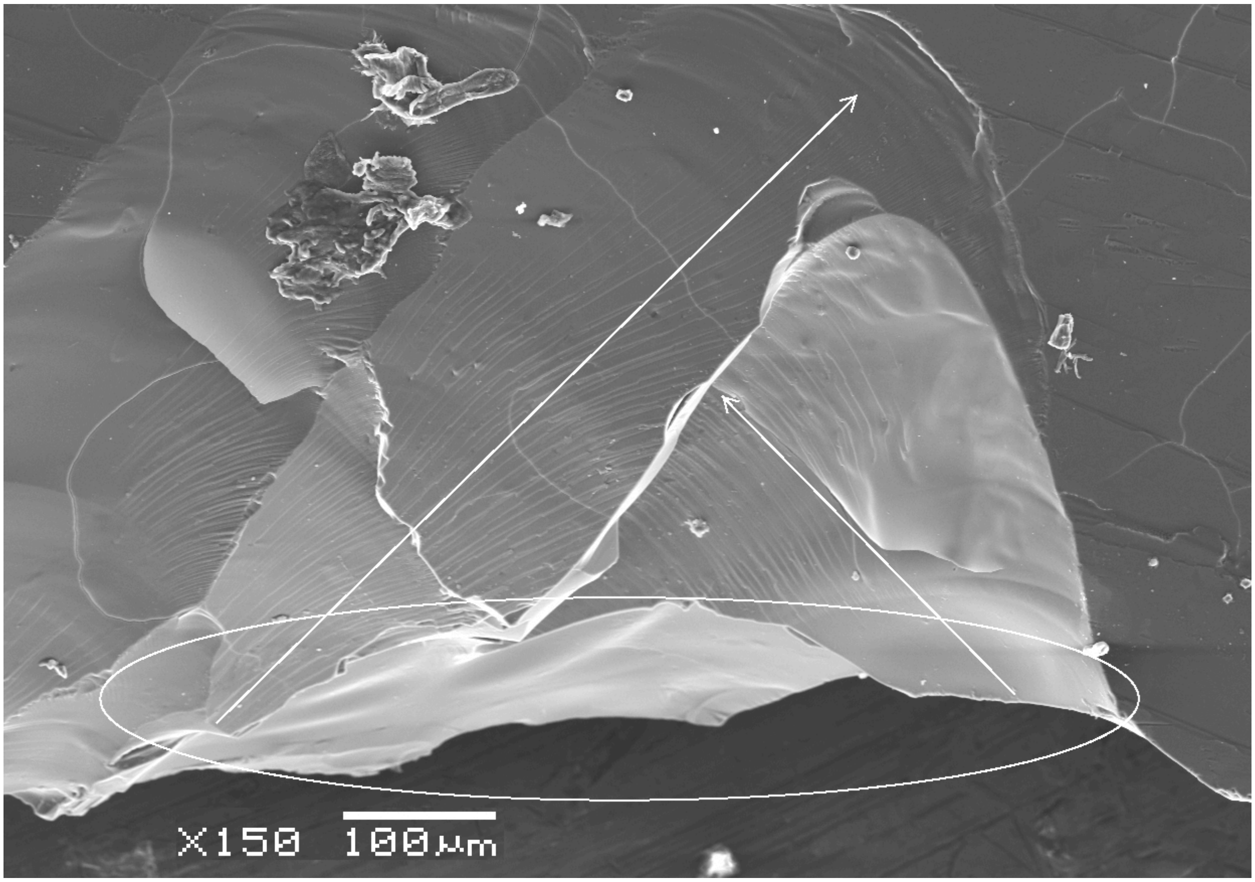


Figure 3.14. Experimental artifact (PAS-080) edge used for sawing a soft wood. Note the bi-directional orientation of microflake scars (arrows indicate direction of release) and half moon break (circled).

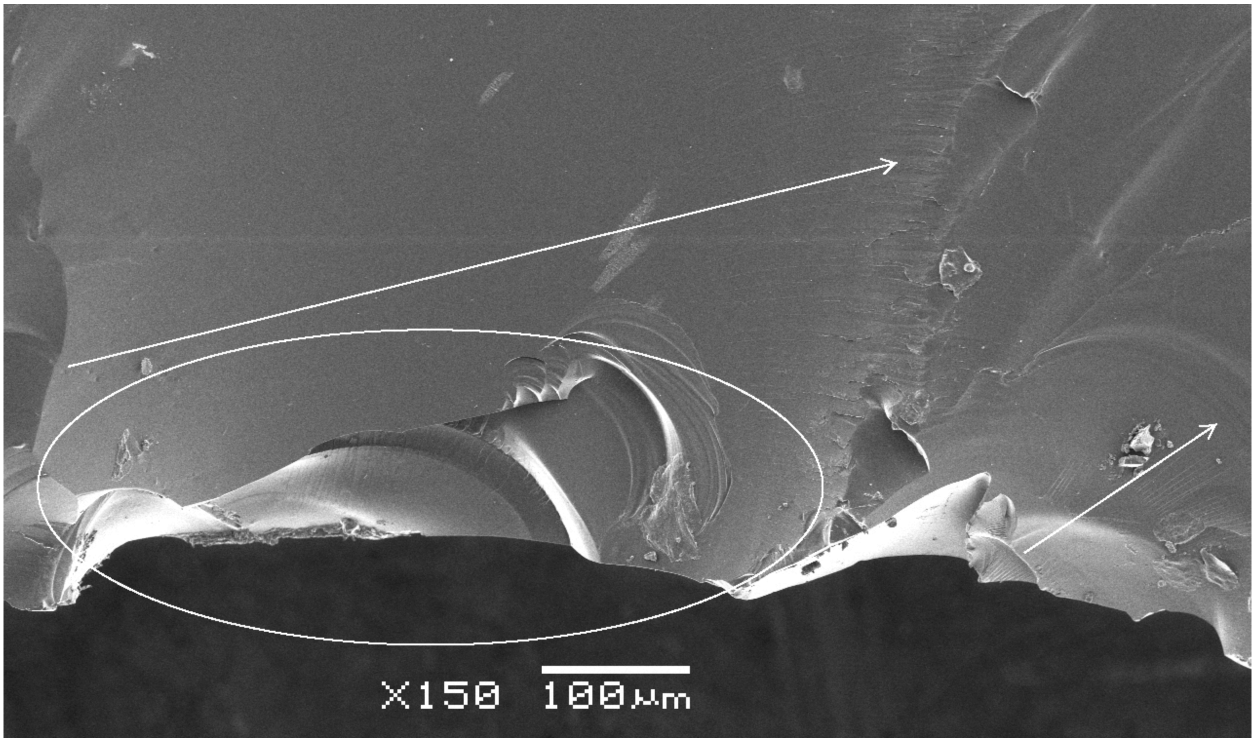


Figure 3.15. Experimental artifact (PAS-088) edge used for defleshing raw meat from bones. Note the half moon breaks (circled), and oblique microflake scars (arrows) with stepped terminations.

Chapter 4

Lithic Technological Organization at Marmonet Drift

This chapter contains a description of the Marmonet Drift (GtJi15) archaeological site geography, excavation history, geological context and stratigraphy, and lithic technology. Step trenches in the upper, middle and lower sections of the main exposures were excavated in 2001, 2002, 2006, and 2010, directed by Stanley Ambrose. This chapter concentrates on the results of excavations in the upper levels of the sequence in 2013 conducted by myself, with guidance on stratigraphic correlations with previous excavations and trench placement by Ambrose. A total of six step trenches have been excavated (figure 4.1). All materials are stored in trays at the National Museum in Nairobi; the KNM accession number for the 2013 excavations is 4444.

Geography

The site is located on in the northwest corner of the Lake Naivasha basin, in the Marmonet River valley near Naibor Ajijik in Narok County of the Rift Valley Province of Kenya. The GPS coordinates are 0° 45' 18.49" South, 36° 10' 31.74" East, at an elevation between 2080-2110 m above sea level. The site is ~2 km east of the base of the Mau Escarpment, and about 28.5 km west-southwest of the town of Naivasha. The track to the west side of Ndabibi Ranch that crosses the southeast margin of the site is a public road, allowing access from the southwest, near Naibor Ajijik primary school. The site is owned by members of the Kamamia family (Samuel, Henry and George Ole Kamamia) and was excavated with their permission and assistance. The site is located on the west bank of the Marmonet River adjacent to a small earthen dam. Local Maasai villagers bring large herds of cattle, sheep and goats to the shallow reservoir to drink, and small groups of donkeys to collect water, on a daily basis. Baboons, ibis, guinea fowl, egrets and Egyptian geese are frequent visitors.

Site Excavation History

The site was discovered and named in 1982 by Ambrose while conducting site survey and excavations at Enkapune Ya Muto (GtJi12). Abundant MSA flaked stone artifacts were observed eroding from paleosols above a volcanic ash bed (VA 9) in the road cut bend on the south side of the site. In 1994 Ambrose and David Kyule revisited the site and observed a rich horizon of MSA artifacts at the base of the main section adjacent to the dam. Ambrose first excavated Marmonet Drift in 2001 as part of an NSF funded research project entitled Chronology of the Middle and Later Stone Age in East Africa. Martin A. J. Williams of Adelaide University was the co-PI, and he described, sampled, and drew the stratigraphic sections, and interpreted the stratigraphy and soil geomorphology. Alan Deino of the Berkeley Geochronology Center conducted single crystal laser fusion (SCLF) radiogenic argon isotope ($^{40}Ar/^{39}Ar$) dates on several of the 16 volcanic ash, tuff and pumice layers stratified within this long sedimentary sequence.

The first major objective of this research project was to document and date archaeological traces of the evolution of modern human behavior in East Africa between 300 and 30 ka. Marmonet Drift was included as a key component of this project because of its potential for contributing to a period of African prehistory (the MSA) that has relatively few sites with firmly dated chronologies and long stratigraphic sequences. The second major objective of the project focused on social and behavioral innovations as responses to environmental change during the MSA. The goal was to collect, identify and compare the chemical composition of obsidian sources and artifacts from archaeological sites in the Rift Valley in order to assess group mobility patterns and the development of regional interaction and exchange networks. This obsidian-sourcing project was based on the pioneering work of Harry Merrick and Frank Brown (1984a, 1984b; Merrick et al. 1994) who showed that there was a dramatic increase in the number of obsidian artifacts made on sources from ≥50 km away in late MSA and LSA sites compared to the earlier MSA in the central Rift at Prospect Farm and Prolonged Drift. Marmonet Drift provided an ideal context for evaluating diachronic change in source exploitation patterns because of its long stratigraphic sequence and close geographic proximity to several primary obsidian source areas.

When the stratigraphic section was first logged in 1994, sedimentary layers were described and numbered beginning at the top of the main section. The volcanic tephra layers were also given layer numbers (figure 4.2). Volcanic layers were then numbered in reverse from the base to the top of the main section. For example VA 7, 8 and 9 were also assigned level numbers 27, 21 and 10, respectively. VA 13 is the highest tuff identified thus far. VA 11 was originally identified by Williams as distinct from VA10, but it is likely reworked VA 10 plus finer ash from the last phase of the eruption that deposited VA 10, so it has been subsumed within VA 10. Because the overlying VA 12 and VA 13 had already been named and established in the section the original IDs were kept and VA 11 has been subsumed in the sequence. The stratigraphic section in figure 4.2 shows VA 0, which was exposed at the base of the section and recognized in 2001, but does not show a volcanic ash layer observed in 1994 within the Holocene soil at the top of the main section. In trench 4 excavations in 2010, level 23 (spit 16) produced small numbers of pumice pebbles and chunks of gray volcanic ash up to 3 cm diameter. This ash and pumice may be derived from an unexposed ash layer between VA 7 and

VA 8. In 2013 Ambrose sampled a lens of pumice pebbles up to 10 cm thick, spanning a width of 4 m was observed near the base of the section ~1 m below VA1, adjacent to the dam. This has been labeled VA 0.5. Trenches 5 and 6 exposed two volcanic layers stratified above the main section (VA 12 and VA 13), raising the total number of stratified volcanic ash, pumice and tuff layers recognized thus far to 15.

Figure 4.3 shows a map of the site and the locations of all excavated trenches. Two trenches were excavated in 2001. First, a 1 m step trench (trench 1a, figure 4.4) was opened to sample the uppermost layers down through the middle of the section. The trench was opened at the top of the main exposures, by the cliff near the backsight datum and was excavated down to what was assumed to be level 22 below the VA 8 platy tuff. This trench was dug ~8 m down and samples of lithic artifacts, bone and volcanic ash samples were collected from all horizons. A second 1 m step trench (trench 2) was opened at the basal horizon of the site (levels 41-44), in order to sample the oldest lithic industry and collect volcanic ash samples for dating. Levels 41-44 comprise archaeological horizon 1 (H1), which has medium-to-high artifact densities and no faunal remains.

In 2002 two more trenches were excavated in order to augment the small sample size of artifacts collected in 2001 from the three oldest archaeological horizons. Trench 2 was reopened and widened to 2 m in levels 43 and 44 as well as excavated deeper (down to level 46) in order to sample the basal pumice (VA 0) for dating. Artifact density decreased with depth and artifacts were completely absent in levels 45-46. The lowest levels of trench 1a were widened to sample H3, adjacent to the VA 8 platy tuff. A 2 x 2 m area was exposed and excavated down ~1 m to below the contact with VA 8 (level 22). Artifact densities were very low. At the time, faunal remains, including burned bone and teeth actually outnumbered lithic artifacts in this horizon.

Martin Williams recognized in 2002 that level 21-22 sediments were actually redeposited fill in a buried erosion cut adjacent to and below the eroded edge of the Platy Tuff (level 21, VA 8). The date of this cut-and-fill is uncertain, but post-dates deposition of VA 8. The absence of LSA artifacts suggests deposition before ~60-50 ka.

The 2006 field season lasted for only five days. It was conducted for the filming of an episode of the National Geographic Society television series "Naked Science", titled "Stone Age Apocalypse", which was broadcast on February 28, 2007 (Stone Age Apocalypse). The film director required an active archaeological excavation to include in the shooting of the documentary. This provided an opportunity to excavate in-situ assemblages from above (H3) and below (H2) the Platy Tuff (VA 8). The Platy tuff is a 75 cm-thick coarsely banded variably welded basaltic tuff, whose upper surface has up to 30 cm of eroded relief. Trench 3 was opened to sample archaeological horizon H3 in levels 19-20 that lie unconformably above VA 8. Trench 4 was initially 1.5 m wide excavated from the top of VA 8 (Level 21) to sample the artifact horizon eroding from *in-situ* fossil soils conformably below VA 8 in level 22. This excavation also provided an opportunity to collect another potentially datable tuff sample from a freshly exposed 75-cm thick exposure of VA 8. Level 22 was dug to ~1.5 m below the base of VA 8. It contains moderate artifact densities, and small amounts of burned bone in the level with the highest artifact densities.

In 2010, Ambrose again carried out a short excavation season at Marmonet Drift. This time as part of a Japanese funded television program series documenting the origins of modern humans. The purpose of the excavation was, again, to showcase active archaeological excavations for inclusion in the shooting of the documentary. This provided an additional opportunity to increase the small samples of lithic artifacts from levels 19-20 (H3) in Trench 3, and levels 22-23 (H4) in Trench 4, and to resample the VA 8 Platy Tuff for dating. Trench 4 was expanded to 2 m wide and down ~1.8 m below VA 8 into level 23. Level 23 (135-180 cm below VA 8) contained few artifacts, but abundant pumice and chunks of gray volcanic ash up to 3 cm diameter, suggesting the presence of an unexposed volcanic ash bed stratified between VA 7 and VA 8.

In 2013 a large-scale excavation was started as part of this dissertation research project. A total of four trenches were excavated over four weeks from June 2 to July 1, 2013. Trench 1b was 2 m wide x 6 meters long and extended the width of the upper half of the original trench 1a from 1 to 3 m. Trench 1b was excavated down to a depth of 8.05 meters below the backsight datum in levels 1 to 11, and produced large samples of artifacts from H4 and H5. Trench 4 was re-opened in an area of 2 x 3 meters below VA 8 and a step containing the lower section of level 22 (left during the 2010 season) was excavated.

Two new step trenches (T5 and T6) were also opened in order to sample levels that are stratigraphically higher and younger than the top of trench 1. Trench 5 was 1 x 6 meters with a depth of 2.2 meters, the base of which appeared to sample the same sediments as level 5 in trench 1. A pale gray pumice bed (VA 12) caps trench 5. It can be traced horizontally to T6, where it marks the base of the excavated deposits, providing a firm stratigraphic correlation between all excavated trenches at the site. Trench 6 was 1 x 6 meters and 3.22 meters deep. These two trenches increased the total thickness of the Marmonet Drift sedimentary sequence by 6.86 meters to a total of 27.86 meters. Stratigraphic levels from all four trenches excavated during the 2013 season are described below. Soil colors are taken from the Munsell Color System and, unless otherwise noted, are for dry soil.

Trench 1b

Trench 1b was laid out using the original grid created in 2001. The southwest corner of 2001 trench 1a was arbitrarily assigned to N200, E100. The grid coordinates for trench 1b are N198-200, E 99-105. The backsight datum was arbitrarily set at 100 m height and all level depths are relative to this point. All level thicknesses are averages of the difference in depth below datum at the top and base measured with the total station at each unit corner for that level. Individual level measurements and thicknesses are listed in table 4.1. Figure 4.5 shows a stratigraphic profile of the completed trench.

Level 1: 99.67 to 98.99 m (68 cm thick); dark yellowish brown (10 YR 4/4); silty clay loam. Massive modern topsoil with possible gray volcanic ash at the base of this level; soil becomes somewhat lighter with depth; medium (few) and fine roots (common) present; irregular but clear lower boundary. This level was split into 1a (35 cm) and 1b (33 cm) during excavation.

Level 2: 98.99 to 98.75 m (24 cm thick); brown (10 YR 4/3); sandy loam. Hard and compact paleosol; fine roots common; subangular blocks with small pumice pebbles; gradual change in soil texture determined the lower boundary.

Level 3: 98.75 to 98.46 m (29 cm thick); yellowish brown (10 YR 5/4); silty loam. Continuation of compact paleosol; black mottled chunks composed of black/gray pumice pebbles; fine roots common; rare carbonate nodules; distinct change in soil composition to pumice bed determined the lower boundary.

Table 4.1. Level measurements and thicknesses for Trench 1b from 2013 excavation.

Level	*Level thickness (cm)*	*Depth below datum*	*Absolute Depth*
Surface	0.33	99.67	0
1a	0.35	99.32	0.35
1b	0.33	98.99	0.68
2	0.24	98.75	0.92
3	0.29	98.46	1.21
4	0.12	98.34	1.33
5	0.26	98.08	1.60
6	0.25	97.83	1.84
7	0.25	97.58	2.09
8	0.29	97.29	2.38
9a	0.17	97.12	2.55
9b	0.19	96.93	2.74
10a	0.16	96.77	2.90
10b	0.17	96.60	3.07
11a	0.15	96.45	3.22
11b	0.16	96.28	3.39
11c	0.20	96.08	3.59

Level 4: 98.46 to 98.34 m (12 cm thick); dark yellowish brown (10 YR 4/4); compacted, dense fine pebble pumice layer. Abundant carbonate nodules present throughout; level excavated to arbitrary flat boundary at the base of the pumice.

Level 5: 98.34 to 98.08 m (26 cm thick); this level was split into 5a (~12 cm; dark yellowish brown (10 YR 4/4); sandy silt loam) and 5b (~14 cm; yellowish brown (10 YR 5/6); clay silt loam). The division is marked by a green and white pumice stringer in the middle of the level (figure 4.6). Massive and moderately well developed paleosol; medium root voids and fine roots rare; some carbonate nodules present; gradual change in soil color and texture determined the lower boundary. Archaeological horizon H5 is found within levels 5 and 6.

Level 6: 98.08 to 97.83 m (25 cm thick); dark yellowish brown (10 YR 3/4); silty clay loam. Massive soft paleosol; root cast carbonates and occasional carbonate nodules present; gradual change in soil color and texture determined the lower boundary.

Level 7: 97.83 to 97.58 (25 cm thick); dark yellowish brown (10 YR 3/6); silty loam. Massive soft paleosol; root cast carbonates and occasional carbonate nodules present; irregular but clear boundary marked by contact with very hard and dense paleosol.

Level 8: 97.58 to 97.29 m (29 cm thick); yellowish brown (10 YR 5/6); sandy loam. Dense, hard, gritty paleosol with pumice pebbles (up to 1 cm); distinct change in soil color and texture determined the lower boundary.

Level 9a: 97.29 to 97.12 m (17 cm thick); dark yellowish brown (10 YR 4/6); pumice-rich (up to 1 cm) sandy silt loam; irregular but clear lower boundary.

Level 9b: 97.12 to 96.93 m (19 cm thick); light olive brown (2.5 Y 5/4); soft and loosely consolidated volcanic ash and pumice (gray and black bicolored) layer (VA 10); irregular but clear lower boundary (figure 4.7).

Level 10a: 96.93 to 96.77 m (16 cm thick); pale brown (10 YR 6/3); silty loam; no carbonates; lower boundary marked by gradual soil color transition (figure 4.8).

Level 10b: 96.77 to 96.60 m (17 cm thick); yellowish brown (10 YR 5/4); silty loam; lower boundary marked by gradual soil color transition.

Level 11a: 96.60 to 96.45 m (15 cm thick); pale brown (10 YR 6/3); silty loam. Massive moderately dense paleosol with medium crumb structure; cindery pumice and carbonate root casts are common; irregular lower boundary marked by gradual soil texture transition.

Level 11b: 96.45 to 96.28 m (16 cm thick); very pale brown (10 YR 7/3); sandy silt loam; very soft paleosol; carbonate nodules are rare; arbitrary flat lower boundary.

Level 11c: 96.28 to 96.08 m (20 cm thick); light yellowish brown (10 YR 6/4); silty loam; very soft paleosol; arbitrary flat lower boundary, marked by an increase in yellow decomposing pumice of the top of VA 9. Archaeological horizon H4 is found within levels 10 and 11.

Trench 4

T4 is a shallow step trench 2 x 5.5 m that cuts 1-2 m into the eroded edge of VA8. A large steel nail was driven into the level 21 Platy Tuff (VA 8) 30 cm above the base to provide a measuring datum. All level depths were recorded as X cm below the base of this tuff. The total thickness of level 22 is 1.53 m, but it was subdivided into eight spits that average 19 cm thick. Spit numbering continued the sequence from levels 19-20 in trench 3 (spits 1-5), so spit 6 is VA

8 (level 21). Spit 7 is thus the first excavation level below VA 8 in level 22, and is labeled spit 22.7. Only spits 13-15 were excavated in 2013 (figure 4.9). Spit 14 defines the base of level 22 at 135 cm below the base of VA 8. Level 23 was excavated in 2010 to an average depth of 1.85 m below VA 8 and subdivided into three spits (15-17). The base of excavation in level 23 was not reached, but the near absence of artifacts in spits 15-17 shows H3 is restricted to level 22. The trench 4 grid (N6384-6386, E 5640-5645) was established using the last 4 digits of GPS UTM coordinates for the northwest corner unit at the top of the trench.

Level 22, spit 7: 0 to 0.13 m (13 cm thick); strong brown (7.5 YR 4/6); silty loam; massive paleosol with some iron stained root voids; arbitrary lower boundary.

Level 22, spit 8: 0.13 to 0.26 m (13 cm thick); light brown (7.5 YR 6/4); silty loam; massive paleosol; arbitrary lower boundary.

Level 22, spit 9: 0.26 to 0.39 m (13 cm thick); light yellowish brown (10 YR 6/4); silty loam; massive paleosol with lighter colored mottling; carbonate nodules rare; arbitrary lower boundary.

Level 22, spit 10: 0.39 to 0.56 m (17 cm thick); strong brown (7.5 YR 5/8); sandy silt loam; massive paleosol with some iron stained root voids, few rounded carbonate nodules and rare pumice pebbles; arbitrary lower boundary.

Level 22, spit 11: 0.56 to 0.76 m (20 cm thick); dark brown (7.5 YR 3/4); sandy silt loam; massive paleosol with carbonate nodules common (up to 17 cm); arbitrary lower boundary.

Level 22, spit 12: 0.76 to 1.03 m (27 cm thick); very dark reddish-brown (no Munsell available); dense massive paleosol; carbonate nodule now absent; arbitrary lower boundary.

Level 22, spit 13: 1.03 to 1.25 m (22 cm thick); dark brown (7.5 YR 3/3); loam; dense, crumb textured massive paleosol; arbitrary lower boundary.

Level 22, spit 14: 1.25 to 1.53 m (28 cm thick); dark brown (7.5 YR 3/4); silty loam; massive weak crumb and extremely dense soil; gradual change to lower soil density defines the lower boundary.

Level 23, spit 15: 1.53 to 1.72 m (19 cm thick); brown (Munsell color not recorded); sandy silt loam; soft massive paleosol with small chunks of light gray volcanic ash; arbitrary lower boundary.

Level 23, spit 16: 1.72 to 1.85 m (13 cm thick); light brown (Munsell color not recorded); silt loam; massive with small pumice grains and chunks of volcanic ash up to 3 cm; arbitrary lower boundary.

Trench 5

The trench 5 grid coordinates (N 6382-6387, E 5604-5605) were established using the last 4 digits of GPS UTM coordinates for the northwest corner unit at the top of the trench. T5 is located on the north side of an E-W trending densely wooded gully on the south side of the main sedimentary outcrop. A wooden stake was hammered into the ground to provide a local measuring datum. It was 1.74 m above the 100.00 m backsight datum used for trench 5, therefore, all depths are measured to the same datum as trench 1b. Trench 5 was excavated in eight levels (figure 4.10); levels 3-8 had arbitrary lower boundaries. Five stratigraphic levels were identified. Notes on Munsell soil colors were, unfortunately, lost after excavation.

Level 1: 101.55 to 101.42 m (13 cm thick); silty clay loam. Massive soft topsoil with roots, rootlets, leaves and pumice pebbles (up to 2.5 cm) extremely common; pumice originates from level 2 volcanic ash and pumice (VA 12). Two patches of burned soil and charcoal fragments were encountered during excavation; irregular lower boundary marked by contact with mixture of soil, ash and pumice.

Level 2: 101.42 to 101.31 m (11 cm thick); silty loam with gray pumice and ash (figure 4.11). This volcanic ash is VA 12. Irregular lower boundary marked by transition to soil without pumice or ash.

Level 3: 101.31 to 100.54 m (77 cm thick); sandy silt-loam. A hard, dense dark red-brown paleosol; lower boundary marked by gradual change in soil color and hardness.

Level 4: 100.54 to 99.58 m (96 cm thick); sandy loam. Very soft, dark brown to black paleosol; lower boundary marked by contact with white pumice stringer.

Level 5: 99.58 to 99.36 m (23 cm thick); sandy silt loam with white pumice stringer at the top of the level. This pumice stringer is tentatively correlated with the pumice in level 2 of trench 1b; this stringer is only slightly higher in elevation, but this difference is expected because trench 5 is further upslope and all beds slope down slightly from west to east toward the Marmonet River. A second tentative stratigraphic correlation with trench 1b is provided by a concentration of green pumice pebbles in a soil core hammered one meter below the base of trench 5. The vertical position is approximately 98.36 m relative to the main datum. This pumice may correlate with the pumice pebble stringer in level 5 of trench 1b at 98.22 m.

Trench 6

Trench 6 is located further upslope (west) of trench 5 in the same densely wooded gully. The primary purpose of this trench was to vertically extend the upper stratigraphic sequence of the site. This location was selected because VA 12 was exposed near the base of the slope in a porcupine burrow. The presence of VA 12 in trench 6 provides a firm stratigraphic connection to trench 5 and the remainder of the site. The base of VA 12 in trench 6 was given the same elevation as the base of VA 12 in trench 5 providing a known elevation with which to calculate the various level depths in trench 6. However, because the deposits all appear to slope gradually toward the Marmonet River, the true elevation of VA12 may be slightly higher. The trench 6 grid (N 6373-6378, E 5572-5573) was established using the last 4 digits of UTM coordinates for the northwest corner unit at the top of the trench. A wooden stake at the top of trench provided an arbitrary measuring datum. All depths listed here are therefore measured to the same datum as trench 1b. During excavation, level 3 was subdivided into levels 3a, 3b and 3c, and level 4 was subdivided into 4a and 4b. Five lithological stratigraphic levels were identified (figures 4.12 – 4.13.

Level 1: 105.10 to 104.56 m (53 cm thick); very dark brown (10 YR 2/2); silty loam. Massive soft topsoil with roots, rootlets, leaves very common; regular boundary marked by appearance of bicolored laminated basaltic tuff blocks, and black scoriaceous pumice (figures 4.14 – 4.15).

Level 2: 104.56 to 103.43 m (113 cm thick); a mixture of soft very dark brown (10 YR 2/2) silty loam, bicolored basaltic tuff blocks and 3-4 cm scoriaceous black pumice bombs. The bicolored tuff does not form an intact layer. It is composed of disintegrating chunks of weakly laminated layers of olive brown basaltic ash (2.5 Y 4.5/5) and black cindery pumice (10 YR 2/1). This tuff was designated VA 13 and two samples (one from the 'upper' part and one from the 'lower' part) were collected for dating purposes. Irregular but clear lower boundary marked by distinct change in soil color and texture and absence of tuff and pumice.

Level 3: 103.43 to 102.49 m (94 cm thick); dark yellow brown (10 YR 3/4 in 3a to 10 YR 3/6 in 3b and 3c); silty loam (3a) to sandy silt loam to silty sand loam (3b) to sandy loam (3c). This horizon is characterized by a gradual texture and color change throughout the level, but without any clear stratigraphic division. The level is very soft/loose and was excavated with trowels. Near the base of the level there are multiple pits that may have been termite burrows. Very irregular lower boundary marked by change in soil hardness.

Level 4: 102.49 to 101.82 m (67 cm thick); dark yellow brown (10 YR 3/6); sandy loam. Harder texture than level 3, but otherwise very similar. This harder soil is not present in all squares of trench, only from N6374 to N6377. Lower boundary marked by clear contact with VA12 ash and pumice mixture in N6378-6379.

Level 5: 101.82 to 101.31 m (51 cm thick); light gray (10 YR 6.5/1); volcanic ash and pumice. This is VA12, and it connects the stratigraphy of trenches 5 and 6 at the site. This level was excavated to a natural lower boundary at the base of VA 12.

Geological Context, Stratigraphy and Geochronology

The sequence of deposits in the complete excavated section is approximately 27.8 meters thick from the base at the Marmonet River to the top of trench 6. The long sedimentary sequence contains a total of 57 identified stratigraphic levels, 13 of which are volcanic ashes or tuffs and the rest being paleosols (figure 4.2). The paleosols were formed primarily on aggrading colluvial sediments transported and re-deposited higher terrain of the footslopes of the Mau Escarpment to the west. Fluvial deposits were not observed, and only one significant erosional unconformity (upper surface of VA 8) has been identified in the entire sequence.

Excavated levels above level 41 represent natural stratigraphic layers defined by color, texture and structure rather than arbitrary spits. Some layers may represent post-depositional changes of sedimentary parent materials due to soil formation processes. Subdivided level spit distinctions of semi-arbitrary thicknesses (between 10 and 25 cm) were often made during excavations in all archaeological horizons for better resolution on vertical artifact distribution.

Four of the 13 volcanic ashes in the sequence have been dated using SCLF $^{40}Ar/^{39}Ar$. New samples have been submitted for dating and are currently being analyzed. Tentative correlations with marine isotope stage chronology of Martinson et al. (1987) are based on the temporal boundaries in Table 2.1.

VA 0, a compacted pumice bed located near the base of the sequence, was dated to 244 ± 13 ka. VA 0.5, a series of pumice lenses ~75 cm above VA0, has been submitted for dating. Archaeological horizon 1 (H1) is thus likely to date within warmer MIS 7. VA 7 is also a dense pumice; it has a preliminary date of ~205 ka. The date on VA 7 is considered preliminary because too much time elapsed between neutron irradiation and argon extraction. It provides a provisional maximum age for overlying archaeological horizon 2 (H2). VA 9, a massive, thick, bi-colored (black and white) alternating pumice and ash layer, was dated twice, once on the black pumice and once on the white pumice, to 110 ± 20 ka and 104 ± 15 ka, respectively. VA 10 was dated to 94 ± 4 k. A visually distinctive dense, variably welded, laminated basaltic Platy Tuff (VA 8) is situated near the midpoint of the sequence and is also observable at several places along the Marmonet River and associated gullies. This tuff has proven to undatable by the $^{40}Ar/^{39}Ar$ technique, and despite three attempts, it has no chronometric age. Because no erosional unconformities were observed between VA 8 and VA 7 the archaeological horizon beneath VA 8 (H2) is likely to be closer in age to 200 ka than to 110-104 ka, and thus likely to date to colder arid MIS 6 (191-130 ka).

The upper surface of VA 8 has up to 30 cm of erosional relief, indicating a substantial unconformity in the depositional sequence. Because of its hardness and high relief of the eroded surface it is likely that a very long but unknown length of time is missing at the site. It is likely that the layers between VA 8 and VA 9 are much closer in age to the two VA 9 dates (110 and 104 ka).

Artifact densities vary throughout the sequence indicating considerable variation in the intensity of occupation over time. Some sections spanning up to 6 m (levels 41-24 and 19-11) have very few (<25) artifacts while some horizons 50 cm thick contain over 2000 artifacts. Six primary periods of occupation have been identified (H1-H6, numbered from the base to the top of the sequence), of which the lowest five horizons are technologically MSA. The highest occurrence (H6), ~25 m above H1 and conformably overlying VA 12, has a small artifact assemblage that has not yet been analyzed. Few diagnostic shaped tools and cores were observed during excavation and washing, so it has not been assigned to either the MSA or the LSA. Future excavations to obtain larger samples of artifacts will be needed to fully understand its characteristics and identity. The forthcoming date for VA 12 will be help establish whether it lies within the era of the MSA/LSA transition.

Levels 41-44 mark a uniform sedimentary unit with arbitrary excavation level divisions and represent the earliest occupation horizon (H1) at the site. Collectively, these levels are ~1 m thick and are situated above a very thick tuff (VA-0, level 46). As mentioned above, the date on this tuff is 244 ± 13 ka so H1 dates roughly to near the beginning of warm, humid interglacial MIS 7. A discontinuous series of pumice lenses was recognized in the 2013 field season within the stratigraphic equivalent of H1. It was labeled VA 0.5, and has been sampled for dating.

Level 22 contains the second major occupation horizon (H2). Its base lies ~250 cm above VA 7 (~205 ka) and so is likely to date to MIS 6. It lies in a dark brown loamy paleosol with pronounced very long light brown powdery vertical root marks. This horizon is capped by the (as yet) undated VA 8 basaltic Platy Tuff, providing a firm stratigraphic position directly beneath a potentially widespread isochronous marker.

The third major occupation horizon (H3) lies in levels 19-20; H3 represents the lowest density occupation phase of the site. The heavily eroded top of VA 8 marks the base of H3, which suggests that the deposits are closer in age to the two VA 9 dates (110 and 104 ka) than to the preliminary date of 205 ka on VA 7. The bright yellow-brown sediments of level 20 become sandier and artifact densities decline with depth. Whether H3 dates to late MIS 6 or early MIS 5 remains uncertain. The strata overlying H3 (levels 13-18) have very few artifacts and appear to represent an occupational hiatus at the site. These levels are capped by the almost 1 m thick and twice-dated VA 9, which forms the base of the next horizon (H4).

Levels 10-11 mark the fourth major occupation horizon (H4). The massive coarse, gritty sandy yellow-brown sediments comprise weathered, decomposing weakly pedogenically altered pumice. It becomes paler and coarser with depth, grading into the underlying VA10 parent material. VA 9 and VA 10 conformably bracket this horizon, which provides a precise chronological placement in the sequence. Unfortunately because of the ranges of error on the two $^{40}Ar/^{39}Ar$ dates, it is not possible to identify the exact MIS 5 sub-stage that this belongs to. The dates are centered close to the MIS 5c/d boundary, but could date anywhere from latest MIS 6/ early 5e, to MIS 5b. However the overlying and relatively precise date of 94 ± 4 ka for VA 10 suggests a date within MIS 5c-d, ~96-116 ka.

Levels 5-6 (H5) mark perhaps the most intense occupation zone at the site. H5 lies in a dark brown loamy paleosol with pronounced very long light brown powdery vertical root marks. Its similarity to the sedimentary context of H2 suggests similar environmental conditions. It conformably overlies VA 10, suggesting a date of ~95-90 ka, which would place it within late

MIS 5c to MIS 5b. VA12 is pale gray unconsolidated gray pumice that is exposed across the entire site. It lies approximately 2.5 m above H5. Its forthcoming radiometric date will provide an upper boundary on the age of H5.

The youngest occupation horizon (H6) lies above the original excavation and so does not continue the same level numbering sequence. This horizon lies in a dark yellow-brown massive sandy silt loam conformably above VA 12, ~1.5 m conformably below the undated VA 13. VA 13 is a heterogeneous, laminated cindery basaltic tuff occurring throughout level 2 in Trench 6. Soil formation processes have disturbed the original bedding. Intact deposits are likely present further upslope. Several intact chunks of VA 13 with clear crystals have been submitted for radiogenic $^{40}Ar/^{39}Ar$ dating. In-situ artifacts were recovered below VA 13 in levels 3 and 4 (total n= 993; 969 obsidian) but have not been studied in detail so it is not clear if the assemblage is MSA, LSA or transitional. Further excavation of these levels may help to define the last stages of the MSA in this region.

LSA and Neolithic artifacts, including backed microliths and decorated pottery, were recovered from Level 1 of Trench 6, and on the surface of this outcrop adjacent to this excavation. Similar artifacts were also recovered in the surface soils while excavating superficial deposits on the slope of Trench 6.

Lithic Technology: Raw Materials

Obsidian dominates flaked lithic raw materials for all six horizons at Marmonet Drift, averaging >98.5% artifacts per level, with various lavas making up a maximum of ~1% in H1 and 1.5% in H5. A total of only 15 quartz and quartzite pieces and 9 chert pieces have been recovered from all levels combined at the entire site. Lavas are readily available in the Marmonet

River valley and throughout this volcanic region, though the specific outcrops that were exploited have not been identified at this time. There are two main types: one is blue-gray and the other is yellow-brown. Both are relatively fine-grained with uniform fracture mechanics suitable for making flake tools. Most flaked lava pieces are informal cores, unretouched flakes and associated flaking debris. Three different types of chert have been recovered; the first is opaque-white (figure 4.16). The second is semi-opaque to translucent (figure 4.17). The third is a blue-brown color (figure 4.18). The artifact in figure 4.18 is covered in pot-lid fractures resulting from thermal exposure and may represent a burned example of one of the other two types.

Due to the volcanic nature of most deposits in the central Rift Valley, chert is not a commonly found raw material. Small, thin, irregular nodules and seams occur locally on Mt. Eburu in association with geothermal activity. Most are unsuitable for flaking. The closest known sources of cherts suitable for flaking are in the Lake Magadi basin (~120 km south of MD) and the Lake Baringo basin (~150 km north of MD) areas. Magadi cherts are particularly diverse in color and nodule morphology. Quartz is not available within the Lake Naivasha basin and must have been procured from Basement System metamorphic rock regions. The nearest sources are at least 70 km south at Ol Doinyo Rasha (SE of Narok town), 120 km SE at Lukenya Hill, or ~150 km north in the Tugen Hills west of Lake Baringo.

Results of the artifact sourcing research piloted (Ambrose et al., 2002) and extended by Ambrose (Ambrose and Slater, 2010; Slater et al., 2012) at Marmonet Drift indicate that site occupants exploited at least seven unique obsidian source groups in the Lake Naivasha basin, including rare pieces from up to ~45 km east on the edge of the Kikuyu Escarpment. In H4 and H5 the closest obsidian sources, 9.5-10.5 km at Sonachi crater lake and Mundui Farm, account for >99% of all obsidian, and Masai Gorge area (~20-28 km) sources account for the rest. The

Sonachi/Mundui source group is virtually absent from earlier horizons, likely because this source formed during an eruption that post-dates H3. Obsidian samples from Sonachi/Mundui are currently being dated. Levels 19-20 and 22 show a remarkable shift to predominantly north Naivasha basin, Masai Gorge and Waterloo Ridge sources 18-28 km away, with a minority from South Naivasha sources (~18-22 km from MD). Conversely, South Naivasha sources predominate (~96%) in Level 43. The rarity of obsidian from distances greater than 30 km, combined with the rarity of chert and quartz from even longer distances, suggests that the Marmonet Drift occupants during MIS 5 and 7 were not highly mobile, with home range sizes likely smaller than those of modern hunter-gatherers in hot, arid environments, ~45 km (Gamble 1993; Gould and Saggers 1985). They appear to have rarely traveled beyond their home ranges or traded raw materials (or finished artifacts) with other groups in the region. Unfortunately, whether obsidian from outlying sources was acquired directly, or through trade systems, cannot be determined at this time.

Horizons 2, 3 and 4 both had a small, but noticeable number of obsidian artifacts that were disintegrating in-situ. These artifacts could not be recovered as complete pieces, but when exposed in-situ, associated fragments could be often be reassembled. Visually, this obsidian has a banded sheen resembling wood grain, composed of fine lines of tiny elongated gas bubbles that were trapped and stretched in the glass as it flowed before it cooled and solidified. This feature characterizes several south Naivasha sources, particularly near Olkaria and Fisherman's Camp (Merrick and Brown's (1984b) Naivasha Lake Edge South group). The effect of trapped gases is twofold: first the bubble lines undermine the strength of the material during tool use making it less dense, weaker and more prone to breakage, and second, over longer periods of burial the obsidian actually starts disintegrating in-situ (figure 4.19). This obsidian appears to represent a single geological source group that was exploited in both H2 and H4. Many other obsidian sources were also exploited (identified based on chemical composition, color, inclusions, sheens, overall flaking quality) in these same horizons, however none seem to have broken down in the same way. Notably, relatively few artifacts made on this disintegrating type of obsidian were recovered from H4 and none from H5, when nearby Sonachi/Mundui high quality glass was used for almost all artifacts.

Obsidian was the primary material quarried for tool production, and with such close proximity (10-28 km) of the site to obsidian sources it is likely that high-quality raw material was rarely in short supply. This suggests that knappers did not have had a lot of pressure to conserve raw material during tool production and maintenance, and that TO strategies including extensive curation of artifacts may not have been practiced to the same extent as at contemporaneous MSA sites further from sources. Enkapune Ya Muto and Ol Tepesi are both within 10-15 km of MD and would have had similar access to high quantity and quality obsidian sources. This is significant because access to raw material is an important variable in toolkit composition in all eras of the Stone Age. Thus for this study, it can be actually be considered a control, rather than unknown variable.

Lithic Technology: Artifact Assemblages

A total sample of 8551 obsidian artifacts was recovered from H2, H4, and H5 during the 2013 field season from trenches 1b and 4 (table 4.2). Trench 1b exposed a total excavated area of 2 x 6 m to a depth of 3.59 m below the surface into levels 1-11. Figures 4.20 and 4.21 show counts and weights of all obsidian artifacts collected per stratigraphic level in trench 1b. A significant increase in the quantity of artifacts occurs in two distinct layers; the first (H5) between 1.33 and 2.09 m (76 cm in levels 5 and 6) and the second (H4) between 2.74 and 3.39 m (65 cm in levels 10-11). VA 10 clearly divides these two horizons and provides a useful boundary between assemblages. Artifact counts drop substantially in levels 7, 8 and 9; only 123 total pieces were collected in levels 8 and 9 combined, suggesting abandonment of the site during and after the eruption(s). Levels 1-4 also have low artifact densities and were not included in this analysis.

Table 4.2. Total count and weight of obsidian artifacts recovered during 2013 excavation

Horizon	Artifact Count	Weight (g)	Mean Wt/Piece
H2	790	788.3	0.99 g
H4	3108	2831.9	0.91 g
H5	4106	2381.0	0.58 g
Total	*8004*	*6001.2*	*0.75 g*

Trench 4 exposed a total excavated area in 2013 of 2 x 2 m to a depth of 0.70 m below the base of VA 8 in level 22, which was subdivided into three arbitrary spits. There is no observable increase in artifact density for any spit in level 22 and all material was analyzed together as part of a single horizon (H2). It is worth noting that the total number of obsidian pieces collected was actually 924, but that 134 were tiny fragments of artifacts damaged during excavation. Because the soil was so dense and compacted picks and hammers were required to excavate, and unfortunately, some artifacts were broken. To avoid artificially increasing assemblage size pieces that were not able to be refit and counted individually were left out of the total count and weight.

There does not appear to be much disturbance or post-depositional damage to artifacts recovered from H2, H4 or H5. All artifact size classes were recovered in amounts consistent with primary discard and there was no indication size-sorting or preferential alignment by flowing water. Four dense concentrations of very small (≤1 cm) trimming flakes were recovered in H4 and H5, suggesting in-situ knapping events and/or repeated use of the same space for tool maintenance, and possibly intentional disposal of flaking debris in small holes. One small insect nest was found in level 6 but there was no evidence for vertical artifact mixing from different horizons due to tunneling or soil expansion/compaction. Artifacts overwhelmingly retained thin, sharp edges, without any of the characteristic large edge snaps or notches observed in use-wear trampling experiments. Therefore, trampling damage was not significant.

Artifact preservation is very good in H5 and H2, with artifacts retaining sharp edges and fresh glassy surfaces indicating relatively rapid burial. Artifacts in H4 generally have much higher degrees of surface weathering and patination, with some artifacts exhibiting different amounts of weathering and patination on different surfaces. This indicates that H4 artifacts were exposed on the ground surface for a longer period of time than H2 or H5, and may represent more of an activity palimpsest. Despite lower sediment deposition rates and longer surface exposure time, the artifacts in H4 did not have a higher degree of trampling damage than those in the other horizons.

	Site ID and Level					
Artifact Type	**MD H2 (N)**	**MD H2 (%)**	**MD H4 (N)**	**MD H4 (%)**	**MD H5 (N)**	**MD H5 (%)**
Backed Piece	0	0.00	0	0.00	0	0.00
Scraper	5	0.63	15	0.48	6	0.15
Notch	0	0.00	4	0.13	1	0.02
Bec	1	0.13	2	0.06	2	0.05
Outil Écaillé	0	0.00	0	0.00	2	0.05
Point	0	0.00	1	0.03	18	0.44
Knife	0	0.00	16	0.51	12	0.29
Burin	2	0.25	29	0.93	26	0.63
Combination Tools	0	0.00	11	0.35	9	0.22
Total Shaped Tools	***8***	***1.01***	***78***	***2.51***	***76***	***1.85***
Total Unshaped Tools	7	0.89	45	1.45	25	0.61
Total Tools	***15***	***1.90***	***123***	***3.96***	***101***	***2.46***
Whole/Prox Flake	157	19.87	535	17.21	762	18.56
Whole/Prox Blade	0	0.00	5	0.16	4	0.10
MFF/DFF Flake	540	68.35	1776	57.14	2519	61.35
MFF/DFF Blade	0	0.00	0	0.00	0	0.00
MFF/DFF DPS Blade	0	0.00	0	0.00	0	0.00
Split Flake	1	0.13	1	0.03	4	0.10
Eraillure Flake	0	0.00	7	0.23	0	0.00
Potlid Flake	0	0.00	1	0.03	0	0.00
Total Primary Debitage	***698***	***88.35***	***2325***	***74.81***	***3289***	***80.10***
PRF	11	1.39	42	1.35	27	0.66
Burin Spall	1	0.13	7	0.23	3	0.07
Microburin	0	0.00	0	0.00	0	0.00
Derived Segment	0	0.00	0	0.00	0	0.00
Bipolar Flake	0	0.00	2	0.06	7	0.17
Trimming Retouch Flake	56	7.09	567	18.24	604	14.71
Tool Edge Fragment	4	0.51	14	0.46	45	1.10
Total Secondary Debitage	***72***	***9.12***	***632***	***20.34***	***686***	***16.71***
Total Debitage	***770***	***97.47***	***2957***	***95.15***	***3975***	***96.82***
Utilized Debitage	***11***	***0.01***	***72***	***0.02***	***73***	***0.02***
Blade	0	0.00	1	0.03	0	0.00
Flake	0	0.00	1	0.03	7	0.17
Radial	0	0.00	4	0.13	3	0.07
Tabular	0	0.00	2	0.06	4	0.10
Opposed Platform	0	0.00	2	0.06	1	0.02
Bipolar	0	0.00	2	0.06	0	0.00
Informal	1	0.13	2	0.06	2	0.05
Fragment	4	0.51	14	0.45	13	0.32
Total Cores	***5***	***0.63***	***28***	***0.90***	***30***	***0.73***
Total Flaked Obsidian	***790***	***100.00***	***3108***	***100.00***	***4106***	***100.00***

Table 4.3. Complete typological composition of 2013 excavation in H2, H4, and H5 at MD.

Horizon 5 (levels 5 and 6)

The excavated lithic assemblage for H5 totaled 4157 pieces: 4106 obsidian, 56 lava, 3 chert, and 2 quartz. Analysis in this dissertation focused solely on the obsidian artifacts with the only exception being artifact #1510, an extraordinary quartz parti-bifacial point (figure 4.22). The typological composition of the H5 assemblage is shown in table 4.3. Flaking waste (i.e. primary and secondary debitage categories) make up the vast majority of the excavated sample, comprising 96.82% of all recovered artifacts. Cores represent only 0.73% of the total sample, of which about one-half are either informal cores or core fragments. Formal shaped tools (1.85%) and unshaped tools (0.61%) comprise a total of 2.46% of the assemblage.

Primary debitage. This category represents the largest portion of the H5 lithic assemblage. It is comprised of whole flakes, proximal flake fragments (PFF), medial flake fragments (MFF), distal flake fragments (DFF), and bipolar, split, and platform removal flakes. None of these pieces display evidence for utilization and are interpreted as having been produced during the early stages of core reduction and flake blank production for formal tools.

Plain (40.3%) and faceted (39.5%) platforms equally dominate the assemblage, with point (17.4%) and dihedral (2.8%) making up the remainder. For complete platforms, the mean width is 7.3 mm, mean thickness is 2.3 mm (PT/PW = 0.32) and external platform angles average 81°. Dorsal proximal faceting is only present on 10.8% of recovered platforms and indicates that edge abrasion or rubbing was not a common strategy for preparing platforms, at least for early stages of reduction. Instead, it appears that knappers simply may have struck farther into the core and exploited a large striking platform, thereby reducing the need to reinforce the edge with abrasion.

For complete flakes, the mean length is 16.6 mm, the mean width is 15.8 mm, and the mean thickness is 3.6 mm. It is worth noting that the average flake in the H5 assemblage is nearly as wide as it is long, suggesting that the cores these were struck from were generally blocky, rather than long and thin. Indeed, blades and blade-like pieces account for only 0.1% of this sample and were not a common, or intentional, product.

The strategy of producing wide flakes with large platforms yields tool blanks that have a wide and thick middle-proximal body with a thick cross-section. This type of blank appears to have been used for producing various formal tool types, such as scrapers or points. Figures 4.23 and 4.24 illustrate one such example, a wide flake with a large bulb of percussion and thick cross-section (#2714). Flakes somewhat larger than this likely would have served as initial blank forms for long use-life tools; ones to be used expediently, retouched, shaped intentionally, used, resharpened, transformed, and finally discarded. Because of the thick midline and width of the flake blank, there is considerable volume to use, resharpen, and shape depending on the needs of the user. Notably, this particular flake has a slight ventral curvature near the distal end and is close to the length at which some of the unifacial points in the H5 assemblage were discarded (see figure 4.23) so straightening the edge would have made it shorter than the average, though not the smallest, discarded point. However, other larger versions of this blank shape would serve that purpose well.

Cores. Cores do not form a large percentage of the assemblage and, when they are present, tend to be small and fragmentary. A total of 30 cores were recovered in H5, 0.73% of the total assemblage. Exactly half are either informal (≤3 flakes removed) or fragments (flaked chunk without a striking platform). The other half is composed of radial (figure 4.25), tabular, or generic flake core types. True Levallois cores are absent. Larger cores were rare; the maximum dimension of the largest core is 59.4 mm, and maximum weight is 34.9 grams. The average size of measurable cores (n=17) was 35.2 x 30.9 x 13.2 mm; this fits well with the primary debitage, which was characterized by wide flakes with thick striking platforms. The flake blank described above is larger (42.4 x 39.7 x 10.3 mm) than the average core indicating that larger cores were being exploited for blank production.

It appears that core preparation strategies did not revolve around producing pre-shaped blanks, but that shaping was carried out after flakes were made. This suggests three possibilities: first, that that large cores were simply not brought to this site, and that people were producing flake blanks somewhere else; second, that cores brought to the site were flaked until exhaustion; or third, that larger cores were carried away from the site as part of a strategy of raw material conservation. In short, whether cores were being flaked on site within the entire sequence of tool production, or if this assemblage represents only the later phase of tool manufacture (i.e. shaping and maintenance) cannot be ascertained.

Secondary debitage. This category represents the second largest portion of the H5 lithic assemblage. It is comprised of burin spalls, tool edge fragments and retouch flakes. These are interpreted as the direct byproducts of tool production or maintenance and so are extremely informative. The most significant feature is the large number of retouch flakes. In total, 604 pieces were classified as retouch flakes from H5, representing 14.7% of the overall assemblage. These pieces are characterized primarily by lipped platforms, diffuse bulbs of percussion, low external platforms angles (EPA), and radial scar patterns on their dorsal faces (figure 4.26). These attributes indicate soft hammer flaking rather than hard hammer or pressure flaking, both of which have more prominent bulbs of percussion and lack a platform lip (Mourre et al., 2010). Many of these pieces may also retain use-wear traces on their dorsal proximal region, though it can be difficult to confidently distinguish these traces from edge abrasion for preparing platforms (i.e. dorsal proximal faceting [DPF]).

Five points regarding platform and flake size dimensions suggest that the various types of retouch flakes were produced during late-stage artifact shaping and resharpening maintenance. First, the mean EPA for retouch flakes (cumulative for all subtypes) is only 56°, which is 25° less than the mean for primary debitage (table 4.4). The low EPA is important because it shows that these flakes were removed from artifact edges that were already thin. This is in contrast to primary debitage flakes, which were being removed from more blocky and thick cores with steeper platform angles. Second, all six mean dimensions for retouch flakes are less than those of primary debitage, with mean differences of EPA, and flake length, width and thickness considered significant by an Independent Samples t-test ($p<0.008$). Finally, higher ratios of PT/Th, W/Th and L/Th for secondary debitage all indicate that they are thinner than primary flaking debitage, providing further support to the notion that they were being removed from thin artifact edges.

Table 4.4. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all debitage in Marmonet Drift H5

	Primary (n=225)					**Secondary (n=247)**					
Attribute	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*t-test of means*
EPA (°)	81	12	14.5	37	124	56	13	23.2	21	109	21.46[#]
PW (mm)	7.3	6.0	82.2	0.1	33.3	6.3	4.1	65.1	0.1	22.2	2.14
PT (mm)	2.3	2.0	87.0	0.1	10.7	2.0	1.8	90.0	0.1	19.0	1.84
L[a] (mm)	16.6	8.3	50.0	4.9	41.5	13.6	6.8	50.0	4.5	47.9	2.97[#]
W (mm)	15.8	7.4	46.8	2.6	45.8	12.0	5.3	44.2	3.7	38.5	6.19[#]
Th (mm)	3.6	2.0	55.5	0.6	12.9	2.4	1.2	50.0	0.9	13.8	8.33[#]
PT/PW	0.32	0.27	84.3	0.11	1.00	0.32	0.21	65.6	0.11	1.26	n/a
PW/W	0.46	0.28	60.9	0.00	1.11	0.53	0.36	67.9	0.00	2.22	n/a
PT/Th	0.64	0.32	50.0	0.02	1.41	0.83	0.52	62.7	0.02	3.77	n/a
W/L	0.95	0.40	42.1	0.23	1.96	0.88	0.46	52.3	0.32	3.60	n/a
W/Th	4.39	1.68	38.3	1.61	11.02	5.00	1.79	35.8	1.22	11.75	n/a
L/Th	4.61	3.18	69.0	1.52	18.41	5.67	2.91	51.3	0.52	16.61	n/a

[a]Sample sizes for length are 104 for primary and 197 for secondary.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

Third, 45.4% of recovered retouch flakes preserve a ‘lipped’ platform, supporting the use of a soft hammer, such as bone or horn. Fourth, qualitative observations of bulbs of percussion show that they are relatively diffuse (with points of percussion indistinct or absent) when compared to primary flaking debitage. Fifth, qualitative observation of negative flake scars on the dorsal faces shows a pattern of removals from multiple directions indicating the presence of multiple retouched edges in close proximity each other. Together, these data indicate frequent maintenance of invasively flaked and thin-edged pieces with soft hammer retouch.

Informal unshaped tools. The unshaped tool category contains casually retouched pieces and comprises 0.61% (n=25) of all recovered artifacts in H5. The majority of these tools have thin edges with use-wear features such as minor angled microflaking and half-moon edge snaps suggesting that they were used for expedient slicing or sawing activities.

Formal shaped tools. This category includes all intentionally shaped tools and comprises 1.85% (n=76) of all recovered pieces in H5. A total of seven distinct formal tool types were identified, along with some artifacts that contained attributes of at least two different tool types on different parts of the artifact (combination tools). The Simpson's Index of Diversity (SID) value for this assemblage is 0.791. A high SID value that reflects the evenness of tool counts among the different types.

Burins represent the most common type, making up 34.2% of all formal tools. Exactly half are single burins, though plàn (23.1%) and dihedral (19.2%) forms are also common. Burins also make up the second largest component of combination tools (22.2%), and are most often combined with either a casually trimmed or knife edge type. Because a burin requires only a single strike, and can be made on a wide variety of edge shapes and angles, it can be produced at almost any stage (early or late) of a tool's use-life.

Points are the next most numerous type in H5, forming 23.7% (n=18) of all formal tools (figures 4.27 - 4.28). The majority of these (n=12) are unifacial, having been shaped by invasive shallow flaking on the dorsal face of a large flake 'blank'. Though classified as unifacial, 11 of 12 do exhibit clear ventral thinning on the bulbs of percussion; however, this flaking does not extend beyond about one-third of ventral face (figure 4.29). Bifacial points make up the remainder (n=6) of the H5 point assemblage and are characterized by completely invasive shallow retouch around the entire perimeter (figure 4.30). Lengths of complete pieces range from 24.5 to 68.9 mm, widths from 17.2 to 45.6 mm, and thickness from 4.8 to 12.0 mm. In terms of morphology, 60% of complete points (9 of 15) have rounded, almost transverse, bits rather than the more traditional pointed ones. Three points are broken across the midline and have no tips so are not included in this calculation. This blunt tip morphology appears to be intentional, as a complete negative scar and bulb are visible as initiating from a distal lateral edge and releasing across the tip (figure 4.31). This technique is similar to that of Chamfered pieces of the early Upper Paleolithic in the Near East (Shea, 2013). Finally, the morphology of the point bases is notable for the wide 'hips' and rounded shape.

The knife type represents the third most common formal tool type recovered in H5, comprising 15.8% of formal tools and 16.6% of combination tool components. The majority of these pieces are characterized by shallow and semi-invasive to invasive unifacial or bifacial retouch, with either a straight continuous or denticulate edge shape. The retouch pattern observed on knives is virtually identical to that of points, though they are not flaked as completely or so obviously shaped. Most often, straight cutting edges (figure 4.28, d-k) were used and maintained rather than a round or convex edge. The fact that knives and points have similar edge morphologies may actually be an expression of similar kinematic functions; this will be examined in more depth with the use-wear analysis. What is significant typologically is that the similar styles of retouch on knives and points means that the two types actually grade into each other. It is possible that, as knives were used and resharpened over time, they became so completely retouched that they were transformed (typologically) into a shallow-edged points.

Finally, scrapers make up 7.9% of recovered formal tools; they are mostly single edge fragments with steep marginal retouch. They are actually most similar to the unshaped informal tools, but were classified as scrapers due to the higher density of retouch and consistency of edge angle. Small numbers of notched pieces, becs, outils écaillés, and combinations of formal and informal types round out the H5 assemblage.

Use-wear analysis. A total of 19 artifacts from H5 were subjected to use-wear analysis (table 4.5). This included ten points, three knives, one scraper, and five casually retouched pieces. These artifacts were observed in order to test the hypothesis that MSA formal tools will have greater intensity (multiple use sessions) and diversity (multiple functions) of use-wear traces than LSA formal tools. Going further, if MSA tools had long use lives with multiple bouts of resharpening, then low frequencies of use-wear features will be found on the retouched areas because these surfaces and edges would have been removed with each bout of retouch. Conversely, unretouched ventral faces should accumulate use-wear traces over the entire life history of an artifact and should have higher densities and diversity of traces.

Table 4.5. Artifacts from H5 subjected to use-wear analysis

Catalog #	*Typological Classification*	*Microflake Scars*	*Striations*	*Functional Interpretation*	*Worked Material Hardness*
1510	Parti-bifacial point	Rare, angled	None	Slicing	Soft
1889	Unifacial Point (broken tip)	Languette fracture, basal crushing	Lateral at base, longitudinal at tip	Hafted projectile point	Hard (impact)
2086	Unifacial point	Lateral at base, possible impact fracture at tip	Lateral at base, longitudinal at tip	Hafted projectile point	Soft/medium
2219	Bifacial point	Lateral at base, originate from fissures	Lateral/diagonal at base, robust and longitudinal at tip	Hafted piercing tool (probable projectile)	Medium
2509	Unifacial point	Lateral at base, originate from fissures	Lateral at base, longitudinal and bi-directional at tip	Hafted projectile and piercing	Medium
2573	Unifacial point	Rare	Very dense in spots, mixed orientations	Piercing and/or slicing	Soft with grit
2728	Unifacial point, utilized	Continuous, bi-directional and angled	Longitudinal (tip) and parallel (left edge)	Hafted projectile and slicing	Soft with grit
2730	Bifacial point	Rare, longitudinal at tip	Rare, parallel	Hafted projectile and slicing	Soft
2830	Unifacial Point (broken tip)	Languette fracture, abrasion on arêtes; resin blob	Lateral at base, longitudinal at tip	Hafted projectile point	Hard (impact)
2832	Bifacial Point (broken tip)	Languette fracture, rare otherwise	Longitudinal and diagonal	Hafted projectile and slicing	Hard (impact)
1940	Bifacial knife	Rare, angled	Rare, parallel	Slicing	Soft

Table 4.5 continued. Artifacts from H5 subjected to use-wear analysis

2080	Combination: scraper, bec	Rare, perpendicular	Rare, perpendicular	Scraping	Soft
2834	Combination: knife, burin	Rare	Parallel, non-continuous	Sawing	Soft
2146	Biface edge frag	Perpendicular, feather and stepped terminations	Rare, perpendicular to 45°	Scraping	Soft/medium
1880	Whole flake, utilized	Bi-directional, angled	Parallel to 45°	Sawing	Medium/hard
2306	MFF, utilized	Bi-directional, angled, rounding, edge snaps	Rare, perpendicular	Sawing/scraping	Soft/medium
2492	MFF, casual trim	Bi-directional, angled	Parallel	Sawing	Soft
2569	PFF, utilized	Feather termination, mixed orientations	Mixed orientations	Sawing	Soft with grit
2719	PFF, casual retouch	Bi-directional, angled with edge snaps	Bi-directional, parallel	Sawing	Soft

Artifact #1510 is classified as a parti-bifacial point, and is the only shaped quartz artifact recovered in this site. Negative retouch flake scars are the most obvious feature visible in all SEM images. There is no use-wear evidence near the tip to indicate its use as a projectile. However, some angled microflake scars and chipping are present on the right edge (figure 4.32). The data suggest this piece was used for light slicing or cutting, rather than as a projectile before it was discarded.

Artifact #1889 is classified as a unifacial point with ventral bulbar thinning and a bending 'languette' fracture on the distal end (figure 4.33). The tip is missing and presumed broken, possibly due to an impact fracture, which would explain why the piece was discarded and replaced. Different wear patterns were observed on the tip and base. Image A shows the break near the tip along with a longitudinal striation (images B-C) that was formed by an object moving from tip toward base, the direction expected if the point were used in a piercing use-action. Images D-F were taken near the base of the piece and show lateral striations and marginal stepped microflake scars perpendicular to the edge; these features may represent wear from a haft, where the materials were wrapped laterally around the base of the piece and leaving the tip exposed.

Artifact #2086 is a complete unifacial point with a trimmed proximal ventral area (figure 4.34). This piece is made on an obsidian source that weathers to a dull patina. Different wear patterns were observed on the tip and base. The lower half of the tool has striations in crisscrossing directions (image A) and one microflake scar that initiates on the termination of a bulbar trim scar and could not have been struck with a hammer (image B). This scar may be the result of rubbing in a tight haft, which is also suggested by the presence of lateral striations nearby (image C). Use-wear near the tip has longitudinal striations (image D) and a burin-type (tranchet) negative scar (image E) along the edge with additional longitudinal microflake scars. These tip wear traces suggest a hafted tool used in a longitudinal use-action such as a piercing projectile and/or cutting.

Artifact #2219 is a complete bifacial point (figure 4.35). It has shallow invasive retouch around the entire perimeter and appears to have been intentionally shaped into the 'point' form. Different wear patterns were observed on the tip and base. Use-wear on the base of the piece is comprised of transverse and diagonal striations (images A-B), some of which are short, wide and interspersed across small areas (image C), suggesting that the indenter was only scratching the surface of the tool for a short distance. Additionally, microflake scars originating from fissures were not intentionally struck with a hammer and suggest that this piece was hafted (images A, C). Use of the tool could have caused slight movement in the haft, generating scratches and microflaking. Nearer the tip, the top one-third or so of the piece, longitudinal striations are most common, with some diagonal ones interspersed. These tip striations are also more robust, with deeper and longer gouges than at the base (images D-G). The differences in striation orientation and robustness indicate different sources of damage for different areas of the tool surface. The lighter, and more laterally oriented wear across the base suggests rubbing in a haft, while the deeper and longitudinal oriented wear near the tip indicates forceful piercing, possibly from use as a projectile or piercing use-action.

Artifact #2509 is a complete unifacial point with ventral bulbar trimming (figure 4.36). Different wear patterns were observed on the tip and base. Mirroring the use-wear pattern on #2219 the features on the base of the point are distinct in their orientation, with lateral striations (image A) and microflake scars that initiate from fissures on the ventral surface (images B-C) and were not struck with a hammer. Towards the tip striations are more common and oriented longitudinally in two directions, both towards and away from the tip (images D-F). This indicates that the tool was likely piercing into and out of an object repeatedly. Together, these data support the use of this piece as a hafted piercing tool or projectile.

Artifact #2573 is a complete unifacial point with ventral trimming near the base (figure 4.37). The ventral face is almost perfectly flat. The absence of curvature from the bulb of percussion indicates that this artifact was initially formed on a very large flake blank. Different wear patterns were observed on the tip and base. Five areas near the base have clear evidence for rubbing and abrasion (images A-E); striations are too dense to count and go in many different directions. Nearer to the tip the dominant orientation is diagonal to the long axis, with a lower frequency than the base (images F-G). For example, image H shows a single long striation that has a weaving track and doubles back on itself, indicating that the indenter moved side-to-side and reversed course while in contact with the tool. Together, these data suggest a hafted tool in a late-stage of its use-life that was used as a cutting tool on soft materials with hard grit or edges. The grit likely reached the center of the piece after the tool edge cut through the outer limit of the material and caused the scratches.

Artifact #2728 is a complete unifacial point with a single ventral bulbar trim scar (figure 4.38). Different wear patterns were observed on the tip and base. Use-wear features are generally rare near the base (image B). Edge crushing, stepped scars (image C) and lateral striations (image D) in this area suggest that this piece may have been hafted. The distal half and tip have low frequencies of striations and microflaking, but they are exclusively along the long tool axis and indicate a longitudinal use-action, such as piercing and/or slicing (images E-F). The left side of the piece has dense angled and bi-directional microflaking (image A) along with parallel striations (image G) indicating a sawing use-action. This piece appears to have been used for both sawing and piercing, possibly as a projectile point and butchery tool.

Artifact #2730 is a complete parti-bifacial point, with the long axis at a right angle to the axis of percussion of the flake blank. Different wear patterns were observed on the tip and base. Shallow invasive retouch covers all but one side of the original ventral face (figure 4.39). Variable directions of scratching (images A-D) near the base and shoulders support the notion that this piece was hafted, while marginal microflake scars (images E-F) with rare striations (images G-H) nearer to the tip indicate piercing and cutting of soft materials. Use-wear features near the tip are rare and mostly superficial. This piece may have been used as either a hafted projectile point or cutting tool.

Artifact #2830 is a broken unifacial point with minimal ventral bulbar trimming (figure 4.40). Shallow, invasive retouch characterize the dorsal face; only two small flakes were struck to thin and remove the bulb of percussion. In this instance, because so few flakes were removed to thin and shape it, the recovered piece was likely not far from its original form (except for the broken tip). Different wear patterns were observed on the tip and base. The tip was removed with a bending 'languette' flake, which may represent an impact fracture from use as a projectile. Near the break is a small series of longitudinal gouges and scratches that suggest a piercing use-action (image A); the variability of width and depth on these features (image B) indicates that at least two different materials were contacted by this piece. On the lower portion of the tool, near the base, lateral striations and rubbing/cracking are common (images C-E). There is also a dark gummy blob that appears to be residue of an adhesive substance that would have been used to help secure the tool in a haft (image C). Together, these data indicate that this tool was used as a hafted point that broke during impact.

Artifact #2832 is a broken bifacial point with shallow invasive retouch covering the entire piece (figure 4.41). Both the middle (base is missing) and tip bit (≤5 mm) have old snaps; the middle break is a bending 'languette' fracture and may have occurred during use as a thrown projectile. A small portion of the original ventral surface remains, and indicates that this discarded form is probably represents a late-stage of this artifact's use-life. Several use-wear patterns were observed on this tool fragment. The ventral surface has higher frequencies of use-wear traces (images A-B) than any other portion of the tool or any other observed tool in the sample. Additionally, striations have variable morphologies and orientations (image C) suggesting a complex functional history that likely involved several different worked materials during a long use-life history. Striations are primarily diagonal to the tool edges (images D) and suggest a slicing use-action. Stepped edge scars, scratching on arêtes (image E) and microflakes removed from fissures or flake terminations (image F) suggest hafting. Finally, the languette fracture in the middle of the piece suggests a buildup of tension perpendicular to the long tool axis before the snap, possibly as the result of an intense impact as a projectile point.

Artifact #1940 is a bifacially flaked knife made on a very thin flake (only 4.2 mm thick). Its plan shape mimics that of the points, with ventral bulbar thinning and semi-invasive to invasive lateral retouch, however its perimeter is not flaked as completely as that of the other points. It may represent an early-stage point pre-form or have been too small to support several rounds of retouch. Use-wear features, including striations and angled microflake scars, indicate a longitudinal use-action, such as cutting or sawing (figure 4.42). Image A shows what appears to be a scratch and/or crack running parallel to the retouched edge, with microflake scars terminating in multiple directions.

Artifact #2080 is a combination tool, with a double side scraper (one straight steep angle and one convex intermediate edge angle) and a retouched corner bit (bec). The steep scraper edge has use-wear features indicating a transverse use-action, probably scraping (figure 4.43). These features included microflake scars, minor edge rounding, and striations perpendicular to the used edge (images A-B). This scraper edge does not appear to have been heavily used, as use-wear features are rare. The bec corner also has perpendicular striations; whether these are the result of scraping or another use-action is uncertain (images C-D).

Artifact #2834 is a combination tool with a denticulate bifacial knife-edge and a triple burin blow (figure 4.44). This complete tool was made on a large flake blank similar to those used for points, and has shallow invasive flaking on both tool faces, including the bulb, which was trimmed extensively. The burin blows all originate form the same place and override a portion of the denticulate edge, indicating that they were struck after the knife retouch. This discarded form represents a late stage of this artifact's morphology, one that was altered several times by retouch. Use-wear on the denticulate edge indicates slicing a soft material; microflake removals are almost completely absent (image A) and striations indicate only one direction of use (image B).

Artifact #2146 is a bifacially retouched tool edge fragment, possibly snapped from torsion (figure 4.45). Under magnification the invasive retouch scars are clearly visible, but are overridden by use-related marginal microflake scars that have a combination of feather and stepped terminations (images A-B) as well as striations (images C-D). Both are primarily oriented perpendicular to the worked edge indicating a transverse use-action. Together these data support the use of this edge for scraping a soft to medium hardness material; it is likely to have been part of a larger scraping tool.

Artifact #1880 is classified as a utilized whole flake. The left dorsal edge of this piece has intense edge damage visible to the naked eye and so was selected for SEM observation (figure 4.46). The edge has marginal, bi-directional, and angled microflake scars and striations that vary from parallel to 45° to the worked edge. This suggests use in a sawing use-action on a medium to hard material.

Artifact #2306 is a heavily utilized medial flake fragment without any intentional retouch. Both faces of the utilized edge were observed (figures 4.47 – 4.48). Marginal and bi-directional angled microflake scars with robust bulbs of percussion characterize the dorsal face (images A-C), while the ventral face has edge rounding, edge snaps (images D-E) and a series of striations perpendicular to the edge (images F-G). Together, these data suggest a sawing use-action on a soft to medium material; however, the perpendicular striations and edge rounding indicate that the worked material(s) was also contacting the tool in a transverse motion, possibly as a scraper. This tool appears to have been used in two different ways.

Artifact #2492 is an unshaped medial flake fragment with a short series of invasive shallow retouch scars on the ventral face. Both faces of the utilized edge were observed (figure 4.49). Angled microflake scars, parallel striations and edge snaps are common on both the ventral (images A-D) and dorsal faces (images E-F). These features clearly indicate a sawing use-action. The majority of microflake scars have feather terminations suggesting sawing a soft material.

Artifact #2569 is a utilized proximal flake fragment that lacks intentional retouch (figure 4.50). Feather terminating microflake scars along with striations of mixed orientations (angled and perpendicular) characterize this edge (images A-C). There is also a large twisting gouge/striation with associated microflaking at one end (image D), which suggests a twisting motion. Overall, the use-wear features indicate sawing of a soft material; at least one hard particle gouged the surface, possibly a small chip form the obsidian tool itself (i.e. autostriation).

Artifact #2719 is a utilized proximal flake fragment with a small area of casual retouch, and is classified as an expedient tool (figure 4.51). Both faces of the utilized edge were observed. Angled microflake scars (image A) and striations (image B) parallel to the worked edge are frequent on both faces of the tool, and a few edge snaps (image C) are present as well. Both the scars and striations indicate two directions of longitudinal slicing (image D), thus a sawing action, while feather terminations on microflake scars suggest a soft worked material.

In summary, four different functions were identified on 19 artifacts. This includes sawing (6), slicing (3), scraping (2), piercing (2), and use as a projectile (6). Seven tools were identified as having been hafted, six of which were further classified as projectiles due to a combination of factors such as tip bending (impact) fractures, longitudinal striations near the point tip, and lateral abrasion and striations near the base. This combination of use-wear features has been observed on hafted points experimentally (Sisk and Shea, 2009; Rots, 2013; Rots and Plisson, 2014; Iovita et al., 2014), as well as archaeologically (Lombard, 2005; Sahle et al., 2013; Wilkins et al., 2012). For formal knives and expedient tools (mostly flake fragments) sawing and slicing were the most often identified functions. For many of these pieces the lateral edges are remarkably straight in the dorso-ventral plane. This would minimize resistance, rotation and edge damage to the artifact during slicing and sawing actions. It would also reduce the potential for tip bending fracture in projectile or piercing (stabbing) kinematics. Notably, due to similarities in use-wear traces for piercing and cutting actions, it is possible that some of the points were used as hafted cutting (butchery?) implements and perhaps served as more formal versions of the expediently retouched fragments. Finally, many of these artifacts had several areas and/or edges with different use-wear features, all of which needed to be assessed together in order to best understand its functional history.

Beyond the functional interpretations, qualitative observations of retouch and surface scratches on formal tools, particularly points, provide support for intense curation. Unretouched ventral faces on points typically contain multiple areas of abrasion and scratching. Some of these scratching features are found near the base and likely resulted from rubbing in a haft; however, some are also found further toward the distal end or bit and probably developed over a long period of use from contact with various materials or being carried around. Retouched faces on these same tools display evidence for several rounds of resharpening, with older flake scar terminations near the thicker midline and younger, shorter scars overlying them nearer to the edges. Together, these features suggest multiple stages of use and resharpening on individual tools. In contrast, smaller informal tools made on flake fragments appear to have been made and used expediently, often with only one or two resharpening sessions before discard. These pieces may also have invasive retouch but the number and overlap of scars does not approach that of the formal points or knives in the assemblage. Regardless, expedient tools likely formed an important component of the toolkit, allowing people to carry out many tasks without sacrificing the volume or time invested in the more formal types.

Pigment use. Evidence for the processing of pigments, specifically red ochre, was also recovered in H5. This included several small chunks of red ochre (figure 4.52) and a water-rolled lava abrader (figure 4.53) with red ochre staining on one rounded corner. The closest sources of red ochre are on top and northeast slopes of Mount Eburru 15-21 km north of the site and Oserian and Olkaria 15-17 km south of the site, so these pieces must have been collected and carried for at least that distance. The stained abrader suggests that people were probably processing the ochre by crushing and grinding it. This powdered form could have been mixed with water, tree resin or fat, and then used to color wood, bone (tools or otherwise), human skin, clothing for ritualized display, or as an ingredient in hafting adhesives (Watts, 2002; Wadley, 2005; Lombard, 2007; Soriano et al., 2009; Wadley et al., 2009; Watts, 2010). These artifacts thus represent potential evidence for symbolic behavior by MD H5 occupants, however a simply functional use cannot be discounted.

Spatial organization. During excavation in H5 four distinct artifact 'clusters' about 10-15 cm in diameter were uncovered that contained extremely dense concentrations of flaking debris (figure 4.54). Cluster #1 (bulk catalog #1517b) contained 548 artifacts, including one bifacial point, one burin, one core and a mix of primary and secondary retouch debitage with lipped platforms. Cluster #2 (#1517c) contained 75 artifacts, including five flakes with radial scar patterns on their dorsal faces similar to those observed on H5 points. These may be the result of early stage thinning and shaping on large flake blanks. Cluster #3 (#1517d) contained 78 artifacts, including a double burin and a mix of primary and secondary debitage with lipped platforms. The size of cluster #4 (#1544b) was smaller than the other three, about 5 cm diameter with 26 artifacts, but was anomalously dense compared to the distribution of the majority of artifacts in the horizon. Unfortunately, I did not have the opportunity to try and refit pieces from each cluster. This could especially informative for cluster #1, which contained a core, primary flaking debris, bifacial point and small retouch flakes. If smaller flakes could be refit onto the core and/or point then different stages of the tool production sequence could be reconstructed.

Technological organization. The lithic assemblage recovered in H5 was primarily focused on retouched tool use and maintenance. In particular, the samples of points, knives, expedient cutting tools, and retouch debitage, including the four clusters, suggest the use and maintenance (i.e. curation) of hafted projectiles along with cutting/sawing activities. Three pieces of data support this conclusion.

First, almost 15% of the total assemblage is composed of secondary retouch flakes. These flakes are typically very thin (mean 2.4 mm), with diffuse bulbs of percussion, lipped platforms, and very low EPAs (mean 56°) indicating shallow and invasive retouch with soft-hammers on thin-edged tools. This retouch technique greatly extends the use-life of a tool because the resharpening flake removes so little of the piece's volume. With a ratio of 7.95 retouch flakes for each formal tool, curation of these types was clearly practiced. Further support for the curation of formal tools is represented by the four small artifact clusters. These clusters also provide evidence for active cleaning and planned spatial organization by site occupants, who likely gathered up sharp debitage and deposited it into holes to avoid cutting their feet. Brandt and Weedman (2002; Weedman, 2006) have observed similar cleaning strategies by the modern day Konso and Gamo ethnic groups in Ethiopia. They often retouch their hide scrapers over a goatskin or wooden container, and then discard the fine sharp debris at a specific dump location away from central household activity areas. The artifact clusters in H5 may represent single knapping events and their associated clean up. Notably, three of the clusters were found in a single meter square with the fourth in the adjacent square, suggesting that this small area was used repeatedly and actively managed, indicating a structured use of space commensurate with longer occupation spans (Yellen, 1977).

Second, cores are rare and ones that were recovered are generally small, fragmented, and exhausted. Similarly, formal tools are typically heavily retouched with features that indicate long use-lives. Together, this suggests that tool blanks were produced rarely, and that individual tools were maintained and reused over and over until they broke or were too small to be used.

Third, use-wear evidence on points includes differential wear patterns for proximal and distal ends. Proximal ends of points overwhelmingly display evidence for hafting while distal ends preserve use-wear features indicative of piercing as thrown or thrust projectile, including impact fractures, and/or cutting. More experiments with unifacial projectile points with this kind of wide bit are needed to see if this pattern of striations can be replicated. Knives and many informal tools also display evidence for cutting and sawing actions. Burins, the most common tool form, may have also contributed in this role. Together, this suggests that the H5 toolkit likely included hunting and butchery tools, probably with hafted spears and knives. Further, the density of striations and microflaking on the ventral faces of points indicates several stages of use and maintenance. The dorsal surfaces have fewer wear features, likely because earlier wear traces were removed by resharpening. Put another way, ventral faces accumulated use traces throughout the tool's entire life history, while the dorsal surface preserved traces that accumulated only since the previous bout of retouch. Most points and knives were used and resharpened several times over relatively long use-lives, indicating they were originally significantly larger than when they were finally discarded. Expediently retouched pieces, including burins and flake fragments, supplemented the toolkit.

One comment should be made about tool blanks and starting size. Platform width and thickness are often used to estimate flake blank size (Dibble and Whittaker, 1981; Dibble and Pelcin, 1995; Braun et al. 2008; Dibble and Rezek, 2009; Clarkson and Hiscock, 2011). However, platforms on formal tools such as points in H5 are rare, typically having been removed to thin and shape the base. I have to use other lines of evidence to estimate original flake sizes. One way to do this is by observing the degree of arc for ripples on the ventral faces of tools. Highly curved and small radius ripple marks are closer the to the point of percussion and the striking platform, and small flakes have smaller radii over the entire ventral surface. Conversely, very large flakes have lower ripple mark arcs at greater distances from the point of percussion.

The wide arcs of ripples on point #2145 indicate that the discarded piece is far from the original flake's platform and bulbar area (figure 4.55). Furthermore, the ripples are perpendicular to the long axis of the point and indicate that the width of the original flake was at least as wide as the discarded point was long. Another point (#2729, figure 4.27a) is >20 mm longer than the next largest, but has the same plan shape, invasive flaking, and bulbar thinning. Notably, this piece has a hairline fracture near the tip and may have been discarded at an earlier stage of its use-life to reduce the chance of failure during use. This piece indicates the minimum starting size of the points and other formal types was likely larger than this piece.

Although only one unmodified flake blank (#2714, figure 4.25d) was recovered from this horizon it allows me to describe the shaping sequence of the diagnostic H5 points. Despite its relatively small size, the blank's morphology provides a suitable example of the likely starting form. Further, by observing the negative scars on retouched points (see figures 4.23 – 4.24) it is possible to describe the removal order of shaping flakes. Blanks were first thinned at the base by inverse trimming of the platform and bulb of percussion; this stage is represented by the bulbar retouch sub-category of secondary debitage, which retains a portion of the convex bulb of percussion and/or errailure scar(s) on its dorsal face. The technique of thinning the base of a point is often suggested as advantageous for hafting because it reduces the weight of the tool, creates a slimmer profile, and may help the piece fit more securely into the haft (Minichillo, 2005; Villa et al., 2005; Villa and Lenoir, 2006; Wilkins et al., 2012; Barham, 2013; Scerri, 2012). Next, invasive soft-hammer flaking on the dorsal face shaped the tool's perimeter. Particularly for unifacial points, the technique of shaping by flaking only on the dorsal side helped to maintain a flat face on the tool and a correspondingly straight edge. This stage of shaping is clearly represented by the 'edge removal' retouch sub-type, which retains the ventral face's distal ripples on its platform (figure 4.26, p-t). However, if the original blank had a small amount of distal curvature, and this was straightened by distal lateral inverse retouch, the evidence for this would survive only in the form of small inverse retouch flakes. None of these were recovered. The flat ventral surface remaining on points at their final discard size suggests careful selection for blanks with no distal dorso-ventral curvature, and thus straight edges that were efficient for slicing and sawing actions, and/or less likely to break when used as projectiles and/or piercing (stabbing) knives.

Horizon 4 (levels 10 and 11)

The excavated lithic assemblage for H4 totaled 3676 pieces; 3655 obsidian, 18 lava and 3 quartz. No chert pieces were recovered. As in H5, the analysis presented here is for the obsidian artifacts. Due to time constraints, only the artifacts (n=3108) from levels 10a, 10b and 11a were analyzed; 11b (n=547) was not included. The typological composition of those three levels is presented in table 4.3. Primary and secondary debitage categories make up 95.1% of the assemblage with cores contributing 0.9%. Formal shaped tools (2.5%) and unshaped tools (1.5%) comprise a total of 4.0% of the assemblage.

Primary debitage. The majority of platforms for whole flakes and PFFs are either plain (41.9%) or faceted (36.4%), with smaller numbers of point (18.2%) and dihedral (3.5%) types. For complete platforms, the mean width is 10.5 mm, mean thickness is 3.1 mm (PT/PW=0.30) and external platform angles average 79°. Dorsal proximal faceting is present on 10.6% of all platforms, and as in H5, core edge abrasion does not appear to have been an important technique in platform preparation. For complete flakes, the mean length is 24.7 mm, the mean width is 19.9

mm, and the mean thickness is 4.5 mm. Blade and blade-like pieces, some of which have utilized edges, are extremely rare and account for only 0.1% of primary debitage. Blade production was clearly not a goal of H4 knappers.

Cores. A total of 28 cores were recovered in H4 (0.9% of the total assemblage). Sixteen of the 28 are either informal or fragmented, and do not provide much useful information about flaking techniques. Of the formal types, radial cores are the most common (14.3%), with tabular (10.7%), bipolar (7.1%) and opposed platform (7.1%) making up the remainder. Bipolar and opposed platform types are quite similar with two striking platforms at opposite ends of the core, but there is little to no evidence in tool morphology or flaking debris to indicate that this type of core morphology was favored by toolmakers at this time. Finally, the small average core size (32.4 x 31.4 x 12.9 mm) and low recovery rate suggest that larger cores were carried away from the site or discarded when they could no longer produce usable flakes.

Secondary debitage. Burin spalls, tool edge fragments and retouch flakes make up the second largest portion of the H4 lithic assemblage. Simply put, the number of retouch flakes recovered is astounding. A total of 567 pieces were identified as such, representing 18.2% of the total assemblage, which is an even higher percent than that of the H5 assemblage. Again, these specialized debitage types reflect late-stages of tool shaping, thinning and resharpening maintenance. For example, the mean EPA, flake length, width and thickness measurements for retouch flakes are all significantly smaller than those of the primary debitage (table 4.6) using Independent Samples t-tests ($p<0.008$). Similar to H5, the EPA and thickness measurements indicate that the edges retouch flakes were being removed from were much thinner than those of the primary debitage. This is further supported by the higher ratio of PT/Th for secondary debitage. Finally, the presence of lipped platforms (52.7%) and diffuse bulbs of percussion indicate that soft-hammer was used extensively during this phase of retouch.

Table 4.6. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all debitage in Marmonet Drift H4

	Primary (n=84)					Secondary (n=106)					
Attribute	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*t-test of means*
EPA (°)	79	13	16.5	50	106	52	13	25.0	19	85	14.32[#]
PW (mm)	10.5	6.8	64.8	0.1	28.2	9.3	6.3	67.7	0.1	35.1	1.24
PT (mm)	3.1	2.1	67.7	0.1	11.0	2.5	1.6	64.0	0.1	8.4	2.07
L[a] (mm)	24.7	14.6	59.1	4.9	75.4	15.6	7.2	46.2	4.4	40.4	3.63[#]
W (mm)	19.9	9.1	45.7	6.6	50.2	14.4	7.1	49.3	5.8	41.4	4.70[#]
Th (mm)	4.5	2.1	46.7	1.4	11.7	2.9	1.6	55.2	0.2	9.3	6.02[#]
PT/PW	0.30	0.19	63.3	0.12	1.00	0.27	0.13	48.1	0.11	1.00	n/a
PW/W	0.53	0.29	54.7	0.01	1.09	0.65	0.30	46.1	0.01	2.39	n/a
PT/Th	0.69	0.31	44.9	0.03	1.28	0.86	1.13	131.4	0.05	11.63	n/a
W/L	0.81	0.52	64.2	0.32	3.38	0.92	0.41	44.6	0.40	2.34	n/a
W/Th	4.42	1.58	35.7	2.24	9.55	4.97	4.93	0.99	0.84	52.25	n/a
L/Th	5.49	2.76	50.2	0.94	14.59	5.38	7.21	134.0	1.28	66.65	n/a

[a]Sample sizes for length are 37 for primary and 80 for secondary.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

One sub-type of retouch present in H4 but not H5, albeit in a small amount (3.2%), is scraper trim. These are distinguished from other retouch flake subtypes by a relatively thick platform or body, larger width than length, and scraper related use-wear traces such as edge rounding and perpendicular (to the edge) striations/microflaking on the dorsal proximal area. The recovery of such pieces indicates in-situ use and retouch of scrapers in H4, something that was not found in the H5 assemblage. Overall, the diversity and large number of retouch flakes recovered indicate that tool maintenance related to shaping and resharpening was a significant activity during this occupation.

Informal unshaped tools. The unshaped tool category contains casually retouched pieces and comprises 1.45% (n=45) of all recovered artifacts in H4. The majority of these tools have thin edges with use-wear features such as microflaking and half-moon edge snaps that suggest slicing or sawing activities.

Formal shaped tools. This category comprises 2.51% (n=78) of all recovered pieces. A total of six distinct formal tool types were identified, along with combination tools. The Simpson's Index of Diversity value for this assemblage is 0.769, nearly the same as that of H5 despite having one less tool type.

Burins represent the most common type in this assemblage, making up 37.2% (n=29) of all formal tools. The majority (65.5%) are single burin bits, but burin plàns (27.6%) are common as well. Burins are also a frequent component of combination tools (27.2%), most often combined with a knife type (figure 4.56). Their abundance may be a result of the relative ease with which a burin blow can be made on almost any edge as well as the functional versatility of such a thick and sharp bit.

Knives are the second most numerous type, forming 20.5% (n=16) of all formal tools and 40.9% of combination tool components. The vast majority of knives (n=13; 81.3%) are shallow angled with semi-invasive or invasive retouch; there is a slight preference for unifacial flaking over bifacial (56% to 44%), but does not appear to have been a significant factor in their production. Most often, convex (43.8%) or denticulate (25%) cutting edges were created, rather than straight or concave. These shapes are not mutually exclusive as artifact #3009 (figure 4.57) actually is a convex denticulate. An additional three pieces share a similar convex or crescent plan shape (figure 4.58). The convex edges of these three pieces all have steep biclinal marginal retouch rather than invasive bifacial retouch. This retouch type is considered a variant of backing to form a blunt edge opposite a sharp edge. It is commonly referred to as Helwan retouch in Epipaleolithic industries of the Levant (Shea, 2013). Helwan retouch has not previously been identified in MSA or Middle Paleolithic industries. Thus, these Helwan backed knives may represent a new tool sub-type for MSA typologies.

Scrapers represent the third most common formal tool type recovered in H4, comprising 19.2% (n=15) of all formal tools. Notably, there does not appear to be a dominant edge shape for H4 scrapers. Denticulate (26.6%), straight, convex and concave forms (20% each) are all present in near equal numbers. Edge angles are primarily steep/vertical (53.3%) but intermediate (26.6%) and shallow (13.3%) angles are also present. It seems unlikely that steep edge angles are solely the result of extensive resharpening because knives made on similar-sized flakes within the H4 assemblage are typically thinner and more invasively flaked. It is more likely that edge angle was a well-controlled variable by knappers, and that steep angles were purposely maintained, possibly for working hard materials such as wood or bone.

One distinctive scraper type was recovered. Figure 4.59 shows four convex end scrapers with retouch on the distal or proximal end, three of which have lateral marginal plano-clinal normal retouch, and similar elongate ovoid plan shapes that narrow toward the base. These three are formally classified as convex end and double convex side scrapers. The proximal ends of two and the distal end of the other (#3343) form the convex end. They resemble ethnographically documented "oval" hide scrapers of the Gurage, Sidamo, Arussi (Gallagher, 1977) and Gamo (Weedman, 2002, 2006; Shott and Weedman, 2007) ethnic groups in the main southern Ethiopian Rift and southwestern highlands. These hide scrapers are shaped to fit a socketed handle. The fourth end scraper (#3314) is retouched on the proximal end of the blank, and lacks retouch on the lateral margins. It is wider than the other three scrapers and its scraper edge is wider than the length in the flake axis. It may have been hafted in a split shaft, which is also used by the Gamo. Considering the diversity of formal attributes and shapes of Ethiopian hide scrapers, this could be functionally similar to the other scrapers. These oval scrapers may represent another new tool sub-type for MSA typologies.

Only a single point was recovered from the entire H4 assemblage; it was strictly unifacial, with no ventral bulbar thinning and only minimal dorsal shaping. This is especially interesting because of the contrast with the large sample of heavily retouched points from H5. The implications of this difference are discussed below. Finally, small numbers of notched pieces, becs, and combination tools round out the H4 assemblage.

Use-wear analysis. The four scrapers from figure 4.59 (described above) were subjected to use-wear analysis (table 4.7). This permitted me to test whether the function implied by the typological category of ‘scraper’ matched the use-wear traces found on such artifacts.

Table 4.7. Artifacts from H4 subjected to use-wear analysis

Catalog #	*Typological Classification*	*Microflake Scars*	*Striations*	*Functional Interpretation*	*Worked Material Hardness*
3156	Convex end and double side scraper	Edge rounding, arête abrasion	Longitudinal from tip, variable on base	Scraping	Soft
3212	Convex end and double side scraper	Edge rounding, marginal trim on base	Longitudinal from tip	Scraping	Soft
3314	Convex end scraper	Edge rounding	Longitudinal from tip. More rare than the other scrapers	Scraping	Soft
3343	Convex end and double side scraper	Edge rounding, rare perpendicular from tip, marginal trim on base	Longitudinal from tip	Scraping	Soft

Artifact #3156 is a convex end and double side scraper on a whole flake with shallow invasive retouch on the distal one-third of the piece (the scraper bit end) (figure 4.60). Longitudinal striations and edge rounding characterize the bit edge (images A-H). These features are consistent with an edge that was used for scraping a soft material, such as dry animal hide. The base of the piece has a much different use-wear pattern with lateral (image I) and crisscrossing striations (images J-L) and arête abrasion (image M). These features are similar to those found on the assemblage of hafted points in H5 and suggest that this scraper was probably also hafted for use. Unfortunately I was not able to determine the extent to which the haft covered the tool face.

Artifact #3212 is convex end and double side scraper with shallow semi-invasive retouch on the distal edge and marginal chipping on the basal edges (figure 4.61). Longitudinal striations originating near the bit and extending into the piece are by far the most common use-wear feature. Edge rounding is also present, though to a lesser extent than #3156 (images A-F). Retouch on the dorsal face near the platform (still present) is marginal and inconsistent. It is possible that this piece was shaped for hafting, especially due to its morphological similarity with the other three samples in this sample, but cannot be confirmed.

Artifact #3314 is classified as a convex end scraper with steep marginal retouch on the proximal rather than the distal end of a flake blank (figure 4.62), possibly because the distal end was too thin to be retouched effectively. There is no retouch on any other part of the tool, and no use-wear on the unretouched end to suggest a tight haft. Similar to the two previous pieces, edge rounding dominates the retouched bit edge (images A-D). Striations (image A) and microflaking (images A, C) are rare compared to the other three scrapers in this sample. Together, these data suggest the use of this piece as either a hand-held or heavily wrapped scraper, possibly in a split haft, and used on a soft material without any grit.

Artifact #3343 is classified as a convex end and double side scraper with intermediate invasive retouch on the proximal one-third of the piece (the scraper bit end) (figure 4.63). Similar to #3314 the convex scraper edge is on the proximal end of the blank, however, the thickness is similar throughout the length of the piece and so the choice does not appear to have been made to exploit volume as I suggested for #3314. Once again, edge rounding (image A) and longitudinal striations (images B-C) are the most common use-wear features near the bit, with some perpendicular microflake scars present as well (images D-E). The base (distal end) is characterized by non-continuous lateral marginal retouch, which may have facilitated hafting. Again, it was not possible to determine the extent to which the haft covered the tool face. Overall, the data support the use of this piece as a soft material scraper.

In summary, use-wear traces on all four pieces are consistent with the function implied by classification in the 'scraper' typological category. Use-wear evidence is similar for all four tools in the sample, with a clear distinction between that of the 'base' and 'bit' ends. Use-wear on the bits is primarily comprised of edge rounding and longitudinal striations, which is consistent with use as scrapers on soft worked materials. Bases typically have lateral and/or crisscrossed striations with some areas of surface abrasion suggesting that they were hafted in sockets, perhaps in a similar fashion to that observed by Gallagher (1977) in modern stone tool hide-scrapers of south central Ethiopia. Notably, Gallagher (1977: 411) also observed that an average of four scrapers are required to scrape one large hide, so these four scrapers could represent a single tool-using event. However, none of these pieces appear to have been completely exhausted at the point of discard and each probably could have been used (and retouched) for several more sessions unless the haft socket was so large as to cover the remaining volume of the piece.

Technological organization. The assemblage of lithic artifacts recovered from H4 indicates that knappers were primarily focused on retouched tool use and maintenance. Heavily retouched tools and secondary debitage associated with resharpening of those tools dominate the assemblage. Cores are typically small and fragmentary indicating they were used to exhaustion, however, the blanks for tools, and thus the cores, must have started out at large sizes. Only the end-stages of this sequence were recovered in this horizon. Two sources of data support this conclusion.

First, no large or unmodified tool blanks were recovered from H4, however, the arc of ventral face ripples on many of the larger tools indicates that they were originally much larger.

For example, figure 4.59b shows the ventral faces of four convex end scrapers, two of which (numbers 1 and 4) have the bit-end created on the proximal end of the piece meaning that the platform and proximal portion of the piece must have been removed during resharpening events. Both of these still have very wide ripples near the bit indicating that the remaining artifact is far from the original bulb. Notably, the other two scrapers (numbers 2 and 3) are both smaller overall but retain their original platforms and may provide examples of the minimum usable size for this formal type. It is worth pointing out that these four pieces were all discarded at a similar size, regardless of the size of their initial flake blank.

Second, over 18% of the total assemblage is composed of secondary retouch flakes. These flakes are significantly shorter, narrower, and thinner than the primary flaking debitage and have diffuse bulbs of percussion with lipped platforms and very low EPAs. A high ratio of retouch flakes to formal tools (7.29:1) provides further support for the intense curation of formal tools. Similar to H5, knappers appear to have produced tool blanks as needed and retouched them intensively over long and complex use-lives.

Horizon 2 (level 22)

The H2 lithic assemblage totaled 799 artifacts, including 790 obsidian and 9 lava. No quartz or chert pieces were recovered. The analysis presented here includes only obsidian artifacts collected during the 2013 field season. This ensures that only a single analyst (myself) classified and measured all the artifacts in this dissertation, meaning that any typological or size comparison made among assemblages is based on a single uniform methodology. However, this limits the sample size for H2 and so it may not provide a fully representative sample of the assemble composition in this level. The typological composition of the H2 assemblage is presented in table 4.3. Together, primary and secondary debitage categories make up 97.47%, cores contribute 0.63%, and combined tools total 1.9%, with 0.9% informal unshaped and 1.0% formal retouched types.

The H2 assemblage appears to be more fragmented than either H4 or H5. Over 42.5% of all recovered pieces were identified as MFFs, compared to 30.0% for H4 and 31.4% for H5. However, as mentioned earlier, the level 22 soils were extremely dense and required picks and hammers to excavate. As a result, more artifacts were broken during excavation than for other levels. Great care was taken to bag broken artifacts individually while digging and to refit freshly broken ones, or at least bag multiple broken fragments as a single piece. Any fragments bearing clear modern damage (n=134) were counted, but excluded from analysis. Ultimately, the same compacted soils that forced heavy-duty excavation methods are likely responsible for the high rate of in-situ broken flakes. As noted above, some pieces were broken in-situ and may have been intrinsically prone to fragmentation due to weakening by bands of trapped gas bubbles.

Primary debitage. Platforms for whole flakes and PFFs are primarily plain or faceted, and small numbers of point and dihedral also present (table 4.8). Dorsal proximal faceting is present on only 2.2% of H2 platforms (much less than H4 or H5) and indicates very little edge abrasion to prepare platforms during flaking. Finally, no blade-like pieces were recovered.

Table 4.8. Percentages of primary debitage platform types identified for each horizon at Marmonet Drift

Platform type	H5	H4	H2
Plain %	40.3	41.9	46.1
Faceted %	42.3	39.9	47.1
Point %	17.4	18.2	6.7
DPF %	10.8	10.6	2.2

Primary debitage platforms in H2 are, on average, wider and thicker than those of H5 and H4. Flake size dimensions are also largest in H2, with larger means in each successively lower and older horizon. A one-way analysis of variance (ANOVA) shows that H5 has significantly smaller sizes in four of six platform and flake measurements compared to H4 and H2 (table 4.9). Differences in mean EPA among horizons are negligible. Ratios of platform width/flake width (PW/W) and platform thickness/flake thickness (PT/Th) are also progressively smaller for younger horizons meaning that flake widths are proportionally narrower, not just absolutely smaller, in the younger MD assemblages.

Table 4.9. Mean (with ANOVA) platform and flake size dimensions, and shape ratios for primary debitage at Marmonet Drift

	Analyzed Archaeological Horizons			
Attribute	*H5 (n=225)*	*H4 (n=84)*	*H2 (n=81)*	*F-statistic*
EPA (°)	81_l	79_l	80_l	0.88
PW (mm)	7.3_l	10.5_m	13.5_m	29.07***
PT (mm)	2.3_l	3.1_l	3.9_m	17.64***
L[a] (mm)	16.6_l	24.7_m	25.1_m	11.27***
W (mm)	15.8_l	19.9_m	20.3_m	13.51***
Th (mm)	3.6_l	4.5_m	5.2_n	18.38***
PT/PW	0.32	0.30	0.29	n/a
PW/W	0.46	0.53	0.67	n/a
PT/Th	0.64	0.69	0.75	n/a
W/L	0.95	0.81	0.81	n/a
W/Th	4.39	4.42	3.90	n/a
L/Th	4.61	5.49	4.83	n/a

[a]Sample sizes for length are 104 for H5, 37 for H4 and 43 for H2.

***p<.001

Means in the same row that do not share subscripts differ at p<0.008 in the Bonferonni comparison.

The largest piece recovered in the H2 assemblage (#3679) is a proximal flake fragment (PFF) that measured 99.7 mm long and 42.5 mm wide. Length and width are not normally recorded for PFFs because they are incomplete, but the overall size was so large, relative to the rest of the assemblage, that it seemed warranted. Because these are minimum measurements the piece was likely somewhat larger and came from a core with at least one dimension >100 mm in size. Another PFF (#3695, utilized) measured 55.6 x 46.0 x 13.9 mm with a 40.5 x 13.9 mm platform. This flake body, and platform especially, indicate a similarly large core. These large flakes provide a minimum estimate of the maximum size of cores from which flakes were struck.

Cores. Five cores were recovered in H2, forming only 0.6% of the assemblage. One is classified as informal and the other four (unmeasured) are simply flaked fragments without any striking platforms. While only the one informal core was measured for H2, it is very similar in size to the average of cores in H4 and H5 (table 4.10). Unfortunately, the low number and uninformative nature of their morphology preclude much useful data regarding techniques of flake production. However, the size of primary debitage indicates that large flakes were being produced from large cores at some point in this horizon. Whether those flakes were made off-site and brought to the site or a few large cores were reduced down to small chunks on-site is uncertain.

Table 4.10. Core size dimensions, weights, and standard deviation and coefficient of variation statistics for all horizons from Marmonet Drift

	H5 (n=17)					***H4 (n=12)***					***H4 (n=1)***				
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
L	35.2	9.4	26.7	17.2	49.5	32.4	8.1	25.0	19.2	46.0	33.0	-	-	-	-
W	30.9	10.9	35.3	11.4	59.4	31.4	11.3	36.0	11.7	52.9	35.8	-	-	-	-
Th	13.2	5.3	40.2	7.7	25.4	12.9	5.7	44.2	6.4	25.2	15.2	-	-	-	-
Wt[a]	9.5	10.8	113.7	0.2	34.9	8.6	12.2	141.9	0.2	54.2	3.6	3.5	97.2	0.1	9.1

[a] Sample sizes for weight include fragmented cores. They are 30 for H5, 26 for H4, and 5 for H2.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

Secondary debitage. Secondary debitage in H2 includes 56 retouch flakes, two tool edge fragments and one burin spall. Retouch flakes represent 7.1% of the total assemblage, less than half of that in H4 or H5. Notably, 48.5% of these retain lipped platforms, similar to H5 and H4, indicating that soft hammers were likely used for flaking at some point (table 4.11). Edge removal, casual trim and scraper trim subtypes occur in small numbers, but no bulb or biface trim types were recovered. Overall, frequencies of edge removal and scraper trim flakes increase in each successively lower horizon, while biface trim flakes decrease.

Table 4.11. Percentages of retouch subtypes identified for each horizon at Marmonet Drift

Retouch sub-type %	H5 (n=337)	H4 (n=188)	H2 (n=32)
General retouch	67.6	66.0	62.5
Edge removal	6.4	10.6	25.0
Bulb trim	2.6	4.3	0.0
Biface trim	23.4	16.0	0.0
Scraper trim	0.0	3.2	6.3
Total	*100.0*	*100.0*	*100.0*

Measured platforms for H2 retouch flakes are, on average, slightly larger than those of H4 and H5 while the flakes themselves are short, wide and thick (table 4.12). The mean EPA is essentially the same for all three horizons. The primary differences among MD horizons for secondary debitage then are sub-type composition and flake size dimensions. Together with the presence of lipped platforms, these data suggest two things; first, that tool retouch was carried out on a relatively smaller scale in H2 compared to H4 and H5, and second, that the retouch technique (invasive with soft-hammer) was similar over time but the tools changed slightly.

Table 4.12. Mean (with ANOVA) platform and flake size dimensions, and shape ratios for secondary debitage at Marmonet Drift

	Analyzed Archaeological Horizons			
Attribute	*H5 (n=247)*	*H4 (n=106)*	*H2 (n=25)*	*F-statistic*
EPA (°)	56_{l}	52_{l}	56_{l}	3.82
PW (mm)	6.3_{m}	9.3_{l}	9.6_{l}	15.31***
PT (mm)	2.0_{lm}	2.5_{m}	3.2_{mn}	6.31***
L[a] (mm)	13.6_{l}	15.6_{l}	13.2_{l}	2.92
W (mm)	12.0_{m}	14.4_{l}	14.2_{l}	7.00***
Th (mm)	2.4_{lm}	2.9_{m}	3.3_{mn}	8.12***
PT/PW	0.32	0.27	0.33	n/a
PW/W	0.53	0.65	0.68	n/a
PT/Th	0.83	0.86	0.97	n/a
W/L	0.88	0.92	1.08	n/a
W/Th	5.00	4.97	4.30	n/a
L/Th	5.67	5.38	4.00	n/a

[a]Sample sizes for length are 192 for H5, 80 for H4 and 21 for H2.

***p<.001

Means in the same row that do not share subscripts differ at p<0.008 in the Bonferonni comparison.

Informal unshaped tools. The unshaped tool category contains casually retouched pieces and makes up 0.89% (n=7) of the analyzed sample from H2. This is proportionally more than H5 (0.61%) but less than H4 (1.45%).

Formal shaped tools. Formal tools are rare in H2, forming only 1.01% (n=8) of the analyzed sample. The Simpson's Index of Diversity value for this assemblage is 0.607, which is low relative to the other two excavated horizons. Scrapers are the dominant type (n=5), and typically have a single steep retouched edge on a flake's distal end. Two burins and one bec form the rest of this category. The bec is significant because of its size; it measures 87.1 mm in length and indicates (again) that knappers were exploiting large cores at earlier stages in the reduction sequence. It is worth noting that previous excavations have also recovered unifacial ovate points (figure 4.64), however, none were recovered in 2013.

Technological organization. The H2 assemblage suggests a more ephemeral occupation than H4 or H5. Cores are rare, and when recovered, are small and fragmentary. Only one retained a striking platform and, though it measures 33.0 x 35.8 x 15.2 mm, is still considerably smaller than the largest flakes and flake fragments recovered in H2. The presence of those large flakes indicates that knappers did initially have access to large blocks, however, cores appear to have been exhaustively flaked to small sizes and/or were broken in the last stages of reduction.

Formally retouched tools and secondary retouch flakes are also relatively rare compared to H4 or H5 (50% or less), suggesting a less intense occupation at this time. Formally retouched tools may also be rare because expediently retouched tools filled their functional niches. On the other hand, it is also possible that larger retouched tools were used and carried away in a heavily curated manner, similar to that proposed for the cores. Together, these features suggest a mobile and opportunistic site use pattern where people did not settle in one place for very long.

Comparison of Technological Organization Strategies

The purpose of this chapter was to describe the geography, stratigraphy, excavation history and lithic technology of three MSA horizons at the Marmonet Drift site. Obsidian artifact assemblages from horizons 2, 4 and 5 were analyzed individually and collectively with quantitative (morphometrics) and qualitative (typological classification and use-wear) methods. Overall, the three assemblages reflect a similar technological organization strategy of moderate to intense curation of large retouched flake tools. Despite the close proximity of the site to many raw material sources, conservation appears to have been an important factor in tool production and use for all levels. Cores are generally rare and exhausted (small and fragmentary) while tools were intensively curated as part of a mobile technological system. However, within this overall similarity there are two main features that distinguish the horizons from each other.

First, there is a measurable reduction in artifact size over time (from old to young) for both debitage and formal tools. The most direct evidence for size reduction is found in the decrease of average weight per artifact from 0.99 g in H2 to 0.77 g in H4 to 0.58 g in H5. Further evidence is found in artifact dimensions; both primary (table 4.9) and secondary (table 4.12) debitage become progressively smaller in younger horizons. Formal tool size also decreases for types present in all three horizons, such as scrapers and burins (table 4.13). Points in H5 are large relative to the other tool types, but are highly standardized in terms of size (CVs for *L*, *W*, and *Th* are all below 30), especially considering the large sample size. In short, the decreased size of artifacts over time reflects an increased abundance of small retouch flakes, smaller primary debitage, and smaller tools.

Table 4.13. Platform and flake size dimensions, and standard deviation and coefficient of variation statistics for the most common formal tool types in each horizon at MD

	Type	*Attribute*	*Mean*	*SD*	*CV*	*Minimum*	*Maximum*
Horizon 5 (levels 5 and 6)	**Burins (n=26)**	*EPA*[a]	83	21	25.3	62	108
		PW[a]	10.6	8.9	84.0	0.1	21.8
		PT[a]	2.7	2.8	103.7	0.1	6.6
		L	18.0	8.7	48.3	7.5	46.0
		W	13.9	6.6	47.5	2.6	26.6
		Th	5.1	2.6	51.0	2.3	13.2
	Points (n=18)	*EPA*[b]	91	20	22.0	78	114
		PW[b]	16.1	2.5	15.5	13.5	18.5
		PT[b]	5.9	1.5	25.4	4.8	7.6
		L	37.7	10.6	28.1	23.9	68.9
		W	26.2	6.5	24.8	17.2	45.6
		Th	7.3	2.0	25.6	4.8	12.0
	Knives (n=12)	*EPA*[c]	83	4	4.8	79	87
		PW[c]	9.6	1.8	18.8	7.6	10.8
		PT[c]	2.8	1.4	50.0	1.2	3.8
		L	37.1	6.7	18.1	20.5	42.8
		W	27.2	7.2	26.5	17.2	43.9
		Th	6.6	2.3	34.8	2.7	10.9
	Scrapers (n=6)	*EPA*[d]	97	-	-	-	-
		PW[d]	22.8	-	-	-	-
		PT[d]	7.6	-	-	-	-
		L	20.7	9.1	44.0	7.2	35.0
		W	19.0	10.5	55.3	7.9	34.6
		Th	8.2	2.3	28.1	4.8	12.0
H4 (levels 10 and 11)	*Type*	*Attribute*	*Mean*	*SD*	*CV*	*Minimum*	*Maximum*
	Burins (n=29)	*EPA*[e]	107	-	-	-	-
		PW[e]	10.1	-	-	-	-
		PT[e]	1.6	-	-	-	-
		L	25.2	10.2	40.5	12.5	49.1
		W	19.1	9.9	51.8	5.3	48.1
		Th	5.5	2.6	47.3	2.3	11.8

Table 4.13 continued. Platform and flake size dimensions, and standard deviation and coefficient of variation statistics for the most common formal tool types in each horizon

	Type	*Attribute*	*Mean*	*SD*	*CV*	*Minimum*	*Maximum*
Horizon 4 (levels 10 and 11)	**Knives (n=16)**	*EPA*[f]	82	-	-	-	-
		PW[f]	7.8	-	-	-	-
		PT[f]	3.7	-	-	-	-
		L	33.6	14.3	42.6	13.7	68.5
		W	23.2	3.6	15.5	15.1	28.1
		Th	5.5	1.6	29.1	3.0	9.8
	Scrapers (n=15)	*EPA*[g]	78	18	23.1	49	101
		PW[g]	13.1	8.3	63.4	1.8	24.3
		PT[g]	7.2	6.4	88.8	0.8	18.6
		L	32.9	11.4	34.7	15.4	47.9
		W	25.5	8.3	32.5	12.3	39.6
		Th	9.1	3.7	40.7	3.5	18.6
Horizon 2 (level 22)	**Scrapers (n=5)**	*EPA*[h]	82	5	6.1	77	86
		PW[h]	16.7	6.1	36.5	10.9	23.0
		PT[h]	7.4	3.3	44.6	3.9	10.4
		L	35.4	15.0	42.4	16.5	56.5
		W	30.4	8.5	28.0	22.3	43.5
		Th	9.7	3.8	39.2	5.4	14.4
	Burins (n=2)	*EPA*[i]	-	-	-	-	-
		PW[i]	-	-	-	-	-
		PT[i]	-	-	-	-	-
		L	30.6	4.9	16.0	27.1	34.0
		W	33.8	1.9	5.6	32.5	35.2
		Th	8.5	1.5	17.6	7.5	9.6

[a]Sample size for platforms on H5 burins is 4

[b]Sample size for platforms on H5 points is 3

[c]Sample size for platforms on H5 knives is 3

[d]Sample size for platforms on H5 scrapers is 1

[e]Sample size for platforms on H4 burins is 1

[f]Sample size for platforms on H4 knives is 1

[g]Sample size for platforms on H4 scrapers is 7

[h]Sample size for platforms on H2 scrapers is 3

[i]Sample size for platforms on H2 burins is 0

Second, there is a clear difference in the typological composition of the two larger and younger horizons, H4 and H5. Horizon 2 is excluded from this discussion because the formal tool count is so low, forming only 1% of the assemblage. Both H4 and H5 are dominated by burins and have similar numbers of invasively flaked shallow-edged knives, however, they are distinguished from each other by the differing numbers of points and scrapers, and by the morphologies of knives. Remarkably, only a single point was recovered in H4 (compared to 18 for H5) while knives and scrapers were identified in greater numbers, despite a smaller assemblage size. Expedient, unshaped tools are also more numerous in H4.

The H5 assemblage is notable for its unique points, most of which are unifacial with wide, rounded tips and deliberately thinned bulbs of percussion to facilitate hafting. Use-wear analysis on a sample of ten points (of a total of 18 recovered) confirms that seven were hafted, and that six were used for piercing, probably as projectiles. The other 40% appear to have been used as hafted knives for slicing/cutting tasks. The morphological features of these points make this industry stylistically distinct from other recognized African MSA industries and raise the possibility of a unique cultural identity at MD and Kenya’s central Rift Valley at large. Systematic comparisons with other MSA sites with equal access to obsidian in this region, namely at Prolonged Drift and Prospect Farm (Anthony, 1978; Merrick, 1975) is required to determine if this point assemblage is stylistically unique. In the four obsidian-dominated assemblages from Prospect Farm analyzed by Anthony (1978) and three from Prolonged Drift analyzed by Merrick (1975) this point style is rare.

The four oval convex end scrapers in H4 also have no obvious correlates in the Prospect Farm and Prolonged Drift assemblages. Anthony illustrates flat oval discoids that are thin and (sometimes) bifacially flaked from the uppermost MSA horizon, in an assemblage that is otherwise MSA in typology and technology (Merrick, 1975). They do not resemble the three elongated oval convex end and side scrapers from MD H4. The Helwan backed knives from MD H4 also have no obvious correlates at either site. These unique features of the H4 and H5 lithic assemblages demonstrate that there is a substantial amount of techno-typological diversity in the later MSA of Kenya after 100 ka. These assemblages differ enough from each other to warrant naming two new MSA lithic industries.

Despite the overall similarity in technological organization between H4 and H5 the difference in typological composition shows that people were using the site in different ways. The dominance of points, knives, and retouch debitage in H5 suggests that it was used as a retooling camp for hunters to repair or replace point-tipped spears and knives while the higher numbers of scrapers, knives, and expedient tools in H4 suggest that it was used more for processing resources. Clearly, this site was an important place on the landscape that was used repeatedly, but in different ways, over tens of thousands of years.

Figures

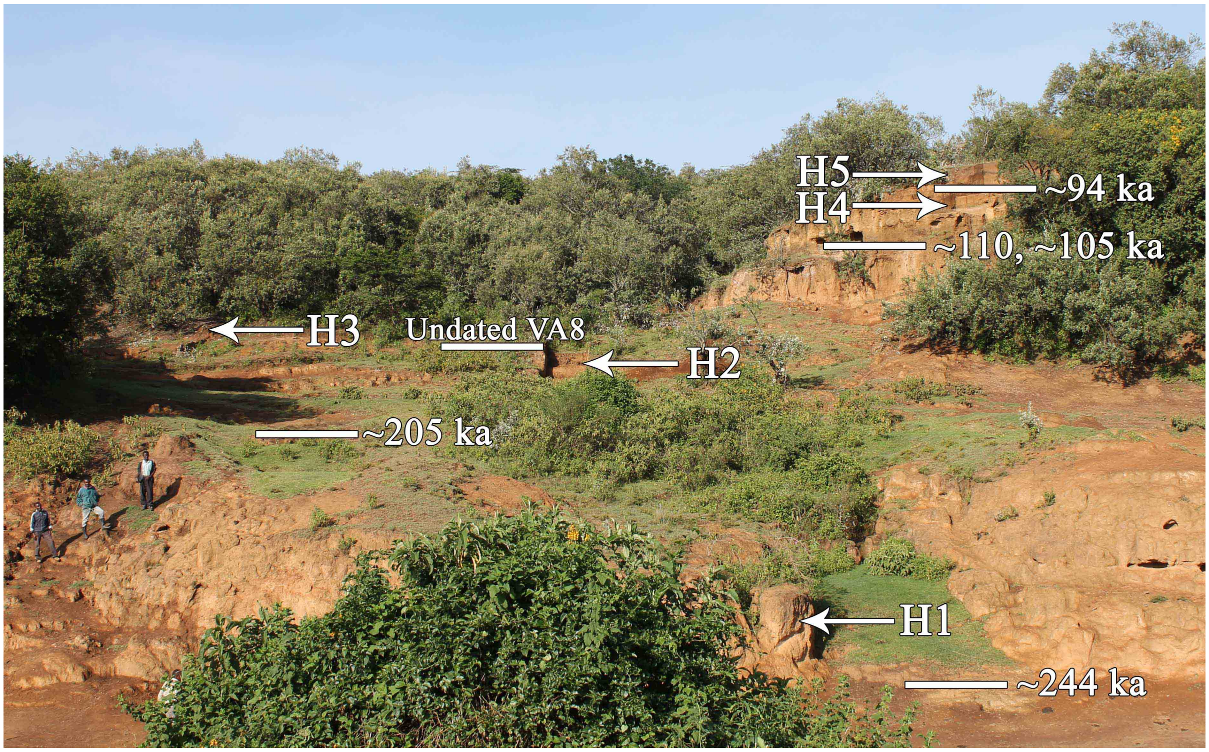


Figure 4.1. Photo of the Marmonet Drift site during 2013 excavation with archaeological horizons (H#) and dated volcanic ashes labeled with their estimated ages. H6 is in the woods behind the tree line and is not visible. Three field assistants are in the bottom left for scale.

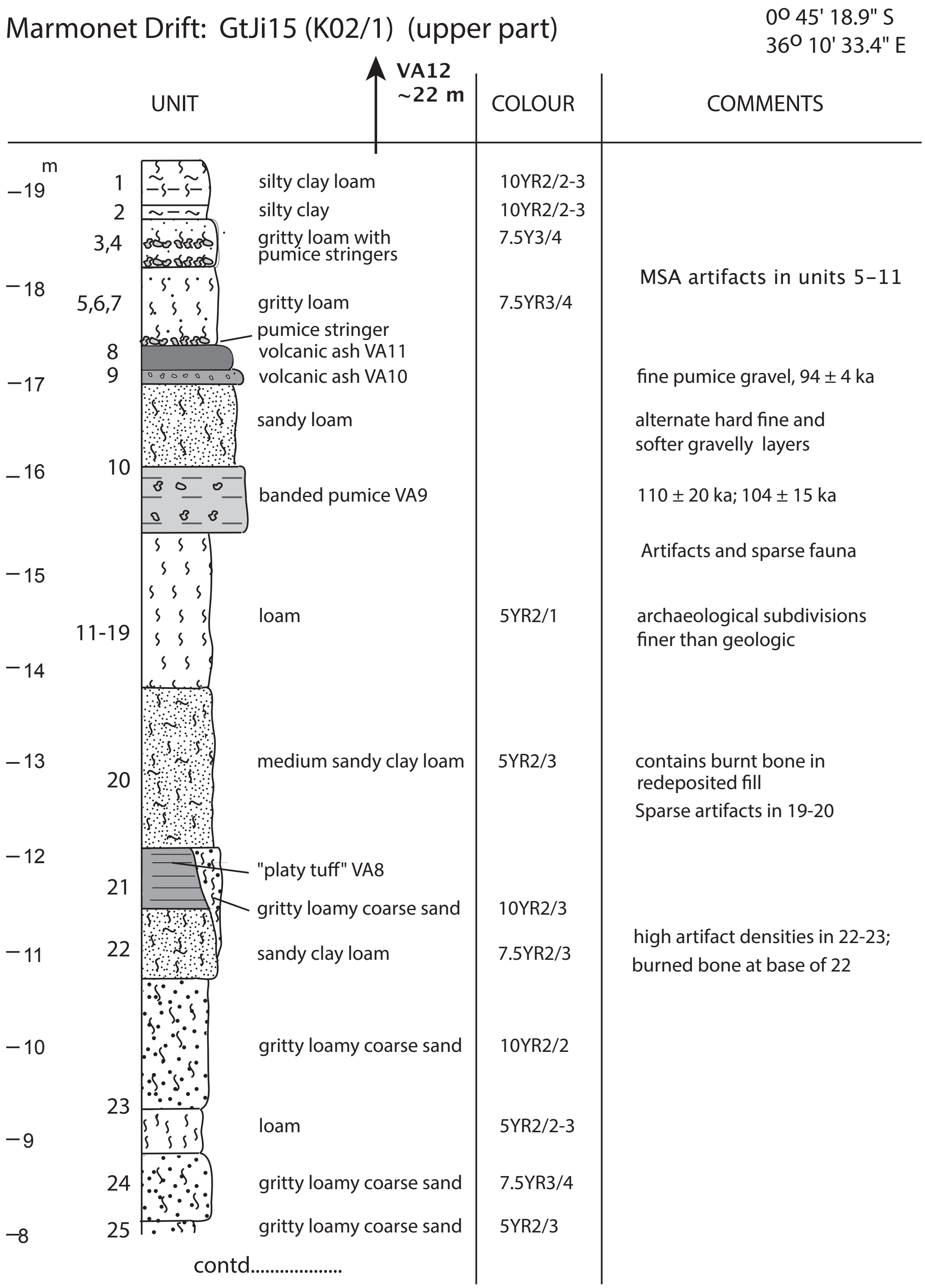


Figure 4.2a. Stratigraphic section drawing of the upper portion of Marmonet Drift. This does not include levels from trenches 5 and 6 excavated in 2013. Drawing courtesy of Martin Williams.

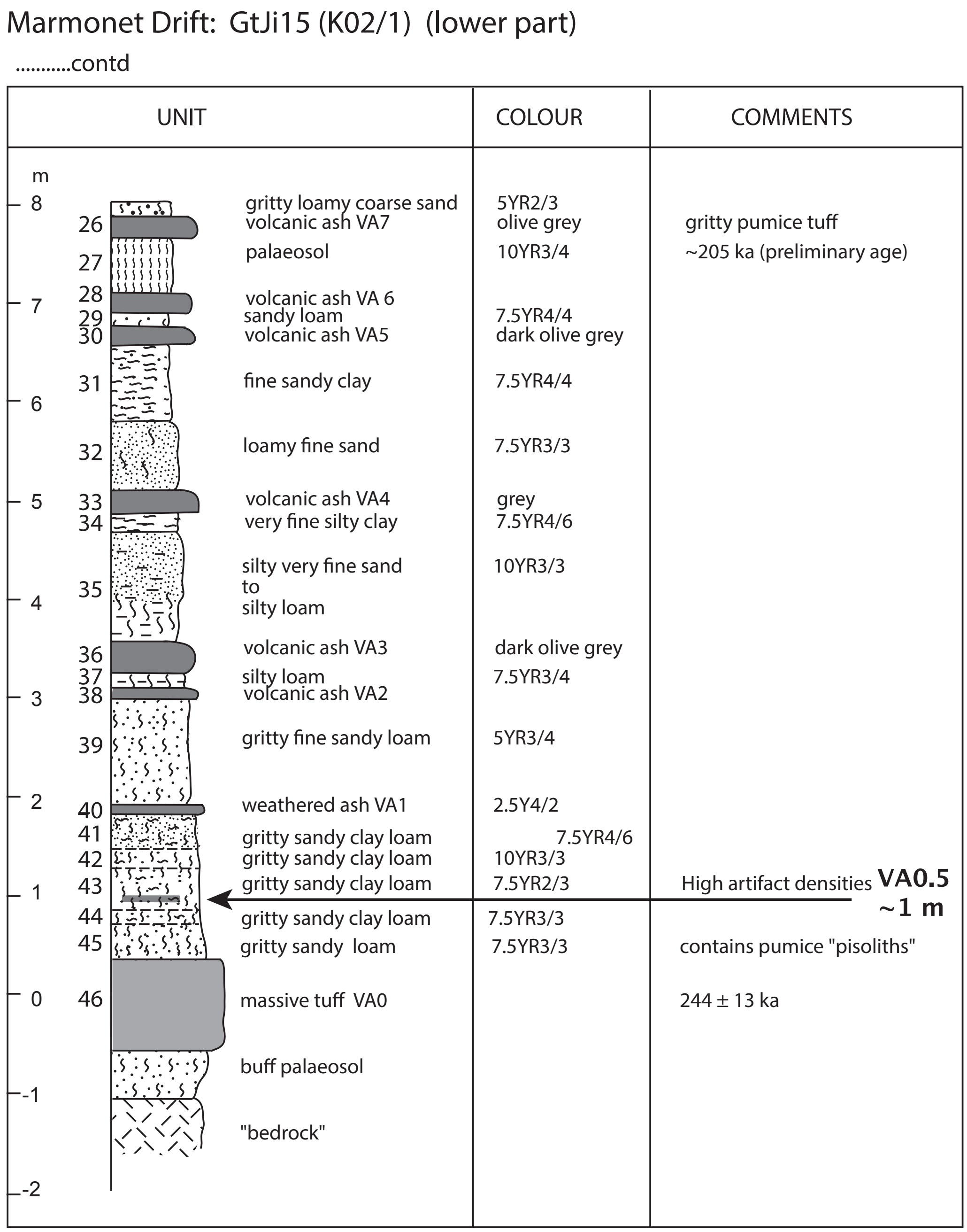


Figure 4.2b. Stratigraphic section drawing of the lower portion of Marmonet Drift. Drawing courtesy of Martin Williams.

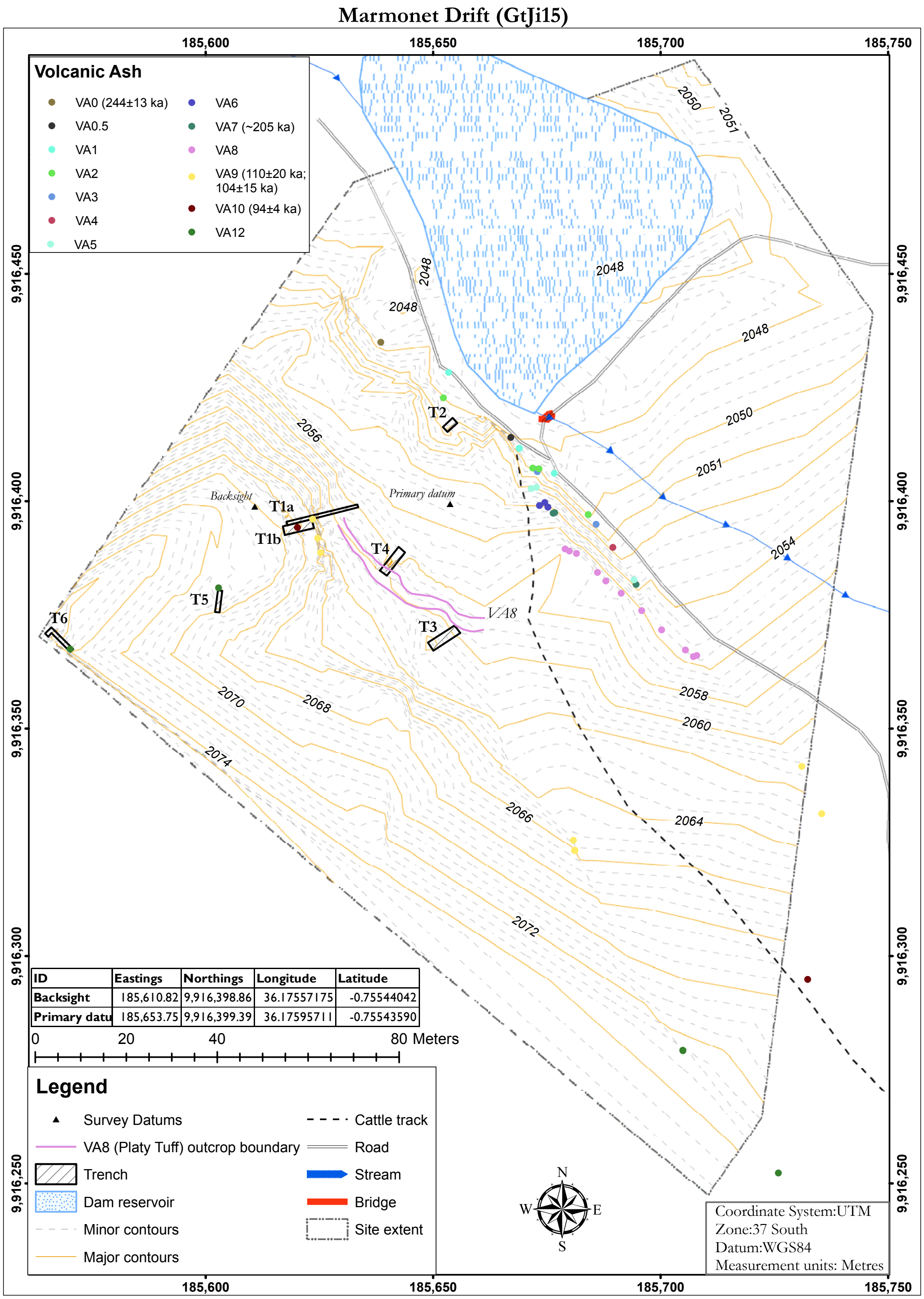


Figure 4.3. Topographic map of the Marmonet Drift site showing the locations of all six excavated trenches (T1 – T6). The colored dots indicate volcanic ashes (see map key for ID).

Figure 4.4. Photo of trench 1a after excavation in 2001. H4 and H5 are visible at the top of the trench.

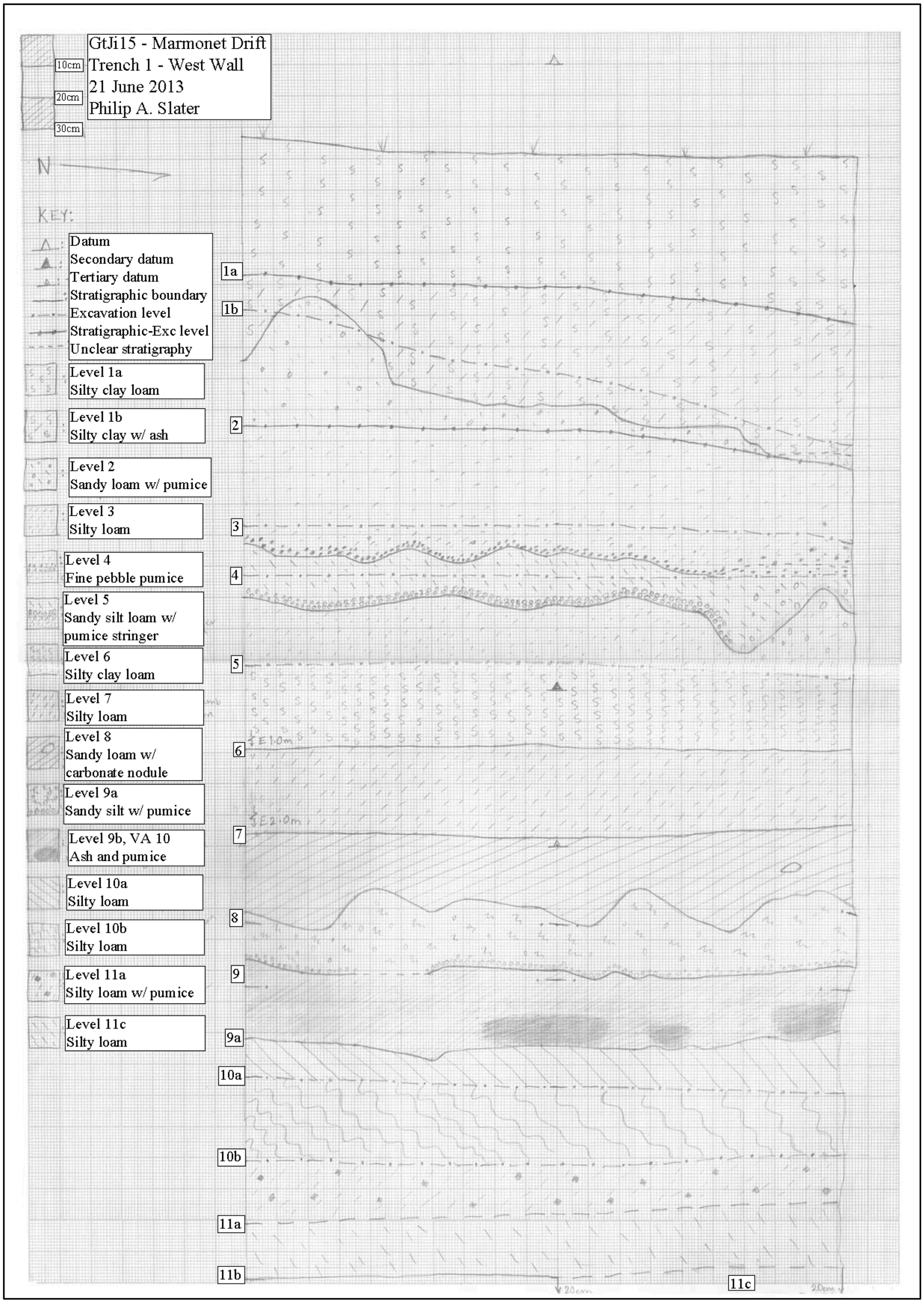


Figure 4.5. Stratigraphic profile drawing of Trench 1b after the 2013 excavation.

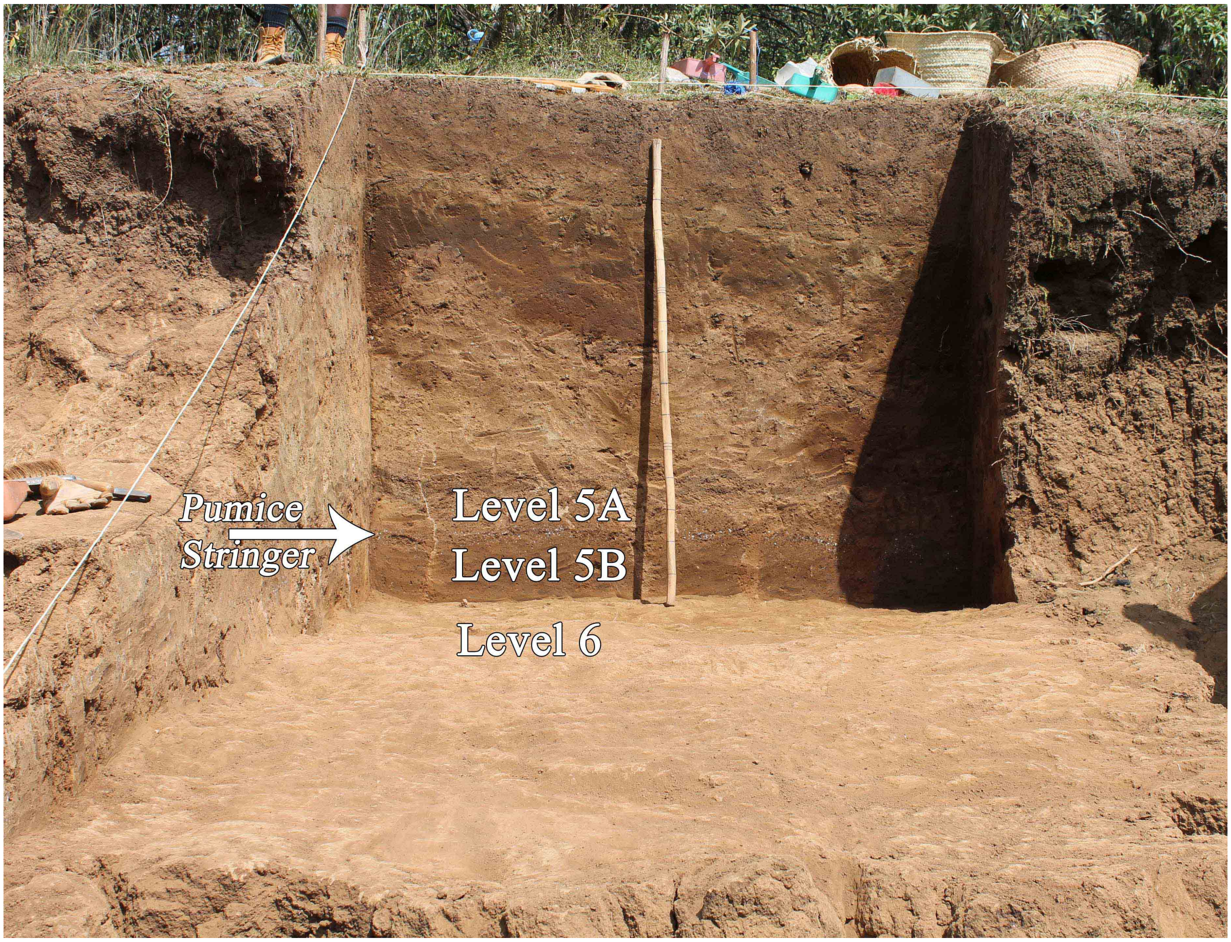


Figure 4.6. Pumice ‘stringer’ used to subdivide level 5 into A and B. Together, levels 5 and 6 make up H5.

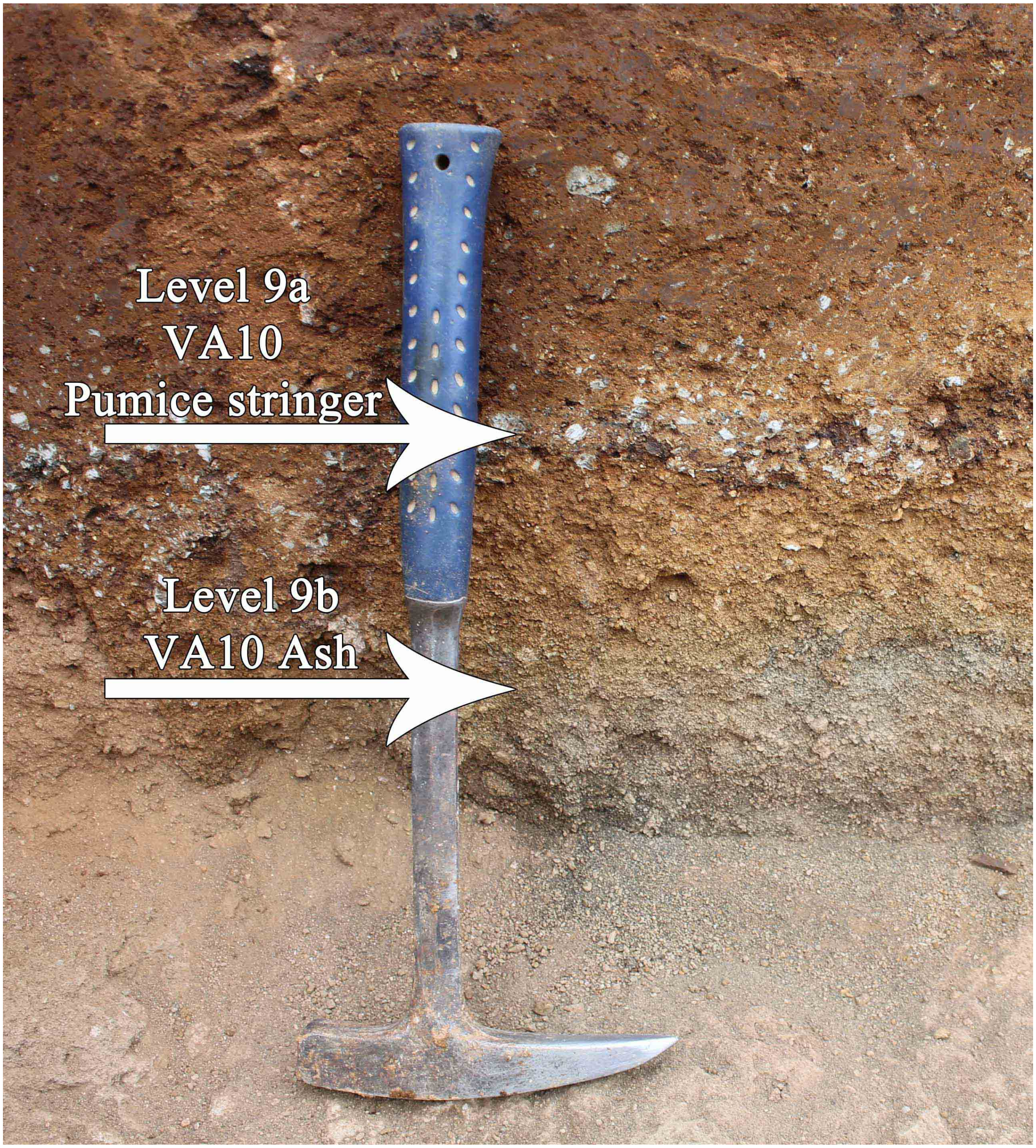


Figure 4.7. VA 10 with pumice stringer and ash, dated to 94 ± 4 ka.

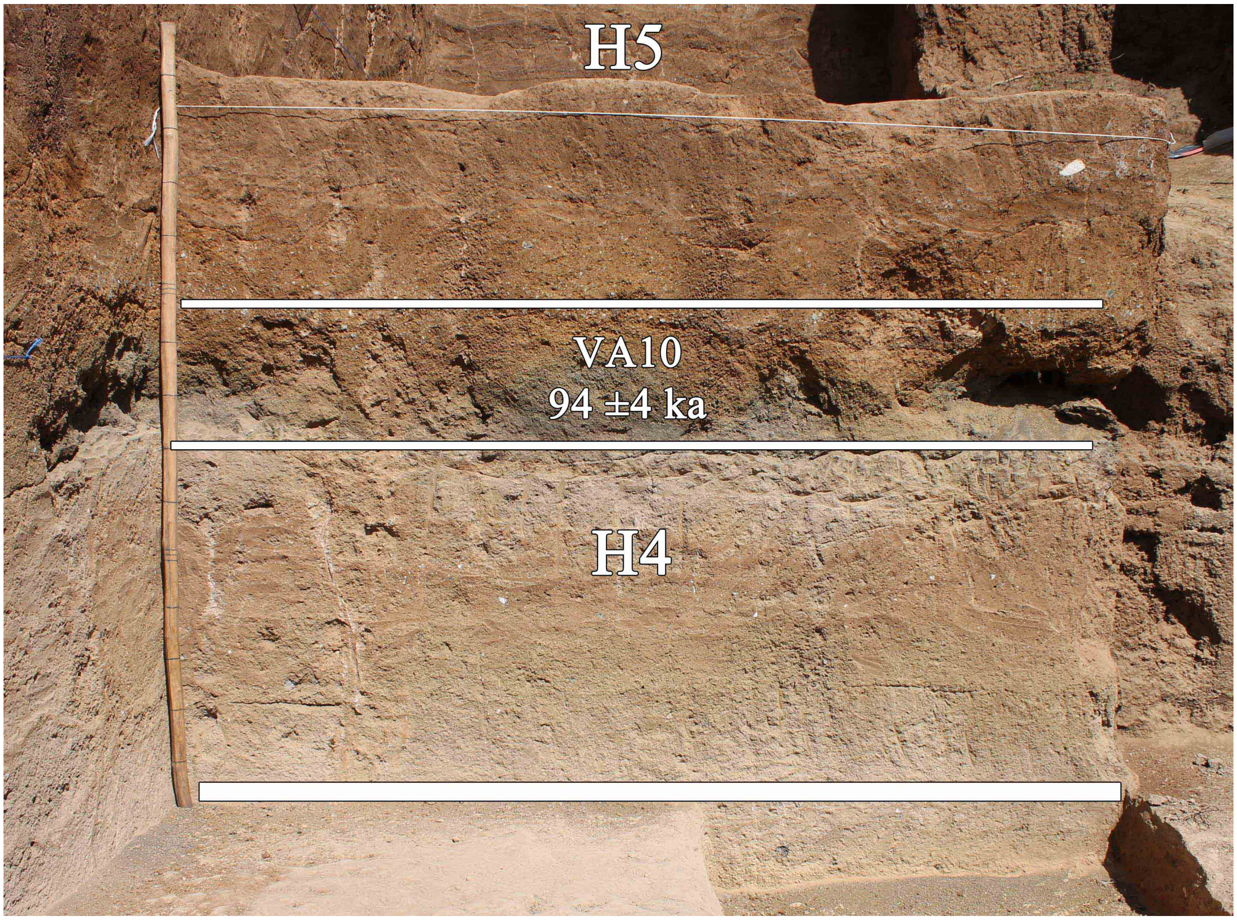


Figure 4.8. Image of trench 1b stratigraphy. H5 is visible above the ledge against the back wall with VA 10 and H4 below. Height of stick is 1.5 m and is marked at 10 cm intervals.

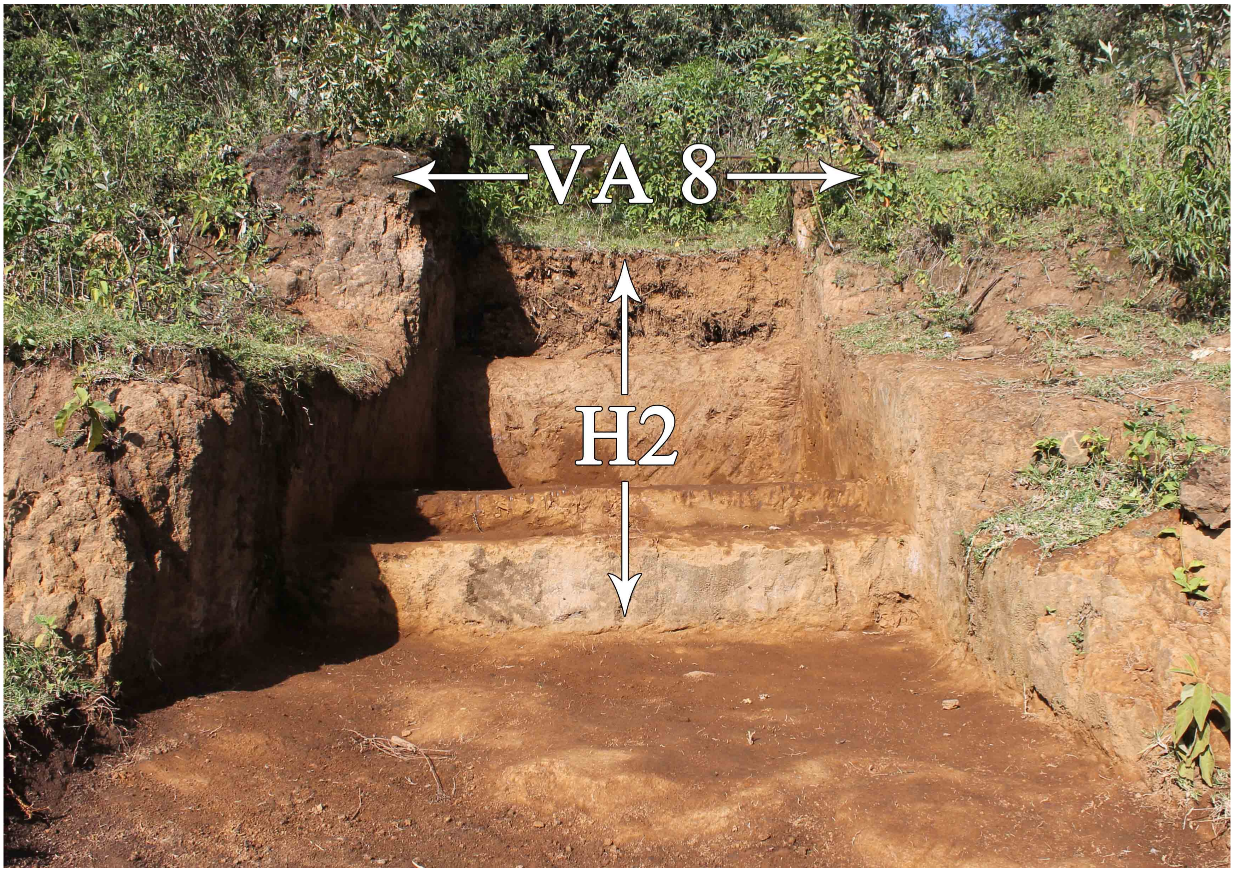


Figure 4.9. Image of trench 4 from 2013 excavation. H2 is visible against the back wall with the undated VA 8 platy tuff stratified above.

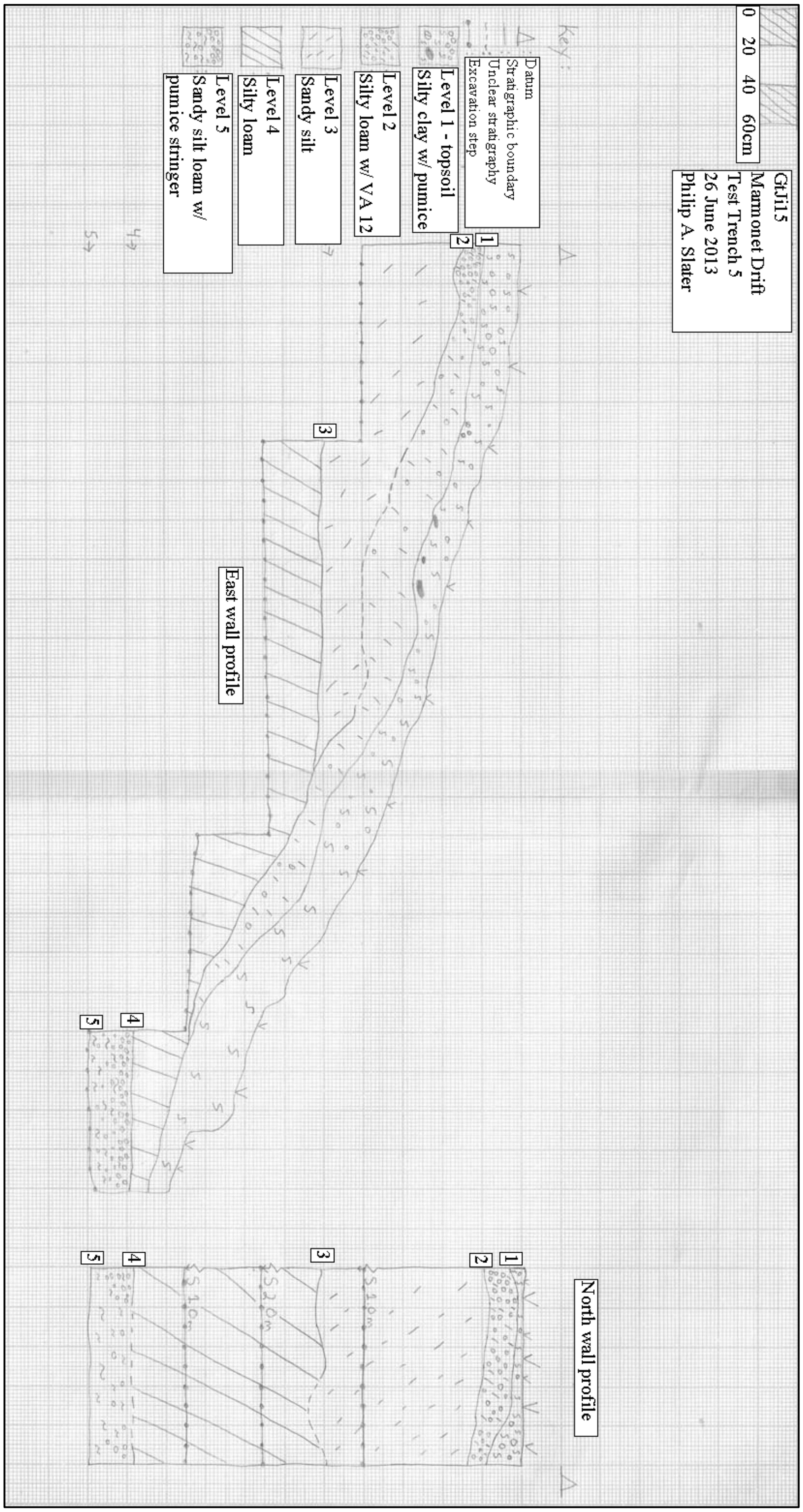


Figure 4.10. Stratigraphic profile drawing of Trench 5 after the 2013 excavation.

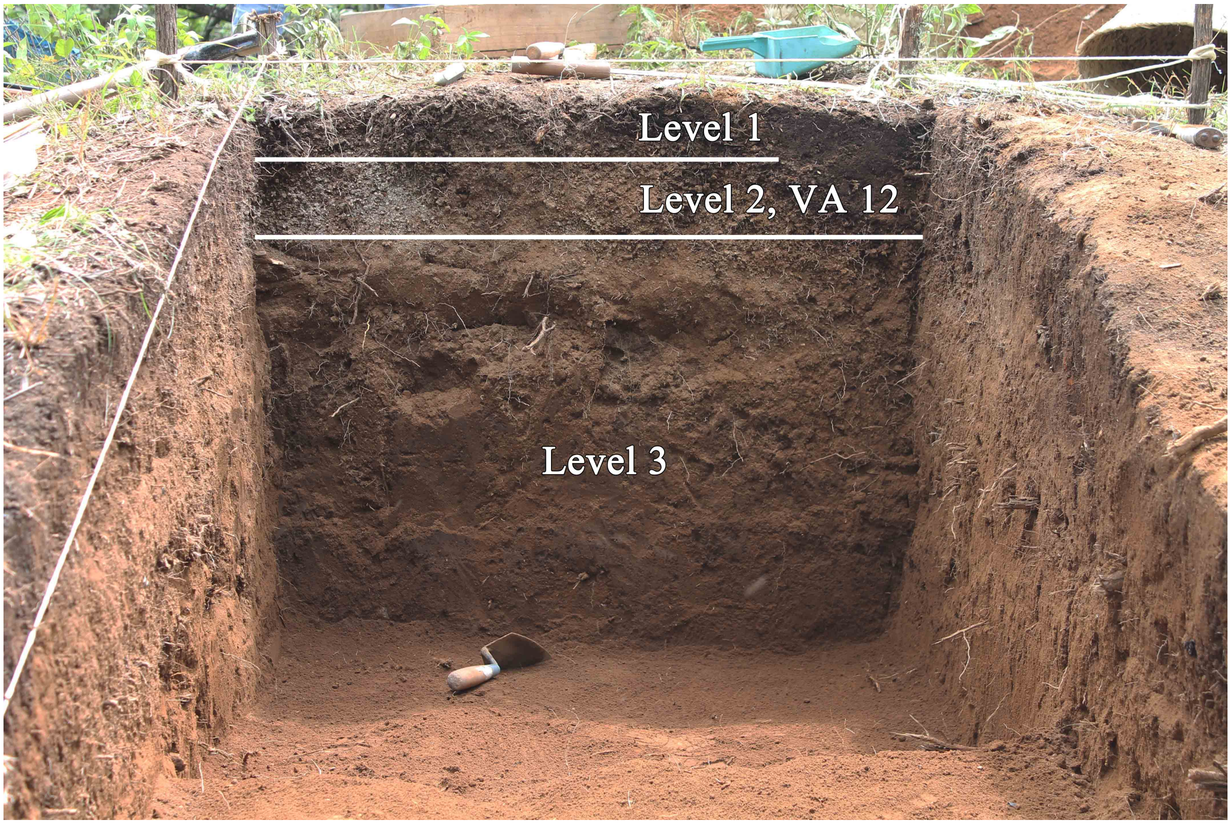


Figure 4.11. Photo of back wall of first step in trench 5. VA 12 is visible in the left side of level 2. The base of this trench connects with trench 1 and links them into a single sequence.

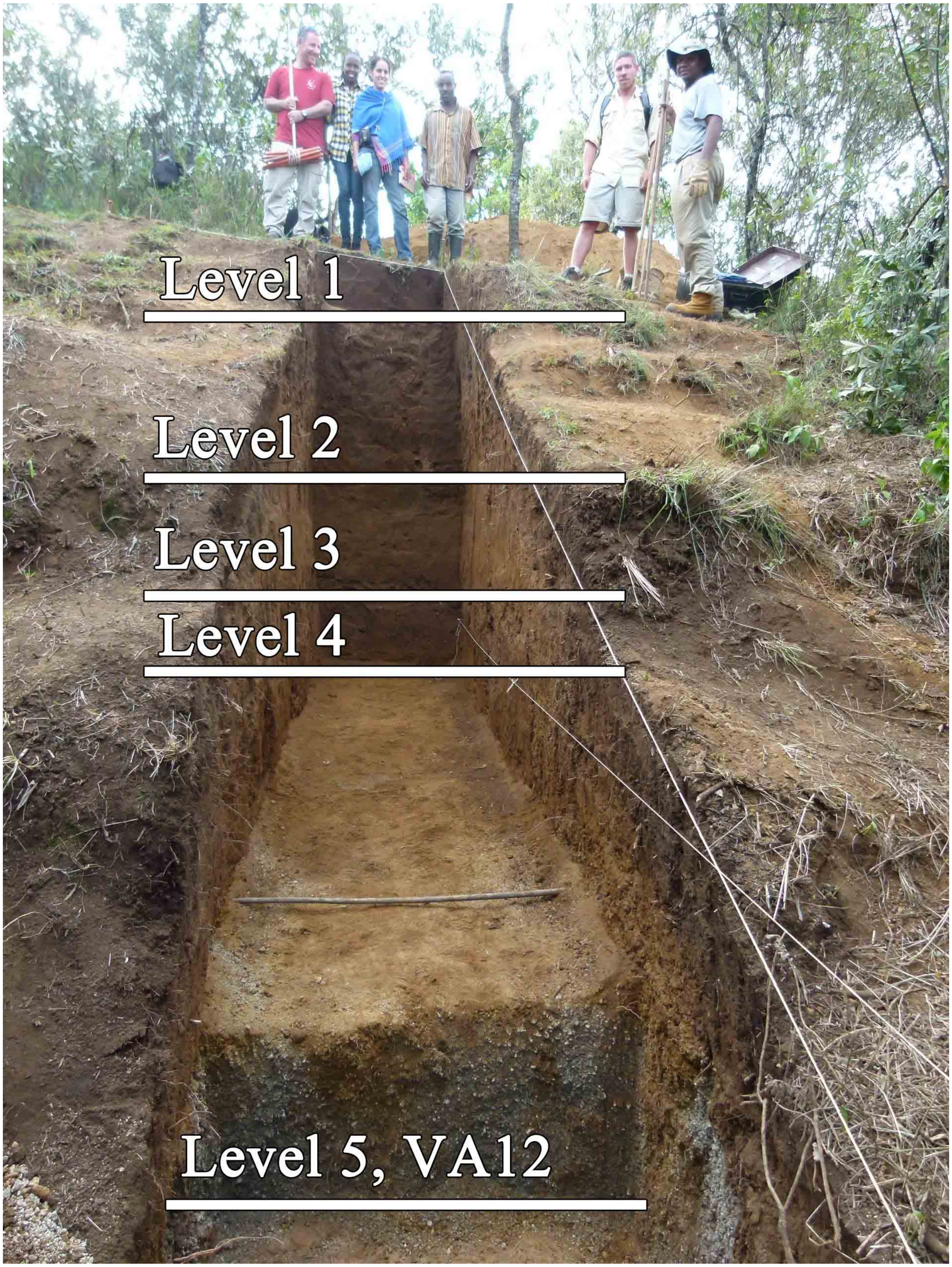


Figure 4.12. Trench 6 from 2013 excavation showing all five horizons, including VA 12 at the base. The presence of VA 12 link this sequence with trench 5 and 1 into a single sequence.

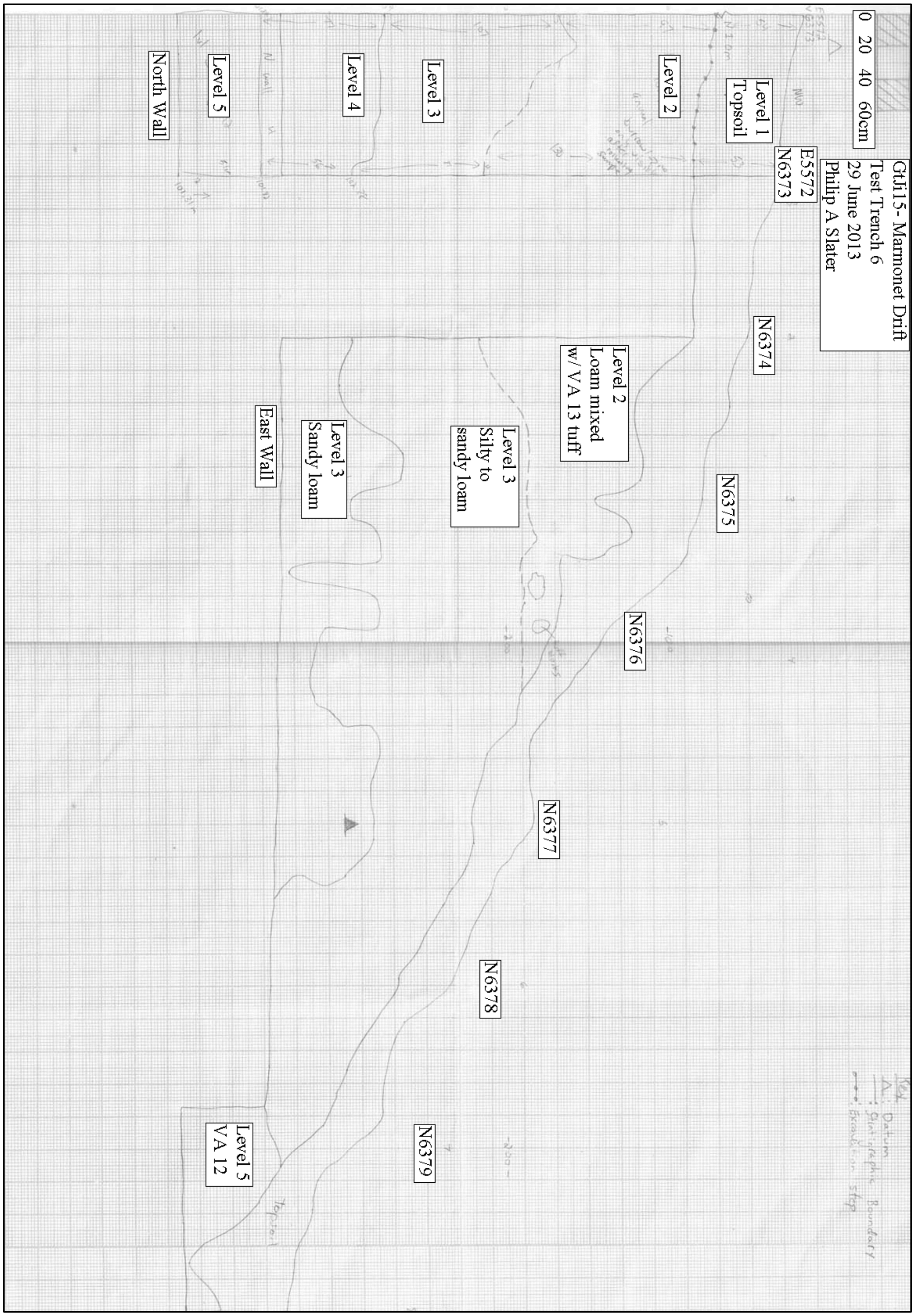


Figure 4.13. Stratigraphic profile drawing of Trench 6 after the 2013 excavation.

Figure 4.14. Bicolored basaltic tuff blocks from VA13, within layer 2 in trench 6.

Figure 4.15. Scoriaceous black pumice ‘bombs’ from VA13, within layer 2 in trench 6.

Figure 4.16. *In-situ* artifact (level 18, H3) made on chert raw material type #1, opaque-white color with brown cortex.

Figure 4.17. Chert raw material type #2 is semi-opaque and glassy. This is the only artifact (trench 1, level 7, #1568) found at the site made on the material.

Figure 4.18. Chert raw material type #3 is a blue-brown color. This piece (trench 1, level 5, #1503) has pot-lid fractures from heating and a small amount of red ochre adhering to the surface in the top left corner.

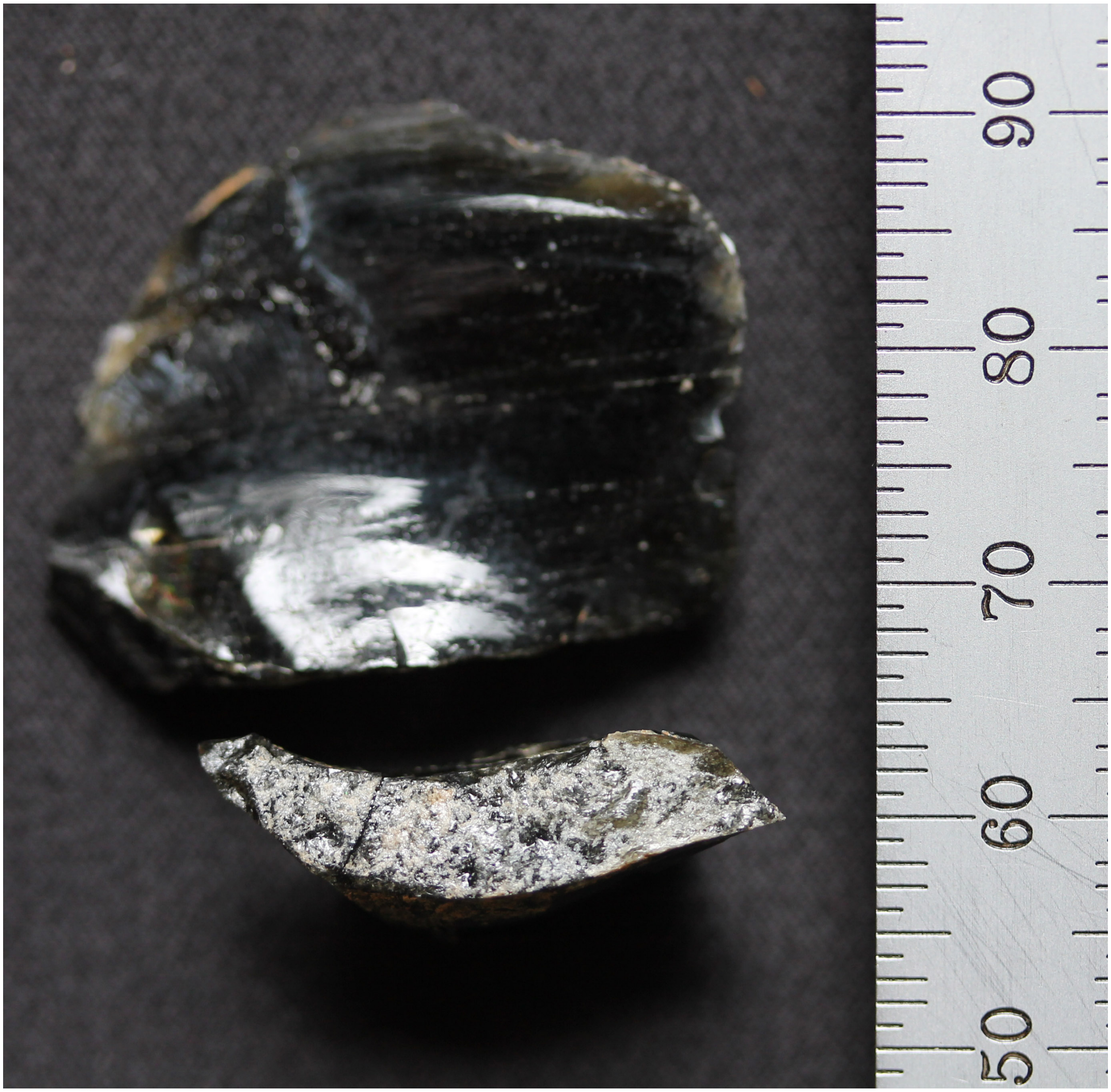


Figure 4.19. Example of the ‘disintegrating’ obsidian from H2 (level 22, artifact #3735). The lower piece has been glued together from multiple fragments already. The bubbly weakness in the middle of the material where pieces crumble is visible.

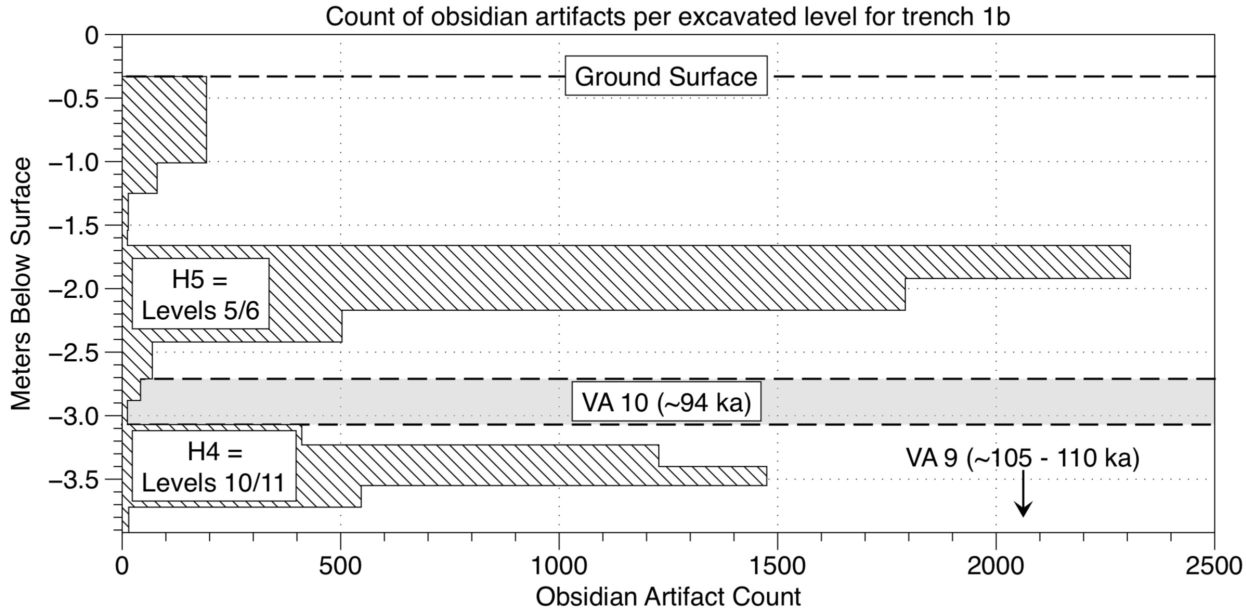


Figure 4.20. Count of all obsidian artifacts collected per horizon in trench 1b.

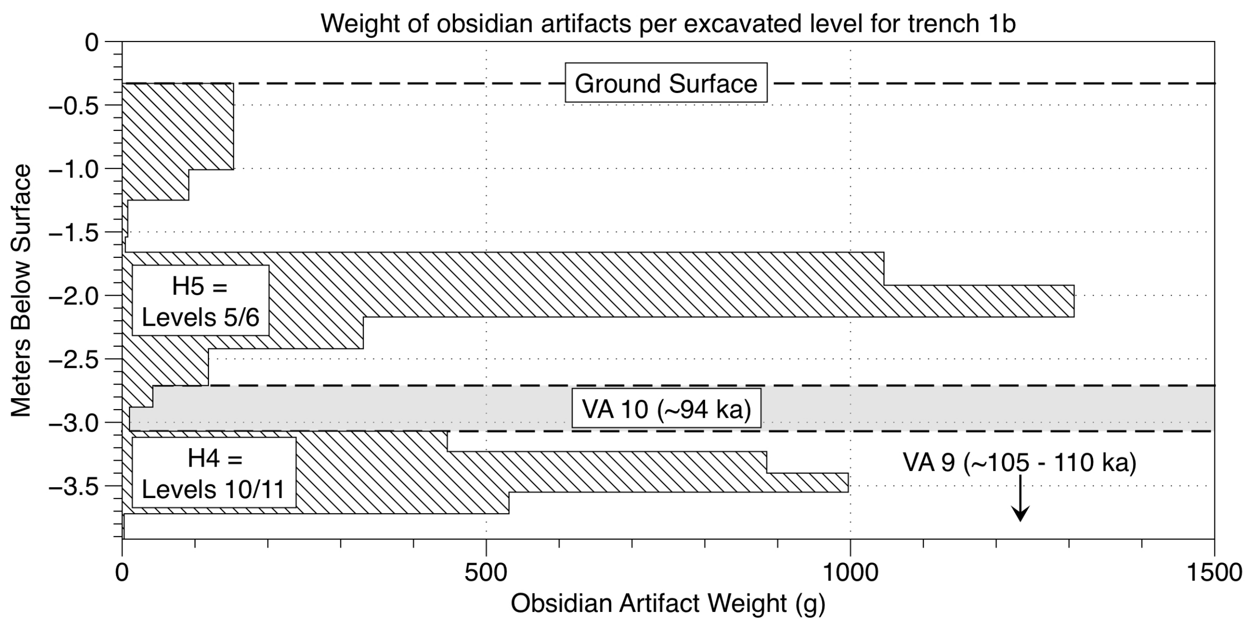


Figure 4.21. Weight of all obsidian artifacts collected per horizon in trench 1b.

Figure 4.22. Dorsal face of unifacial quartz point with basal thinning (trench 1, H5, #1510). It measures 48.8 x 28.9 x 12.0 (mm).

Figure 4.23. Photo of a wide and thick flake from a radial core (#2714) on left and a unifacial point (#2509) on the right (dorsal faces). Larger flake blanks with this shape likely served as blanks for retouched tools in H5 such as points and knives.

Figure 4.24. Photo of a wide and thick flake from a radial core (#2714) on left and a unifacial point (#2509) on the right (ventral faces). Note the robust untrimmed bulb on the blank (the two large visible scars are from errailure flakes) and the bulbar trimming on the point.

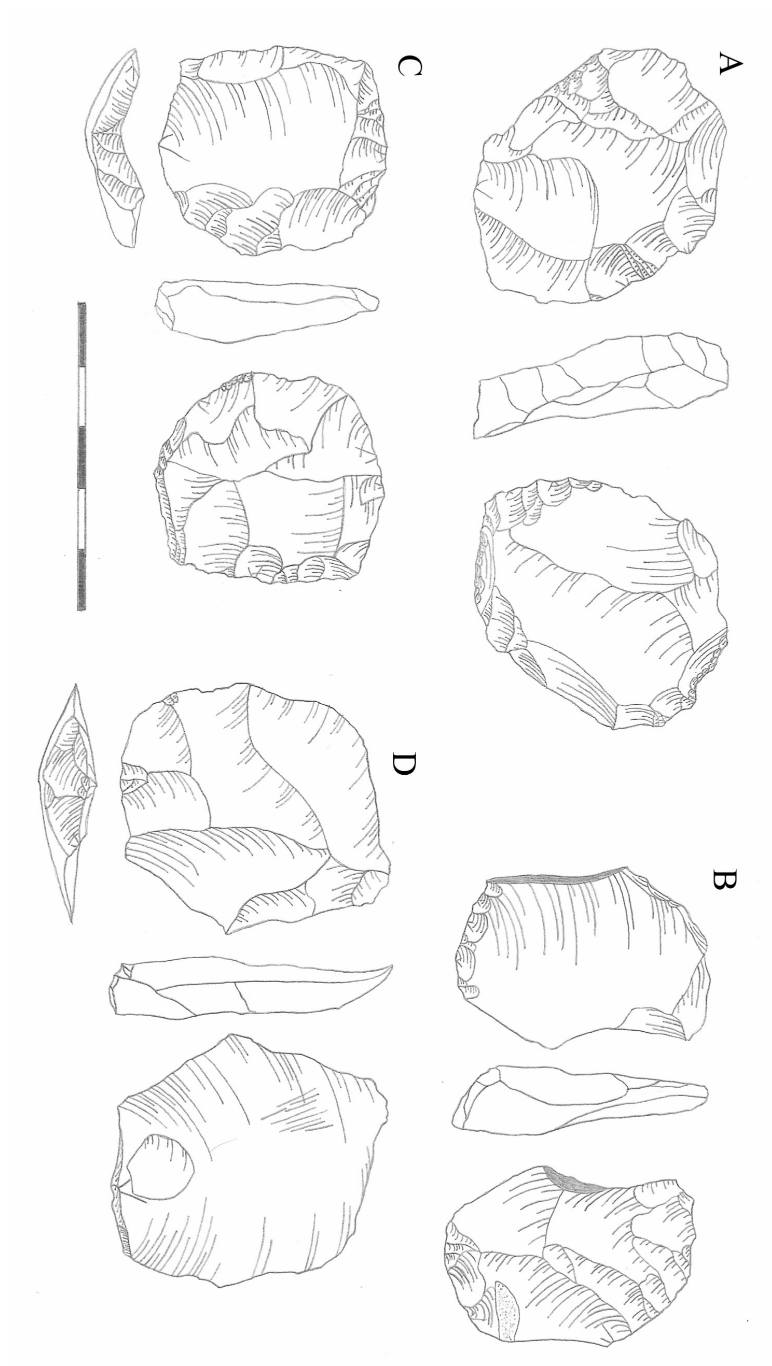


Figure 4.25. Sample of cores (A-C) and radial core flake blank (D) from trench 1, H5. (A) Semi-radial/opposed platform core (#2860); (B) tabular core (#2764); (C) Levallois flake core (#2052); (D) Flake with faceted platform and radial dorsal scar pattern (#2714). Scale is in cm.

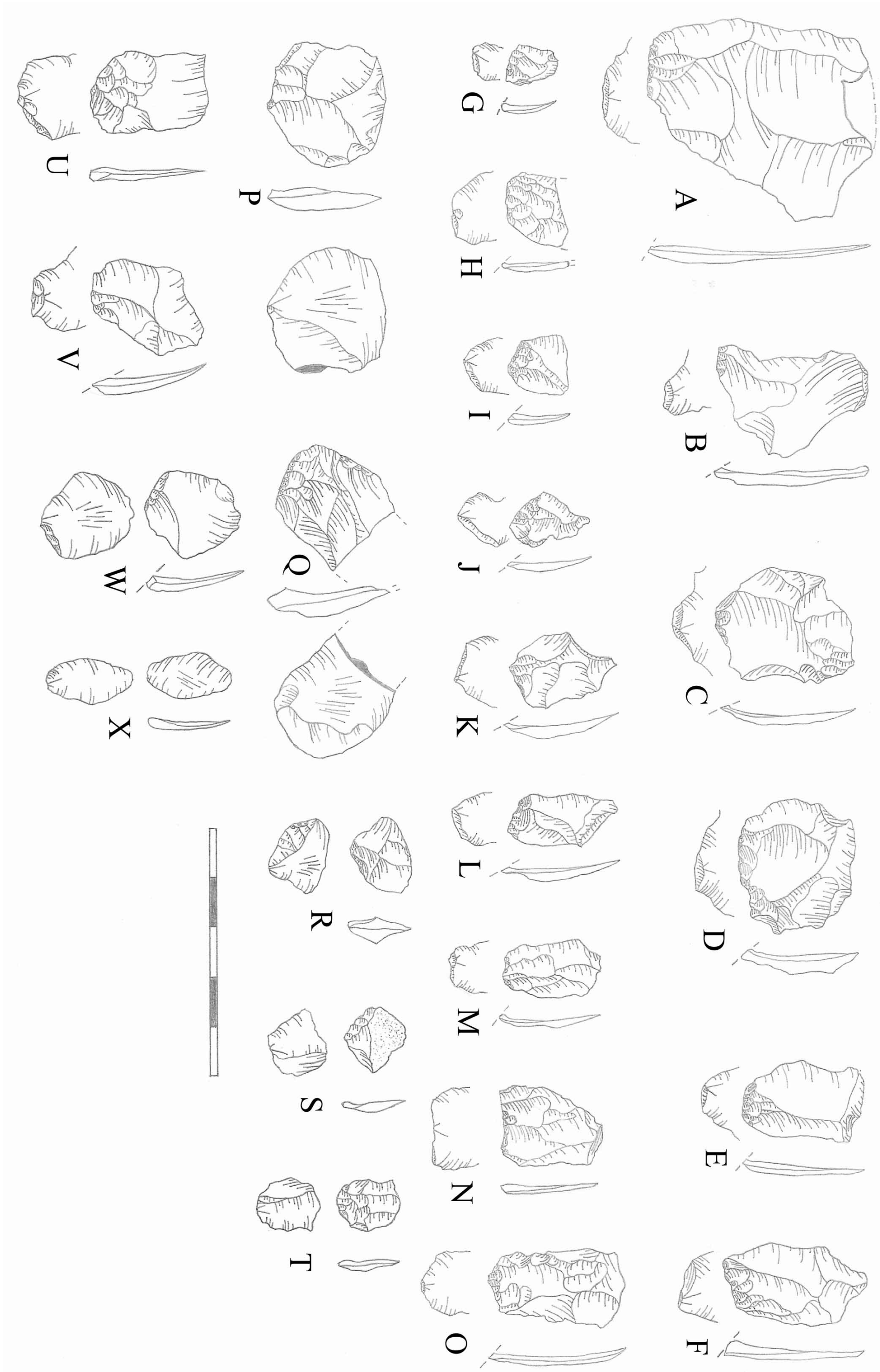


Figure 4.26. Sample of secondary retouch flake types from trench 1, H5. (A-O, U-V) Shallow invasive unifacial flakes with lipped platforms; (P-T) Edge removal flakes; (R) Biface retouch; (W-X) Bulbar trimming flakes. Scale is in cm.

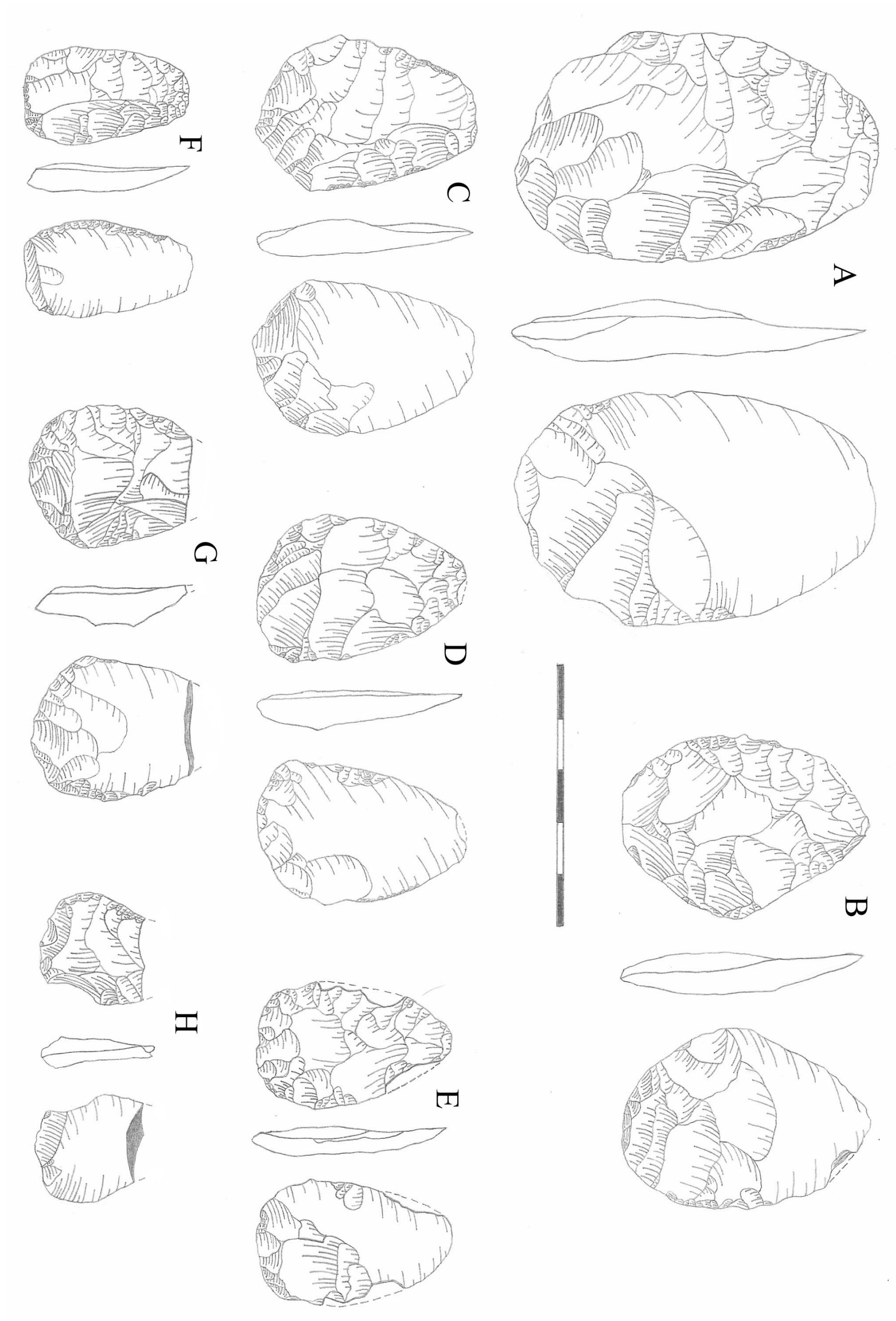


Figure 4.27. A sample of points from trench 1, H5. (A) Unifacial point with a trimmed bulb, #2729; (B) Parti-bifacial point, #2086; (C) Unifacial point with a trimmed bulb, #2509; (D) Unifacial point with a trimmed bulb, #2573; (E) Parti-bifacial point, #2085; (F) Unifacial point with a trimmed bulb, #2728; (G) Unifacial point with a trimmed bulb, #1889; (H) Unifacial point with a trimmed bulb, #2830. Scale is in cm.

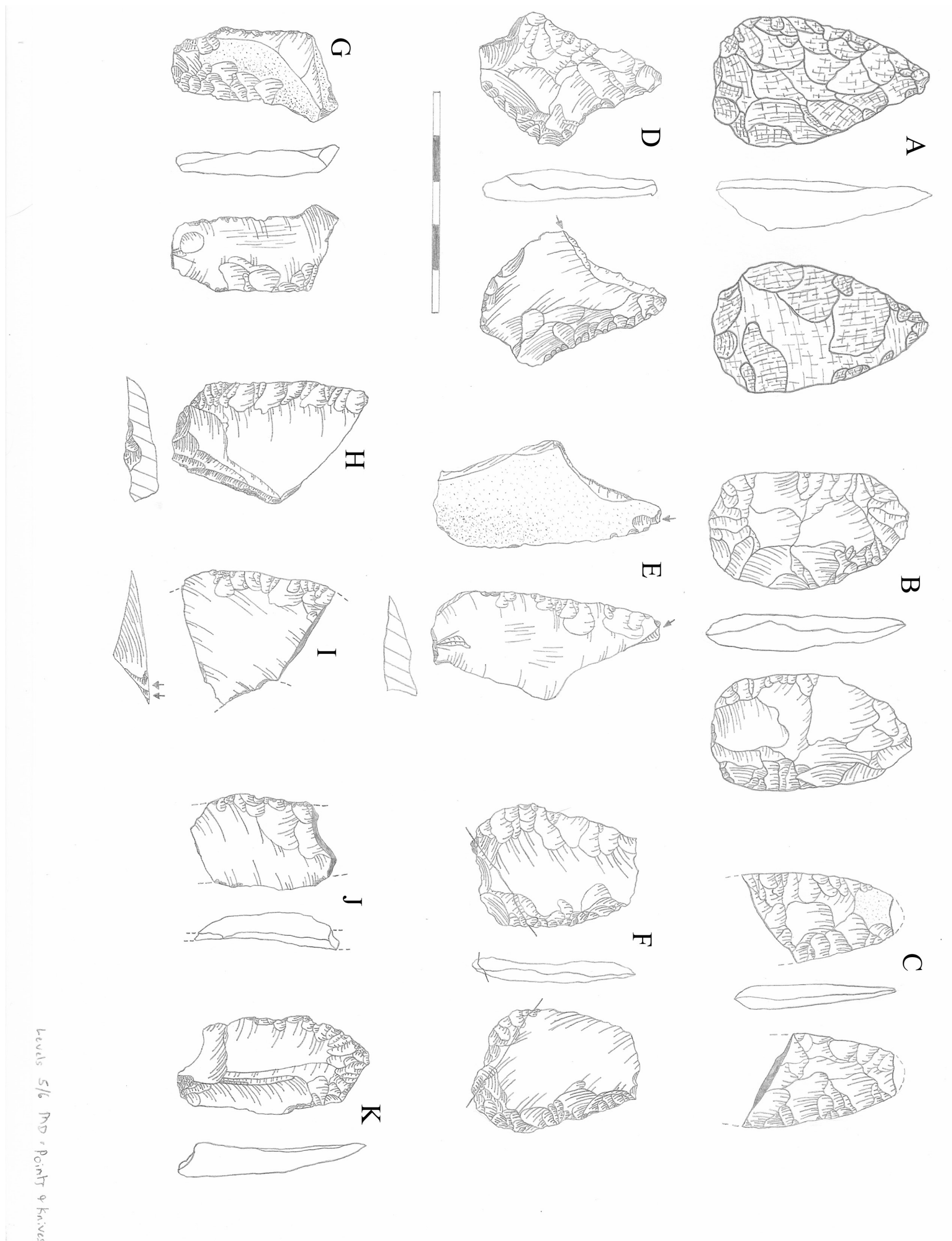


Figure 4.28. Sample of points and knives from H5. (A) Parti-bifacial point made on quartz, #1510; (B) Bifacial point, #2219; (C) Bifacial point, #2832; (D) Transformed tool, #2834: bifacial knife (pseudo denticulate), burin blow, bifacial denticulate retouch; (E) Transformed tool, #2582: knife (inverse shallow and invasive), dihedral burin; (F) Bifacial knife with refit, #1940; (G) Double side knife, #2576; (H) Single side knife, #1993; (I) Combination tool, #1998: knife, burin; (J) Bifacial knife, #2307; (K) Unifacial/Tongati knife, #2371. Scale is cm.

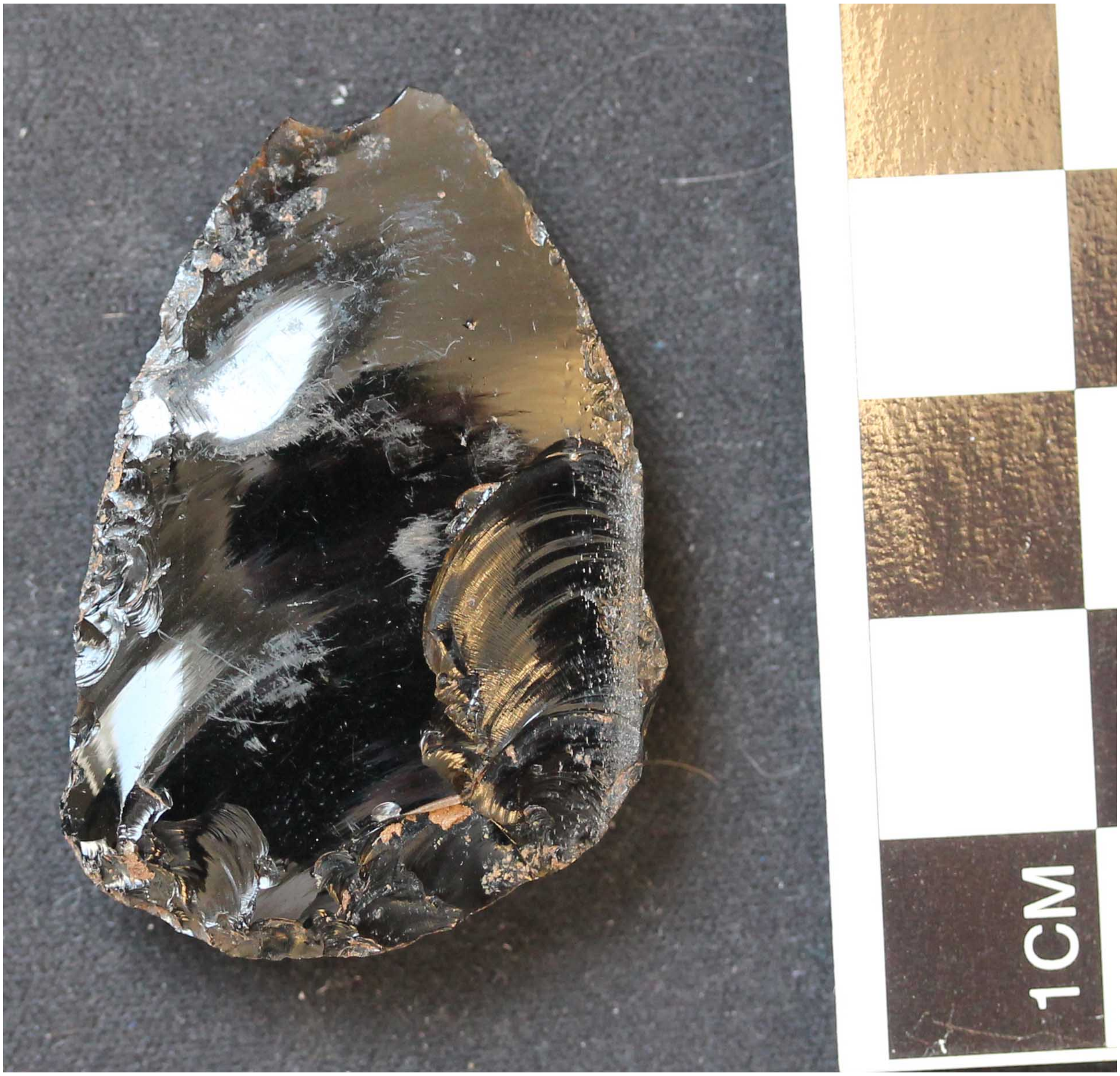


Figure 4.29. Unifacial point with bulbar thinning from trench 1, H5 (#2573). The bulbar thinning is characteristic of the majority of points recovered in H5. Note the intense abrasion and scratching across the ventral face, which suggest a long use-life.

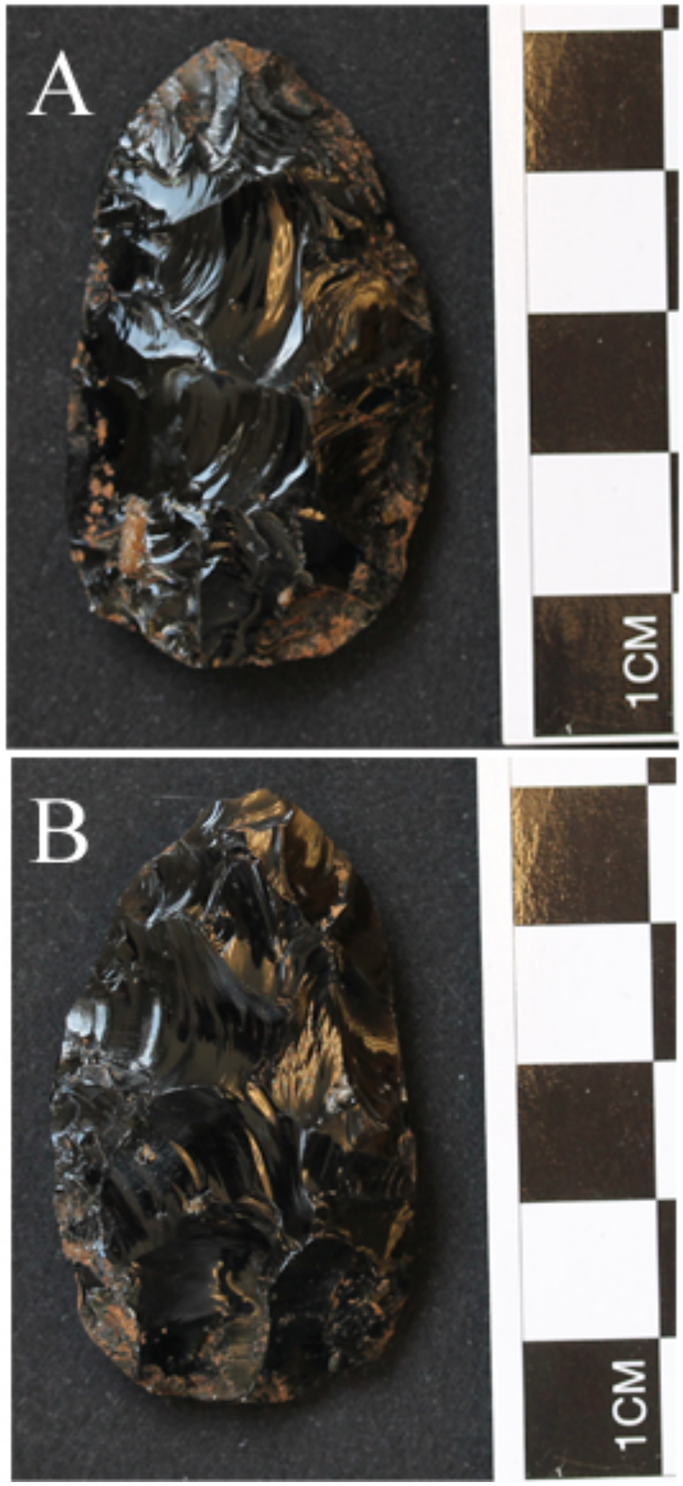


Figure 4.30. Two sides of a bifacial point from trench 1, H5 (#2219).

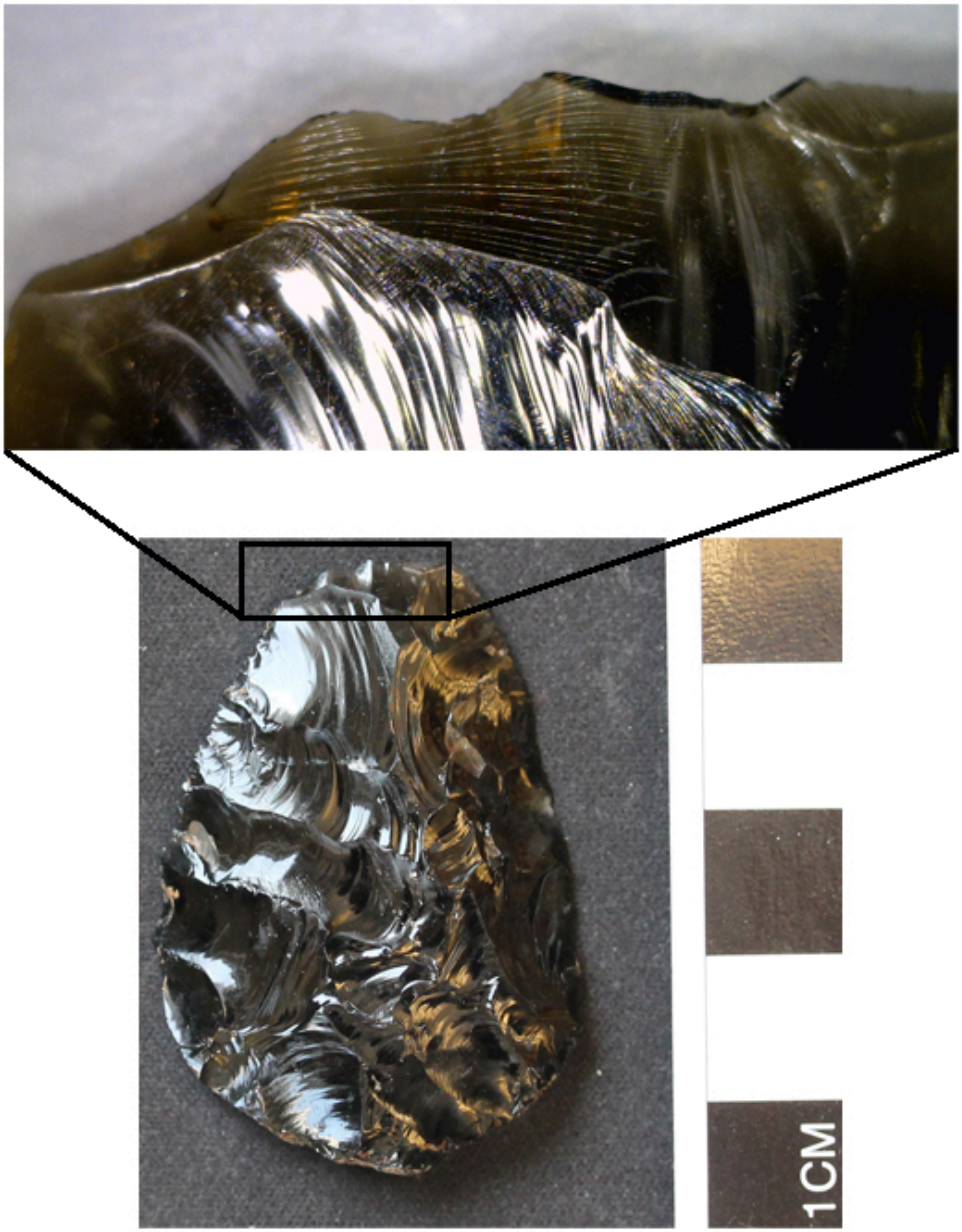


Figure 4.31. Transverse bit on a unifacial point (#2509).

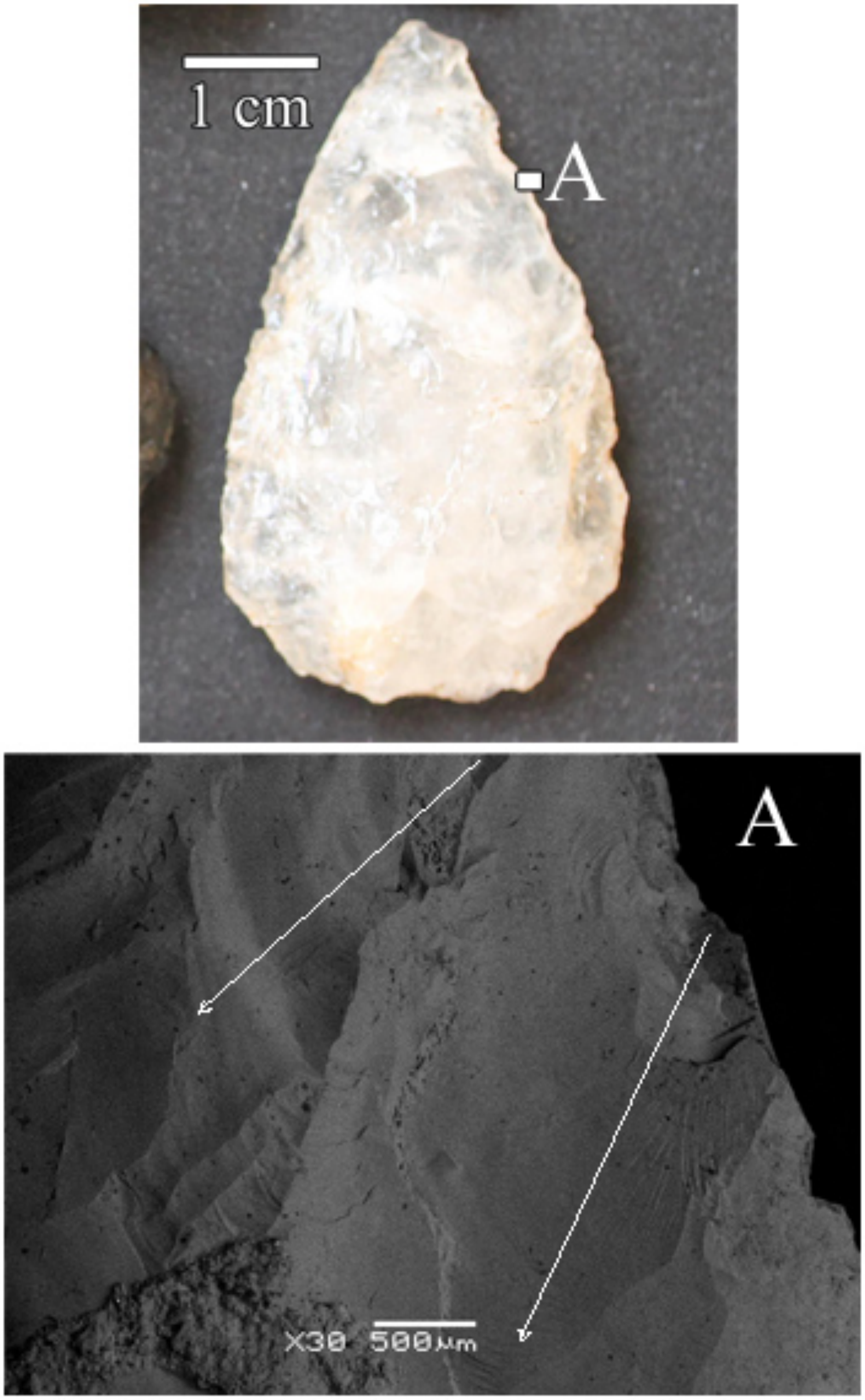


Figure 4.32. Photo of parti-bifacial point (#1510) dorsal face. (A) SEM micrograph of right edge showing angled microflake scars suggesting this piece was used for slicing.

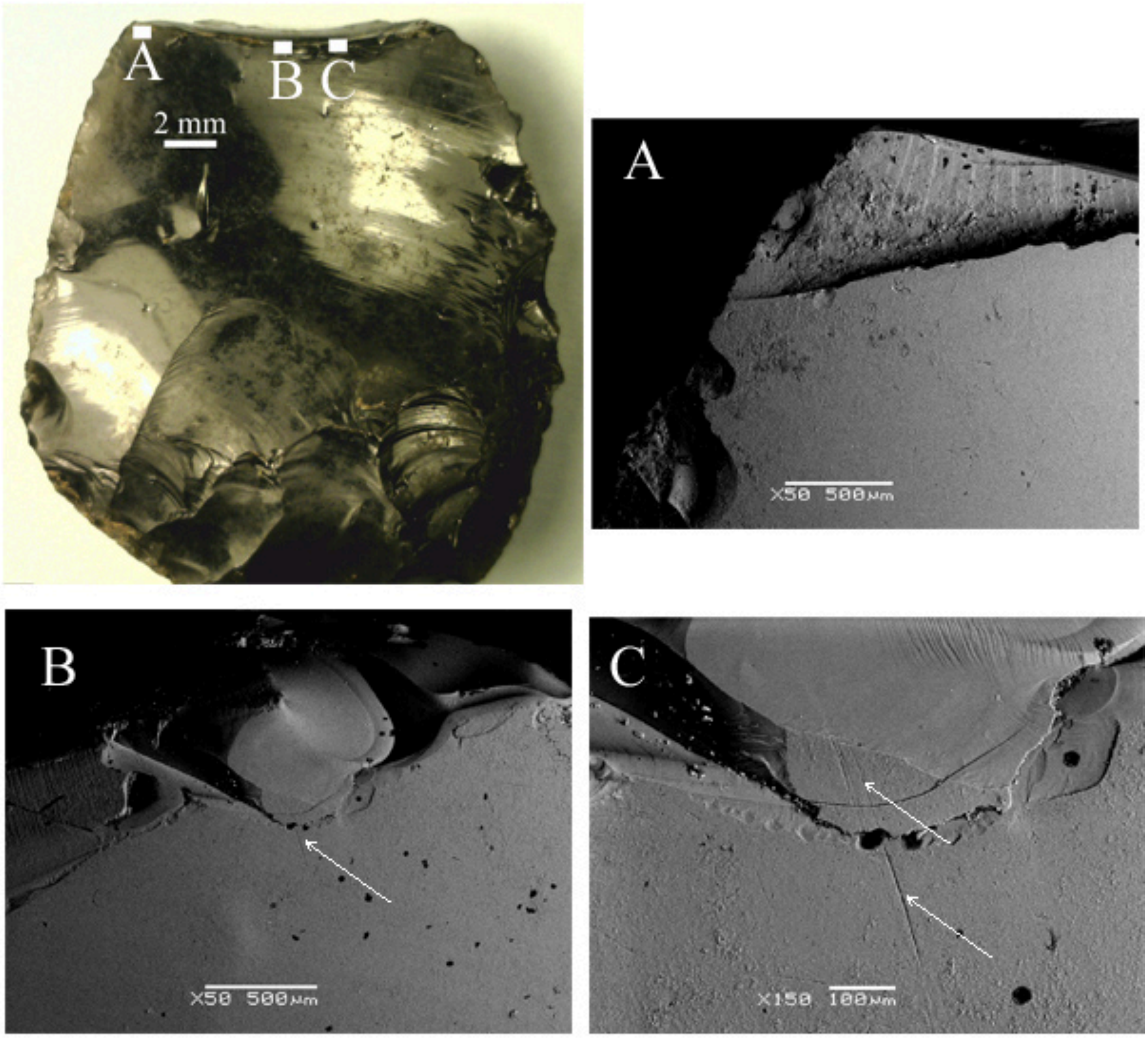


Figure 4.33. Photo of a unifacial point with bulbar thinning (#1889). (A) SEM micrograph of bending 'languette' fracture on distal end; (B-C) longitudinal striations (arrows) on the medial portion of the tool; (D-E) Striations (arrows) and stepped microflake scars (circle) on both lateral edges. The two eye-shaped features (in squares) in image E are natural imperfections in the glass. The use-wear features on the base suggest that this piece was hafted while the broken tip suggests an impact fracture from use as a projectile.

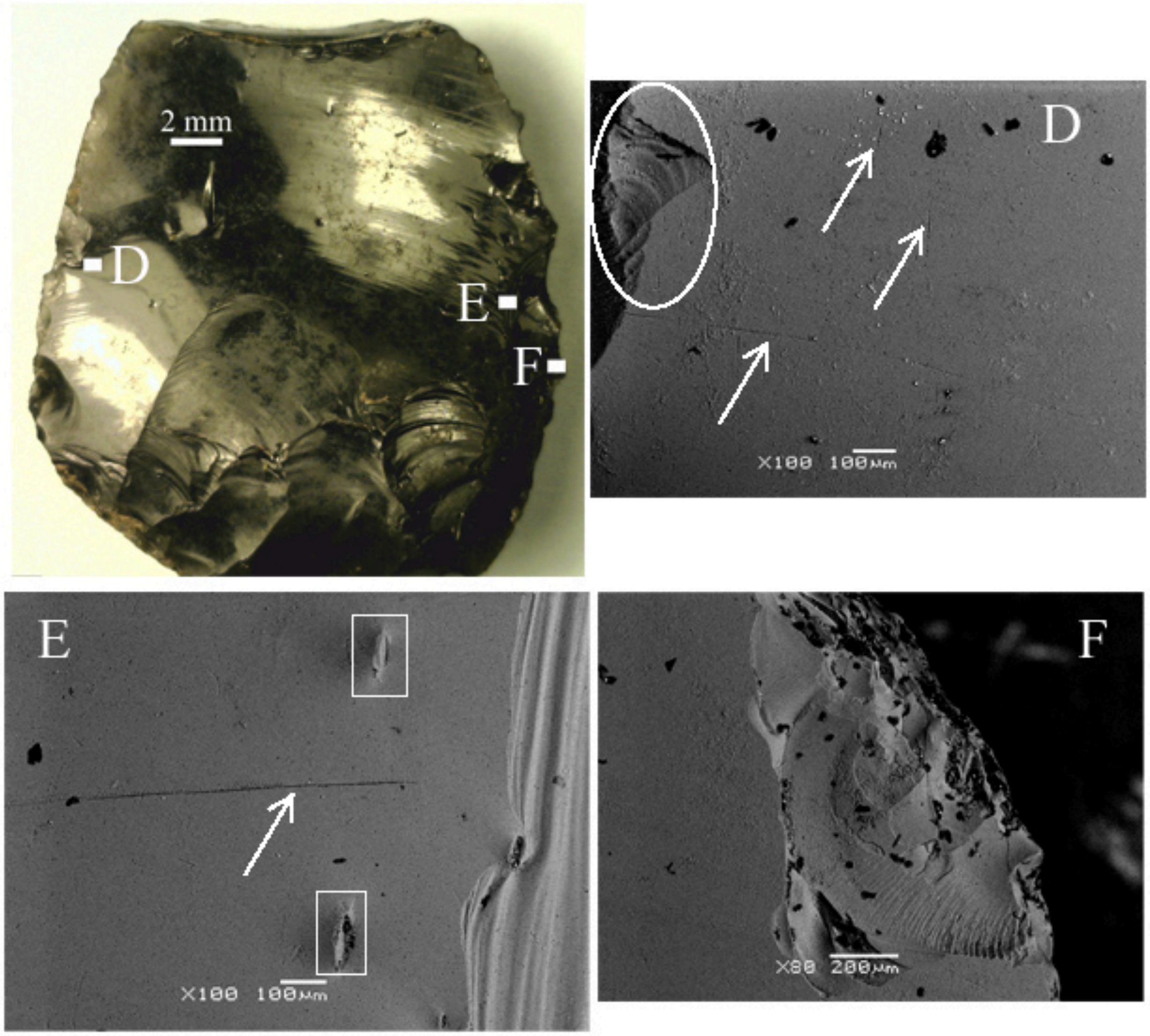


Figure 4.33 continued.

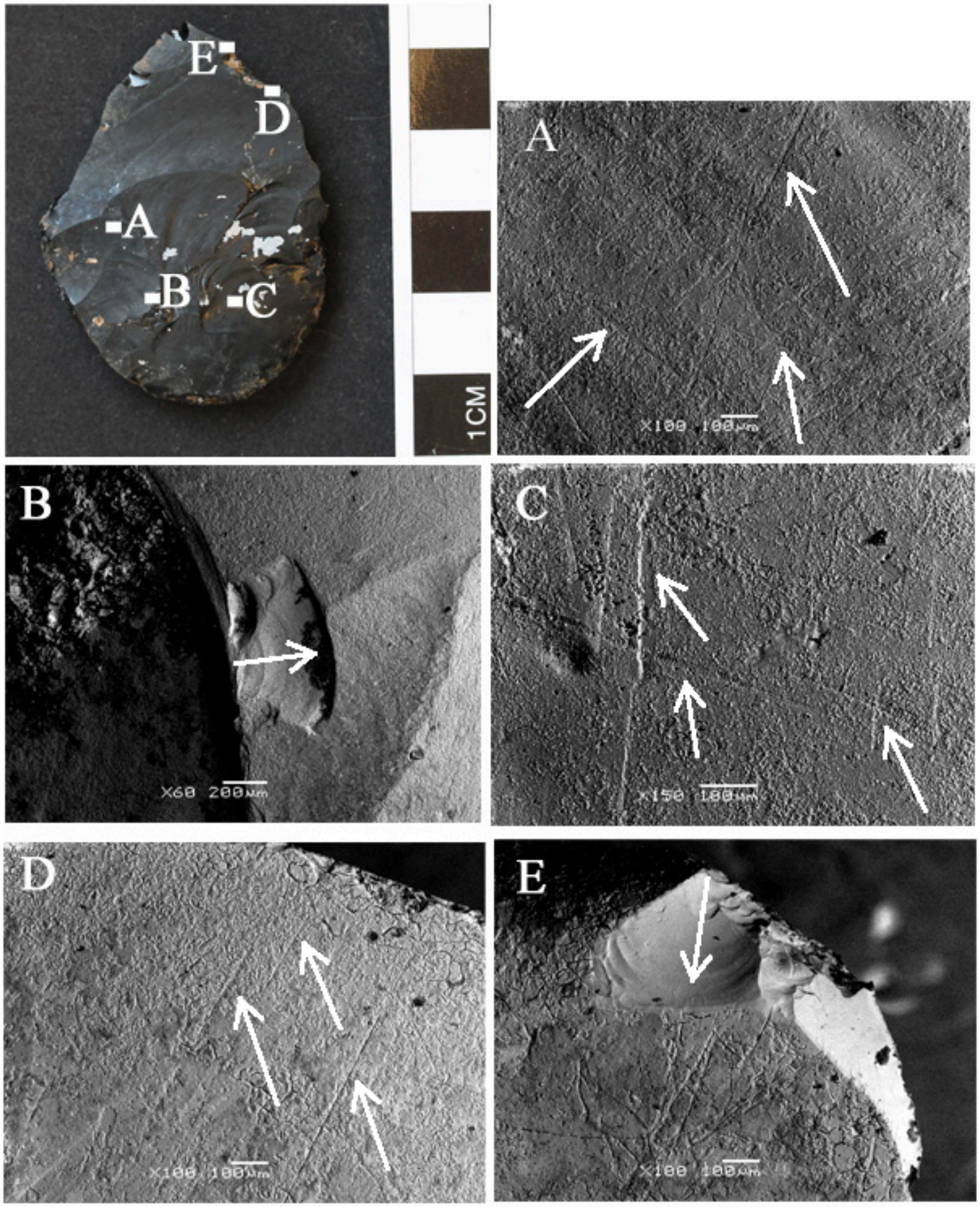


Figure 4.34. Artifact #2086 is a complete unifacial point with bulbar trimming and an anomalous patina. (A, C) SEM micrographs of laterally orientated striations and microflake scars (B) near the base; (D) longitudinally orientated striations and microflake scars (E) near the tip. These features suggest a hafted tool used in a longitudinal use-action such as a piercing projectile.

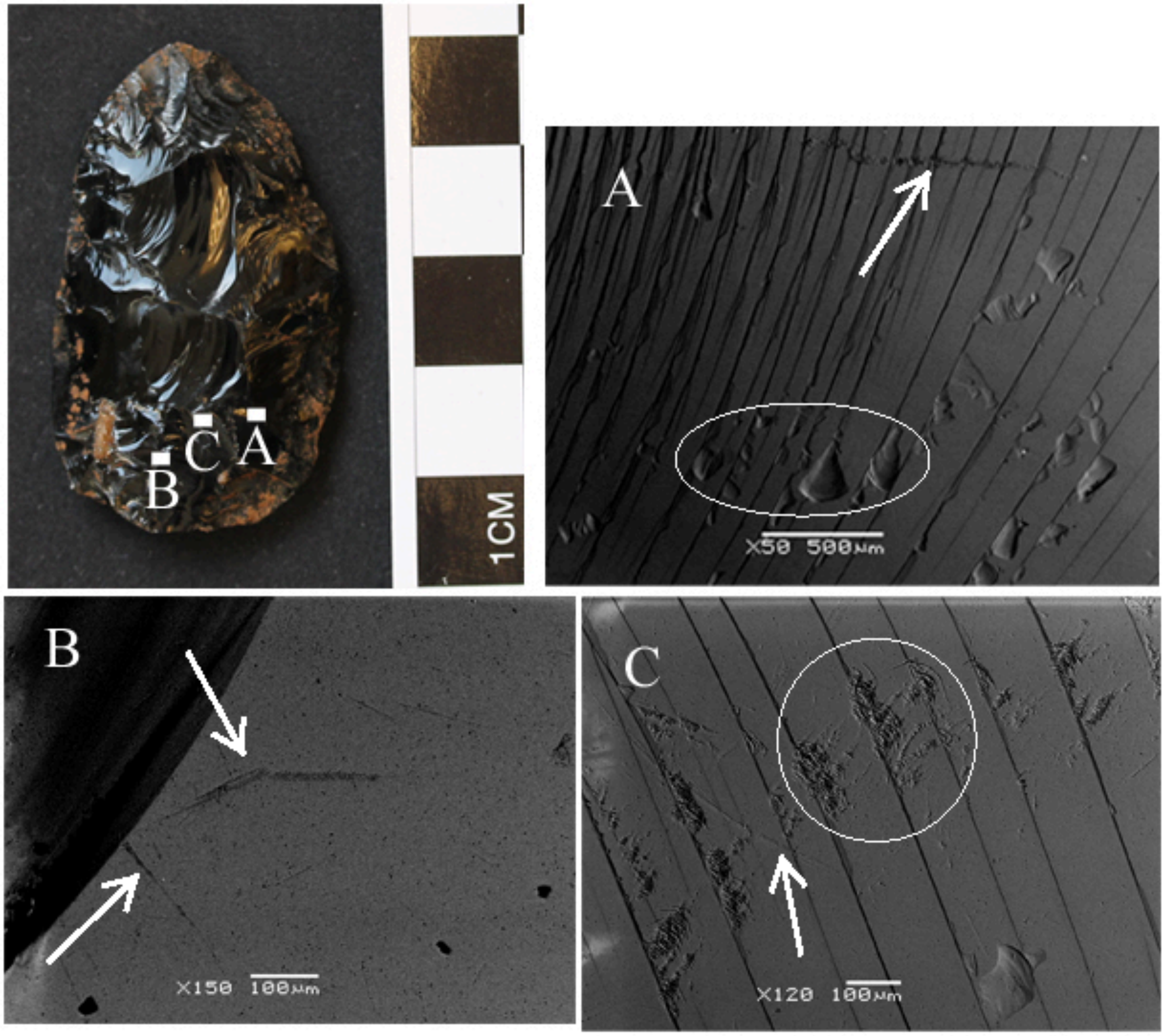
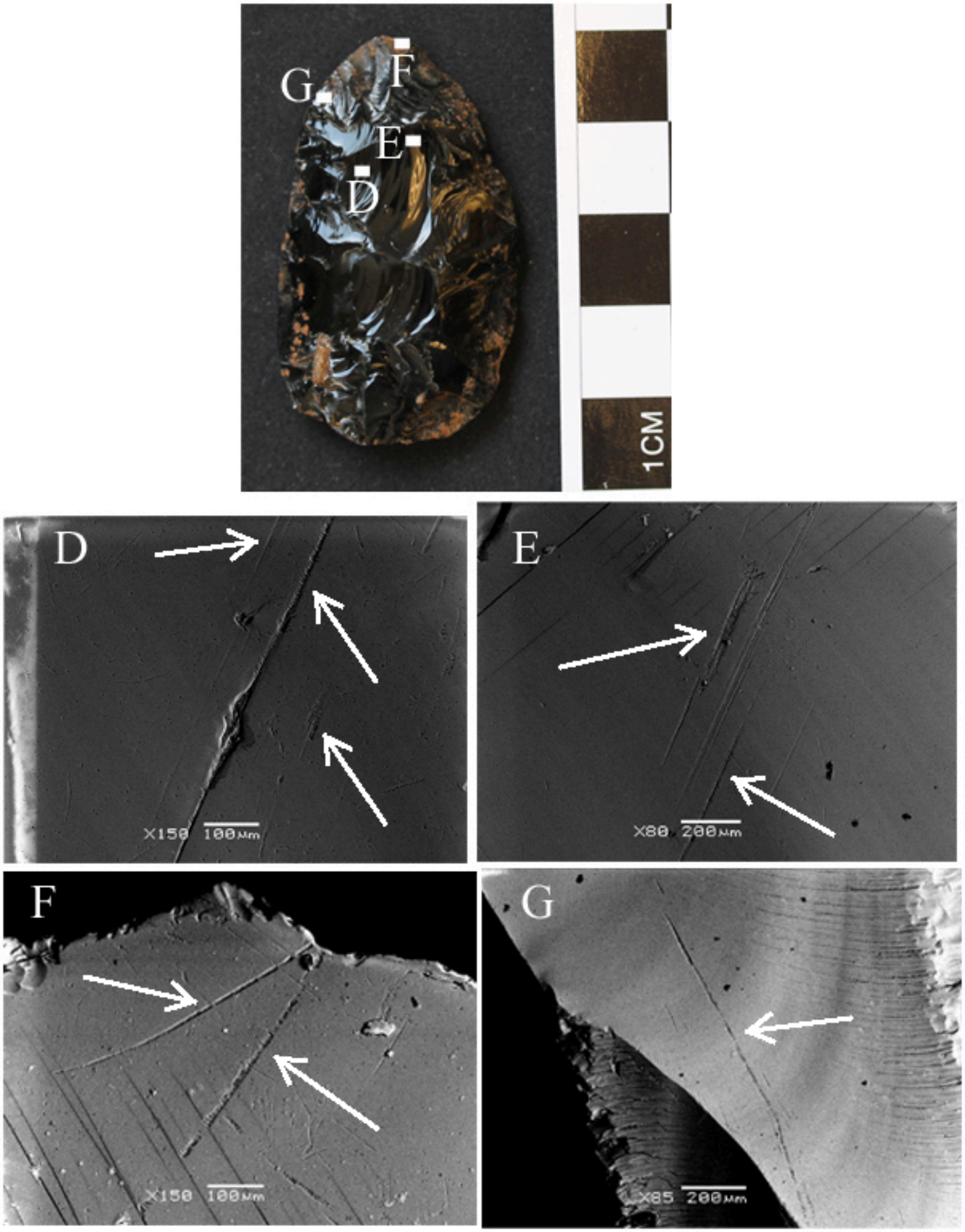


Figure 4.35. Photo of a complete bifacial point (#2219). (A-C) SEM micrographs of laterally orientated striations (arrows) and microflake scars (circled) that originate from fissures. (D-G) Striations (arrows) nearer to the point tip are longitudinal or diagonal to the tool axis. The laterally oriented wear across the base suggests this piece was hafted, while the longitudinal wear traces near the tip indicate forceful piercing, possibly from use as a projectile.



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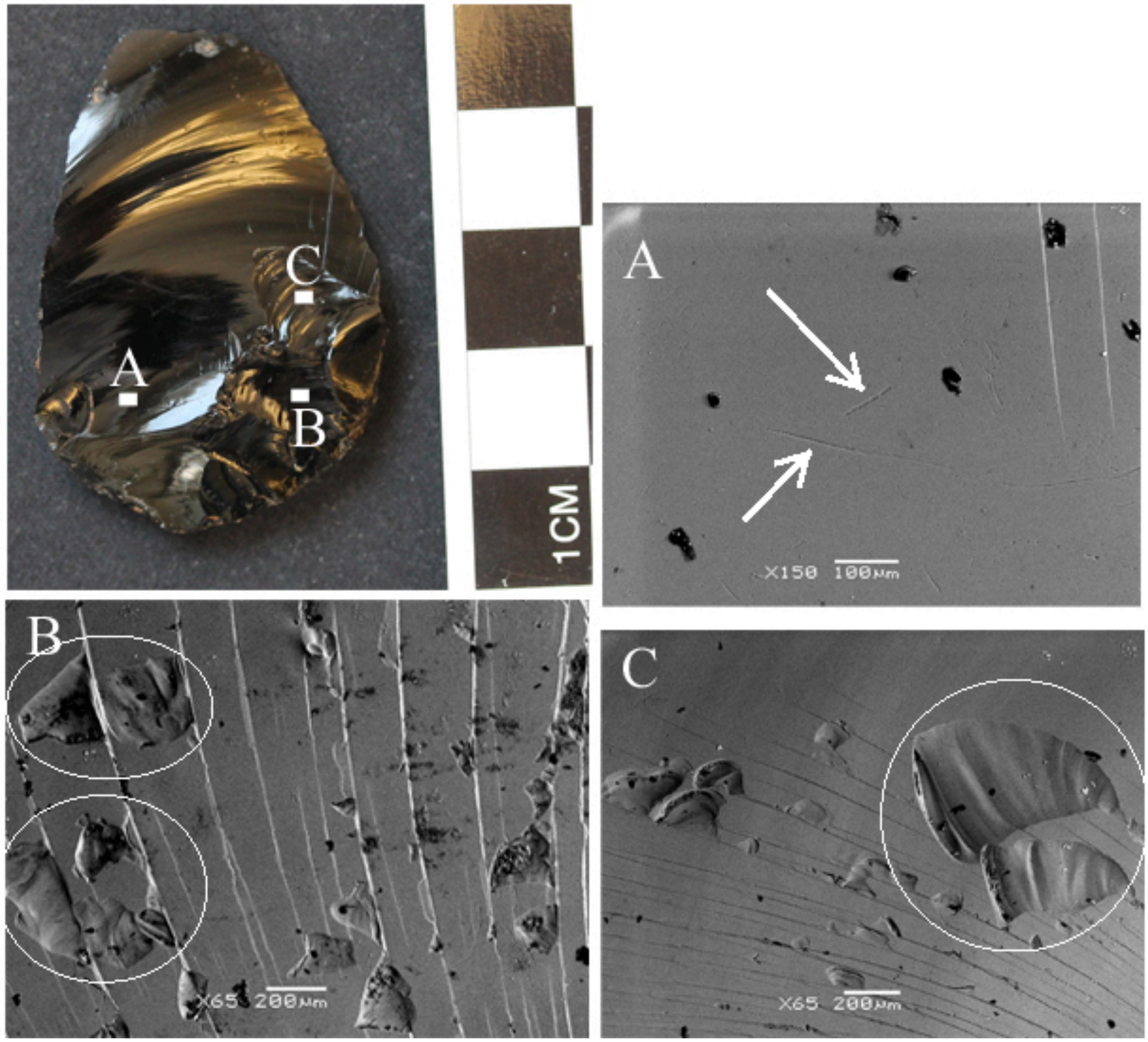
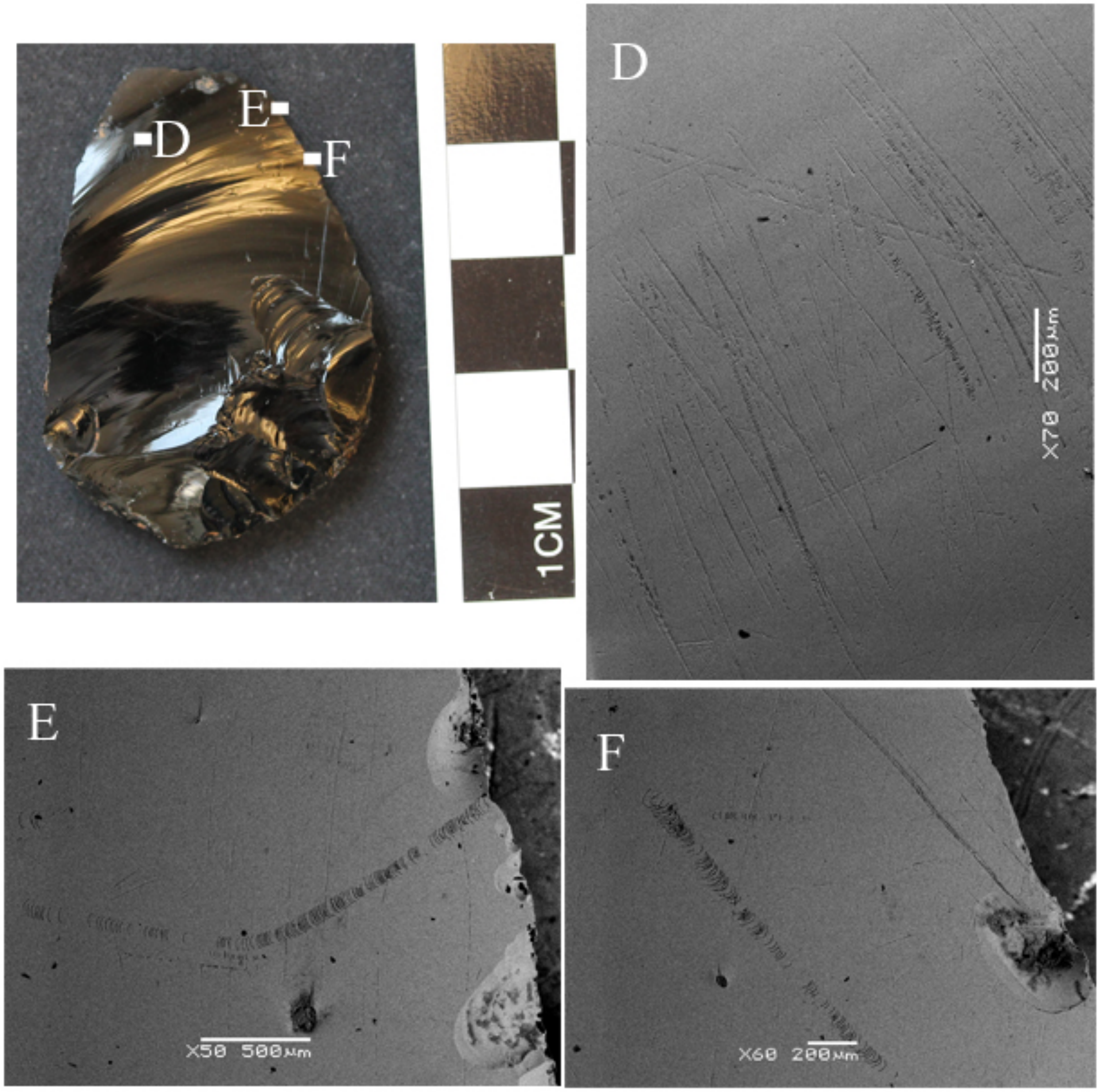


Figure 4.36. Photo of a unifacial point with bulbar trimming (#2509). (A) SEM micrographs of laterally orientated striations and microflake scars (B-C) that initiate from fissures; (D-F) longitudinally orientated striations that indicate two directions of scratches. These features support the use of this piece as a hafted piercing tool or projectile.



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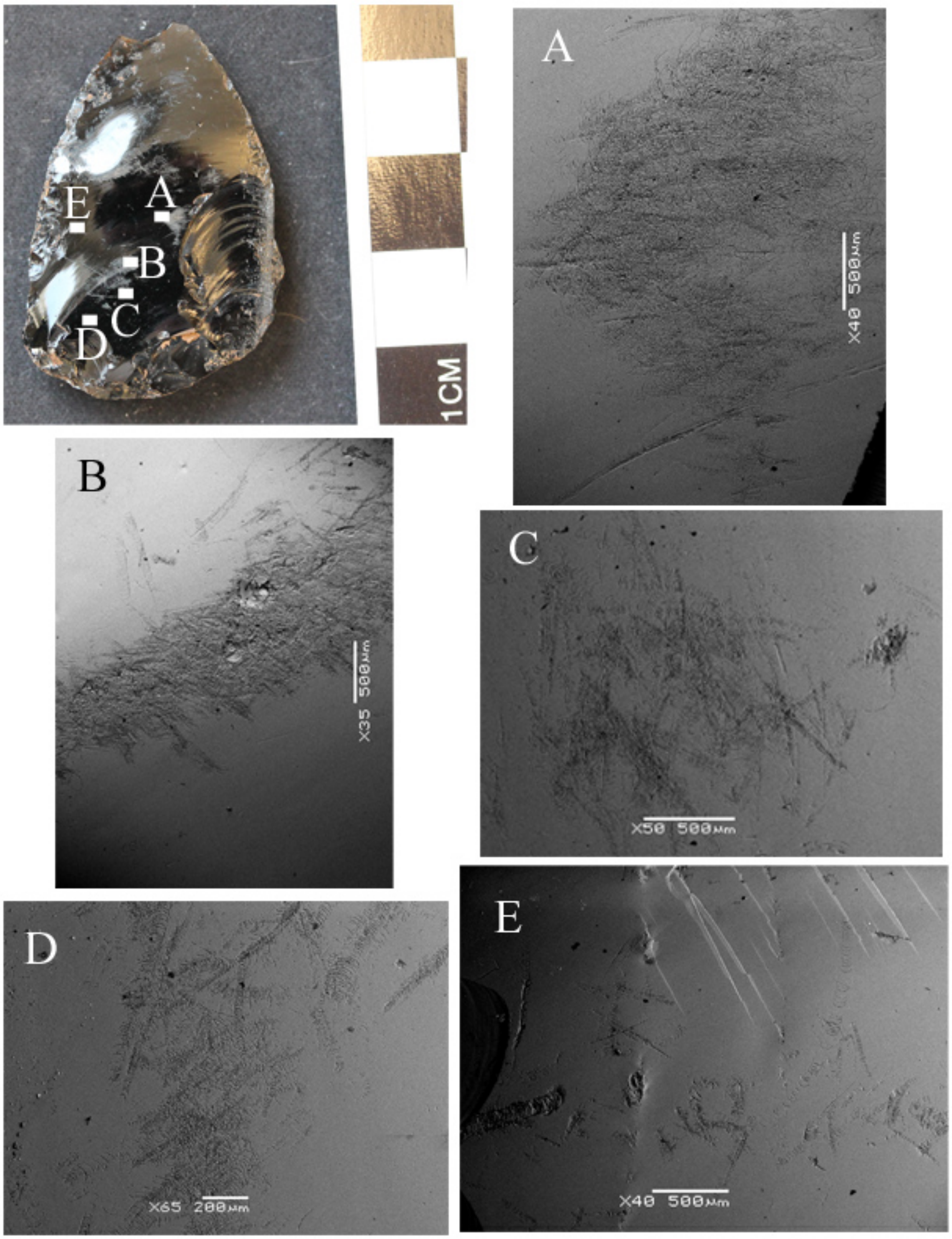


Figure 4.37. Photo of a unifacial point with bulbar trimming (#2573). (A-E) SEM micrographs of laterally orientated striations and large areas of abrasion; (F-H) striations near the tip are diagonally orientated. These features suggest the piece was used as a hafted cutting tool.

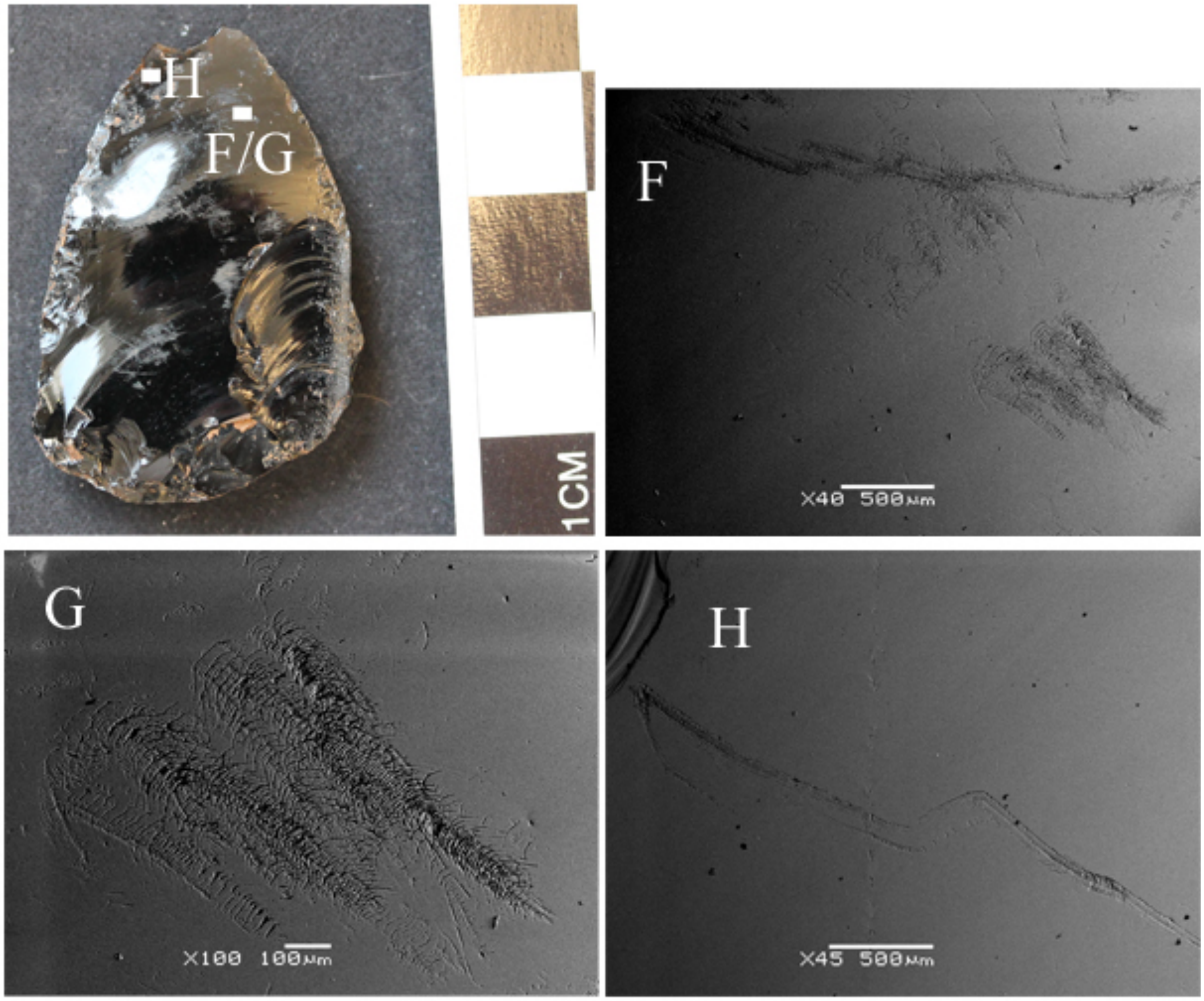


Figure 4.37 continued.

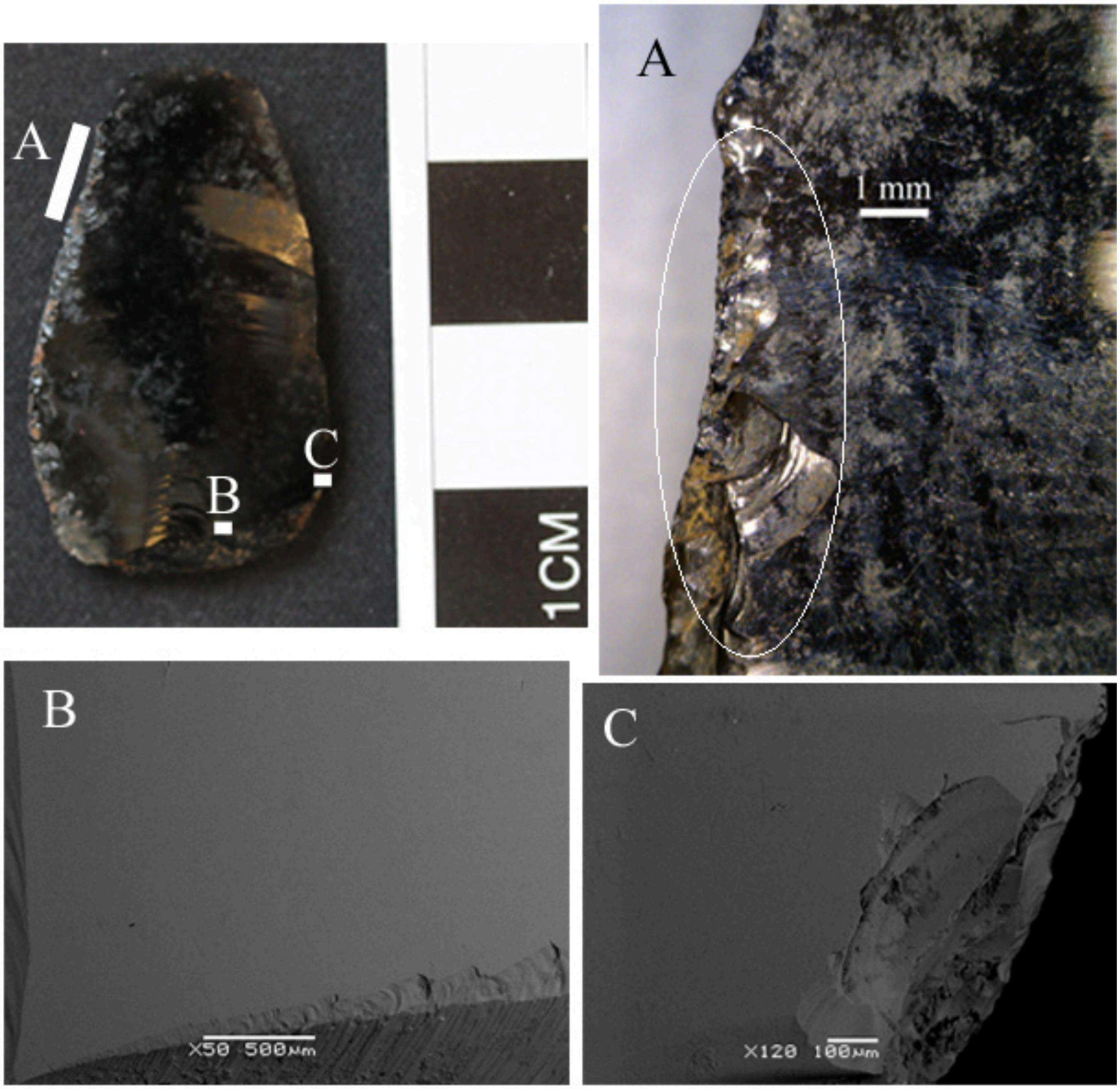


Figure 4.38. Photo of a unifacial point with a single bulbar trimming flake scar (#2728). (A) Dinolite micrograph of casual retouch on the left side; (B) SEM micrograph of small microflake scars initiating from an arête; (C) marginal microflake scars with stepped terminations; (D) crisscrossing striations; (E-G) low frequencies of striations and microflaking orientated longitudinally near the tip. Together, these features suggest the piece was hafted and used for a piercing or slicing use-action.

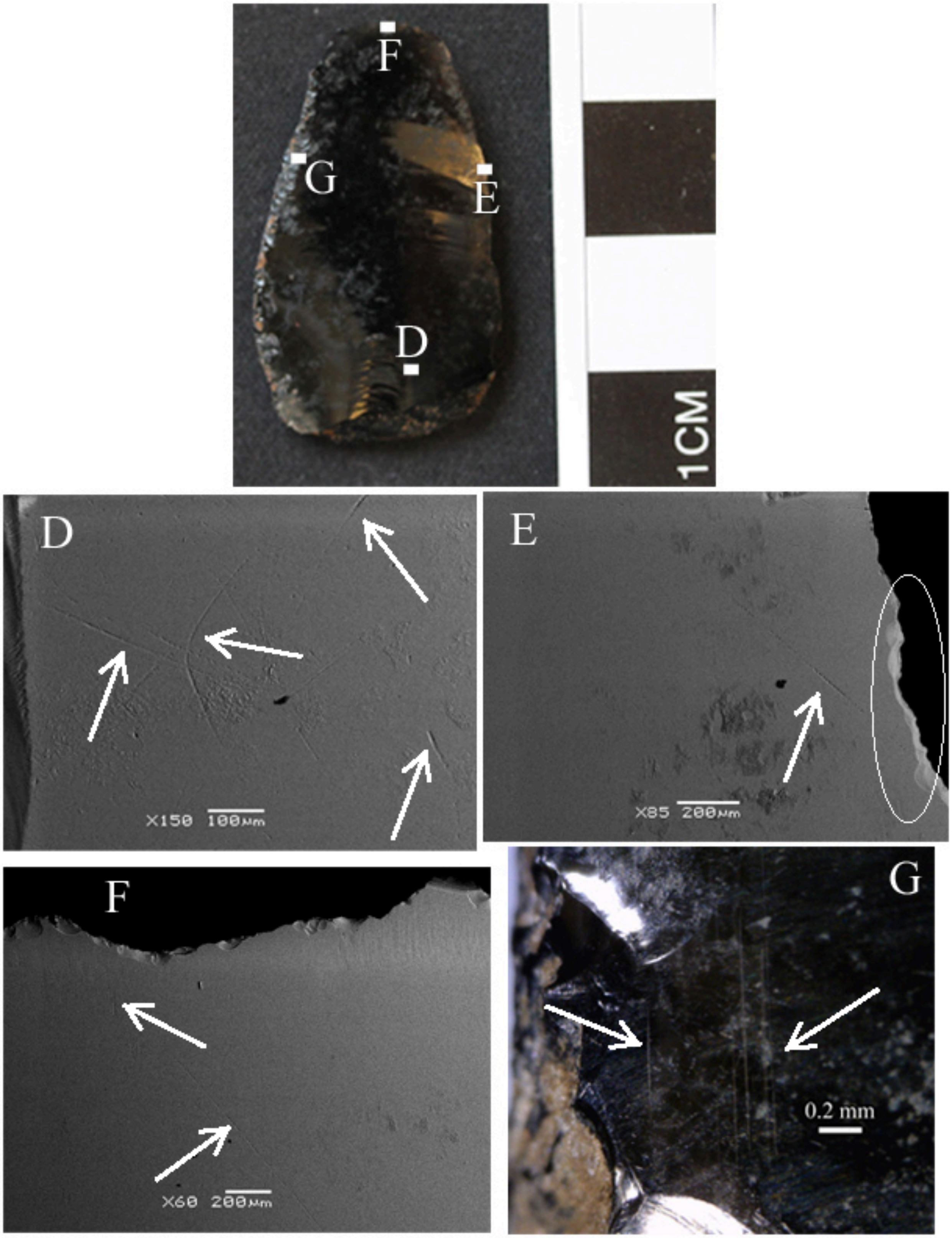


Figure 4.38 continued.

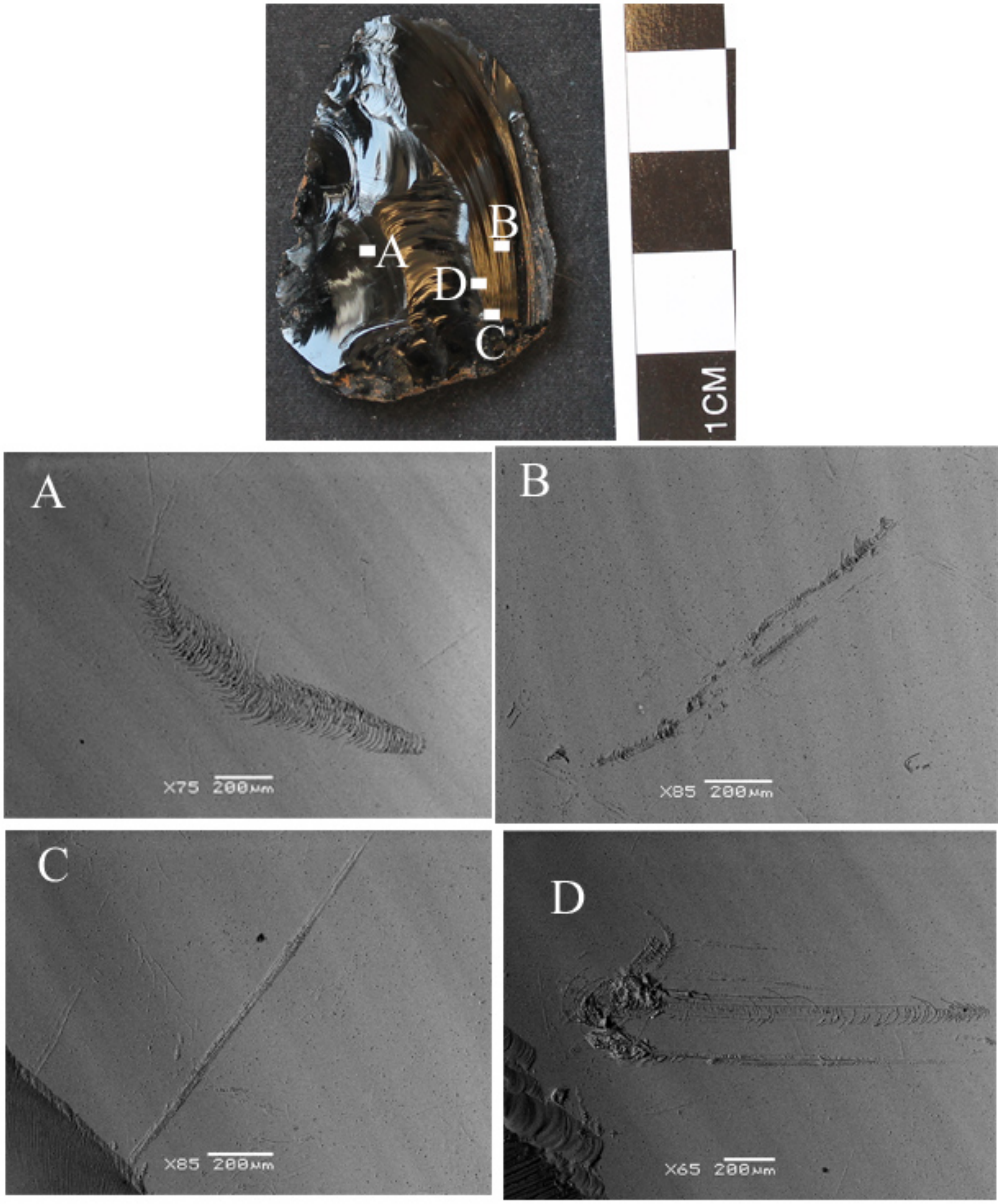
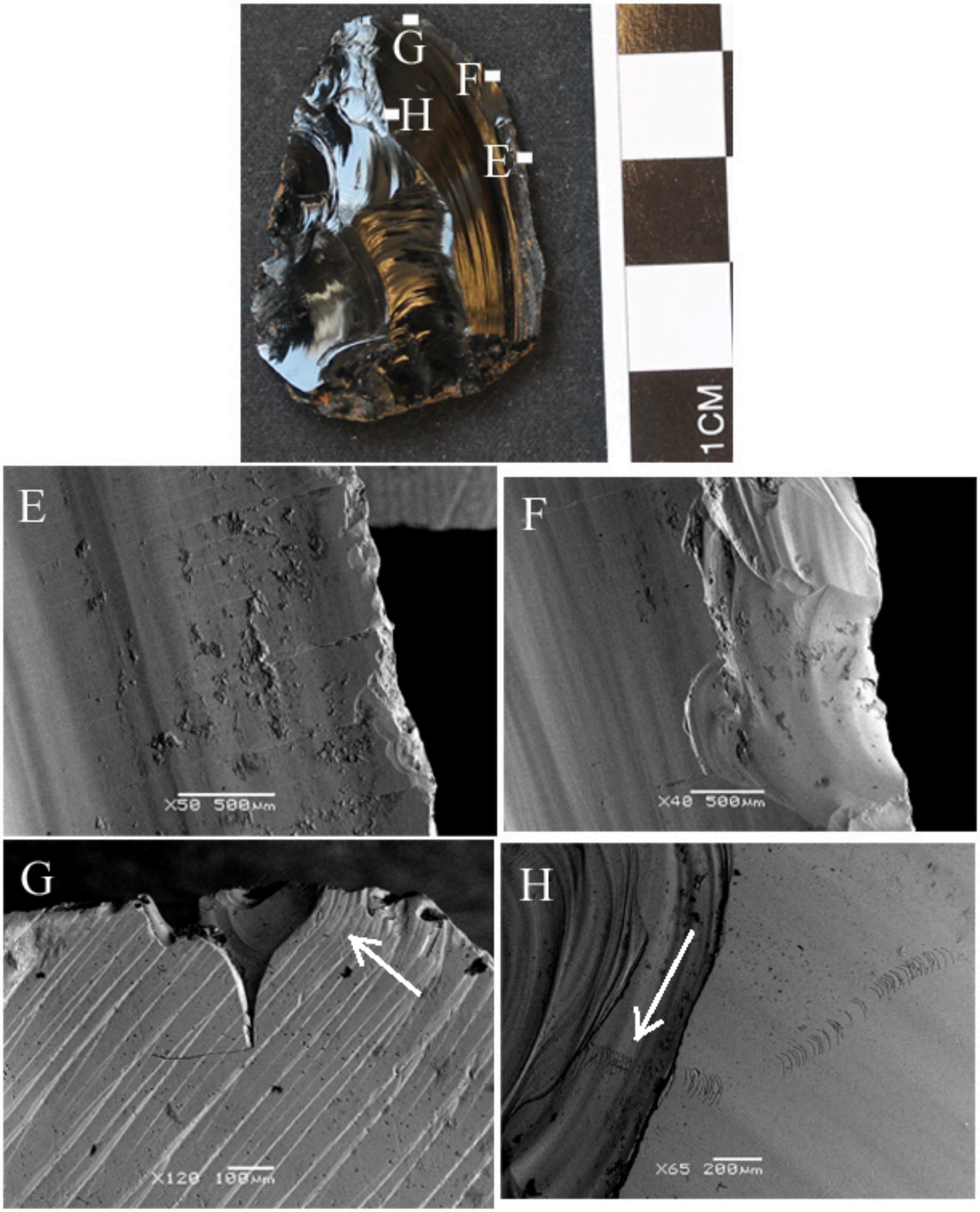


Figure 4.39. Photo of a parti-bifacial point with intense bulbar trimming (#2730). (A-D) SEM micrograph of striations going in multiple different directions near the base; (E-G) marginal microflake scars with feather terminations and striations (G-H; arrows) on the distal portion of the tool. These features suggest this piece was hafted and used for slicing soft materials.



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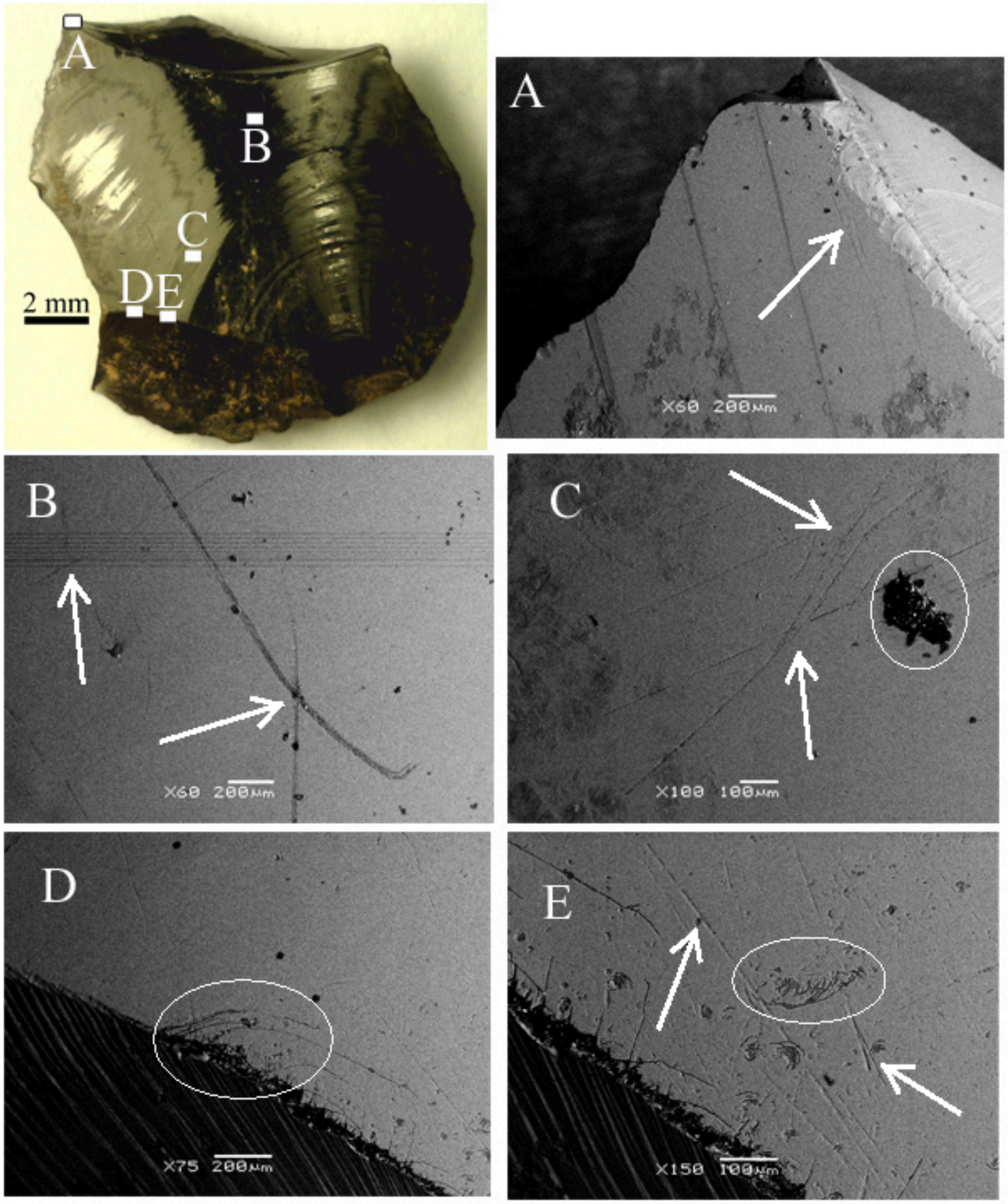

Figure 4.40. Photo of a broken unifacial point with bulbar trimming (#2830). (A-B) SEM micrograph of longitudinal striations near the snap (A) and on the medial portion (B) of the tool face; (C, E) lateral and diagonal striations; (D-E) cracking on scar terminations; (C) a dark gummy blob that may be an adhesive residue. Together, these features suggest this piece was hafted and broken during a longitudinal use-action such as projectile or piercing tool.

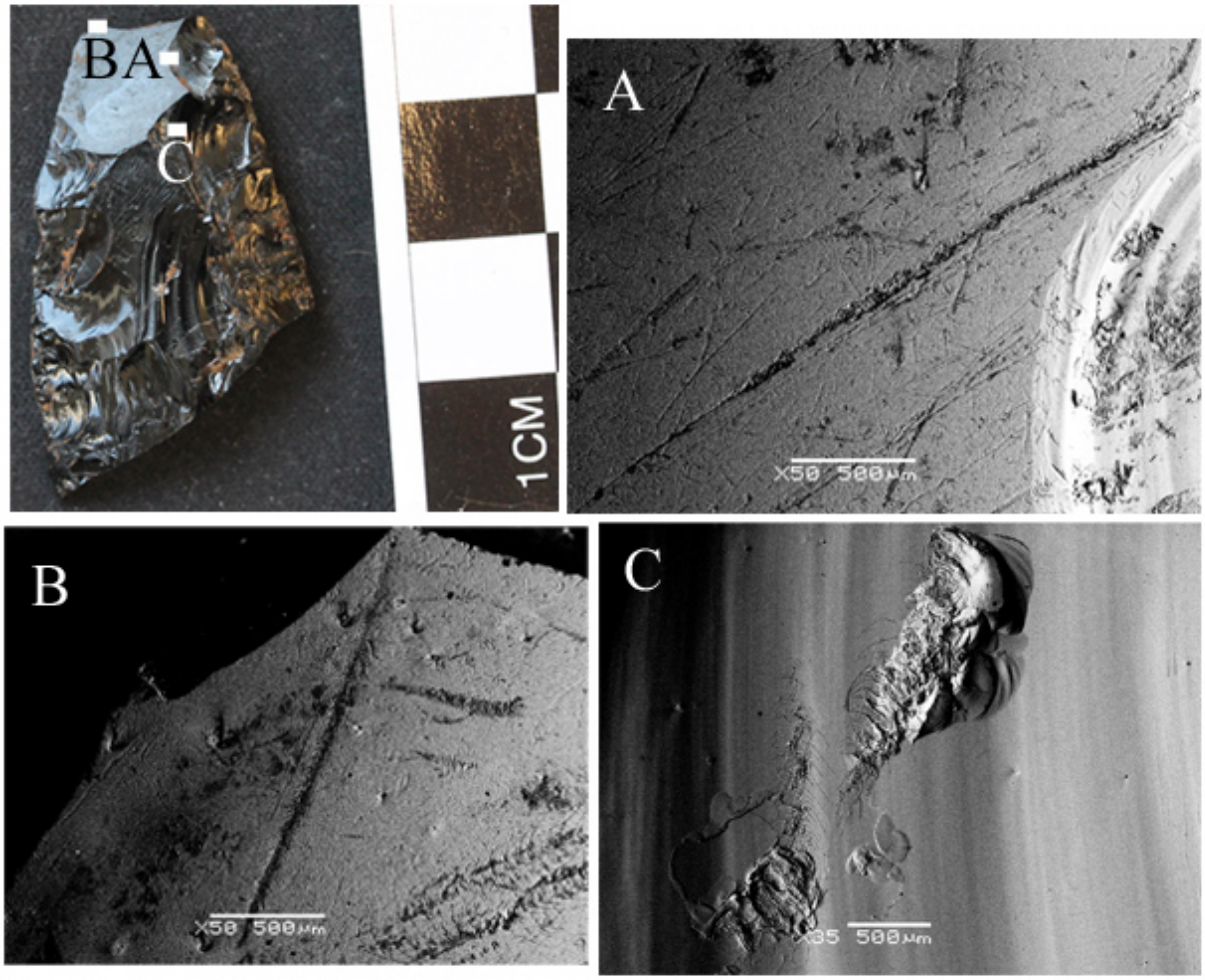

Figure 4.41. Photo of a broken bifacial point with bulbar trimming (#2832). The small flat area near the tip likely represents the ventral face of the piece and has a high density of use-wear features compared to the more recently retouched areas, suggesting this is either a *pièce rétrouvée* or has a long use-life history. (A-C) SEM micrographs of striations and gouges suggest multiple directions of cutting or piercing use-action; (D-E) angled microflake scars (white arrows) and striations (black arrows) on the lateral edge; (E) arête abrasion (square) and microflakes initiated at fissures (F; circle) suggest hafting.

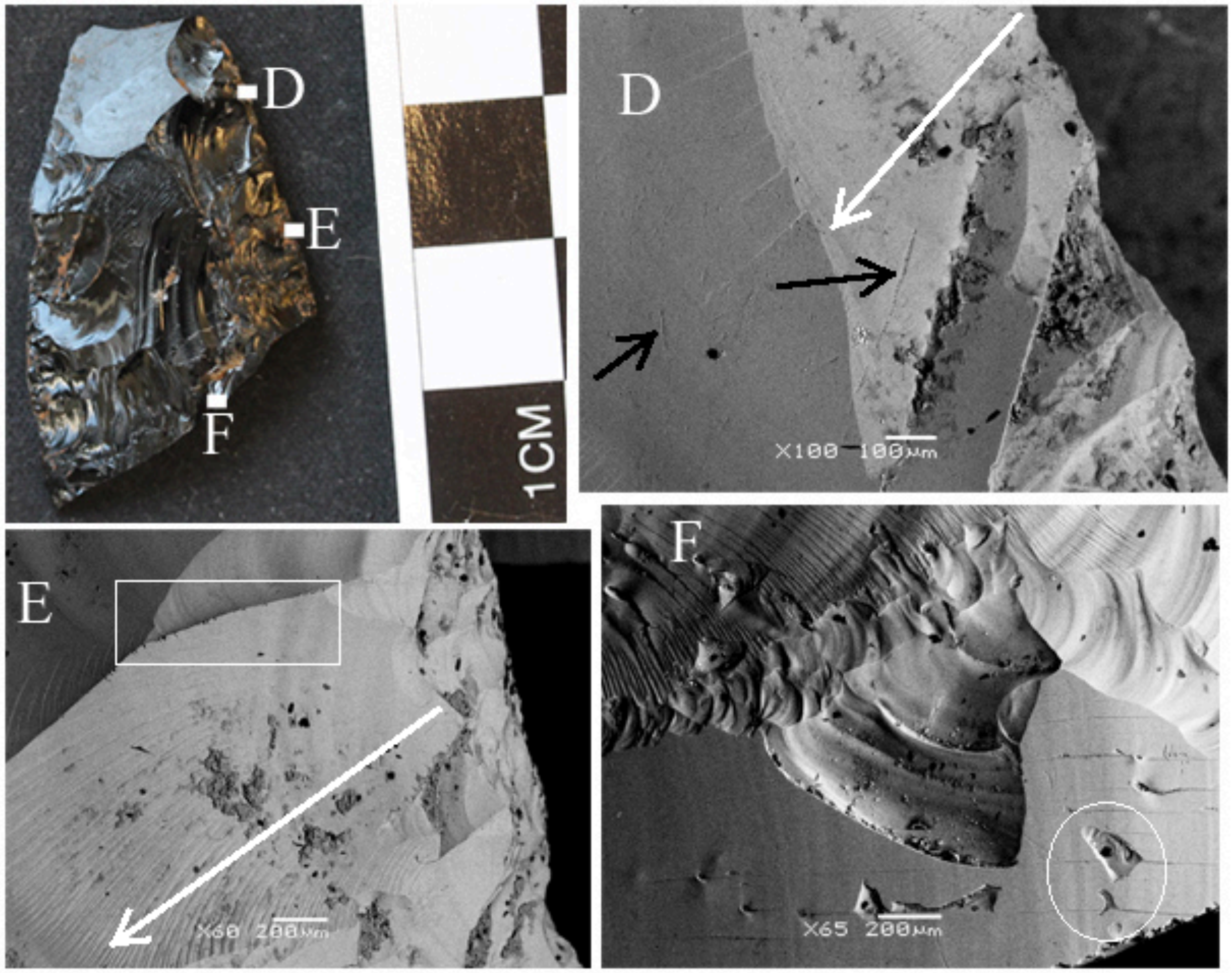

Figure 4.41 continued.

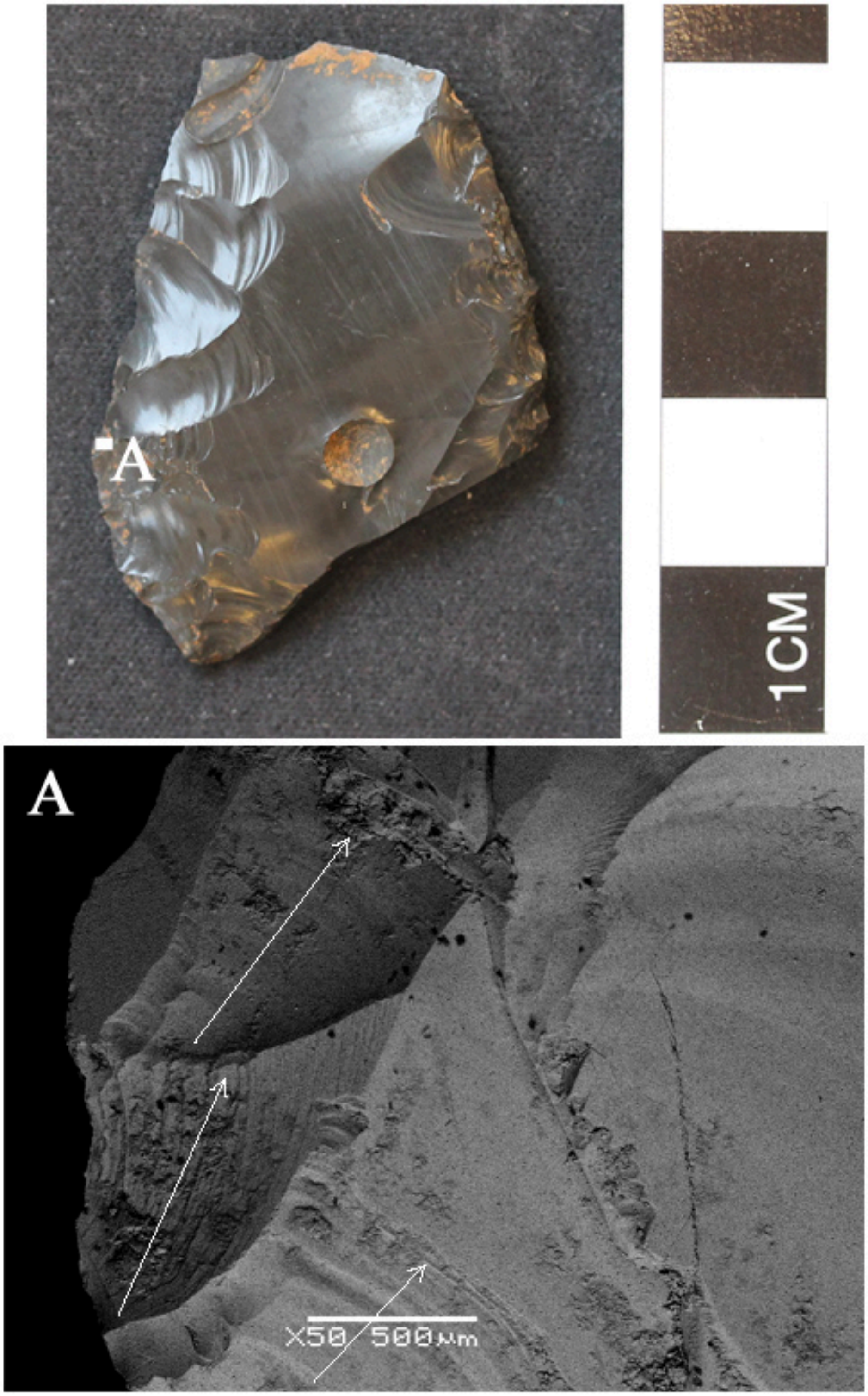

Figure 4.42. Photo of a bifacially flaked knife (#1940). (A) SEM micrograph of angled microflake scars along the edge. Probable longitudinal use-action, such as cutting or sawing.

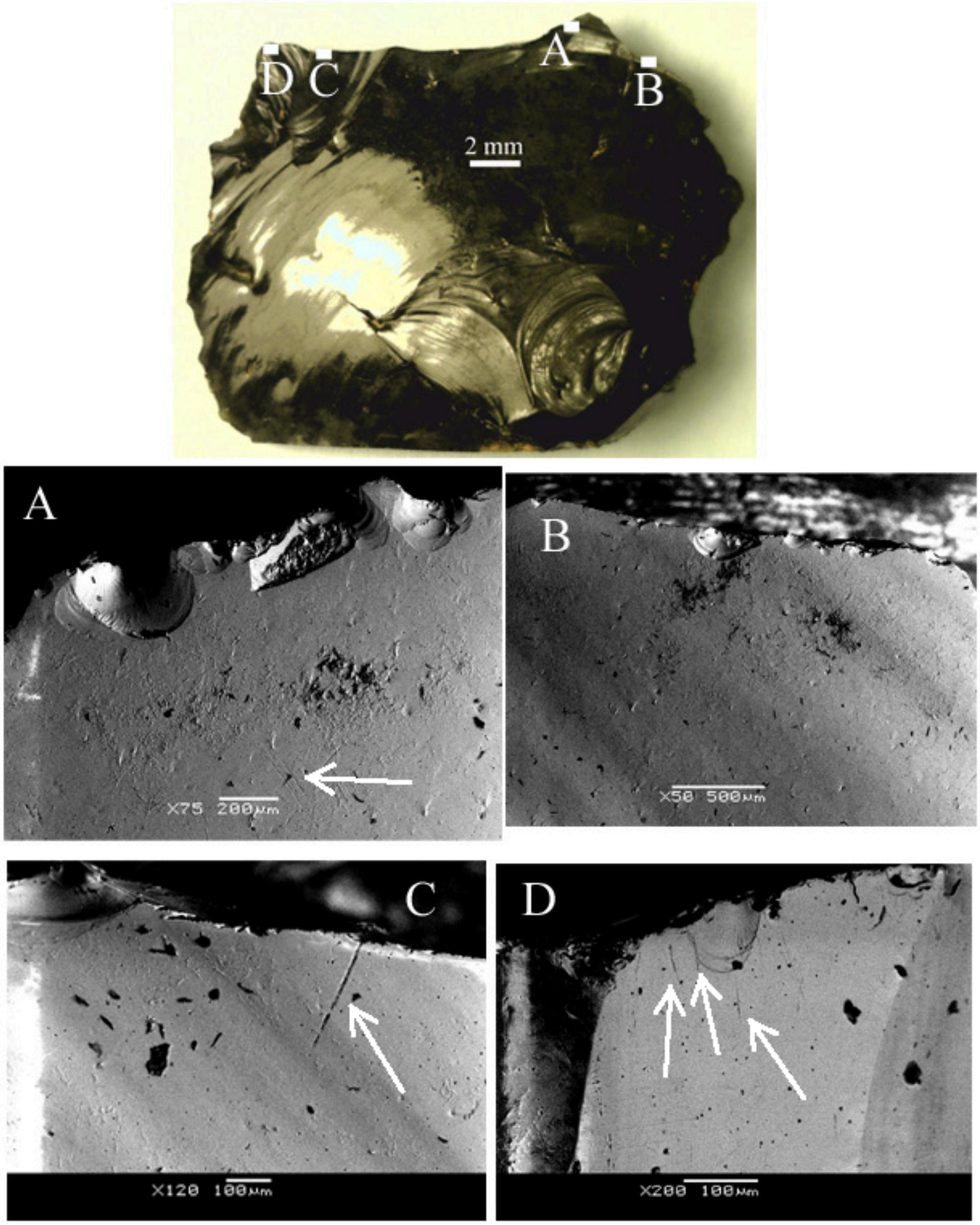

Figure 4.43. Photo of combination tool, with a double side scraper and a retouched corner bec (#2080). (A-B) SEM micrographs of microflake scars and striations (arrow) perpendicular to the worked edge and minor edge rounding; (C-D) Striations perpendicular to one edge of the bec (see arrows). Images A and B suggest a scraping use-action.

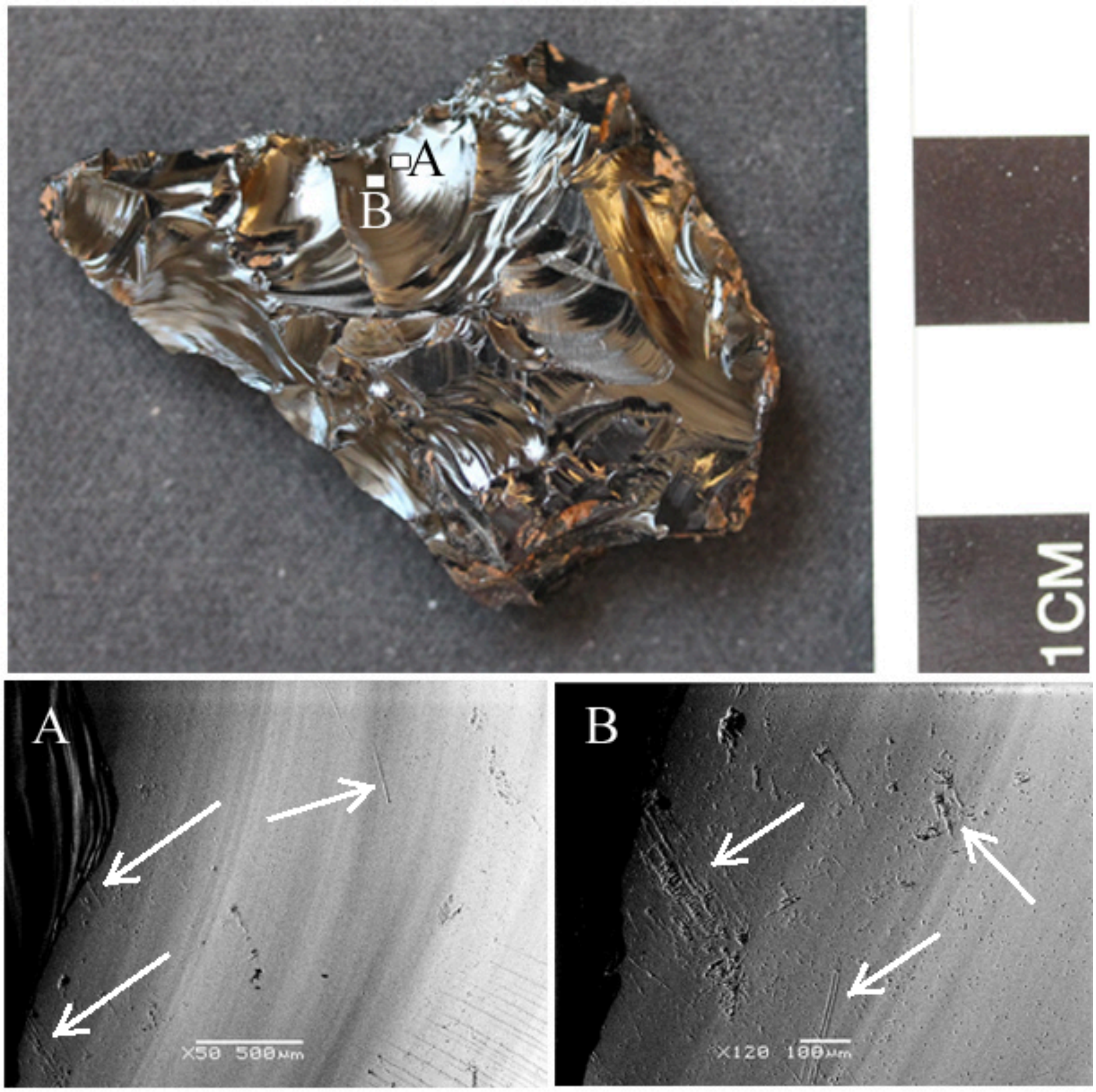

Figure 4.44. Photo of a combination tool with a denticulate bifacial knife and burin (#2834). (A-B) SEM micrographs of striations angled to the worked edge suggest a slicing use-action.

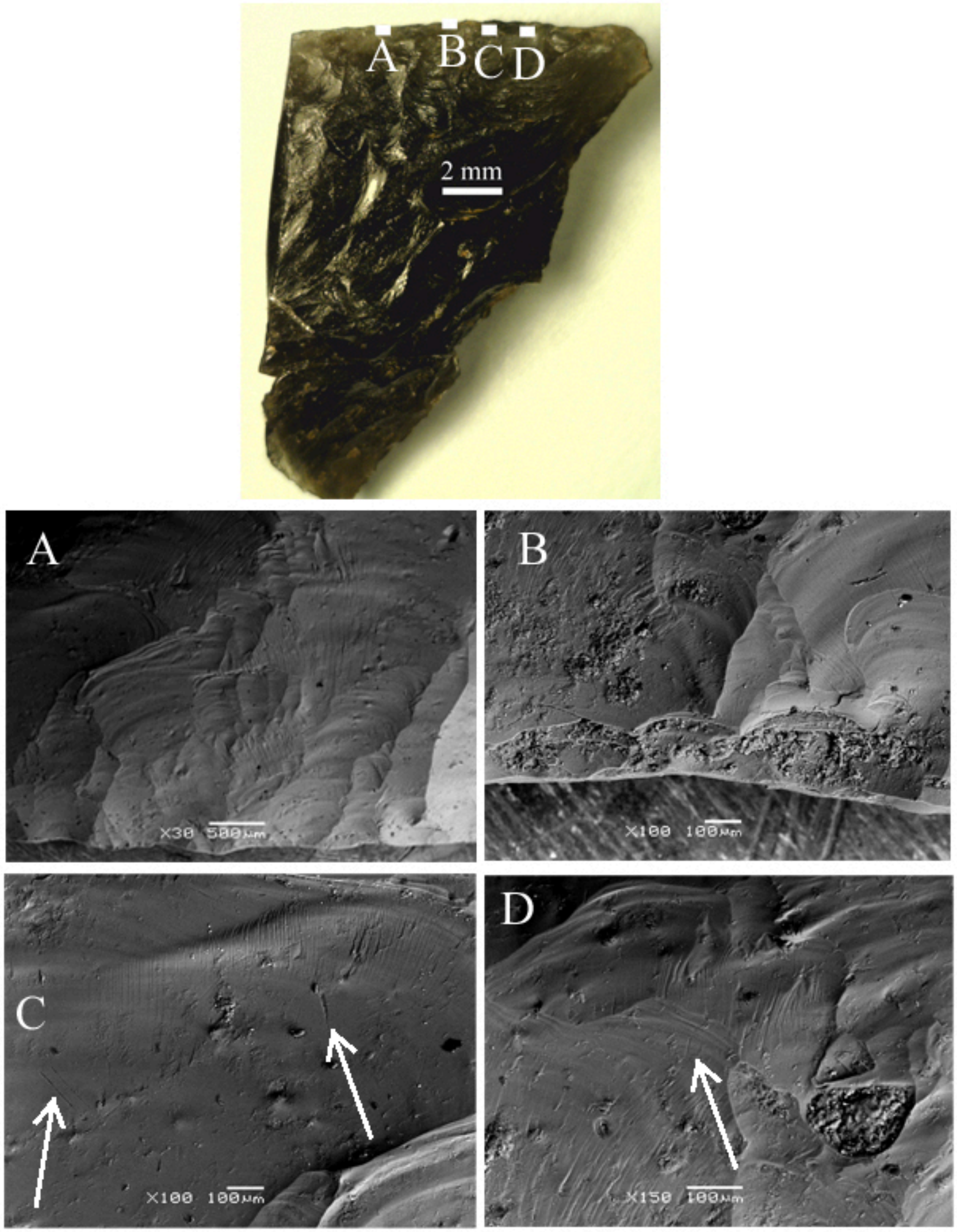

Figure 4.45. Photo of a bifacially retouched tool edge fragment (#2146). (A) SEM micrograph of feather and stepped (B) microflake terminations with striations (C-D) inside the scars. These data support the use of this edge for scraping a soft to medium hardness material.

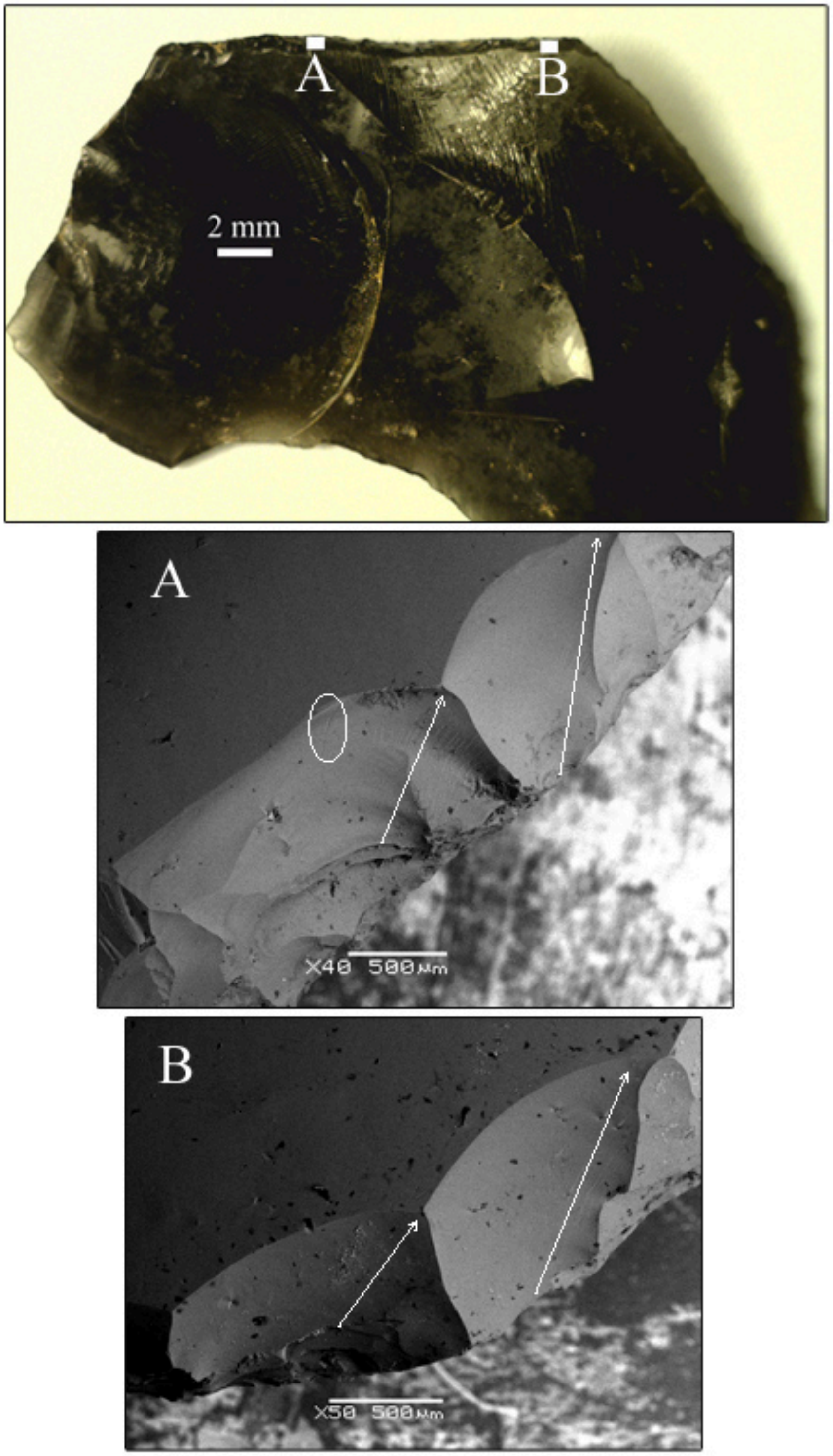

Figure 4.46. Photo of a utilized whole flake (#1880). (A-B) SEM micrographs of marginal, bi-directional, and angled (see arrows) microflake scars with rare striations (circled). These features suggest a sawing use-action on a medium to hard material.

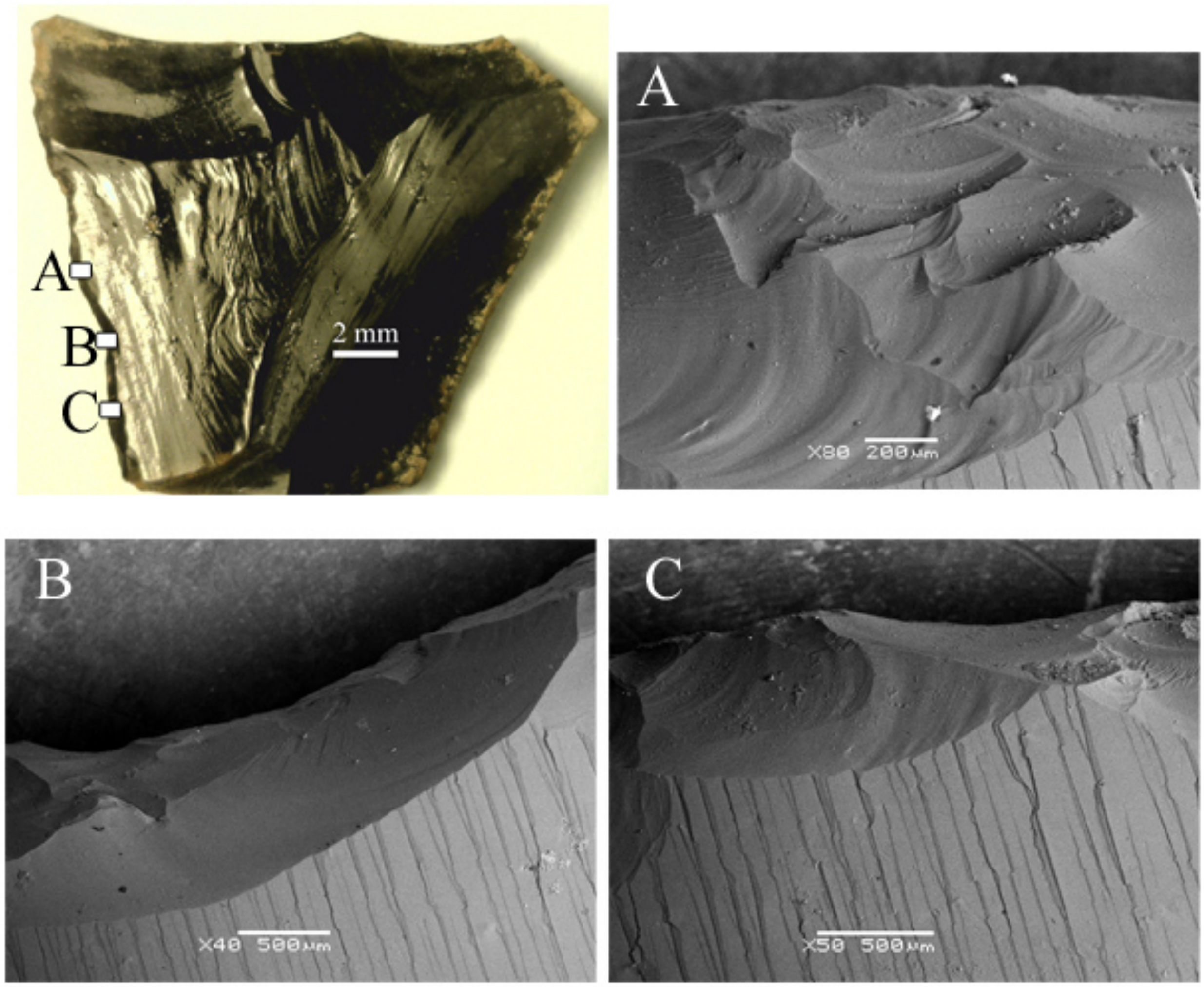

Figure 4.47. Photo of dorsal face of heavily utilized medial flake fragment, an expedient tool (#2306). (A-C) SEM micrographs of marginal and bi-directionally angled microflake scars with robust bulbs of percussion. Stepped (A) and feather (B-C) terminating scars are both visible. These features suggest a sawing use-action on a soft to medium material.

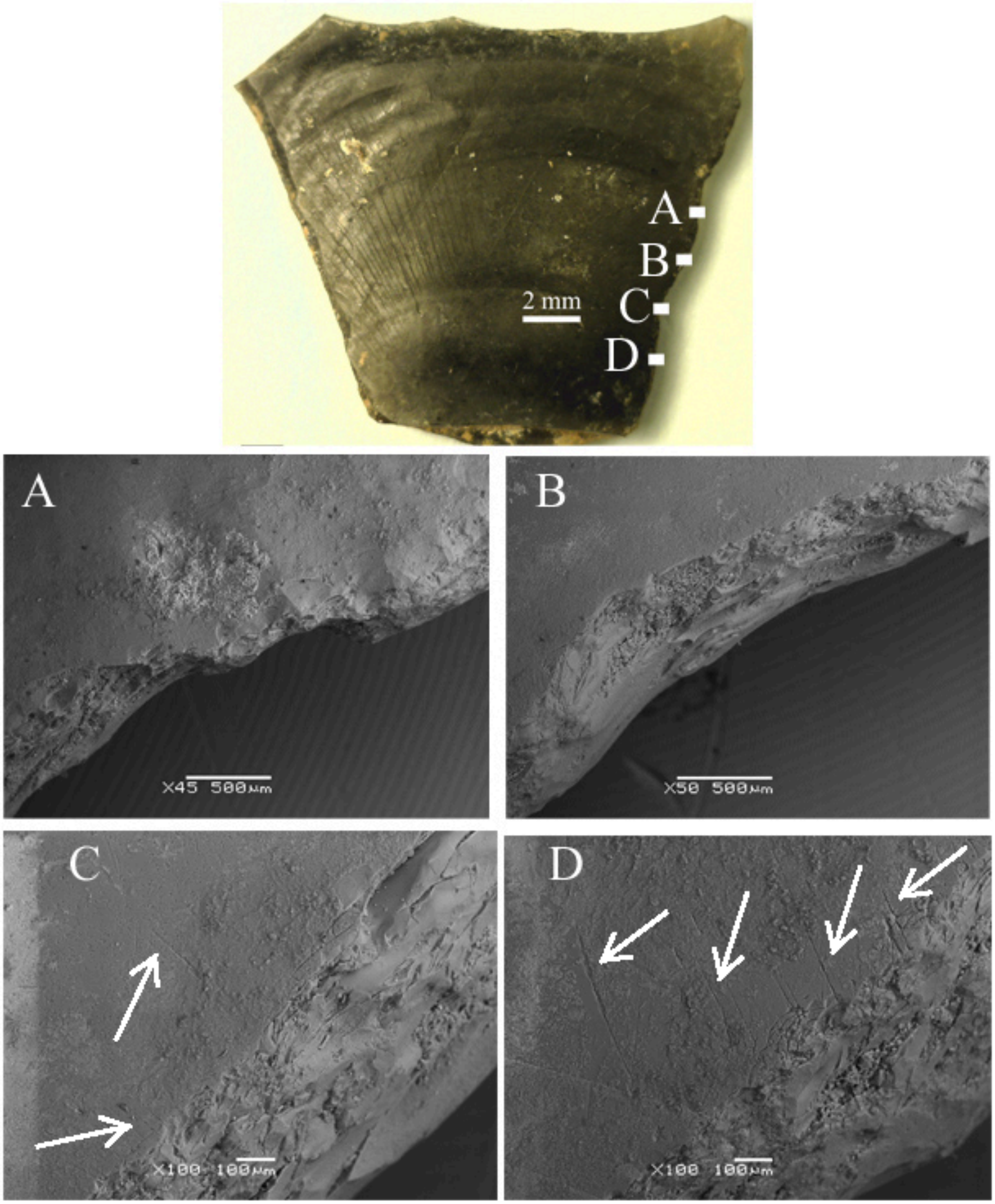

Figure 4.48. Photo of a ventral face of heavily utilized medial flake fragment, an expedient tool (#2306). (A-B) SEM micrographs of edge snaps and rounding, as well as striations (C-D) perpendicular to the worked edge. These features suggest a scraping use-action.

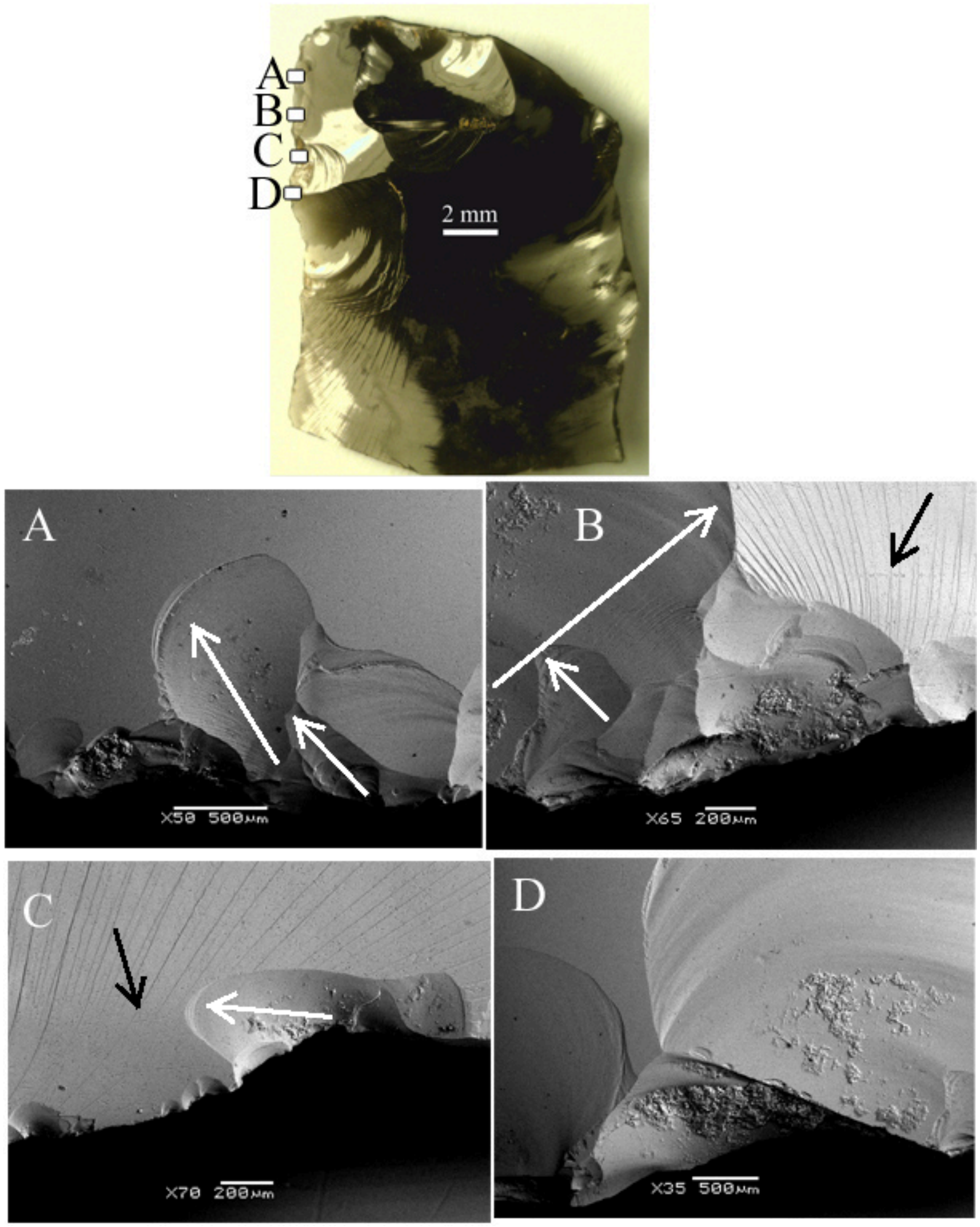

Figure 4.49. Photo of a medial flake fragment with invasive shallow retouch, an expedient tool (#2492). (A-B, E) SEM micrographs of angled microflake scars (white arrows); (B-C, F) striations parallel or diagonal to the worked edge (black arrows); (D) half-moon break or snap. These features indicate a sawing use-action on a soft material.

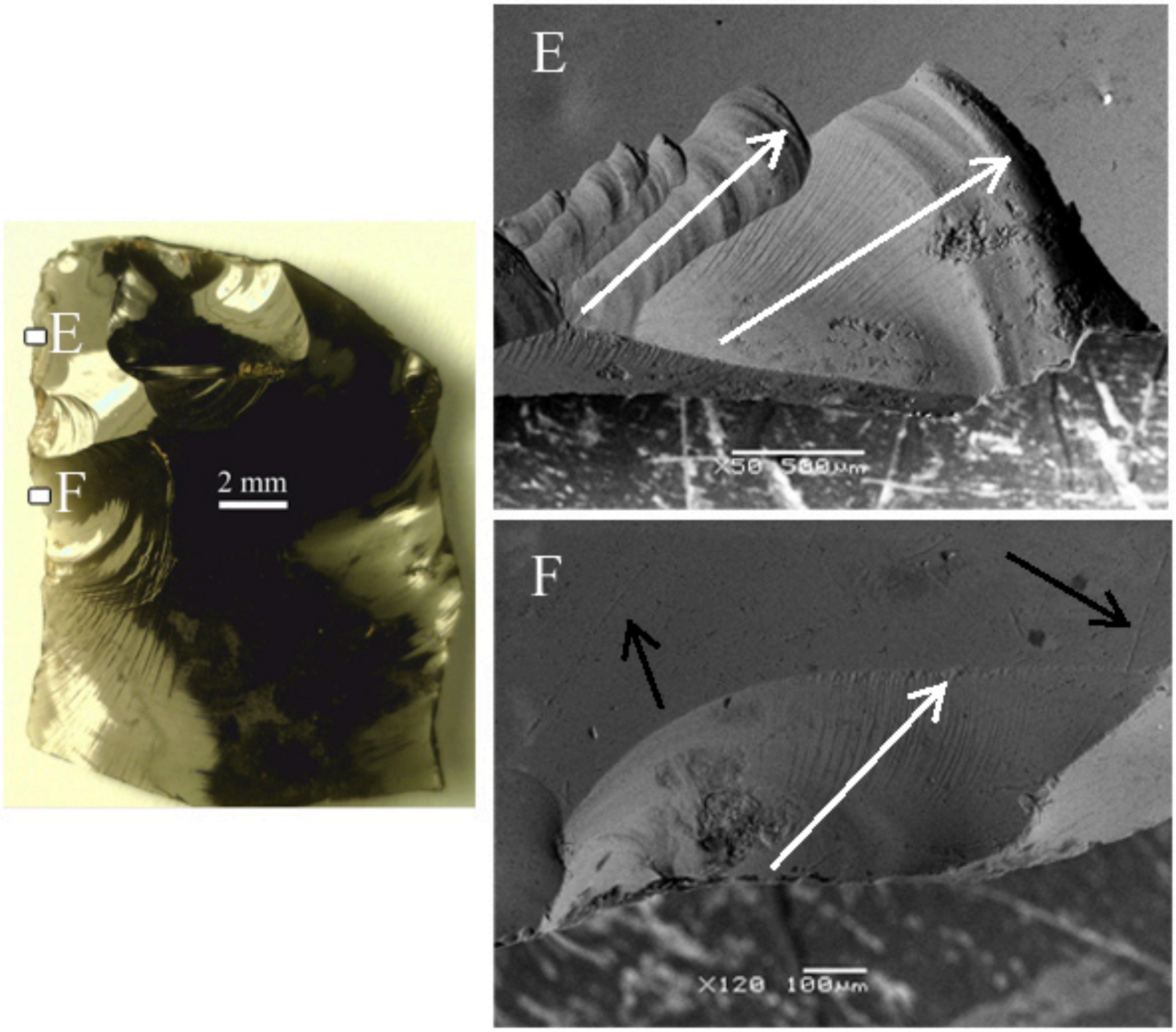

Figure 4.49 continued.

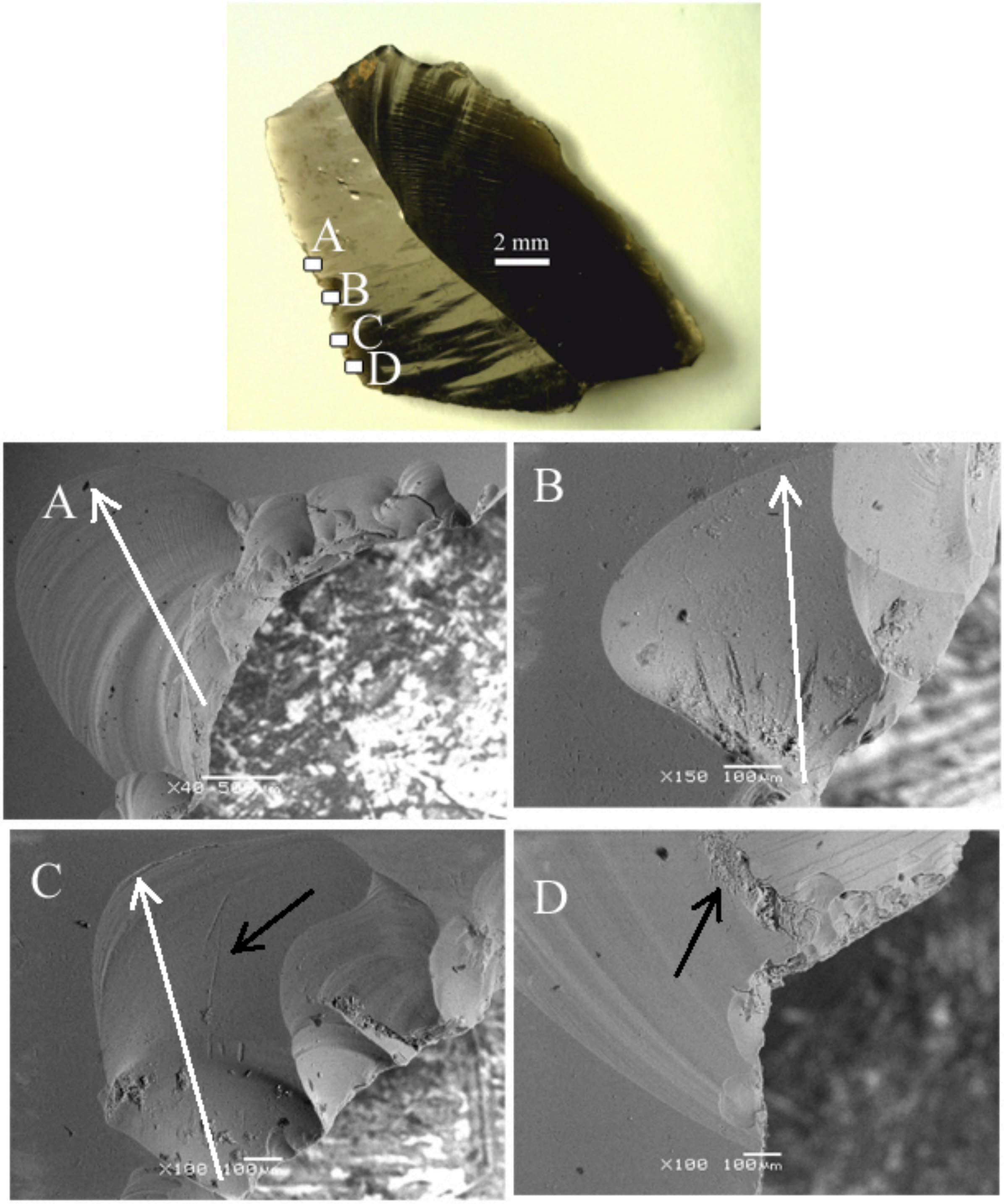

Figure 4.50. Photo of a utilized proximal flake fragment, an expedient tool (#2569). (A-C) SEM micrographs of angled microflake scars (white arrows) with feather terminations and striations (C-D; black arrows). Use-wear features indicate sawing of a soft material with gritty particles.

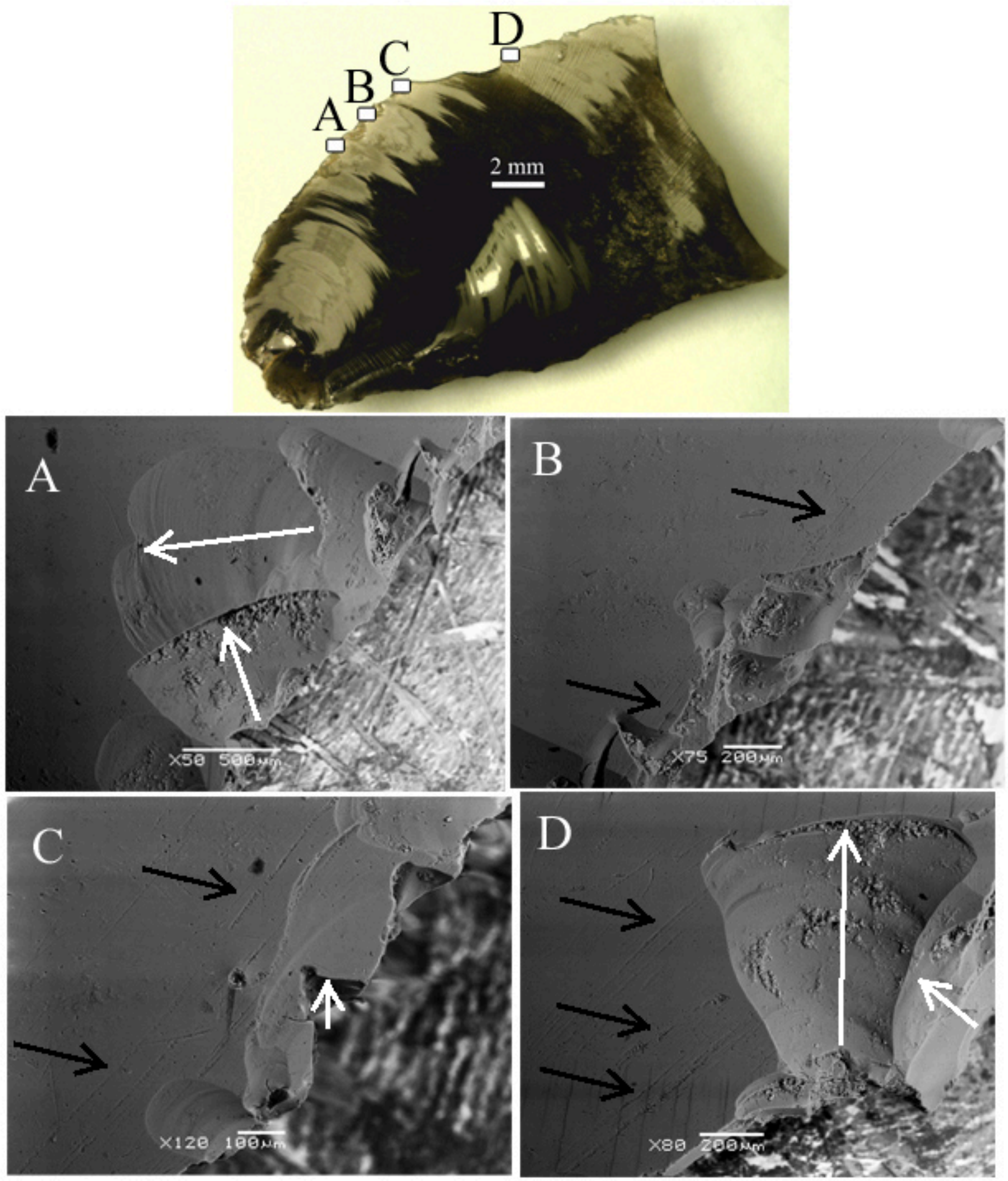

Figure 4.51. Photo of a utilized proximal flake fragment, an expedient tool (#2719). (A-D) SEM micrographs of bi-directional angled microflake scars (white arrows) and striations (B-D; black arrows) parallel to the worked edge. These features suggest a sawing use-action on a soft to medium hardness material.

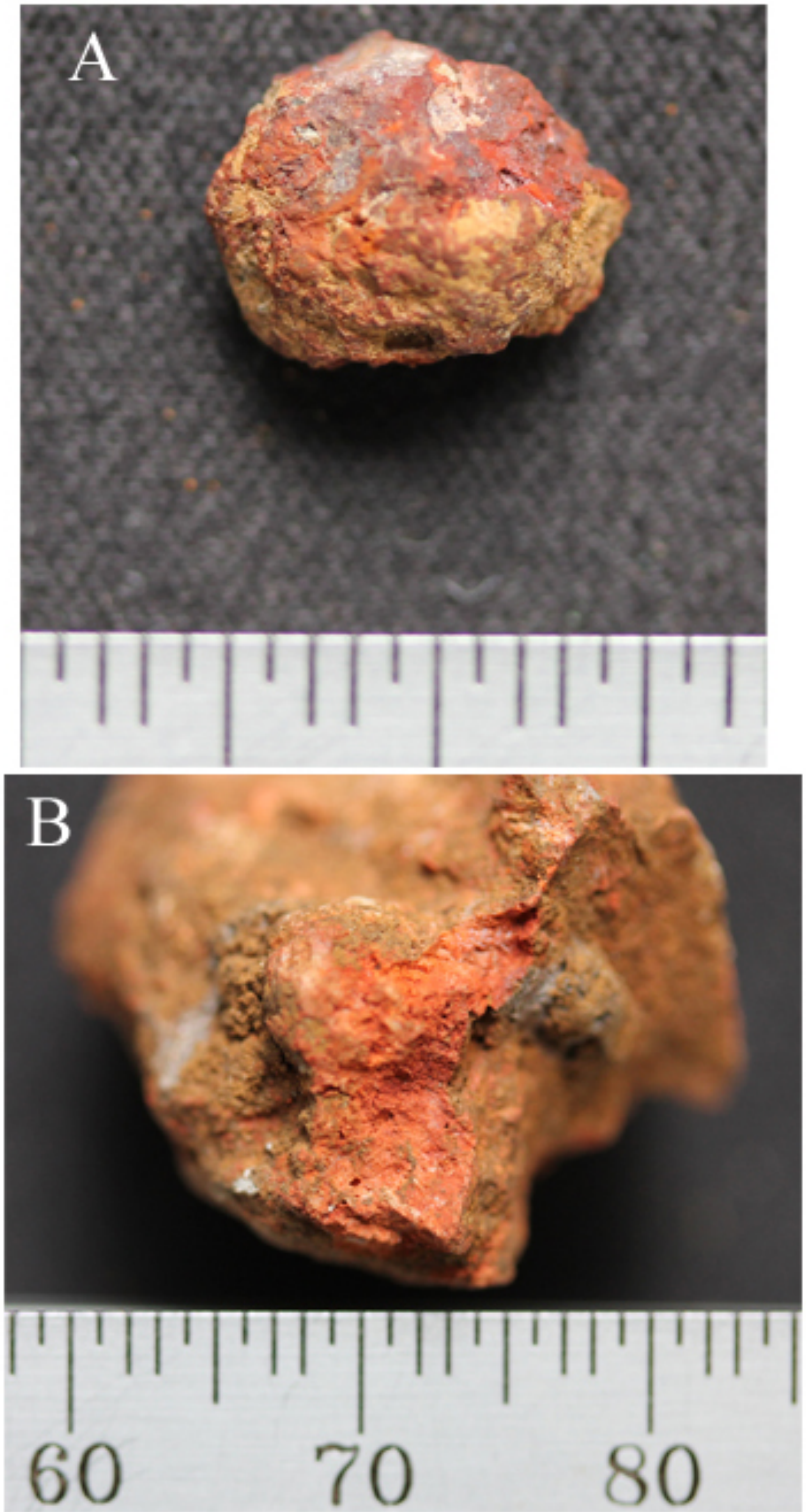

Figure 4.52. Red ochre chunks recovered in H5. (A) #1512; (B) #1547.

Figure 4.53. Lava hammer stone and pigment processor (#1519) with red ochre staining on one rounded end (image A on bottom right corner) and one abraded area (image B on upper right).

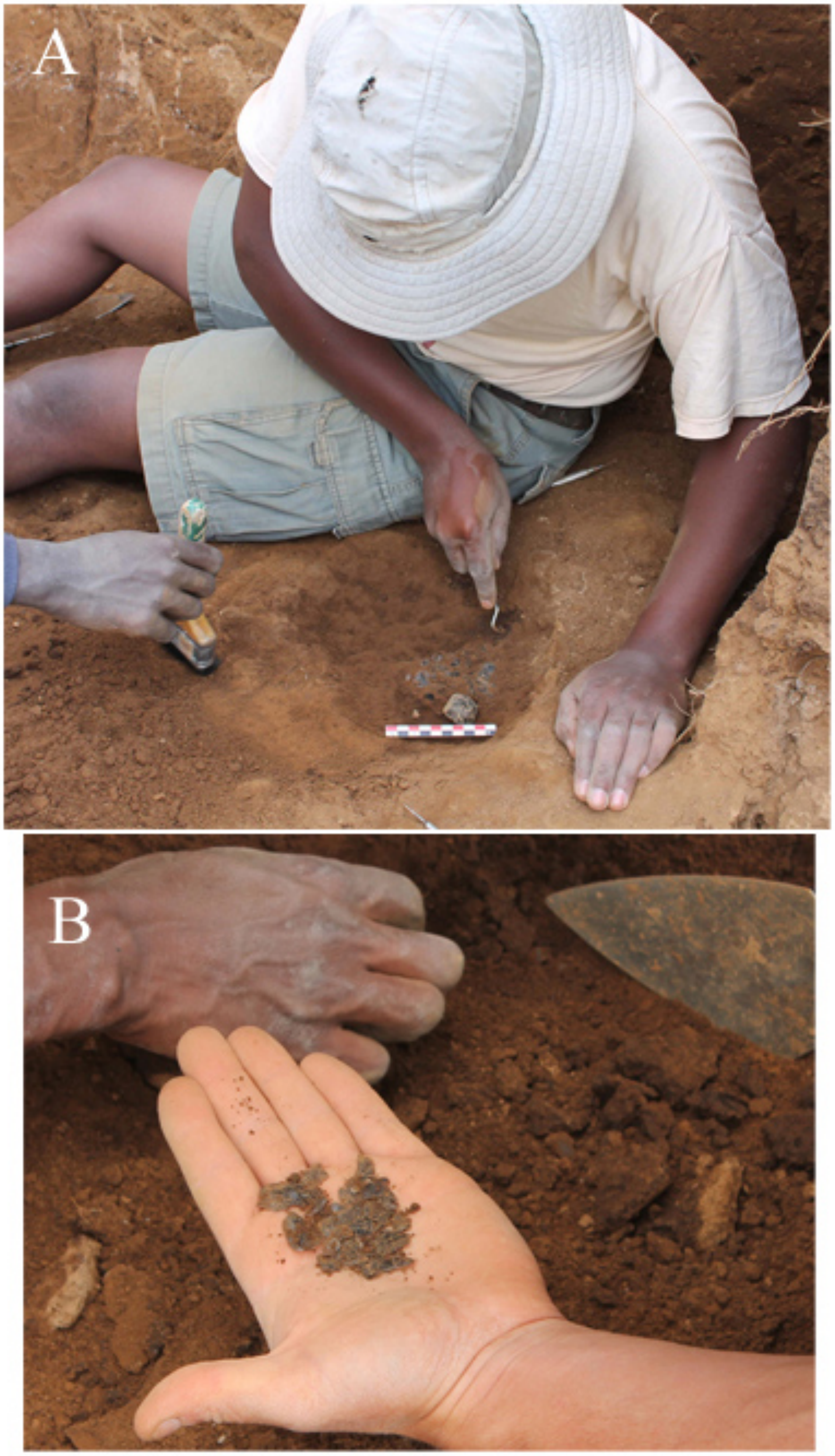

Figure 4.54. (A) Excavating artifact cluster #1 from trench 1, H5 with a brush and dental pick. A total of four dense concentrations of small retouch flakes (B) were found in an area of ~1 sq. m.

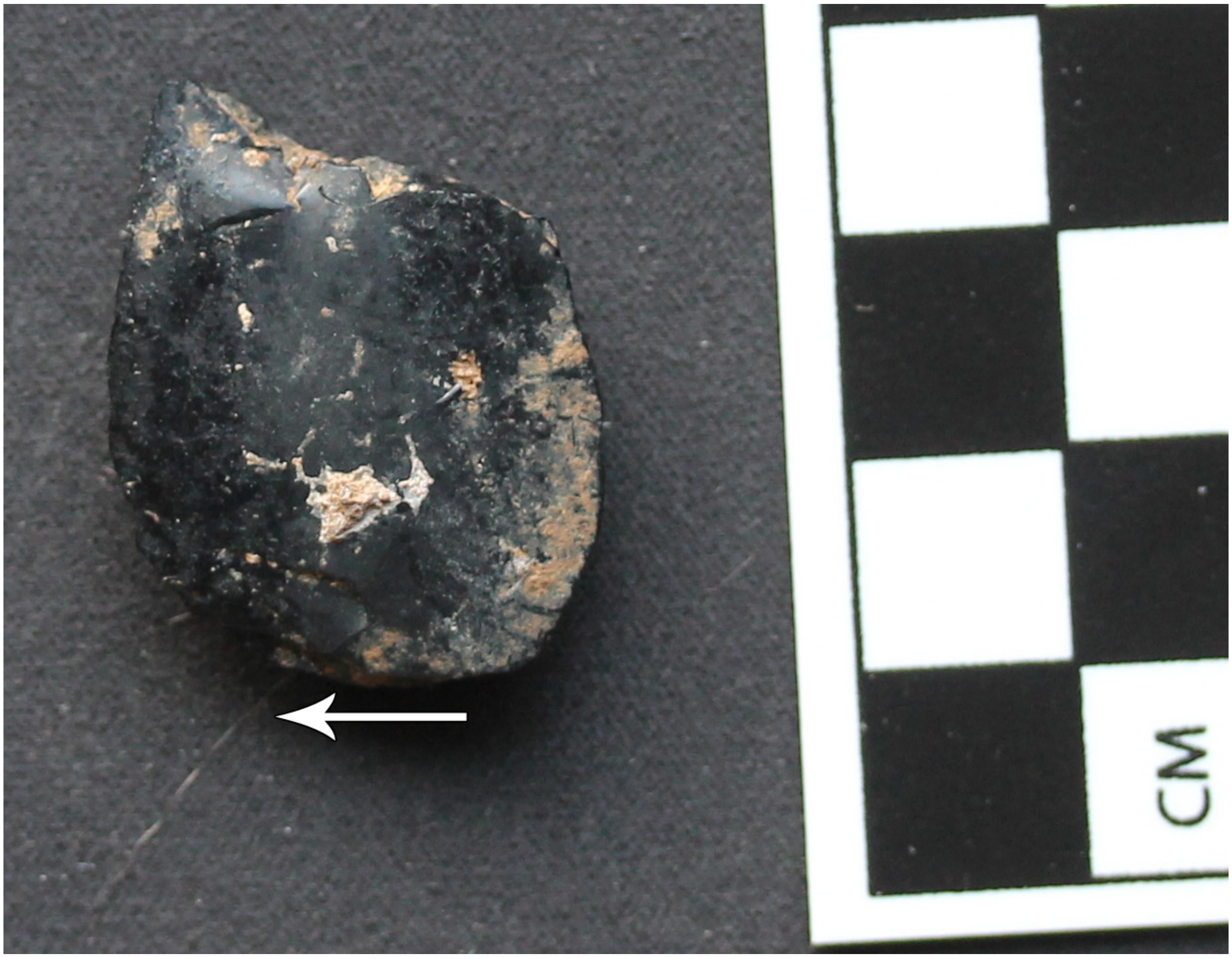

Figure 4.55. Unifacial point (#2145). Arrow indicates direction of the original flake blank's distal end. The ripples are perpendicular to the long axis of the point indicating that the width of the original flake was at least as wide as the point's final form was long.

Figure 4.56. Combination tool (#2902); double burin and double denticulate knife. Note that the platform is present and the distal end is snapped; this was a large flake.

Figure 4.57. Helwan backed denticulate knife/scraper (#3009) from H4.

Figure 4.58. Helwan backed denticulate knives/scrapers (A, #3009; B #3279). The other two pieces (C, #3280; D, #3278) lie on the boundary between convex side and circular scrapers.

Figure 4.59. Photo of scrapers from H4. Pieces labeled 1 (#3156), 2 (#3212), and 3 (#3343) are convex end and double side scrapers. Number 4 (#3314) is a transverse scraper with the retouched edge on the proximal end. Note the extensive weathering visible on the dorsal face of the third scraper to the right. This weathering is common in the H4 assemblage overall, suggesting a long surface exposure.

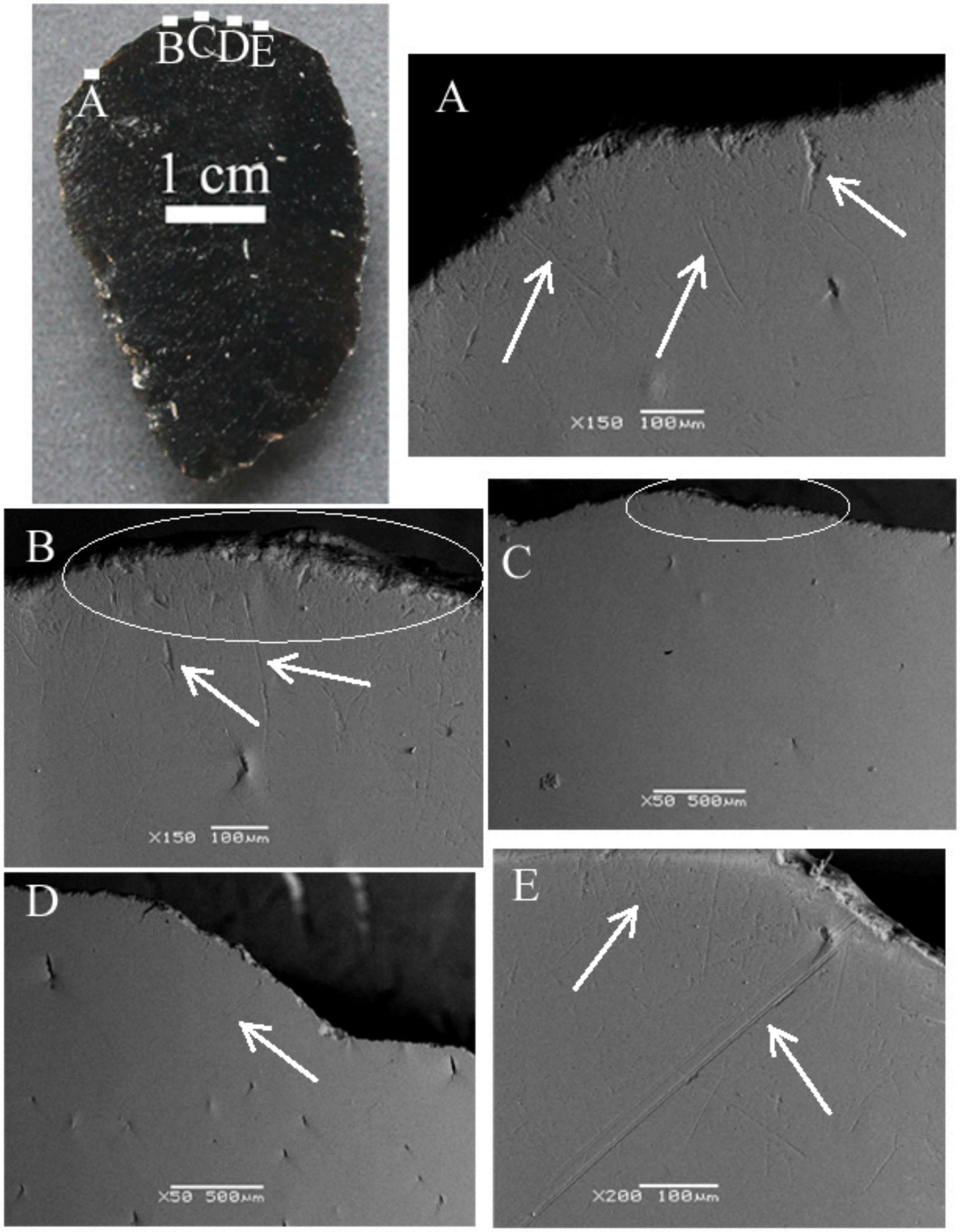

Figure 4.60. Photo of a convex end and double side scraper (#3156). (A-H) SEM micrographs of longitudinal striations and rounding on retouched edge; (I-J) lateral and crisscrossed striations are common across the medial portion of the tool; (K-L) striations and arête abrasion (M) on the base. Together, these features suggest this tool was hafted and used for scraping soft materials.

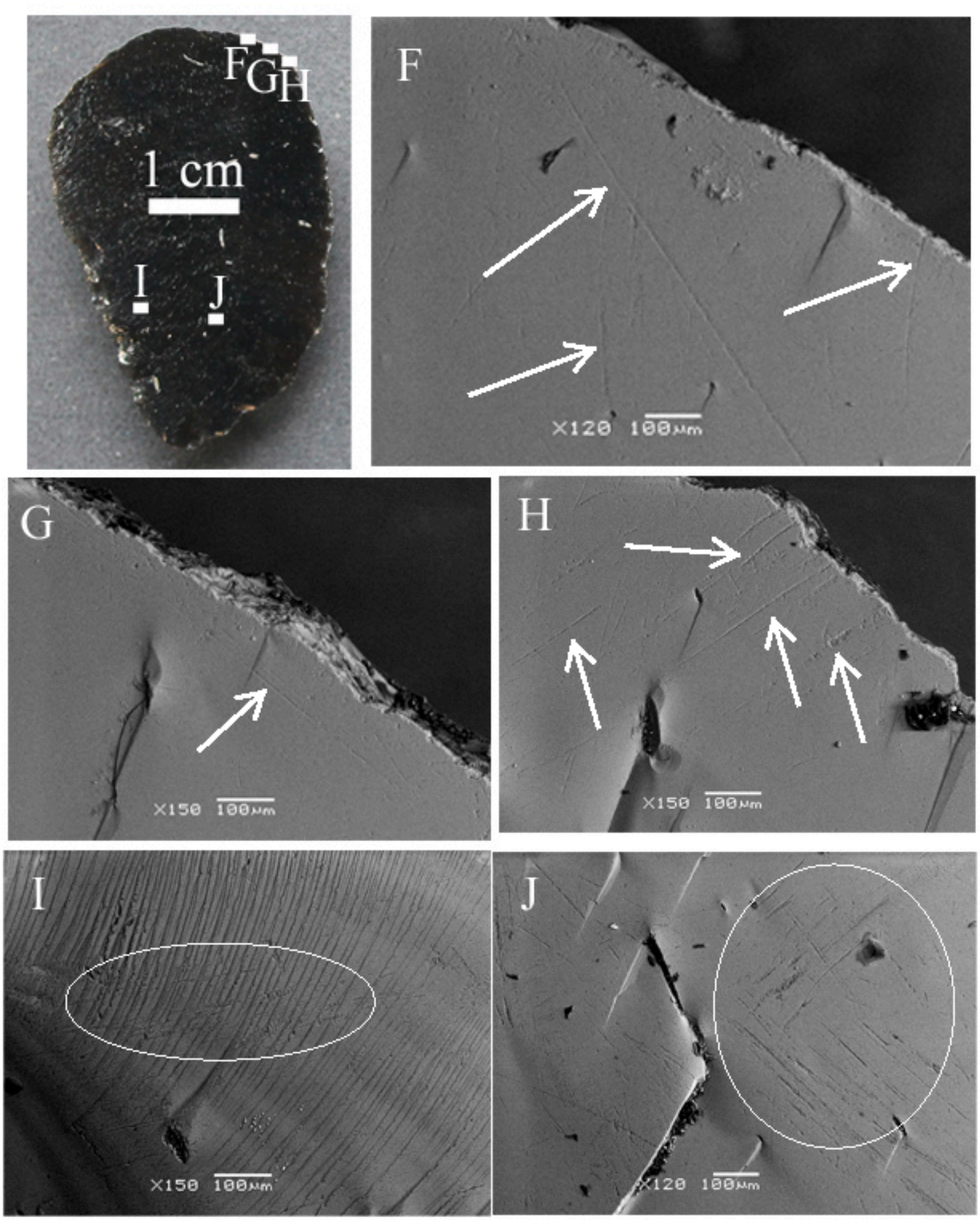

Figure 4.60 continued.

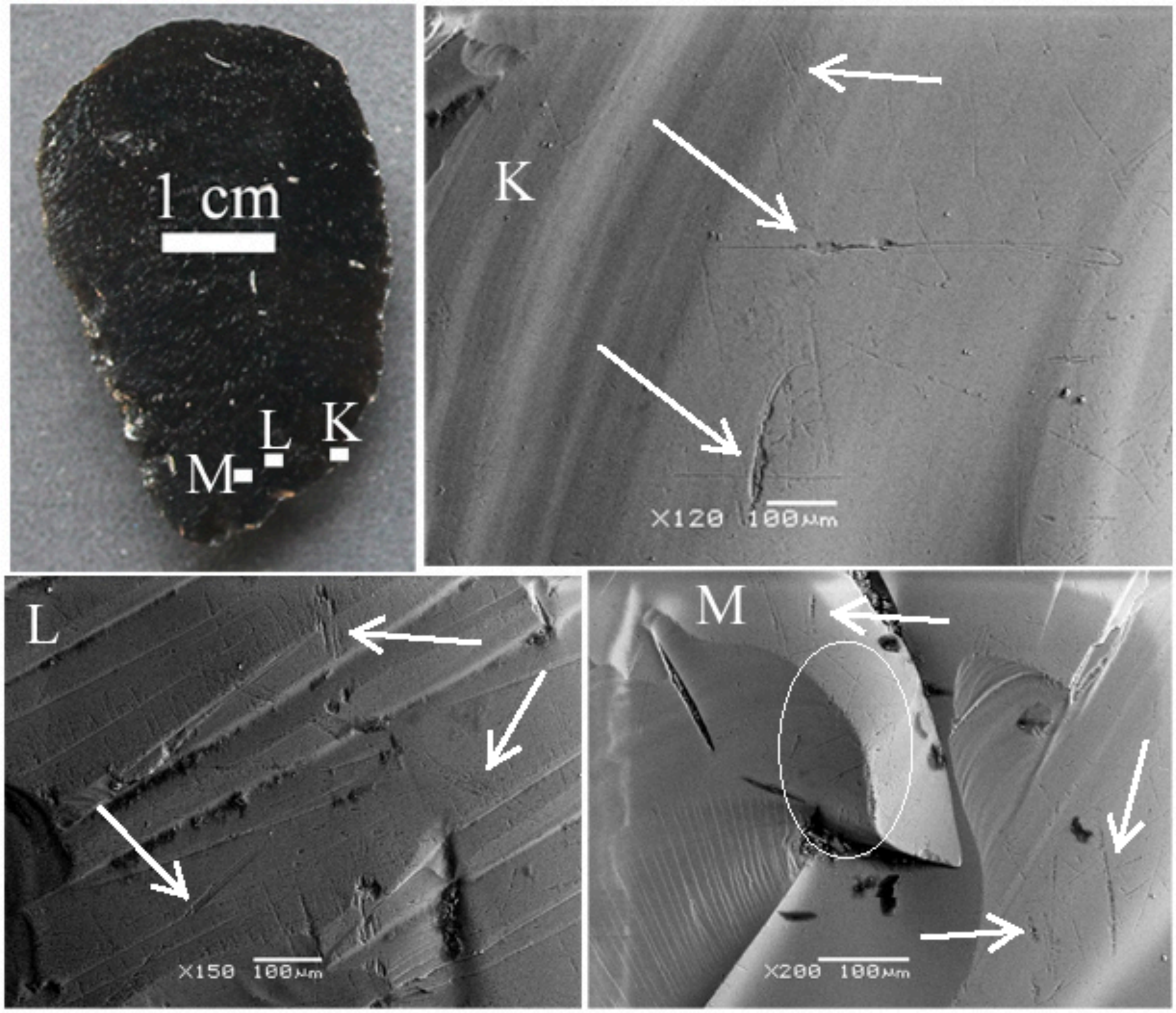

Figure 4.60 continued.

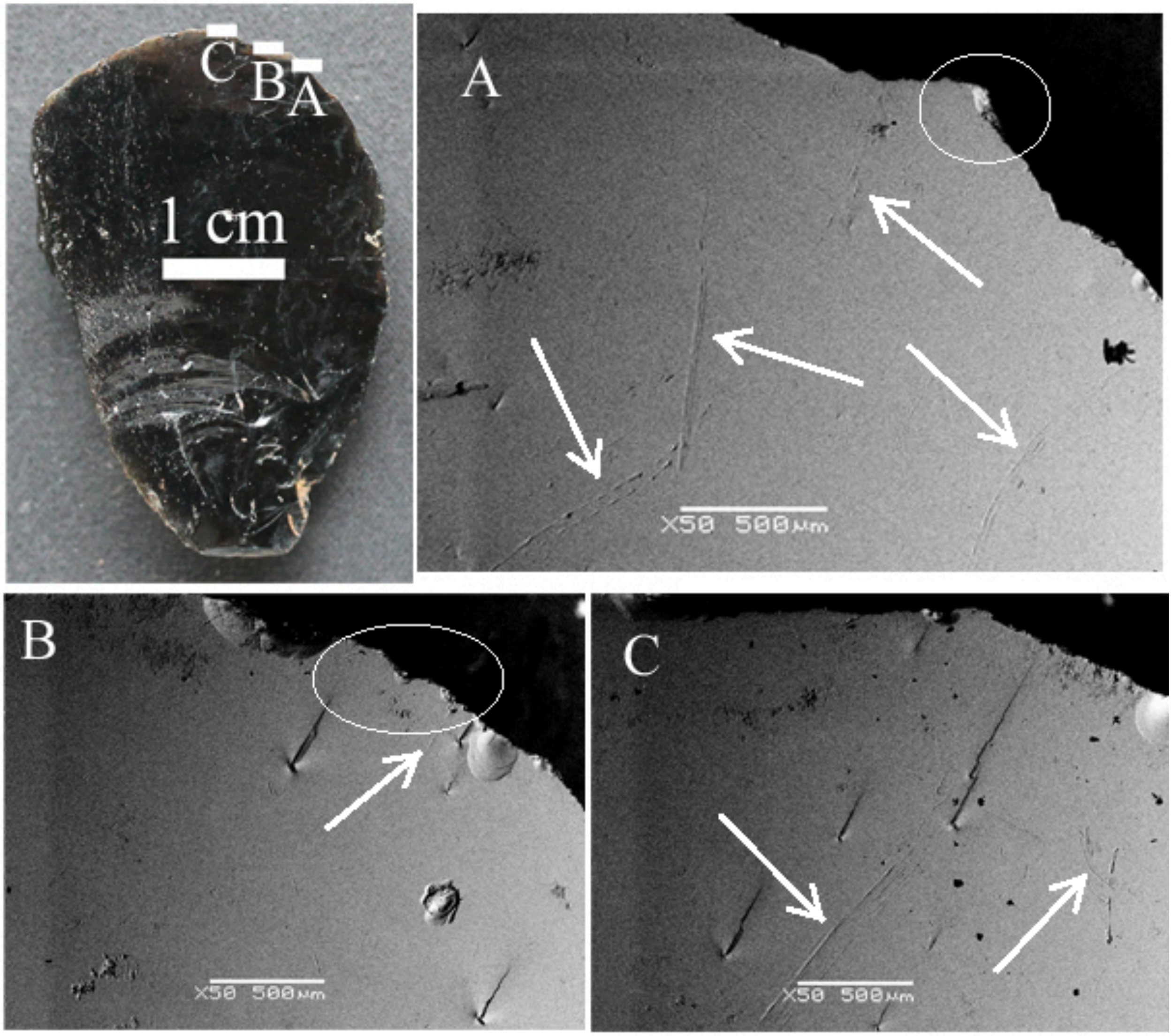

Figure 4.61. Photo of a convex end and double side scraper (#3212). (A-D) SEM micrographs of diagonal/longitudinal striations (arrows) and minor edge rounding (circles) near the retouched edge; (E-F) higher magnification images of striations in B and C. Together, these features suggest this edge was used for scraping soft materials with some hard or gritty particles.

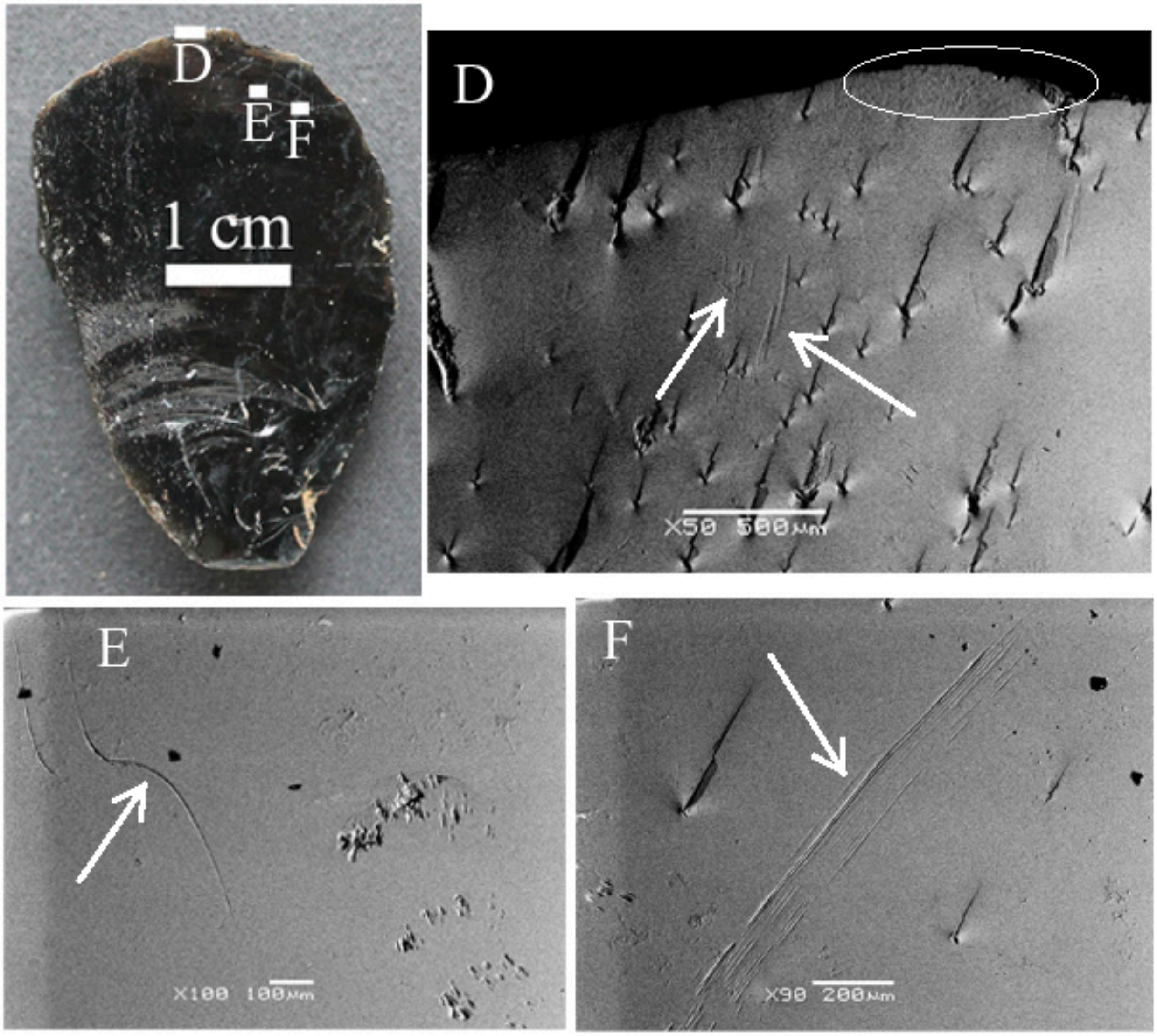

Figure 4.61 continued.

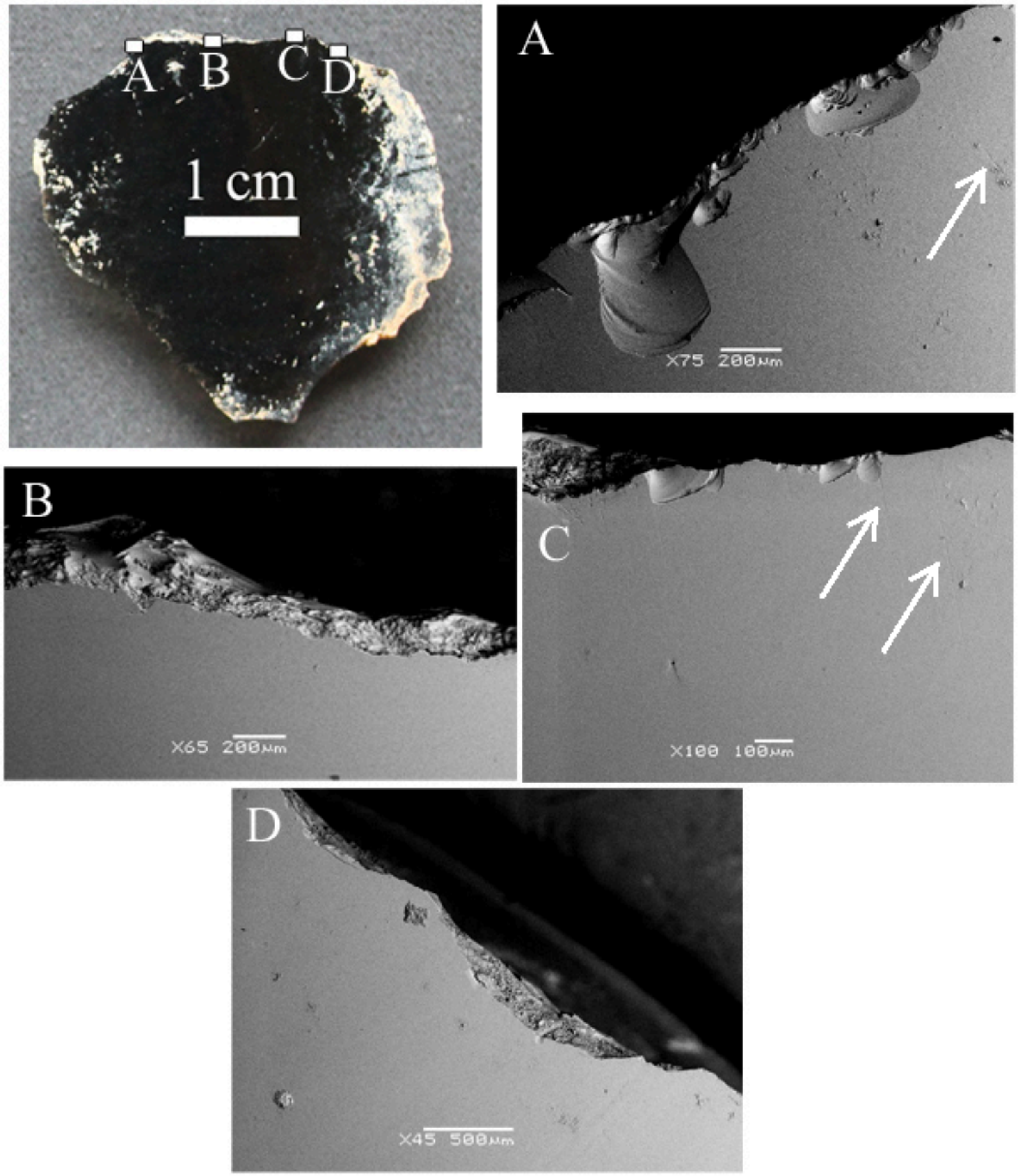

Figure 4.62. Photo of a transverse scraper with the retouched edge on the proximal end (#3314). (A-D) SEM micrographs of edge rounding and rare perpendicular microflaking. Striations (A, C) are also rare. Suggests use of retouched edge for scraping a soft material.

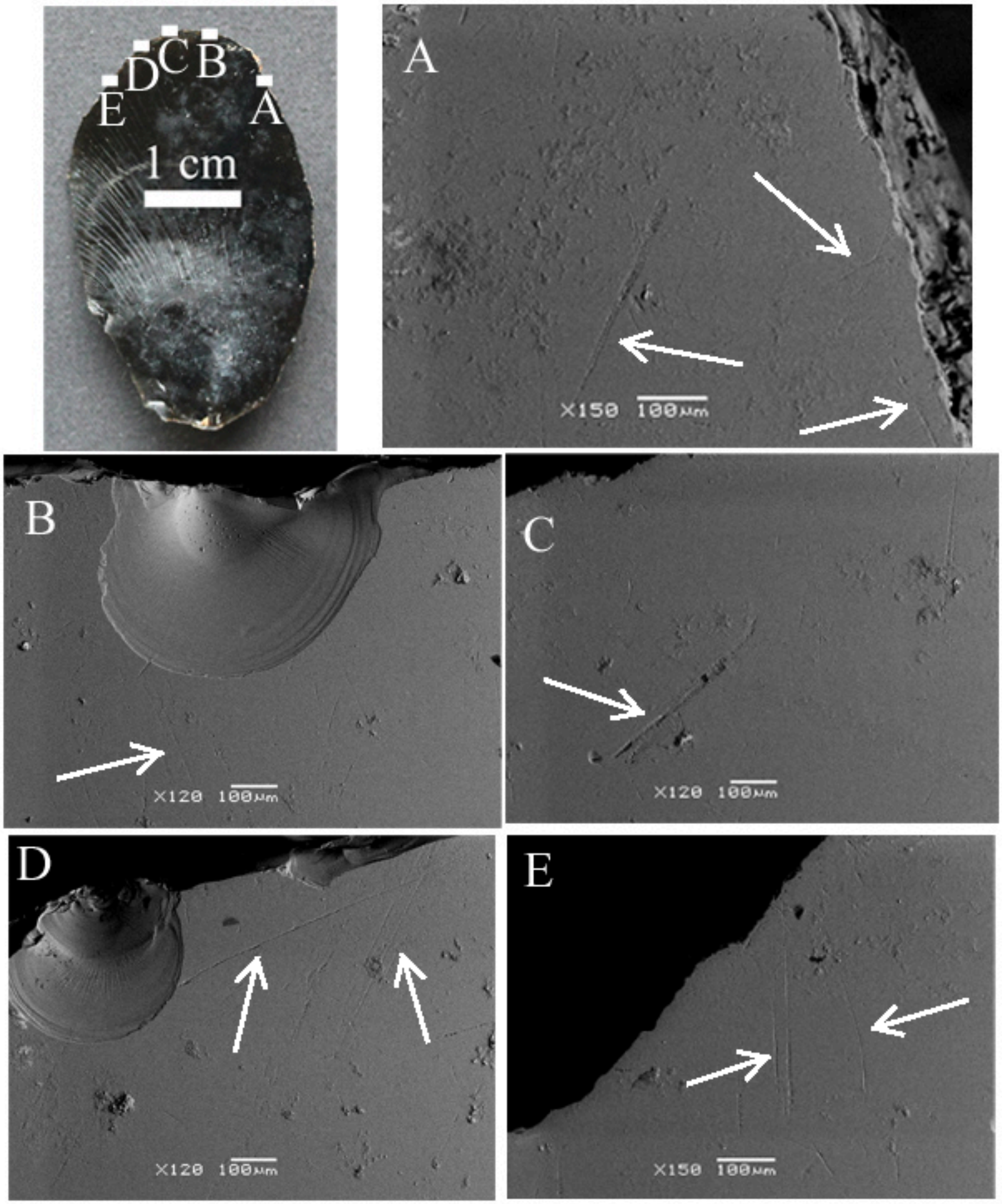

Figure 4.63. Photo of a convex end and double side scraper (#3343). (A-E) SEM micrographs of striations (multiple directions) and minor edge rounding (A, D) suggest use of retouched edge for scraping soft materials.

Figure 4.64. Photo of a freshly excavated unifacial point from the 2010 excavation in level 22.

The length of the point (from proximal/bottom to distal/top in the photo) is about 5 cm.

Chapter 5

Lithic Technological Organization at Enkapune Ya Muto

This chapter comprises a description of the Enkapune Ya Muto rockshelter (EYM, GtJi12) site geography, stratigraphy, excavation history, and lithic technology from the 'GG1' and 'DBL1.3' horizons. The GG1 industry is dated to between 55-40 ka, and represents the earliest known 'microlithic' Later Stone Age industry in the world. The overlying DBL1.3 industry is dated to between 40-35 ka and is contemporary with the earliest LSA and Upper Paleolithic technologies in African and Eurasia. These assemblages provide crucial 'middle-aged' data between Marmonet Drift and Ol Tepesi for evaluating long-term diachronic change in technological organization strategies spanning the MSA and LSA in Kenya.

Geography

Enkapune Ya Muto is located 9.5 km south of Marmonet Drift, on the eastern slopes of the Mau Escarpment on the west side of the Lake Naivasha basin in Narok County of the Rift Valley Province of Kenya (see figure 3.1). The rockshelter is situated at ~2400 m above sea level at the head of a gully system incised between two elevation steps on the escarpment. The lower step is at 2200 m and the higher at 2500 m; the higher step extends 9 km south of the site while north slopes gradually down over 8 km to join the lower step. The escarpment rises steeply to 2730 m directly above the rockshelter to the third step, which forms the Nasampolai valley. The crest of the Mau Escarpment (3070 m) forms the west side of the Nasampolai Valley. Ambrose first discovered it in 1982 through a Masai informant from the Naibor Ajijik location, who also noted that local Masai and Kikuyu used the site periodically for ritual slaughter and meat feasting activities. The nearest obsidian sources are located 10.5 km east of the site at the Mundui/Sonachi source area, which is the dominant source for the Marmonet Drift H5 and H4 assemblages, and 13 km SE of the site in the Oserian/northern Hells Gate National Park area.

Site Excavation History, Stratigraphy and Chronology

Enkapune Ya Muto was excavated twice under the direction of Stanley Ambrose, first in 1982 with a 2 x 2 m test pit and 1 x 4 m step-trench (figure 5.1), and second in 1987 with a 10^2 m pit adjacent to the first test pit. The first excavation was carried out with the goal of finding mid-Holocene archaeological occurrences for investigating the transition to food production in Kenya. This goal was fulfilled and exceeded because the 5.2-meter deep sequence includes one late-MSA/Early LSA transition and two early LSA horizons beneath an erosional unconformity that separates deposits younger than 6.4 ka from those older than 35 ka. Excavations in 1987 were undertaken to obtain 1) a larger sample of MSA and early LSA artifacts and 2) materials for accurately dating the MSA/LSA transition. Both of these goals were achieved as well, and EYM now provides a well-dated sequence documenting the Later Iron Age, Elmenteitan Neolithic, the transition to herding among middle to late Holocene Eburran LSA hunter-gatherers, the earliest LSA in Africa, and the MSA/LSA transition in highland central Kenya (Ambrose, 1998a).

All stratigraphic descriptions are derived from Ambrose's (1984: 108-113) dissertation and dates are from a report on the chronometric dating of this sequence (Ambrose, 1998a). The complete sequence of excavated deposits is approximately 5.2 meters thick from the ground surface down to bedrock. The sedimentary sequence contains a total of 16 primary stratigraphic levels, three of which are volcanic ashes, and the rest being anthropic sediments with varying proportions of natural sediment inputs. Strata were named with acronyms based on their sedimentary color, texture, and composition, such as RBL4 for the fourth Red-Brown Loam. Strata exceeding 10 cm in thickness were excavated in levels (spits) of 10 cm or less in thickness. For example DBL1.3 is the third spit within the first dark brown loam.

Samples of obsidian artifacts from lithic assemblages of the GG1 and DBL1 horizons were analyzed for this dissertation. Ambrose (1984) named the DBL1 industry “Sakutiek” after a valley of the same name located farther up the Mau Escarpment and the GG1 industry “Nasampolai” after a nearby trading center above the site on the Mau Escarpment. VA 3, a fine grained, dense, compact pale gray pumice and ash layer caps the DBL1 horizon and provides a clean stratigraphic break from the overlying Holocene deposits. DBL1 is a ~25 cm thick layer of dark brown gritty loam with clear upper and lower boundaries, and high densities of artifacts with sharp, fresh edges, and comminuted carbonized organic matter and faunal remains. It is also notable for its abundance of ostrich eggshell ornaments, including drilled beads and perforated and unmodified fragments representing all stages of bead manufacture. The underlying GG1 horizon is 110-170 cm thick. Its sedimentary matrix is composed of moderately sorted, wind-deflated angular blue-gray gravels with occasional lenses and one distinct layer of sandier orange and brown sand within GG1 named OL1. Fragments of roof fall and larger blocks are also common. The upper boundary with DBL1 is stained from the dark brown color while the lower is clear and easily distinguished. Faunal remains are rare, with variable preservation, and artifact densities are extremely low. Ostrich eggshell is absent. Obsidian artifact edges are sharp and fresh, despite the coarse deposits. Red ochre is preserved on several backed microlithic artifacts, which also indicates good preservation of surfaces and edges.

A total of 35 radiocarbon dates were run on the EYM sequence, with 34 on charcoal and one on ostrich eggshell carbonate. Ambrose (1998a) has already summarized the site's chronology in its entirety, and so I will only discuss the dates relevant for the analyzed assemblages here. Radiocarbon dates range from ~520 BP in Iron Age deposits at the top back to at least 50 ka in RBL4 at the base. Six major cultural horizons were identified: Holocene levels include Later Iron Age, Elmenteitan Neolithic, Eburran phase 5 (with pottery and domestic animals), and Eburran Phase 4 (pre-ceramic). Pleistocene levels include the Sakutiek LSA, Nasampolai LSA and Endingi MSA/LSA transitional industries. The base of the Holocene deposits (RBL3.2) represent a dripline lag deposit comprising a dense concentration of water-rolled and battered, trampled artifacts. This lag deposit is all that remains of early Holocene and late Pleistocene occupations younger than VA3. This unconformity represents almost 30,000 years of occupation between 6350 and 35,800 BP (uncalibrated ages).

Eight samples were dated from the lower horizons (table 5.1), however, due to long storage times (2-4 years) and/or samples with low carbon content, two of the dates were considered unreliable or minimum estimates. For example, a sample of carbon- and bone-rich sediment from DBL1.2 dated to 16,300 BP was rejected because of its low carbon content and long storage time. Two samples of charcoal-impregnated sediment from DBL1.2 gave dates of 29,300 ± 750 and 35,800 ± 550 BP. The younger date is considered unreliable because of its low carbon content. Two dates on a bulk sample of ostrich eggshell carbonate from DBL1.3 produced dates of 37,000 ± 1100 BP on the outer fraction and 39,900 ± 1600 BP on the innermost fraction of the eggshell, which is consistent with the oldest charcoal date from DBL1.2. The base of this stratum (DBL1.4), which has the highest densities of ostrich eggshell artifacts, has not been dated and so the Sakutiek Industry occupation began prior to 40 ka.

Three radiocarbon dates come from the RBL4 horizon with the Endingi Industry at the base of the sequence. The first was a sample of decomposing charcoal from a hearth and was submitted two years after collection. It provided a minimum estimate of >26,000 BP based on a short counting time. A date of 29,280 BP combined two small charcoal samples from adjacent squares and was analyzed four years after collection. The largest charcoal sample was submitted only six months after collection, and dated at the high precision low background lab at the University of Washington, Seattle. It dates to 41,400 ± 700 BP. A systematic study by Haas et al. (1986) has shown that long storage times (3+ years) yield systematically younger radiocarbon dates due to absorption of modern contamination. Variation in dates on samples from the same level at EYM is consistent with this study.

Obsidian hydration dating was used to supplement the radiocarbon dates. Three samples, one each from DBL1.3, GG1.3 and RBL4.2, were analyzed. Temperature-adjusted hydration rates (present temp – 5° C) provide dates of 35,860 (DBL1.3), 46,410 (GG1.3) and 32,458 (RBL4.2). Because the RBL4 date was the youngest, despite being the lowest in the sequence, and did not agree with its associated radiocarbon date, it was rejected. It is likely that the original hydration layer on the obsidian piece physically weathered off and reformed, providing an anomalous result. Thermal alteration in a hearth could also affect hydration rate and apparent age of this specimen.

Table 5.1. List of dates and their associated levels from EYM levels below VA 3 (Holocene). All dates were reported by Ambrose (1998a).

Dating Technique	*Material*	*Stratum/Level*	*Date BP*
Radiocarbon	Charcoal	DBL1.2	35,800 ± 550
Radiocarbon	Ostrich eggshell carbonate (outer)	DBL1.3	37,000 ± 1100
Radiocarbon	Ostrich eggshell carbonate (inner)	DBL1.3	39,900 ± 1600
Obsidian hydration	Obsidian	DBL1.3	35,860 ± 2183
Obsidian hydration	Obsidian	GG1.3	46,410 ± 2758
Radiocarbon	Charcoal	RBL4.1	41,400 ± 700
Obsidian hydration	Obsidian	RBL4.2	32,458 ± 1247

Finally, sediment deposition rates were also used as a way to refine the chronology. These were calculated by dividing the age difference between DBL1 and GG1 dates with their difference in depth and multiplying by average thicknesses of the levels. Ambrose concluded that the GG1 horizon was deposited between >40,000 and 55,000 BP. The DBL1 Sakutiek Industry was bracketed to 35,000 to 40,000 BP.

The uncalibrated Pleistocene radiocarbon dates were noted to be minimum estimates of true age because cosmogenic nuclide production rates for this period were extremely high (Ambrose, 1998a). Miller and Willoughby (2014) used Oxcal v4.2 with the 'INTCAL09' dataset to calibrate the 39,900 BP date on ostrich eggshell from DBL1.3 to an age range of 41,820-47,660 BP at the 96.5% confidence interval (two standard deviations). The temperature-adjusted obsidian hydration dates are thus also underestimates, and should be recalculated with a lower average temperature. Although precise and accurate dating is not possible with any methods that can be used on the EYM Pleistocene deposits, they are stratified and undisturbed by burrowing, so their relative ages are indisputable. In summary, the Sakutiek Industry dates to greater than 35 ka, the Nasampolai to significantly greater than 40 ka, and the Endingi Industry, which marks the MSA/LSA transition, likely dates to greater than 55 ka.

Lithic Technology: Raw Materials

Obsidian represents the dominant raw material type for all flaked stone assemblages at EYM, averaging 99.5% of artifacts in DBL1 and GG1/OL1 (Ambrose, 2001b), with lavas, chert, quartz and quartzite making up the remainder. Lavas are ubiquitous in the Rift Valley and are locally available in the shelter bedrock. Some chert may be available as inclusions in volcanic deposits. However, quartz and quartzite derive from Basement System metamorphic rocks, whose closest outcrops are located 62 km to the southwest in the Loita/Mara Plains, and reflect long distance travel and/or exchange with neighboring groups. Obsidian sources are high quality and plentiful within 10-25 km of the site. Most of the major source groups used for obsidian artifacts in highland Kenya and northern Tanzania are located in the Naivasha basin, including south (Oserian, Ol Karia and Hell's Gate), west (Sonachi/Mundui), and north basin/Mt. Eburu sources (Ol Orengenai, Masai Gorge, upper Mt. Eburu, Waterloo Ridge, and Ilkek). As with the Marmonet Drift and Ol Tepesi assemblages in this dissertation, constraints on the availability of raw material were unlikely to have been a significant factor in lithic technological organization strategies.

Lithic Technology: Artifact Assemblages

A total of 3173 obsidian artifacts were sampled for analysis from the DBL1 and GG1 horizons at EYM. Bulk bags with desired sample sizes and from similar areas of excavation were selected from museum trays. To minimize the possibility of a bag's spatial location in the site affecting the artifact content, due to possible spatial organization related to tool use, I selected bulk bags from the different levels near the same meter squares. A sample size of 1500 pieces per horizon was considered sufficient for typological and statistical analyses of size dimensions. One unit (level within a square) bag for the DBL1.3 horizon was adequate, while four unit bags were necessary to obtain the minimum sample size for the GG1 horizon (table 5.2).

Table 5.2. Total count and weight of obsidian artifacts sampled for analysis from Enkapune Ya Muto

Stratum	Bag Catalog #	Artifact Count	Weight (g)	Mean Wt/Piece (g)
DBL1.3	29953	1677	598.81	0.36
GG1.1	26423	126	100.35	0.80
GG1.1	26425	171	126.72	1.35
GG1.1	29980	1117	653.83	0.59
GG1.2	26440	82	133.88	1.63
GG1 Total	*n/a*	*1496*	*1014.78*	*0.68*
EYM Total	**n/a**	**3173**	**1613.59**	**0.51**

Artifact preservation is generally good for both horizons, with fresh and sharp edges on most artifacts. Mineral coating and root mark encrustations were present on some artifacts in both horizons and their frequencies increased with depth in GG1. The mineral type is unknown; it does not react with hydrochloric acid and is not removed by ultrasonic water bath treatment. Unfortunately, this obscured technological features on some artifacts.

DBL1 Horizon: Sakutiek Industry

Stratum DBL1 is on average 25 cm thick, and was excavated in four semi-arbitrary levels (spits) that were labeled DBL1.1 to DBL1.4 that averaged 6.25 cm thick. The Sakutiek Industry is restricted to this sedimentary stratum. The total excavated lithic assemblage from DBL1 is approximately 63,900 pieces, with >280 pieces per cm per m^2, reflecting an intense occupation of the site. A sample of 1677 pieces was analyzed from bulk bag #29953 in DBL1.3. The typological composition is presented in table 5.3. Primary and secondary flaking waste comprises 94.4% of all artifacts. Cores represent 0.42%. All tools combine to form 3.28%, including 1.6% informal pieces and 1.67% formal shaped types.

Primary debitage. Platforms for whole flakes and PFFs include equal percentages of plain (42.5%) and faceted (42.2%), with small numbers of point platforms (15.4%). Negative flake scars (facets) on platforms typically originate right at the dorsal platform edge, and spread toward the interior of the core and the ventral face of the future flake (figures 5.2-5.3). These were removed just before the flake itself. Micro-flaking on the dorsal proximal area (i.e. dorsal proximal faceting [DPF]) of flakes occurs on 10.9% of platforms. This also occurs just before the flake is removed and results from abrasion with a hammer stone down and away from the platform. Together, faceted platforms or DPF were observed on over 50% of all primary debitage, including many blades. This indicates that knappers were carefully and intentionally preparing platforms on their cores between individual flake removals. Micro-faceting on platforms and dorsal proximal faceting (DPF) appear to be mutually exclusive core edge preparation techniques, where the abrasion is either *up and onto* the platform (creating faceted platforms) or *down and away* from it (creating plain platforms with abraded exterior edges and

DPF). Both techniques have the same effect of strengthening the core's edge for future hammer strikes by reducing the thin overhang left from the negative bulb of percussion from previous flake removals.

	Site ID and Level			
Artifact Type	**EYM GG (N)**	**EYM GG (%)**	**EYM DBL (N)**	**EYM DBL (%)**
Backed Piece	15	1.00	7	0.42
Scraper	1	0.07	8	0.48
Notch	5	0.33	6	0.36
Bec	0	0.00	1	0.06
Outil Écaillé	6	0.40	2	0.12
Point	0	0.00	0	0.00
Knife	0	0.00	0	0.00
Burin	1	0.07	3	0.18
Combination Tools	2	0.13	1	0.06
Total Shaped Tools	***30***	***2.01***	***28***	***1.67***
Total Unshaped Tools	50	3.34	27	1.61
Total Tools	***80***	***5.35***	***55***	***3.28***
Whole/Prox Flake	280	18.72	348	20.75
Whole/Prox Blade	112	7.49	19	1.13
MFF/DFF Flake	613	40.98	883	52.65
MFF/DFF Blade	241	16.11	162	9.66
MFF/DFF DPS Blade	6	0.40	5	0.30
Split Flake	3	0.20	5	0.30
Eraillure Flake	10	0.67	8	0.48
Potlid Flake	1	0.07	0	0.00
Total Primary Debitage	***1266***	***84.63***	***1430***	***85.27***
PRF	11	0.74	4	0.24
Burin Spall	1	0.07	1	0.06
Microburin	0	0.00	0	0.00
Derived Segment	9	0.60	9	0.54
Bipolar Flake	5	0.33	6	0.36
Trimming Retouch Flake	102	6.82	163	9.72
Tool Edge Fragment	4	0.27	2	0.12
Total Secondary Debitage	***132***	***8.82***	***185***	***11.03***
Total Debitage	***1398***	***93.45***	***1615***	***96.30***
Utilized Debitage	***40***	***0.03***	***32***	***0.02***
Blade	2	0.13	1	0.06
Flake	2	0.13	0	0.00
Radial	0	0.00	0	0.00
Tabular	1	0.07	1	0.06
Opposed Platform	0	0.00	0	0.00
Bipolar	5	0.33	1	0.06
Informal	3	0.20	2	0.12
Fragment	5	0.33	2	0.12
Total Cores	***18***	***1.20***	***7***	***0.42***
Total Flaked Obsidian	***1496***	***100.00***	***1677***	***100.00***

Table 5.3. The complete typological composition of the two analyzed EYM horizons.

For all complete platforms, the mean width is 5.1 mm, mean thickness is 1.7 mm (PT/PW = 0.33), and external platform angles (EPA) average 89°. Primary debitage mean length is 15.2 mm, mean width is 11.9 mm, and mean thickness is 2.9 mm. True blades and blade fragments account for 13.9% of the primary debitage. Size dimensions support the typological distinction between flakes and blades with table 5.4 showing that, on average, DBL1.3 blades are significantly longer and narrower (lower W/L and W/Th ratios and higher L/Th) than flakes using an Independent Samples t-test ($p<0.008$). The mean thickness is essentially the same for both flakes and blades.

Table 5.4. Mean platform and flake size dimensions, shape ratios, and and standard deviation and coefficient of variation statistics for flakes and blades in Enkapune Ya Muto DBL1.3 sample

Attribute	**Flakes (n=274)**					**Blades (n=19)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	89	13	14.6	59	124	86	16	18.6	55	118	0.98
PW (mm)	5.2	4.1	78.8	0.1	20.6	3.8	2.6	68.4	0.1	8.3	1.53
PT (mm)	1.7	1.3	76.5	0.1	7.1	1.6	1.1	68.8	0.1	4.1	0.52
L[a] (mm)	14.0	6.5	46.4	5.4	40.7	21.2	5.7	26.9	13.4	34.1	-4.48[#]
W (mm)	12.1	4.7	38.8	4.7	32.3	8.7	2.0	23.0	4.8	12.1	6.31[#]
Th (mm)	2.9	1.4	48.3	0.7	9.9	2.9	0.8	27.6	1.3	4.1	-0.17
PT/PW	0.33	0.26	78.8	0.08	1.20	0.42	0.24	57.1	0.29	1.00	n/a
PW/W	0.43	0.26	60.5	0.01	1.00	0.44	0.28	63.6	0.01	0.91	n/a
PT/Th	0.59	0.30	50.9	0.03	1.12	0.55	0.32	58.2	0.03	1.06	n/a
W/L	0.86	0.44	51.2	0.46	3.75	0.41	0.08	19.5	0.28	0.51	n/a
W/Th	4.17	1.54	36.9	1.21	10.90	3.00	0.99	33.0	1.63	4.92	n/a
L/Th	4.83	1.99	41.2	1.19	11.71	7.31	1.89	25.9	4.17	10.77	n/a

[a] Sample sizes for length are 93 for flakes and 19 for blades.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

Cores. Seven cores were identified in the DBL1.3 sample (0.42%). Two of these were broken or fragmented, and not measured. The five other cores, two blade, two flake, and one bipolar, are quite small (figure 5.4). The maximum single dimension of any core is less than 33 mm and maximum weight is only 6.2 g (table 5.5). Their small size indicates that knappers were completely exhausting cores, probably to conserve raw material. Negative scars on the largest core (#33405, tabular blade) show that the blades produced during the final stage of this piece's use-life would have been no more than 30 mm long.

Table 5.5. Core size dimensions, weights, and and standard deviation and coefficient of variation statistics for the Enkapune Ya Muto DBL1.3 sample

	Combined (n=5)					**Flake and Bipolar (n=3)**					**Blade (n=2)**				
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
L	19.1	9.2	48.2	9.1	32.8	13.9	4.7	33.8	9.1	19.8	29.7	4.5	15.2	26.5	32.8
W	17.9	6.2	34.6	11.4	25.9	16.7	6.6	39.5	11.4	25.9	20.3	6.5	32.0	15.7	24.9
Th	10.9	6.3	57.8	4.9	22.5	11.6	7.8	67.2	4.9	22.5	9.5	3.1	32.6	7.3	11.7
Wt[a]	3.3	1.9	57.6	0.8	6.2	2.1	1.4	66.6	0.8	3.5	5.9	0.4	6.8	5.6	6.2

[a] Sample sizes for weight include fragmented cores. They are 7 for Combined, 5 for Flake, and 2 for Blade.
Note that sample sizes were too small to run meaningful statistical comparison

Bipolar flaking was an important core reduction strategy, with one bipolar core and two outils écaillés (figure 5.5) in this sample. A small number of bipolar flakes were also identified. Despite their classification as a tool type, outils écaillés should be considered on a morphological continuum from retouched tools (pieces with identifiable dorsal and/or ventral primary flake surfaces) with scalar, stepped, and battered bipolar edge damage, to bipolar cores whose surfaces are entirely covered by scalar negative flake scars and negative flake scars from opposed platforms. Distinctive bipolar flaking features also include robust bipolar ripples and steep scaled or stepped retouch, most often on two opposed ends and both faces of the piece.

Secondary debitage. Retouch flakes, derived segments and one burin spall comprise the secondary debitage category of the DBL1.3 assemblage. The vast majority of retouch flakes (93.9%) are simple casual trim, with scraper trim (4.3%) as the second most common. Only one biface trim retouch flake with a faceted platform was identified, suggesting that retouch was primarily on the dorsal faces of unifacial pieces.

Supporting the typological distinction between primary and secondary debitage classes, the mean platform width and thickness and flake length, width and thickness measurements for retouch flakes all significantly differ from those of primary debitage (table 5.6) using Independent Samples t-tests ($p<0.008$). Mean EPA measurements were not significantly different between debitage classes, and both are ≥85° indicating that extremely steep edges were the most commonly retouched edge and core platform angle. Overall, the secondary debitage reflects resharpening maintenance of unifacial pieces with steep edges, most likely scraping tools, despite the classification of only a small percentage as the scraper trim sub-type. Two derived segments attest to the segmentation of blades, and possibly the production of microliths. No microburins were recovered in this or previously studied DBL1 assemblages, which suggests that the technique had not been invented or was not practiced by Sakutiek Industry knappers.

Table 5.6. Mean platform and flake size dimensions, shape ratios, and and standard deviation and coefficient of variation statistics for all debitage in Enkapune Ya Muto DBL1.3 sample

Attribute	**Primary (n=293)**					**Secondary (n=163)**					*t-test of*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*means*
EPA (°)	89	13	14.6	55	124	85	16	18.8	35	126	2.42
PW (mm)	5.1	4.1	80.4	0.1	20.6	4.1	3.4	82.9	0.1	18.9	2.74[#]
PT (mm)	1.7	1.3	76.5	0.1	7.1	1.3	1.0	76.9	0.1	5.4	4.00[#]
L[a] *(mm)*	15.2	6.9	45.4	5.4	40.7	9.4	3.9	41.5	3.1	26.5	8.06[#]
W (mm)	11.9	4.6	38.7	4.7	32.3	10.2	3.6	35.3	0.3	24.7	4.52[#]
Th (mm)	2.9	1.4	48.3	0.7	9.9	2.2	1.0	45.5	0.9	5.5	5.94[#]
PT/PW	0.33	0.26	78.8	0.08	1.20	0.32	0.26	81.3	0.10	1.00	n/a
PW/W	0.43	0.26	60.5	0.01	1.00	0.40	0.47	117.5	0.01	10.67	n/a
PT/Th	0.59	0.30	50.8	0.03	1.12	0.59	0.34	57.6	0.02	2.16	n/a
W/L	0.78	0.45	57.7	0.28	3.75	1.09	0.50	45.9	0.05	3.39	n/a
W/Th	4.10	1.56	38.0	1.21	10.90	4.64	1.62	34.9	0.25	10.67	n/a
L/Th	5.24	2.17	41.4	1.19	11.71	4.27	1.72	40.3	0.82	9.89	n/a

[a]Sample sizes for length are 113 for primary and 151 for secondary.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

Informal unshaped tools. The unshaped tool category contains casually retouched pieces and comprises 1.6% (n=27) of all recovered artifacts in DBL1.3. Five were classified as blades and 22 as flakes. These expedient tools are without significant alteration of either edge shape or angle, and have simple marginal chipping or very minor retouch (figure 5.6).

Formal shaped tools. Formal shaped tools comprise 1.7% (n=28) of all identified pieces in the DBL1.3 sample. A total of six distinct formal tool types were identified, not including two subtypes of backed microliths. One combination tool was also recovered (curved-backed and geometric crescents). The Simpson's Index of Diversity (SID) value for this assemblage is 0.82 if all microliths are combined and 0.847 if the two subtypes are calculated separately. Both of these values are high and indicate a great degree of typological diversity within the assemblage.

Scrapers represent the most common type, making up 28.6% (n=8) of all formal tools. One combination tool also has a scraper-type edge, though it does not fit the dominant morphology represented by the other conventional scrapers. Three of the eight scrapers were only edge fragments and so no data was collected on their morphology, however the other five all have convex bits made on the retouched distal ends of blades (figure 5.7). This short, wide morphology is typically accompanied by steep lateral retouch. They conform to the formal tool type of thumbnail scraper that is considered a hallmark of the African LSA Wilton industries (Ambrose, 1998a). Trimmed lateral margins suggest that these were shaped to fit a socketed haft (Weedman, 2002, 2006).

Backed microlith is the second most numerous type in this DBL1.3 sample, forming 25% (n=7) of all formal tools. The majority of these are curved-backed (n=5 or 71.4%) and the rest are geometric crescents (n=2 or 28.6%). One of the curved-backed pieces is truncated at the distal end of the blade, and retains the faceted platform (figure 5.8). Four of the seven microliths display use-wear traces on their unmodified edges that suggest use as cutting/sawing implements (figure 5.9). Steep 'backing' retouch on all microliths suggests their use as part of hafted composite tools. Backing retouch most often originates from the ventral face down onto the dorsal face, but some have bidirectional (bipolar) backing originating from the dorsal and ventral faces (figure 5.10).

Notched pieces (n=6), burins (n=3) and one bec combine to form the remaining 35.7% of the formal tool sample. Half of the notches are the result of a single large blow, while the other half were formed by several small retouch flakes within a concavity, similar to a concave scraper. Small burins and one bec were formed by a similar pattern of fine, directed retouch (figure 5.11). Both of these types display a robust bit suitable for piercing, drilling, grooving or boring functions. Many of these tools retain traces of use-wear on their retouched bits suggesting intentionality in the creation of this edge morphology. One final point to note, in his initial analysis Ambrose (1998a) identified low frequencies of thin, parti-bifacially flaked knives and flattened discoids, tools more typical of flake-based MSA industries than microlithic LSA ones. I did not find any of these types in my sample.

Technological organization. The lithic artifact sample analyzed from the DBL1.3 horizon's Sakutiek Industry reflects a technological organization strategy focused on the production and use of convex end scrapers and microliths, both made on blades, with lower numbers of boring or drilling tools such as burins. Flakes and flake fragments were expediently retouched more often than blades, which were more often used as blanks for formal tool types. Lastly, the combined presence of bipolar cores, outils écaillés, and bipolar flakes, some of which are utilized, support the use of bipolar reduction as a tertiary technological strategy.

The low number of cores in the DBL1.3 sample precludes a thorough understanding of tool blank production, however it appears that blades and flakes were being produced for different purposes. Despite their small size at discard, the blade cores were evidently still producing viable blanks for microliths (figure 5.12). Complete negative scars on core #33405 measure about 25 mm in length, which is longer than the mean length for microliths; these would have been viable blanks for making microliths. Scrapers, on the other hand, likely had much longer use-lives than microliths and so likely started out longer and (possibly) wider than their discarded forms, on larger sized blade blanks. Notably, because the thickness of a blade is essentially the same along the entire length of the piece the thickness of a scraper would not change much over its lifespan, rather the piece would mainly be reduced in length. Table 5.7 confirms that the mean thickness of DBL1.3 microliths was significantly smaller than that of scrapers using an Independent Samples t-test ($p<0.017$). In short, both scrapers and microliths were made on blades, however, thicker blanks were selected for scrapers while thinner blanks were selected for microliths meaning that blank production was closely correlated with the resulting tool type.

Table 5.7. Mean size dimensions, and standard deviation and coefficient of variation statistics for scrapers and microliths from Enkapune Ya Muto DBL1.3

Attribute	**Microliths (n=7)**					**Scrapers (n=8)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
Length (mm)	21.9	3.5	16.0	17.3	26.1	17.5	4.0	22.3	13.3	22.2	2.27
Width (mm)	10.1	3.1	30.7	5.5	13.6	14.8	5.9	39.9	8.4	26.4	-1.89
Thickness (mm)	3.2	0.6	18.8	2.6	4.2	5.3	1.8	34.0	2.5	8.2	-3.01[#]

[#]*p<0.017* is the adjusted value for statistical significance using the Bonferroni correction.

The preference by knappers for different blank thicknesses is most likely due to the differing functions of microlith and scraper tool classes. Thin-edged microliths are fragile and are best suited as replaceable components for short-term cutting tasks and projectile inserts, while thicker edges are more robust and better suited for withstanding the more substantial pressure applied during scraping tasks. Based on the differences in edge thickness between these two classes there must have been a major difference between the lengths of their use-lives. Because microliths are too thin to be retouched in a way that restores an effective cutting edge, they were more likely discarded and replaced as they became dull from use. In contrast, if the convex end scrapers were used like those made by modern Ethiopian hide workers, then scraper edges were maintained through marginal retouch as long as the piece was long enough to extend out past the limit of the haft. Both the morphology and size dimensions of the DBL1.3 secondary retouch flakes support this interpretation; the dominant form being a short, wide flake with a plain (typically ventral face) platform, near vertical EPA (85°), and dorsal proximal use-wear. It is clear that the DBL1.3 retouch flakes are primarily derived from the curation of thick and steep-edged scrapers, rather than thin cutting edges (i.e. microliths).

A final comment should be made regarding the overall size of DBL1.3 artifacts. They are extremely small, with the average weight per artifact being only 0.36 g. The small average size of artifacts (see figures 5.7 – 5.12 and table 5.7), in conjunction with the presence of backed microliths, supports the characterization of LSA assemblages as microlithic. Part of this 'microlithization' is reflected in the abundance of very small retouch flakes (almost 10% of the assemblage), the morphology of which is consistent with retouch of convex end (thumbnail) scrapers. Another point regarding these scrapers, if they are similar to the socketed scrapers made by modern Ethiopian hide workers then their sides were trimmed to fit a socketed handle. The convex end of 13 modern scrapers studied by Shott and Weedman (2007: fig. 8) were retouched an average of 3.5 times (total range was 1-8 resharpening events) before discard. If initial shaping of the end scraper edge and lateral margin retouch on two sides occurred at the same site, this would add up to three more edge-equivalents of small flaking debris per scraper, raising the average to 6.5 retouching events. This would result in a large percentage of small, thick-edged retouch flakes in an assemblage, similar to that of the DBL1.3 sample.

GG1 Horizon: Nasampolai Industry

The total excavated lithic assemblage for the GG1 horizon is 6129 pieces. This is less than 10% of the size of the overlying DBL1. despite the horizon being between five to six times as thick. Densities of both lithic artifacts and fauna indicate a low-intensity occupation of the site during this time. A sample of 1496 pieces was analyzed from four bulk bags from three squares in the highest spit in this bed, and one from the second level: #26423 (GG1.1, n=126), #26425 (GG1.1, n=171), #26440 (GG1.2, n=82) and #29980 (GG1.1, n=1117). Because the GG1.1 samples are directly overlain by the very high-density occupation of DBL1.4 it is likely that the GG1.1 assemblage includes some artifacts from the base of the DBL1.4 occupation. This potential for mixing is considered while comparing these assemblages. The complete typological composition is presented in table 5.3. Primary and secondary flaking waste comprises 90.78% of all artifacts, while cores represent 1.2%. All tools together form 5.35% of the sample, with informal tools making up 3.3% and formal tool types making up 2.0%.

Primary debitage. Platforms for primary debitage are primarily plain (53.9%) with smaller numbers of faceted (30.4%) and point (11.9%) types. Dorsal proximal faceting is present on 12.5% of platforms. This technique appears to be mutually exclusive from platform faceting for core edge preparation; table 5.8 shows that in only one case of all primary debitage does DPF and platform faceting appear on the same piece, while plain and especially point platforms have considerably higher percentages of DPF.

Table 5.8. Primary debitage platform preparation from Enkapune Ya Muto GG1 sample

Platform Type	Dorsal Proximal Faceting		Percent DPF (%)
	No	Yes	
Plain	149	21	14.1
Faceted	86	1	1.2
Point	26	11	42.3
Cortical	12	1	8.3
Total	*273*	*34*	*12.5*

For all complete platforms, the mean width is 5.2 mm, mean thickness is 1.9 mm (PT/PW = 0.37), and external platform angles average 89°. For all complete primary debitage, the mean length is 17.4 mm, the mean width is 13.9 mm, and the mean thickness is 3.4 mm. True blades and blade fragments account for 29.7% of the primary debitage sample and indicate that controlled blade production was a significant technological strategy for GG1 knappers. This typological distinction is supported by size dimensions, which show that, on average, blades are significantly longer than flakes using an Independent Samples t-test ($p<0.008$), while also being slightly narrower (table 5.8).

Table 5.9. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for primary debitage in Enkapune Ya Muto GG1 sample

Attribute	**Flakes (n=204)**					**Blades (n=102)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	87	13	14.9	54	118	93	11	11.8	67	136	-3.79[#]
PW (mm)	5.5	4.7	85.5	0.1	34.1	4.6	3.3	71.7	0.1	18.3	1.93
PT (mm)	1.9	1.7	89.5	0.1	11.7	1.7	1.1	64.7	0.1	5.2	1.77
L[a] (mm)	15.3	6.4	41.8	5.1	35.5	24.7	9.7	39.3	11.0	47.6	-4.82[#]
W (mm)	14.4	7.1	49.3	5.9	52.1	12.8	4.8	37.5	5.3	32.4	2.28
Th (mm)	3.3	1.9	57.6	1.0	12.0	3.4	1.6	47.1	1.1	9.9	-0.24
PT/PW	0.35	0.26	74.3	0.11	1.46	0.37	0.30	81.1	0.15	2.33	n/a
PW/W	0.38	0.26	68.4	0.00	0.96	0.36	0.22	61.1	0.01	0.91	n/a
PT/Th	0.58	0.30	51.7	0.02	1.00	0.50	0.28	56.0	0.03	1.00	n/a
W/L	0.94	0.39	41.5	0.50	2.35	0.52	0.07	13.5	0.26	0.51	n/a
W/Th	4.36	1.81	41.5	1.42	11.60	3.76	1.50	39.9	1.45	8.92	n/a
L/Th	4.64	1.87	40.3	1.19	10.09	7.26	3.03	41.7	2.98	14.88	n/a

[a] Sample sizes for length are 100 for flakes and 28 for blades

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

Cores. A total of 18 cores were identified in the GG1 sample, 1.2% of the assemblage. Five were classified as broken or fragmented and not included in core size analyses. Three blade, five bipolar (figure 5.13), and five flake (figure 5.14) cores were identified and measured. Table 5.10 shows that the mean length is rather small, only ~20 mm with maximum single dimension of 34.1 mm. Weight is also typically small, averaging only ~4 g.

Table 5.10. Core size dimensions, weights, and standard deviation and coefficient of variation statistics from Enkapune Ya Muto GG1

	Combined (n=12)					Non-Blade (n=11)					Blade (n=1[a])
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Measurement*
L (mm)	20.3	7.0	34.5	9.9	32.8	21.1	6.8	32.2	9.9	32.8	11.8
W (mm)	17.9	8.8	49.2	6.7	34.1	18.7	8.8	47.1	6.7	34.1	7.9
Th (mm)	9.2	3.8	41.3	5.2	19.1	9.4	3.9	41.4	5.2	19.1	8.6
Wt[b] (g)	3.7	4.2	113.5	0.4	17.0	4.3	4.8	111.6	0.4	17.0	3.2

[a] Note that there were two blade cores in the sample but one was not measured.

[b] Sample sizes for weight are 18 for Combined, 11 for Non-Blade, and 2 for Blade.

[#] $p<0.017$, which is the adjusted value for statistical significance using the Bonferonni correction.

Though the recovery of complete blade cores is rare, two examples of overstruck blades provide evidence of blade core use-life and morphology. Pieces #33995 and #34069 are both snapped distal ends of overstruck blades that retain the complete striking platforms from the opposed end of the blade core from which they were struck. Because they retain their opposed platforms it is possible to estimate the width and thickness, though not the length, of those cores. Their widths are 26.8 and 40.5 mm (mean 33.7) and thicknesses are 10.5 and 12.5 (mean 11.5). Based on these estimates, both of the broken blades were struck from cores at least three times as wide and about 50% thicker than the complete ones discarded after reduction. The negative scars of previous blade removals on these overstruck pieces permit estimates of blade widths at earlier stages of reduction. On piece #33995 there are four major scars that measure 7.4, 10.3, 13.7 and 14.1 mm wide (figure 5.15); on piece #34069 there are five major scars that are 6.7, 7.4, 10.8, 12.1 and 13.6 mm wide (figure 5.16).

Another relevant piece for this discussion is #34126. This is a platform rejuvenation flake from a blade core with a series of six removals perpendicular to the flake's long axis (figure 5.17); these scars measure 7.1, 8.1, 8.2, 10.3, 11.5, and 12.4 mm wide. Together these 15 negative blade scars have an average width of 10.3 mm, which is smaller (by 2.5 mm) than the sample of primary debitage blades actually measured, but still wider than the complete blade cores. It is important to remember that these measurements represent the minimum width, as the entire length of the piece is not preserved and may have been wider farther down from the striking platform. The average width of the scars is not surprising because the rest of the primary debitage shows that knappers were exploiting a large range of blade (and flake) core sizes. It also confirms that the small blade cores were in the last stages of useful production and probably represent the baseline size for discard.

Finally, bipolar knapping appears to have been another important technological strategy for GG1 knappers. Five bipolar cores, six outils écaillés (figures 5.18 – 5.19) and five bipolar flakes all show a similar morphology, with stepped or scaled retouch on opposed ends and both faces. Most of these pieces are quite small (< 30 mm) and were discarded at the end of their use-lives when usable flakes were no longer being produced. It is also possible that the edges of bipolar cores and outils écaillés were preferred tools and these pieces represent the end of their usefulness in that role.

Secondary debitage. Retouch flakes are the most common type of secondary debitage, along with small numbers of derived segments, four tool edge fragments, and one burin spall. Together these form 8.83% of the total GG1 sample. The vast majority of retouch flakes (95.1%) are simple unifacial trimming flakes, with scraper trim (3.92%) as the next most common (figures 5.20 – 5.21) and one (0.98%) lipped biface retouch flake (figure 5.22). Retouch flakes have smaller average sizes for all size dimensions compared to the primary debitage sample, with length, thickness and platform EPA all considered significantly different (table 5.11) using an Independent Samples t-test (*p*<0.008).

Table 5.11. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all debitage in Enkapune Ya Muto GG1 sample

Attribute	**Primary (n=306)**					**Secondary (n=102)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	89	13	14.6	54	136	83	16	19.3	40	118	4.16[#]
PW (mm)	5.2	4.3	82.3	0.1	34.1	5.0	4.2	84.0	0.1	20.3	0.24
PT (mm)	1.9	1.5	78.9	0.1	11.7	1.4	1.2	85.7	0.1	7.1	2.52
L[a] (mm)	17.4	8.2	47.1	5.1	47.6	9.8	3.8	38.8	4.4	26.7	8.61[#]
W (mm)	13.9	6.4	46.0	5.3	52.1	12.3	4.6	37.4	5.5	32.6	2.32
Th (mm)	3.4	1.8	52.9	1.0	12.0	2.6	1.3	50.0	1.0	7.1	4.11[#]
PT/PW	0.37	0.27	73.0	0.11	2.33	0.28	0.29	103.6	0.12	1.00	n/a
PW/W	0.37	0.25	67.6	0.00	0.96	0.41	0.28	68.3	0.01	1.00	n/a
PT/Th	0.56	0.30	53.6	0.02	1.00	0.54	0.31	57.4	0.03	1.02	n/a
W/L	0.80	0.42	52.5	0.26	2.35	1.26	0.53	42.1	0.55	3.61	n/a
W/Th	4.09	1.74	42.5	1.42	11.60	4.73	1.74	36.8	2.27	13.27	n/a
L/Th	5.12	2.49	48.6	1.19	14.88	3.77	1.66	44.0	0.98	9.36	n/a

[a] Sample sizes for length are 128 for primary and 98 for secondary.

[#] *p<0.008*, which is the adjusted value for statistical significance using the Bonferonni correction.

Despite the significantly lower EPA, retouch flakes still have an average of 83° indicating that steep edges were the most common retouched edge angle. Similar to the DBL1.3 sample, plain platforms and dorsal proximal use-wear and/or faceting were the most diagnostic features for identifying retouch flakes. Additionally, these debitage have shorter lengths than widths suggesting that they were removed perpendicular (along the thickness axis) to long and thin pieces. In these cases, the length of the retouch flake would have been limited by the thickness of the piece it was derived from. Overall, these edge maintenance flakes appear to be derived from steep-edged unifacial pieces such as scrapers, although they likely also include the small flakes removed during backing of microliths.

Informal unshaped tools. The unshaped tool category contains casually retouched pieces and comprises 3.34% (n=50) of all recovered artifacts in the GG1 horizon. Fifteen blades (30%) were identified as casually retouched and the rest are flakes or flake fragments. These expedient tools have simple marginal chipping or very minor retouch (figures 5.23 – 5.24).

Formal shaped tools. This category comprises 2.0% (n=30) of all identified pieces in the GG1 sample. A total of five distinct formal tool types were identified, however there were also five different subtypes of backed microliths identified. Two combination tools were also recovered. The SID value for this assemblage is 0.699 if all of the microliths are combined and 0.797 if the microlith subtypes are calculated separately. The diversity obviously increases when different microlith types are calculated separately, however, it is difficult to say whether these typological differences had any meaningful implications in terms of the way they were used.

Microliths are the most common type (n=15), representing 50% of all formal tools. The morphology of backing in the sample is quite variable with curved (n=6), oblique (n=2), orthogonal (n=2), and straight-backed (n=2) present as well as geometric crescents (n=3) (figures 5.25 – 5.26). Three pieces were made on whole blades (without a truncation), and retain micro-faceting platforms without DPF (figure 5.27). Similar to the DBL1.3 microlith sample, backing is primarily initiated from the ventral face side (figures 5.28 – 5.29). Four pieces display utilization damage on the unmodified edge, all suggesting use as cutting implements (figure

5.30). Also recovered were two small fragments that appear to have broken during production (figures 5.31 – 5.32). The bulb of percussion from a direct segmentation or backing blow is visible in figure 5.32c. Of particular significance are traces of red ochre that have stained the surface near and on the backed edges (figure 5.33). The location of these traces suggest that these pieces were hafted parallel to the long axis, either in a shaft slot/groove or as a point in an oblique or transverse position.

Outils écaillés represent the second most common formal type (n=8; two were components of combination tools); these were described above in conjunction with bipolar cores above. Notched and denticulate pieces were the third most common (figures 5.34 – 5.35), with burins (one was a component of combination tool) and a single scraper rounding out the sample. The notched pieces grade into what could be called concave scrapers, with relatively steep continuous retouch inside a large edge concavity. Only the backed microliths in this assemblage display morphological features that suggest hafting.

Technological organization. The GG1 horizon is characterized by the production of faceted platform blades, large backed microliths, and outils écaillés. True blades account for about 30% of the total assemblage and indicate that the production of blade blanks for microliths was the primary technological goal. Despite the fact that only very small blade cores were found in this sample, the large average size of primary debitage blades (figure 5.36), core platform rejuvenation flakes, and the microliths themselves, it is clear that the cores started out much larger in size. Indeed, it seems that large blades were preferred for making tools, and that smaller cores and flakes may have been more suitable for bipolar (i.e. outils écaillé) production.

Artifact curation by GG1 knappers appears to have been relatively rare. Two pieces of data support this notion; first, less than 7% of the total assemblage was identified as small secondary retouch debitage, and second, backed microliths comprise 50% of all formal retouched tools. Only one scraper was identified (3.3% of formal tools), which contrasts starkly with the DBL1.3 sample where scrapers comprise 28.6% of formal tools. The morphological overlap between notches and concave scrapers could account for this discrepancy. Informal, casually retouched pieces are actually much more common (3.3% of the assemblage) in GG1 than formal tools (2.0%) and may account for some of the small retouch debitage. Many retouch flakes in GG1 are short, wide, and have steep EPAs, which would suggest that they are derived from scrapers, as with the DBL1.3 sample. Although Ambrose (1998a) identified a small number of scrapers in his original analysis of GG1, I only identified one in my sample so this possibility seems unlikely. Although notched pieces could account for some of this retouch debitage I think it is more probable that, due to their similar size and dorsal scar patterns to microlith-backed edges, most are derived from the backing of large microliths (figures 5.37 – 5.38). Considering the large size of the GG1 backed artifacts, it is likely that shaping them required removing a large amount of the blank, and generated many small secondary flakes with high EPAs.

The emphasis on backed microlith production also accounts for the overall low frequencies of secondary retouch flakes. After initial shaping of the backed edge, resharpening is unnecessary because the backed edge is not the working edge (scraping, cutting, etc.) rather it is intentionally blunted. The sharp thin edge opposite the backed edge is considered the functional edge for slicing and cutting, or piercing if hafted as the point of a projectile. Because backed microliths are so thin, the sharp edge cannot be effectively resharpened. Therefore it is much more effective to simply replace the component. Unlike end scrapers on blades, microliths would only generate one bout of secondary retouch debris. Finally, low frequencies of secondary debitage can account for the higher average weight per piece of the total artifact assemblage in GG1 (0.68 g) compared to DBL1.3 (0.36 g).

The GG1 horizon's Nasampolai Industry reflects a low-intensity occupation of EYM and represents the oldest true LSA blade industry in East Africa, dating to 55-40 ka. Radial and/or Levallois type prepared cores and associated tools are absent, unlike the Howiesons Poort of South Africa, which is dated to MIS 4 (Jacobs et al., 2008). This supports the interpretation that core preparation in GG1 was fully characteristic of the LSA, and focused on the production of large blade blanks for microliths and expedient tools with a small bipolar component. Large faceted platforms on some flakes and blades are present in GG1, which is more typical of MSA blank production, however, other 'transitional' technological features are rare or absent.

Comparison of Technological Organization Strategies

Enkapune Ya Muto rockshelter preserves two early LSA microlithic industries that were analyzed as part of this dissertation. The DBL1 and GG1 horizons have both been dated with combined radiocarbon and obsidian hydration techniques; the DBL1 Sakutiek industry dates to >35-40 ka and the GG1 Nasampolai industry, which is conformably stratified beneath the Sakutiek industry, dates to 40-55 ka. Because of the antiquity of these two microlithic industries they are significant for our understanding of the MSA/LSA technological transition.

Both the DBL1 and GG1 industries represent examples of true 'blade' production, meaning that knappers systematically prepared cores (platforms and overall morphology) for the sequential removals of long, narrow and thin flakes (i.e. blades). This strategy contrasts with the 'preferential' or 'classic' Levallois technique, in which only one large flake is removed from a core face before the platform and flake release surface geometry is adjusted (Boeda, 1995; Lycett and Eren, 2013). Recurrent Levallois cores, including unidirectional, bidirectional, and centripetal varieties, however, can generate a larger number of flakes before rejuvenation of the flake release surface. In Upper Paleolithic and LSA blade cores, once the platform angle, narrow core face geometry and first longitudinal ridge are prepared, many long narrow blades can be removed before the core geometry requires maintenance. Blades are removed sequentially, using the arêtes from previous removals as a guide for the next strike. Each blade that is removed creates two new arêtes on the core face. Blades are typically struck from a point on the platform directly above the ridges rather than in the concavity between them. Platform maintenance involves mainly strengthening the platform by abrading the overhanging edge above negative bulbs of percussion. Abrasion by rubbing the hammerstone down from the platform edge to the flake release surface is identifiable by plain platforms with and abraded edge and DPF. Most, but not all, of these DPF removal flakes are smaller than the secondary retouch flakes generally recovered with the 0.5 mm screens used in these excavations. Abrading the platform edge in the opposite direction, from the core face toward the center of the platform, removes predominantly very small flakes from the edge and creates micro-faceted platforms. There is little need to reshape the core again unless a blade hinges or steps during removal, or if the platform angle becomes unsuitable.

This technique of production allows for blades to be produced quickly and efficiently, as well as in a way that standardizes their morphology. Blades are standardized (consistent size and shape) because each removal follows that of a previous one, using the same arêtes on the same core, and so length, width and thickness are well controlled. Standardization is pronounced when compared to radial or Levallois flakes where the knapper prepares the core to produce a single large flake, and then must re-prepare the platform and arête positioning in order to produce the next one. Rather than sequential removals like with blades, flakes from radial cores are made in a stepwise fashion where the core's size and shape changes slightly between each removal, and thus produces flakes that vary slightly from each other in their size and shape. This is a significant point, because it means that any single tool type (e.g. scraper, point or knife) made on several flakes from a radial core should vary in their initial morphology to a greater extent than if those same tools were made on blades. Extensive shaping or resharpening through retouch can also more greatly affect the size and shape of flake-based artifacts, especially those made on larger, thicker blanks. This concept will be explored in greater depth in chapter 7, when lithic assemblages from all three archaeological sites analyzed in this dissertation are compared.

Tables 5.12 – 5.14 present size dimensions for all primary debitage, and separated dimensions for flakes and blades in both horizons. For both DBL1.3 and GG1 the samples of primary debitage identified as blade have lower CVs for all dimensions except EPA, than samples identified as flake. The samples of blades are also significantly longer than flakes and, in the case of DBL1.3 blades, significantly narrower as well using an Independent Samples t-test ($p<0.008$). Blade production in both horizons produced more consistently shaped blanks than flake-based core reduction, and those blades were then preferentially selected as blanks for producing formal tools, primarily backed microliths (GG1 and DBL1.3) and scrapers (DBL1.3).

Table 5.12. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all primary debitage at Enkapune Ya Muto

Attribute	**DBL1.3 (n=293)**					**GG1 (n=306)**					*t-test of*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*means*
EPA (°)	89	13	14.6	55	124	89	13	14.6	54	136	-0.62
PW(mm)	5.1	4.1	80.4	0.1	20.6	5.2	4.3	82.3	0.1	34.1	-0.07
PT (mm)	1.7	1.3	76.5	0.1	7.1	1.9	1.5	78.9	0.1	11.7	-1.19
L[a] (mm)	15.2	6.9	45.4	5.4	40.7	17.4	8.2	47.1	5.1	47.6	-2.23
W (mm)	11.9	4.6	38.7	4.7	32.3	13.9	6.4	46.0	5.3	52.1	-4.33[#]
Th (mm)	2.9	1.4	48.3	0.7	9.9	3.4	1.8	52.9	1.0	12.0	-3.55[#]
PT/PW	0.33	0.26	78.8	0.08	1.20	0.37	0.27	73.0	0.11	2.33	n/a
PW/W	0.43	0.26	60.5	0.01	1.00	0.37	0.25	67.6	0.00	0.96	n/a
PT/Th	0.59	0.30	50.8	0.03	1.12	0.56	0.30	53.6	0.02	1.00	n/a
W/L	0.78	0.45	57.7	0.28	3.75	0.80	0.42	52.5	0.26	2.35	n/a
W/Th	4.10	1.56	38.0	1.21	10.9	4.09	1.74	42.5	1.42	11.6	n/a
L/Th	5.24	2.17	41.4	1.19	11.7	5.12	2.49	48.6	1.19	14.9	n/a

[a] Sample sizes for length are 113 for DBL1.3 and 128 for GG1.

[#] *p<0.008*, which is the adjusted value for statistical significance using the Bonferonni correction.

One notable difference between the two horizons related to production is the size of artifacts. First, the average weight per piece of all artifacts in the GG1 sample (0.68 g) is almost double that of DBL1.3 (0.36 g). Second, table 5.12 shows that the average size of all primary debitage in the GG1 horizon is larger in every recorded dimension, with width and thickness considered significantly larger using an Independent Samples t-test (*p<0.008*). This occurrence is further supported when flakes and blades are separated and compared independently (tables 5.13-5.14), and for secondary debitage as well (table 5.15). In particular, pieces #33832, #33848, #34135 and #34181 (figure 5.36) from the GG1 horizon are examples of large blades that were not observed in the DBL1.3 tool or debitage sample. These large blank sizes are necessary when knappers are making large microliths such as #32237 (figure 5.26). This blade tool, even after it was truncated and backed, is still larger in size, at 57.6 x 23.6 x 8.5 mm, than the largest unmodified blade found in either DBL1.3 or GG1 (table 5.16). This tool may represent an outlier in terms of size, however that cannot be confirmed as knappers in both horizons most likely preferentially selected the largest blades as blanks for tool production. Sizes of recovered artifacts in both horizons (tables 5.17-5.18) support this as well. In short, there is evidence for a size reduction (microlithization) in artifact size over time from GG1 to DBL1.3 at EYM.

Table 5.13. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for primary debitage flakes at Enkapune Ya Muto

Attribute	**DBL1.3 (n=274)**					**GG1 (n=204)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	89	13	14.6	59	124	87	13	14.9	54	118	1.22
PW (mm)	5.2	4.1	78.8	0.1	20.6	5.5	4.7	85.5	0.1	34.1	-0.57
PT (mm)	1.7	1.3	76.5	0.1	7.1	1.9	1.7	89.5	0.1	11.7	-1.57
L[a] (mm)	14.0	6.5	46.4	5.4	40.7	15.3	6.4	41.8	5.1	35.5	-1.48
W (mm)	12.1	4.7	38.8	4.7	32.3	14.4	7.1	49.3	5.9	52.1	-4.02[#]
Th (mm)	2.9	1.4	48.3	0.7	9.9	3.3	1.9	57.6	1.0	12.0	-3.00[#]
PT/PW	0.33	0.26	78.8	0.08	1.20	0.35	0.26	74.3	0.11	1.46	n/a
PW/W	0.43	0.26	60.5	0.01	1.00	0.38	0.26	68.4	0.00	0.96	n/a
PT/Th	0.59	0.30	50.9	0.03	1.12	0.58	0.30	51.7	0.02	1.00	n/a
W/L	0.86	0.44	51.2	0.46	3.75	0.94	0.39	41.5	0.50	2.35	n/a
W/Th	4.17	1.54	36.9	1.21	10.9	4.36	1.81	41.5	1.42	11.6	n/a
L/Th	4.83	1.99	41.2	1.19	11.7	4.64	1.87	40.3	1.19	10.1	n/a

[a a] Sample sizes for length are 93 for DBL1.3 and 100 for GG1.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

In terms of formal tool composition, both horizons focused on the production of blade-based tools. Knappers in GG1 were more focused on microliths and bipolar reduction with outils écaillés, whereas DBL1.3 knappers produced much greater numbers of scrapers and notches, along with microliths, but very few écaillés. Overall typological diversity is greater for DBL1.3 (SID = 0.82) compared to GG1 (0.70) reflecting a greater evenness of tool type counts. Even if all five microlith subtypes are separated for GG1 the SID value is still less than that of DBL1.3 (0.80).

Table 5.14. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for primary debitage blades at Enkapune Ya Muto

Attribute	**DBL1.3 (n=19)**					**GG1 (n=102)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	86	16	18.6	55	118	93	11	11.8	67	136	-2.39
PW (mm)	3.8	2.6	68.4	0.1	8.3	4.6	3.3	71.7	0.1	18.3	-0.99
PT (mm)	1.6	1.1	68.8	0.1	4.1	1.7	1.1	64.7	0.1	5.2	-0.34
L[a] (mm)	21.2	5.7	26.9	13.4	34.1	24.7	9.7	39.3	11.0	47.6	-1.58
W (mm)	8.7	2.0	23.0	4.8	12.1	12.8	4.8	37.5	5.3	32.4	-6.22[#]
Th (mm)	2.9	0.8	27.6	1.3	4.1	3.4	1.6	47.1	1.1	9.9	-1.22
PT/PW	0.42	0.24	57.1	0.29	1.00	0.37	0.30	81.1	0.15	2.33	n/a
PW/W	0.44	0.28	63.6	0.01	0.91	0.36	0.22	61.1	0.01	0.91	n/a
PT/Th	0.55	0.32	58.2	0.03	1.06	0.50	0.28	56.0	0.03	1.00	n/a
W/L	0.41	0.08	19.5	0.28	0.51	0.52	0.07	13.5	0.26	0.51	n/a
W/Th	3.00	0.99	33.0	1.63	4.92	3.76	1.50	39.9	1.45	8.92	n/a
L/Th	7.31	1.89	25.9	4.17	10.77	7.26	3.03	41.7	2.98	14.88	n/a

[a] Sample sizes for length are 19 for DBL1.3 and 28 for GG1.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

In his original analysis of DBL1 Ambrose (1998a: 383) noted low frequencies of thin, parti-bifacially flaked knives and flattened discoids, tools more typical of MSA industries. I did not observe these types during my analysis, rather, I observed a focus on microliths and convex end (thumbnail) scrapers. Considering the long potential resharpening lifespan of convex end scrapers and the abundance of secondary retouch flakes from steep-edged tools, this was clearly the dominant tool type in the DBL1 Sakutiek Industry. The GG1 sample has fewer scrapers and more backed microliths, accompanied by much lower frequencies of secondary retouch flakes. The consistency of retouch location and morphology on scrapers (from DBL1.3) and microliths (from both horizons) imply that these pieces were hafted as components of composite tools.

Table 5.15. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all secondary debitage at Enkapune Ya Muto

Attribute	**DBL1.3 (n=163)**					**GG1 (n=102)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	85	16	18.8	35	126	83	16	19.3	40	118	1.03
PW(mm)	4.1	3.4	82.9	0.1	18.9	5.0	4.2	84.0	0.1	20.3	-1.94
PT (mm)	1.3	1.0	76.9	0.1	5.4	1.4	1.2	85.7	0.1	7.1	-1.04
L[a] *(mm)*	9.4	3.9	41.5	3.1	26.5	9.8	3.8	38.8	4.4	26.7	-0.89
W (mm)	10.2	3.6	35.3	0.3	24.7	12.3	4.6	37.4	5.5	32.6	-4.28[#]
Th (mm)	2.2	1.0	45.5	0.9	5.5	2.6	1.3	50.0	1.0	7.1	-2.79[#]
PT/PW	0.32	0.26	81.3	0.10	1.00	0.28	0.29	103.6	0.12	1.00	n/a
PW/W	0.40	0.47	117.5	0.01	10.67	0.41	0.28	68.3	0.01	1.00	n/a
PT/Th	0.59	0.34	57.6	0.02	2.16	0.54	0.31	57.4	0.03	1.02	n/a
W/L	1.09	0.50	45.9	0.05	3.39	1.26	0.53	42.1	0.55	3.61	n/a
W/Th	4.64	1.62	34.9	0.25	10.67	4.73	1.74	36.8	2.27	13.27	n/a
L/Th	4.27	1.72	40.3	0.82	9.89	3.77	1.66	44.0	0.98	9.36	n/a

[a] Sample sizes for length are 151 for DBL1.3 and 98 for GG1.

[#] *p<0.008*, which is the adjusted value for statistical significance using the Bonferonni correction.

One final observation concerning microlith production in both DBL1.3 and GG1 is that microburins are completely absent. Dorsal percussion segmentation (DPS) on blade fragments is also extremely uncommon. DPS provides an alternative to the microburin technique for segmenting blades by simply placing the blade ventral face down and tapping on a dorsal arête. This typically splits the blade transversely and yields two segments that could be used for making microliths (by backing one side), burins (by striking on the snap) or other tool types. Since both of these secondary debitage types are missing, it is more likely that microliths and other blade tools were being made on whole blades with the platform and distal end being removed by retouch. Both horizons even have microliths that retain their platforms as part of the backed edge. This mode of retouch would also account for some of the secondary retouch flakes with the characteristic steep EPA, short length and large width.

Table 5.16. Largest unmodified blade[a] in each Enkapune Ya Muto horizon

Horizon	*EPA°*	*PW (mm)*	*PT*	*L*	*W*	*Th*
DBL1.3	110	0.1	0.1	34.1	9.7	3.8
GG1	124	2.7	0.8	47.6	16.5	4.5

[a] Largest blade was determined using length; #33110 for DBL1.3 and #33327 for GG1.

Table 5.17. Size dimensions and standard deviation and coefficient of variation statistics for formal tool types in the GG1 horizon at EYM

Type	*Metric*	*Mean*	*SD*	*CV*	*Minimum*	*Maximum*
Backed Microliths (n=15)	*L*	26.0	12.2	46.9	7.6	57.6
	W	11.4	5.1	44.7	4.9	23.6
	Th	4.2	1.7	40.5	1.5	8.5
Notches (n=5)	*EPA*[d]	103	9	8.7	92	111
	PW[d]	8.7	2.7	31.0	5.0	11.2
	PT[d]	3.2	1.0	31.3	2.1	4.5
	L	22.0	10.4	47.3	8.5	35.6
	W	18.2	4.0	22.0	13.7	23.2
	Th	5.9	1.5	25.4	4.3	7.9
Outils Écaillés (n=2)	*L*	15.6	4.7	30.1	9.3	23.3
	W	15.6	4.4	28.2	10.6	21.7
	Th	5.0	1.5	30.0	2.9	6.9

[a] Sample size for GG1 notch platforms is 4

Table 5.18. Size dimensions and standard deviation and coefficient of variation statistics for formal tool types in the DBL1.3 horizon at EYM

Type	*Metric*	*Mean*	*SD*	*CV*	*Minimum*	*Maximum*
Scrapers (n=8)	*EPA*[a]	80°	-	-	-	-
	PW[a]	15.2	-	-	-	-
	PT[a]	7.2	-	-	-	-
	L	17.5	4.0	22.9	13.3	22.2
	W	14.8	5.9	39.9	8.4	26.4
	Th	5.3	1.8	40.0	2.5	8.2
Backed Microliths (n=7)	*EPA*[b]	88°	-	-	-	-
	PW[b]	11.3	-	-	-	-
	PT[b]	3.3	-	-	-	-
	L	21.9	3.5	16.0	17.3	26.1
	W	10.1	3.1	30.7	5.5	13.6
	Th	3.2	0.6	18.8	2.6	4.2
Notches (n=6)	*L*	9.6	5.0	52.1	6.1	17.0
	W	10.5	3.3	31.4	8.5	15.3
	Th	3.5	1.0	28.6	2.3	4.3
Burins (n=3)	*EPA*[d]	73°	-	-	-	-
	PW[d]	7.6	-	-	-	-
	PT[d]	3.8	-	-	-	-
	L	18.8	2.9	15.4	17.0	22.1
	W	13.6	4.1	30.1	8.9	16.0
	Th	4.0	0.7	17.5	3.5	4.8
Outils Écaillés (n=2)	*L*	23.7	5.9	24.9	19.5	27.8
	W	21.0	2.2	10.5	19.4	22.5
	Th	5.7	0.0	0.0	5.7	5.7

[a]Sample size for DBL1.3 scraper platforms is 1

[a]Sample size for DBL1.3 backed microlith platforms is 1

[a]Sample size for DBL1.3 scraper platforms is 1

The purpose of this chapter was to describe the lithic technology of two early LSA horizons at Enkapune Ya Muto rockshelter. Obsidian artifact assemblages from the DBL1.3 and GG1 horizons were analyzed in several ways and compared in terms of their technological organization. Overall, despite differences in blade size preference (i.e. larger average size in GG1) and typological composition (e.g. more curated scrapers but fewer microliths in DBL1.3), these two horizons both represent early LSA industries focused on the production of blades and microlithic tools.

Figures

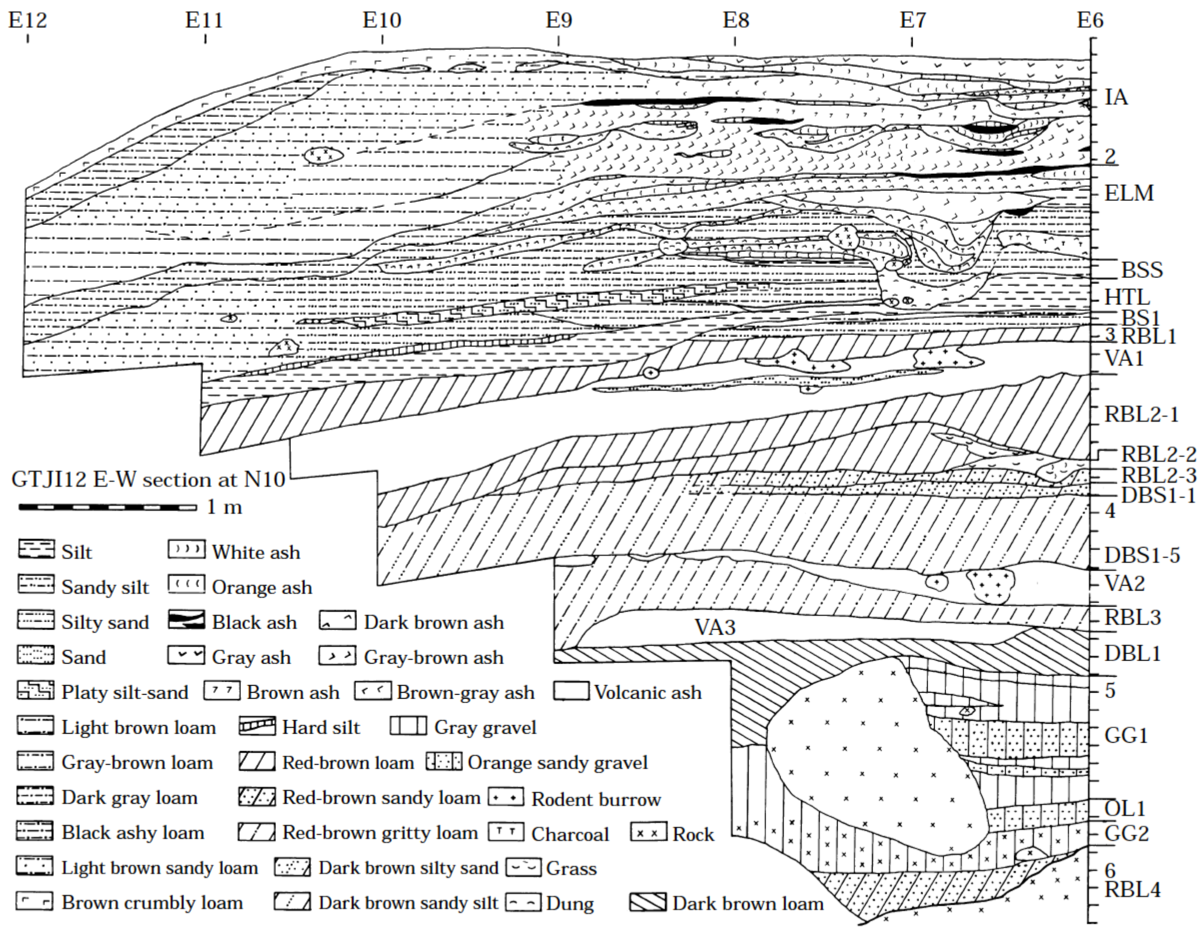

Figure 5.1. Stratigraphic section drawing of 1982 excavation at Enkapune Ya Muto. The DBL1 and GG1 horizons are visible near the bottom of the section on the right. The dripline is located between E9 and E10. Figure used with permission from Ambrose (1998a: 381, figure 1).

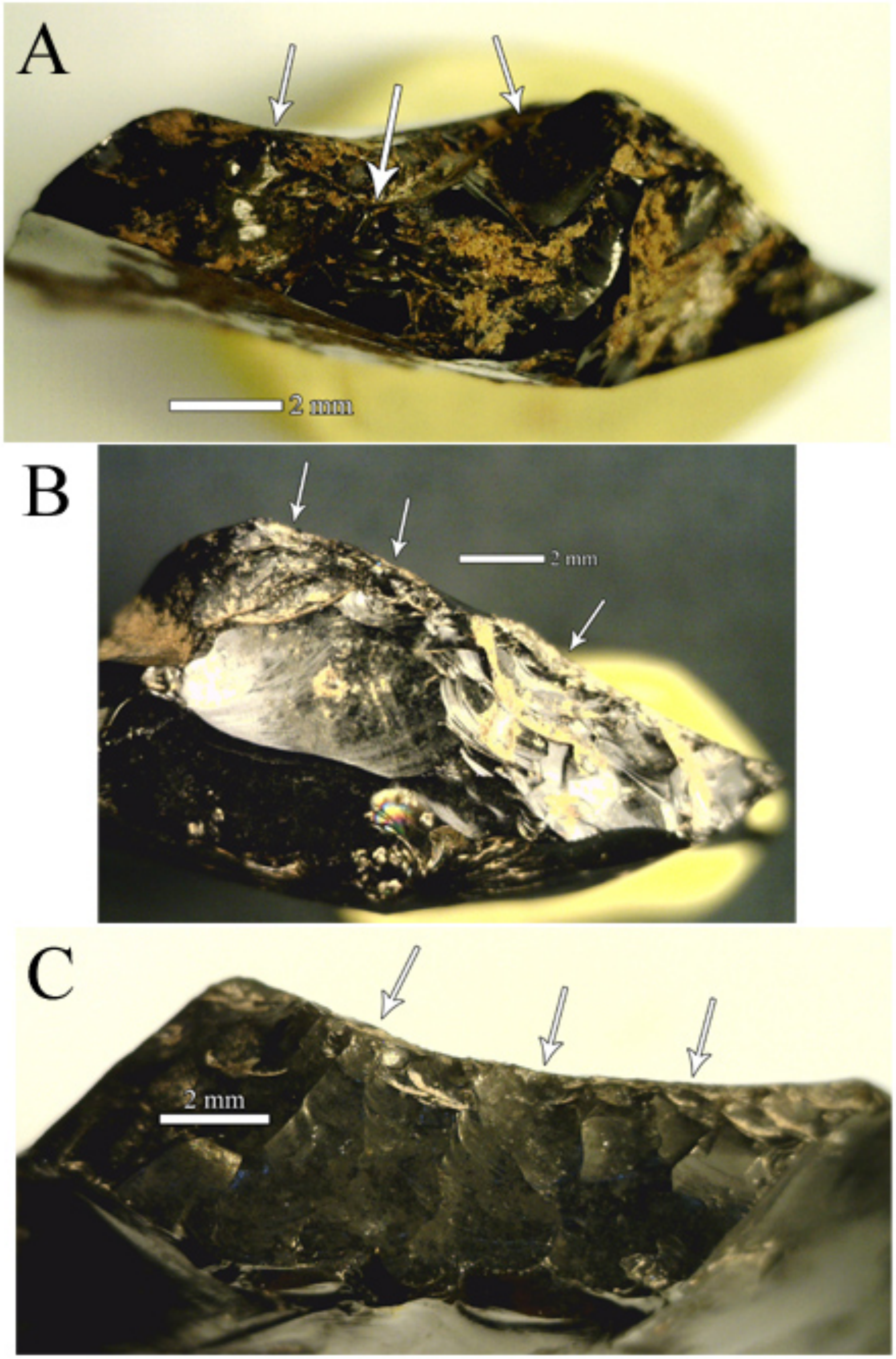

Figure 5.2. Photos of microfaceted platforms on primary debitage from the DBL horizon. Arrows indicate direction of retouch onto the platforms, away from the artifact's dorsal face.

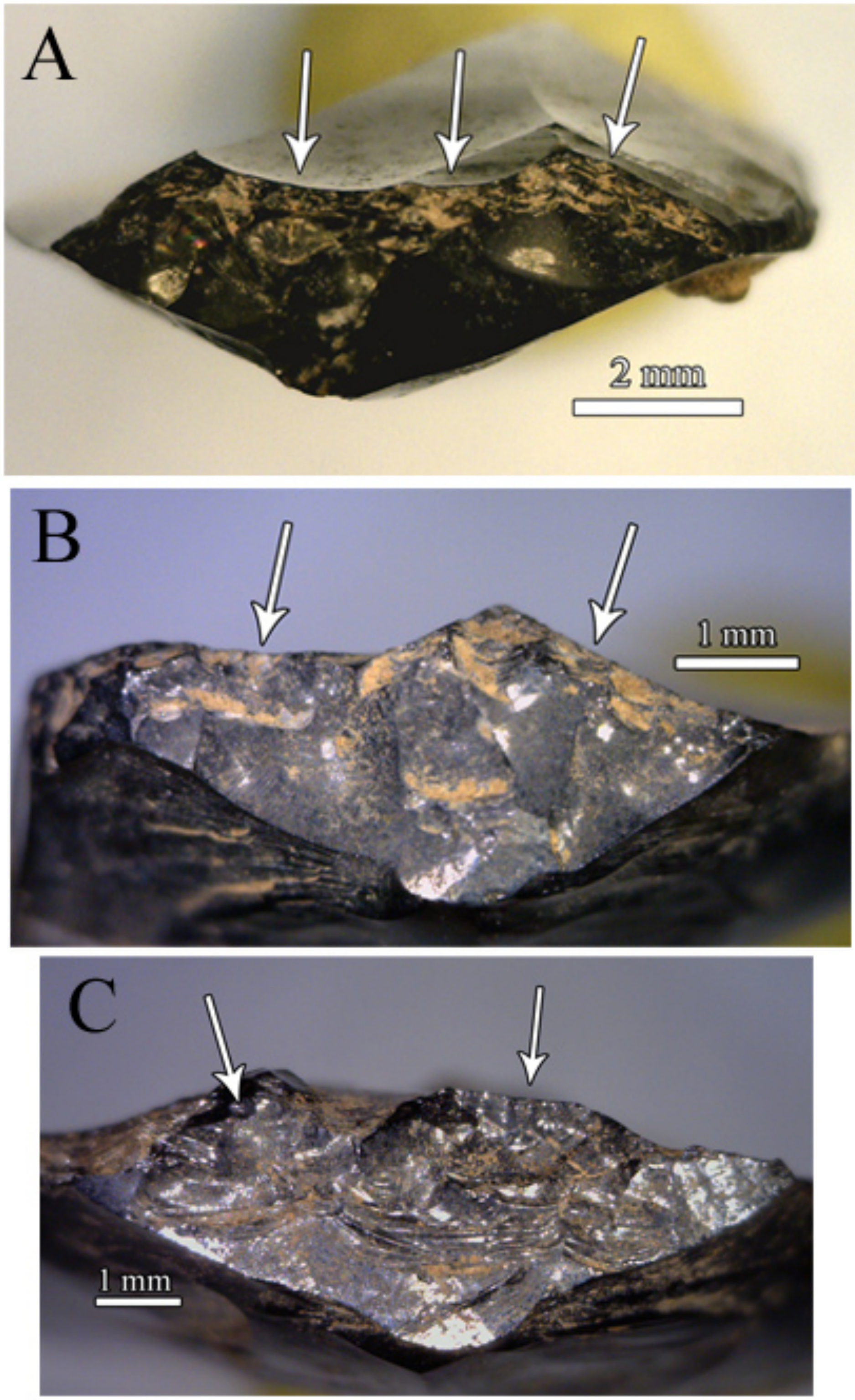

Figure 5.3. Photos of microfaceted platforms on primary debitage from the DBL horizon. Arrows indicate direction of retouch onto the platforms, always from the artifact's dorsal face.

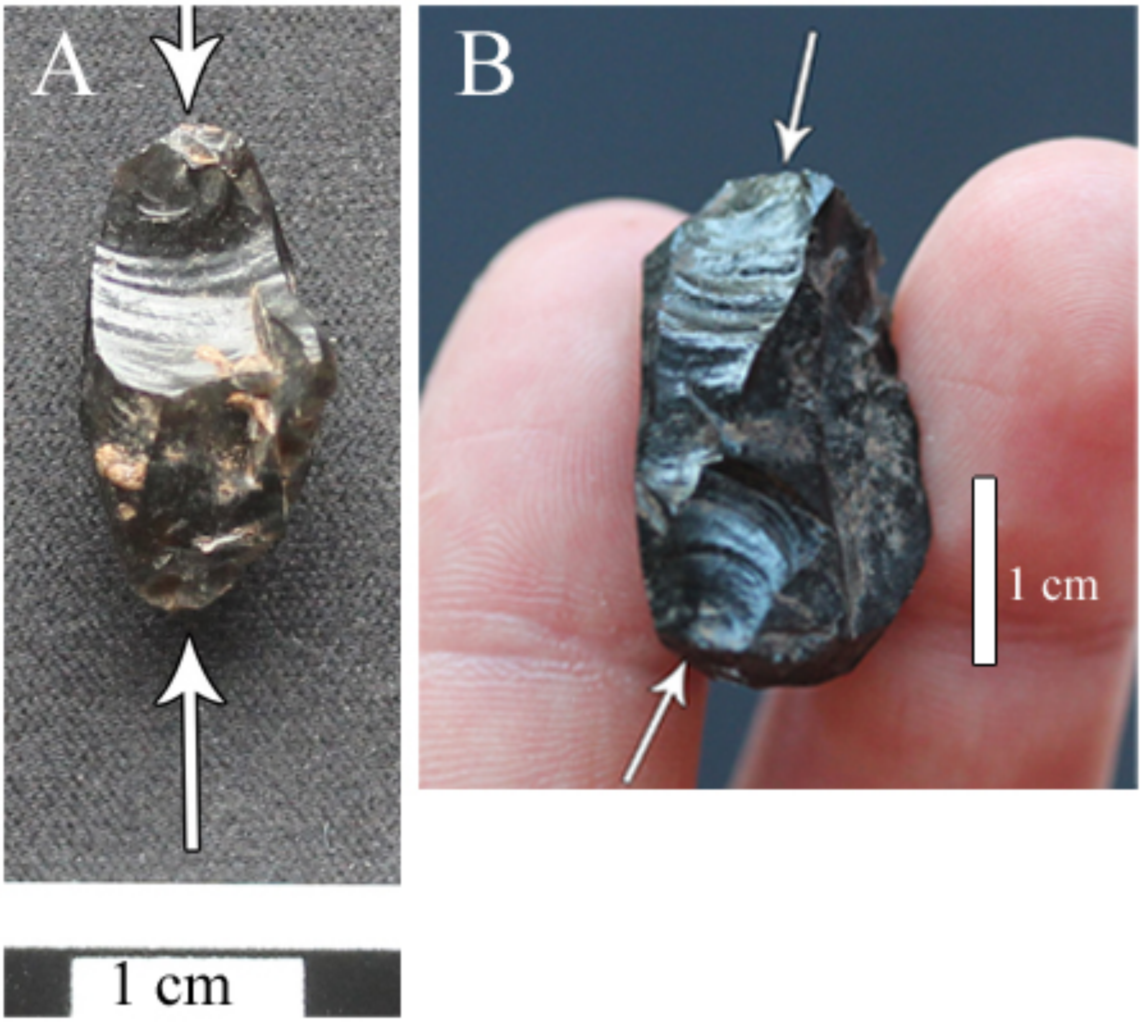

Figure 5.4. Photos of two cores from the DBL horizon. (A) Bipolar core (#33586); (B) exhausted microblade core (#33580) with opposed platforms. These pieces are visually similar but the difference in curvature of the flake release surfaces indicate that #33586 (concave surfaces) was struck on an anvil, while #33580 (convex surfaces) was struck while held in a hand.

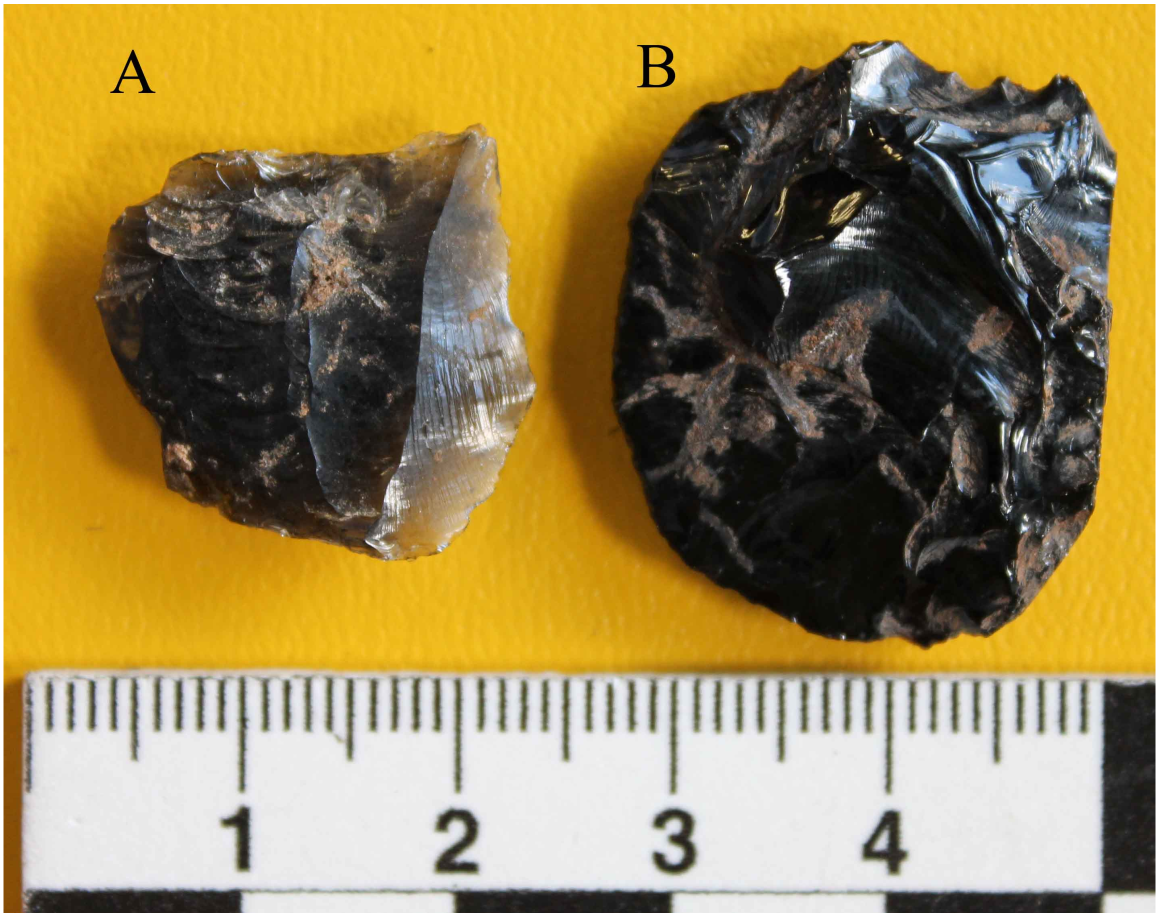

Figure 5.5. Outil écaillés from the DBL horizon (A, #33395; B, #33396).

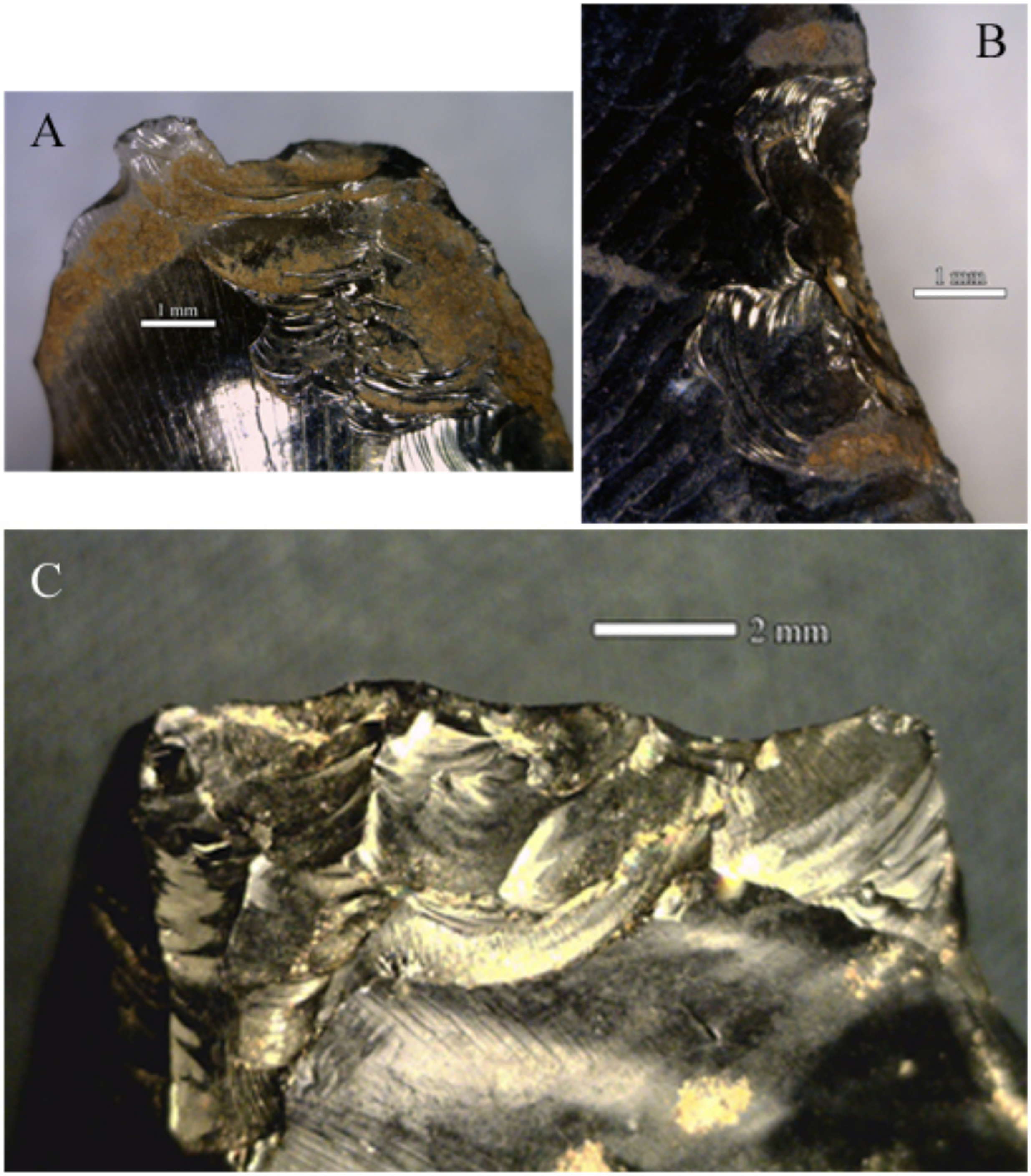

Figure 5.6. Photos of casually retouched edges from the DBL horizon. A and B are the same piece (#33399). The retouch on piece C (#33330) is écaillé like, or scaly, but is not bifacial so is classified as casual.

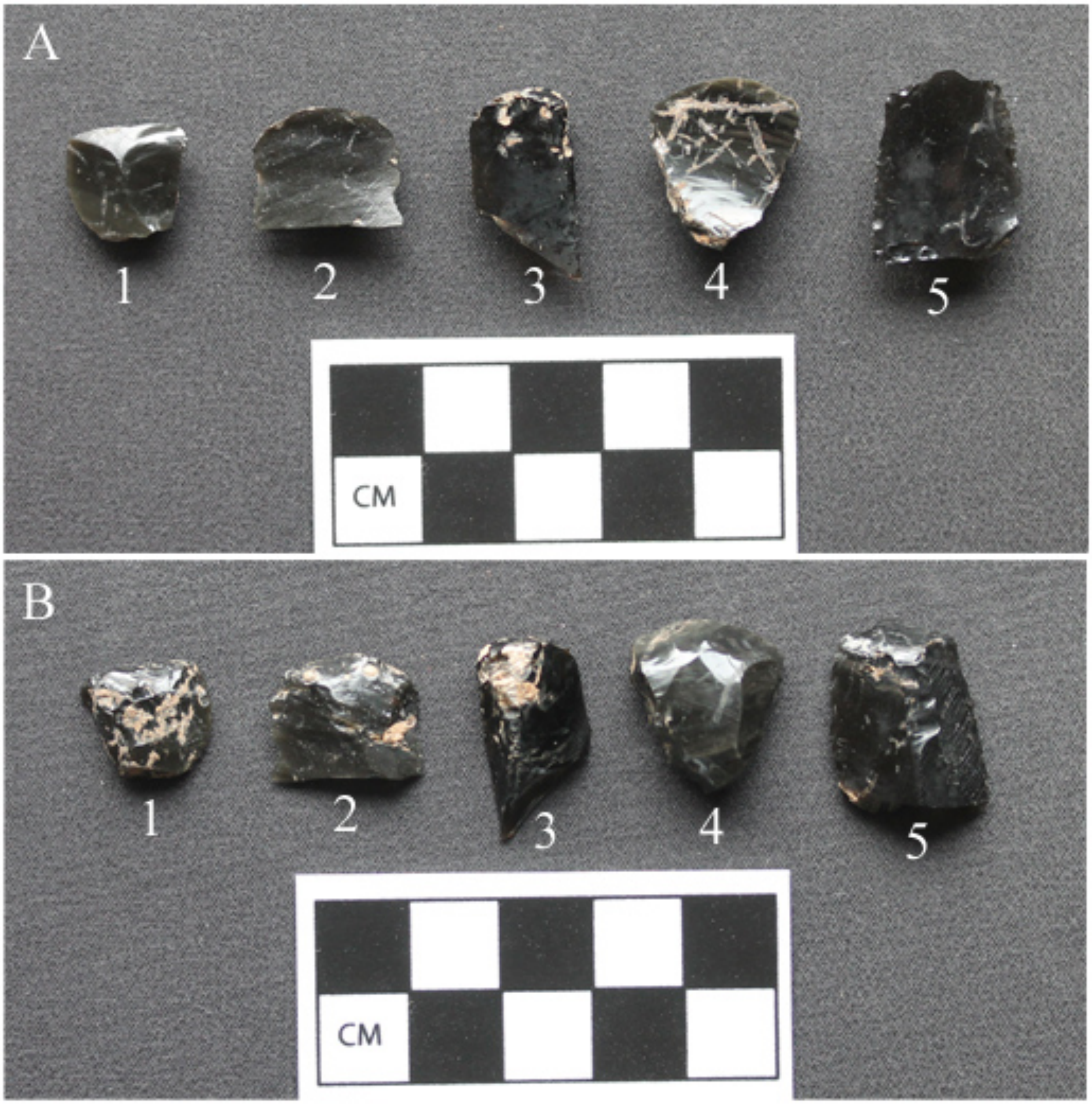

Figure 5.7. Photos of dorsal (A) and ventral (B) faces of convex end scrapers made on blades from the DBL horizon. These are also known as thumbnail scrapers (Ambrose, 1998). From left to right: #33374, #33375, #33376, #33377, and #33378. Pieces 1 and 4 have extensive retouch on the lateral margins, possibly to facilitate hafting.

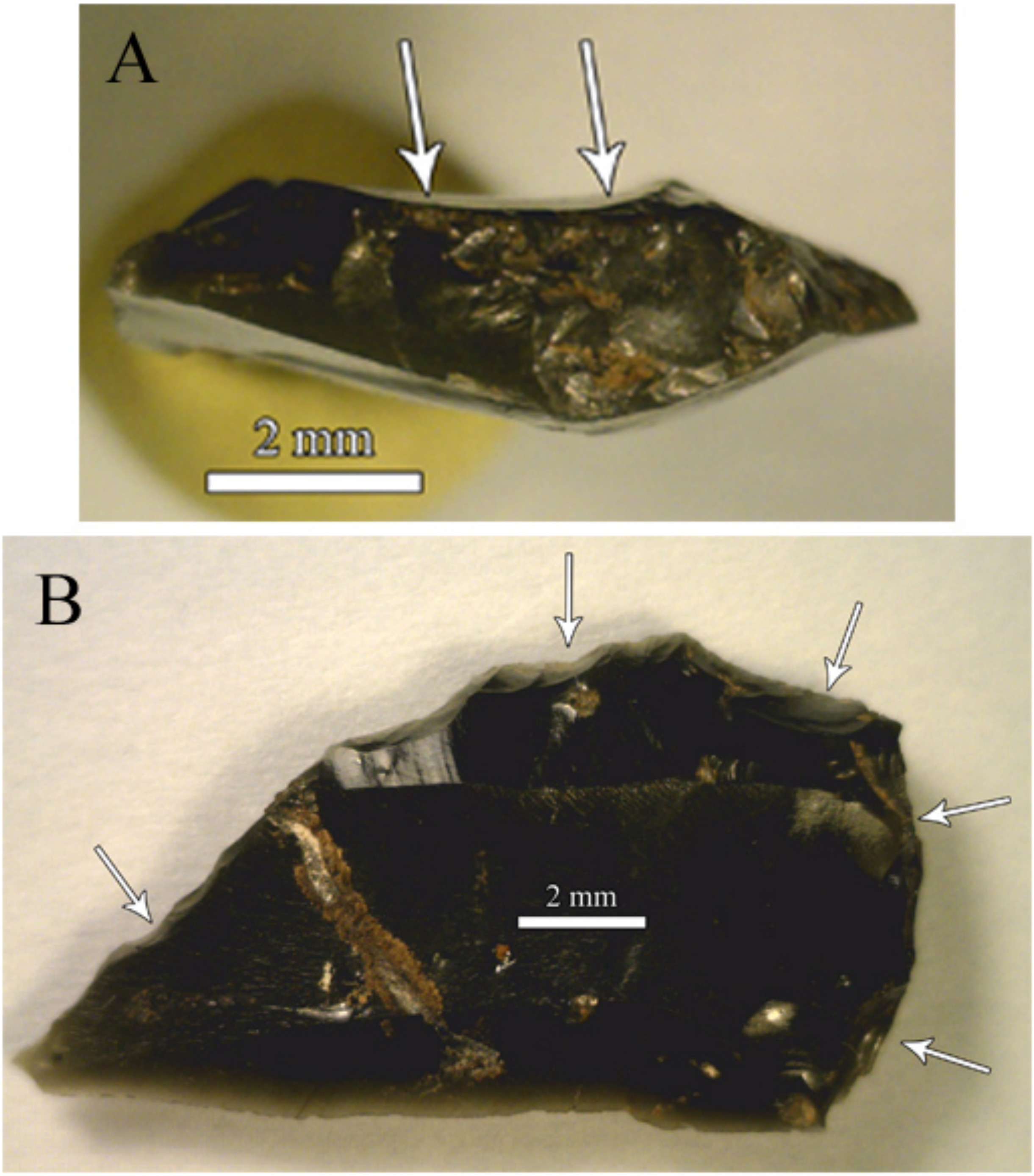

Figure 5.8. Curved-backed microlith made a non-truncated blade (#33401). (A) The faceted platform is retained on this piece. Arrows indicate direction of retouch onto the platform, initiated from the dorsal face. (B) Arrows indicate the location of backing, including the platform, which is on the right side of the piece in this photo.

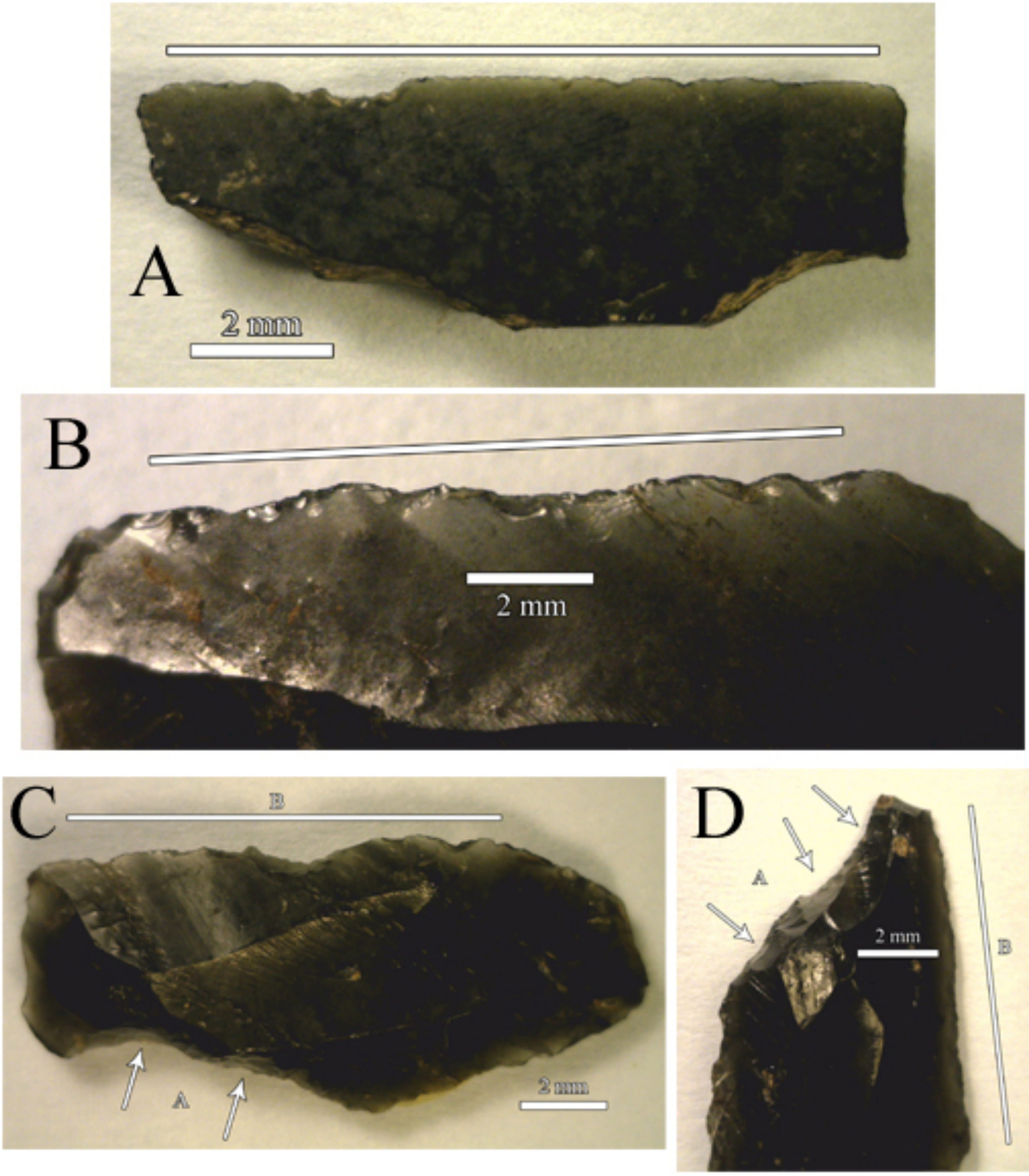

Figure 5.9. Backed microliths with use-wear traces on their unmodified edges. The arrows indicate backing and the bars indicate utilized edges. (A) #33369; (B-C) #33361; (D) #33372.

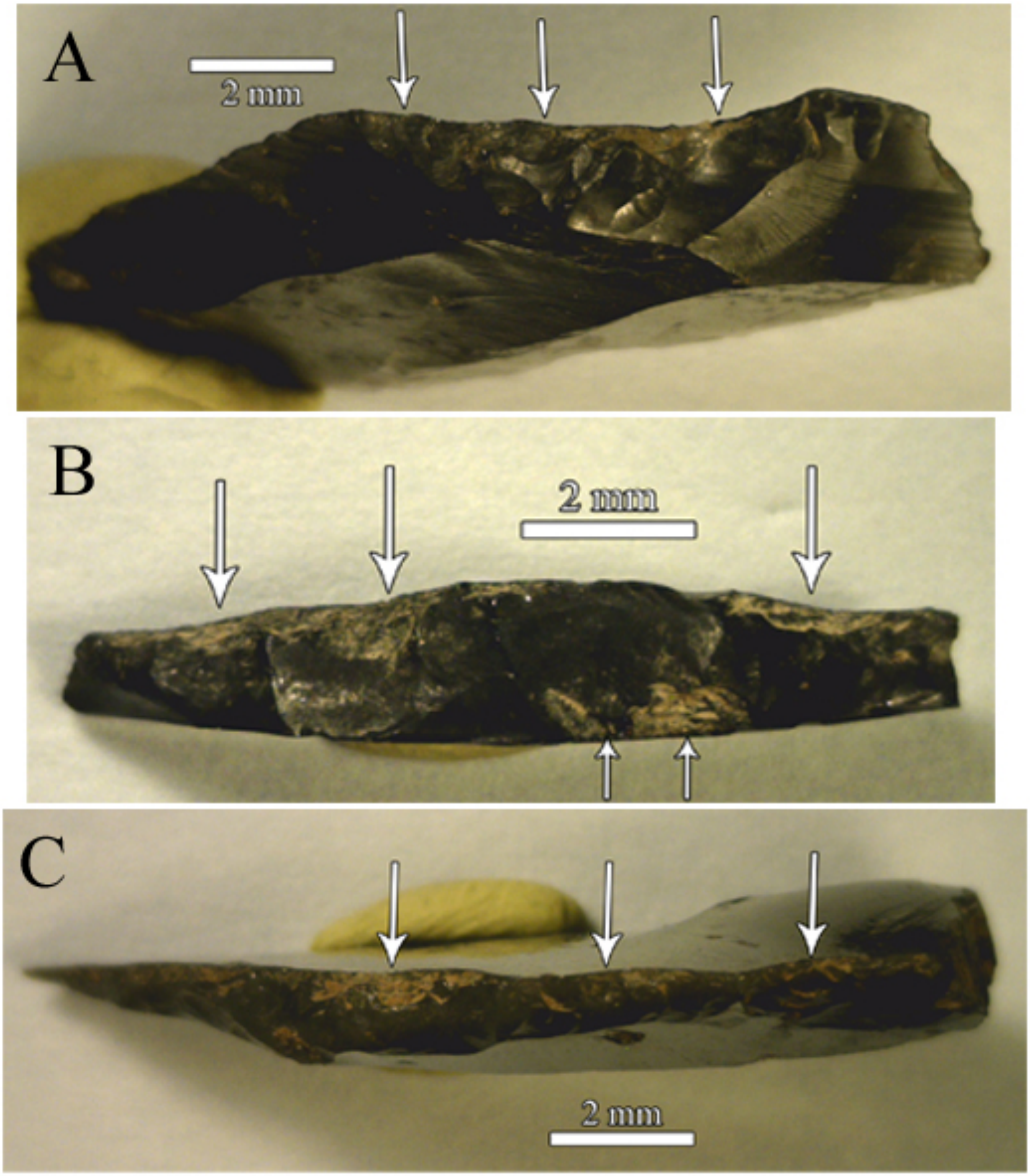

Figure 5.10. Microlith backed edges. Arrows indicate direction of backing blows. (A) #33361; (B) #33369 with alternate bidirectional backing; (C) #33401.

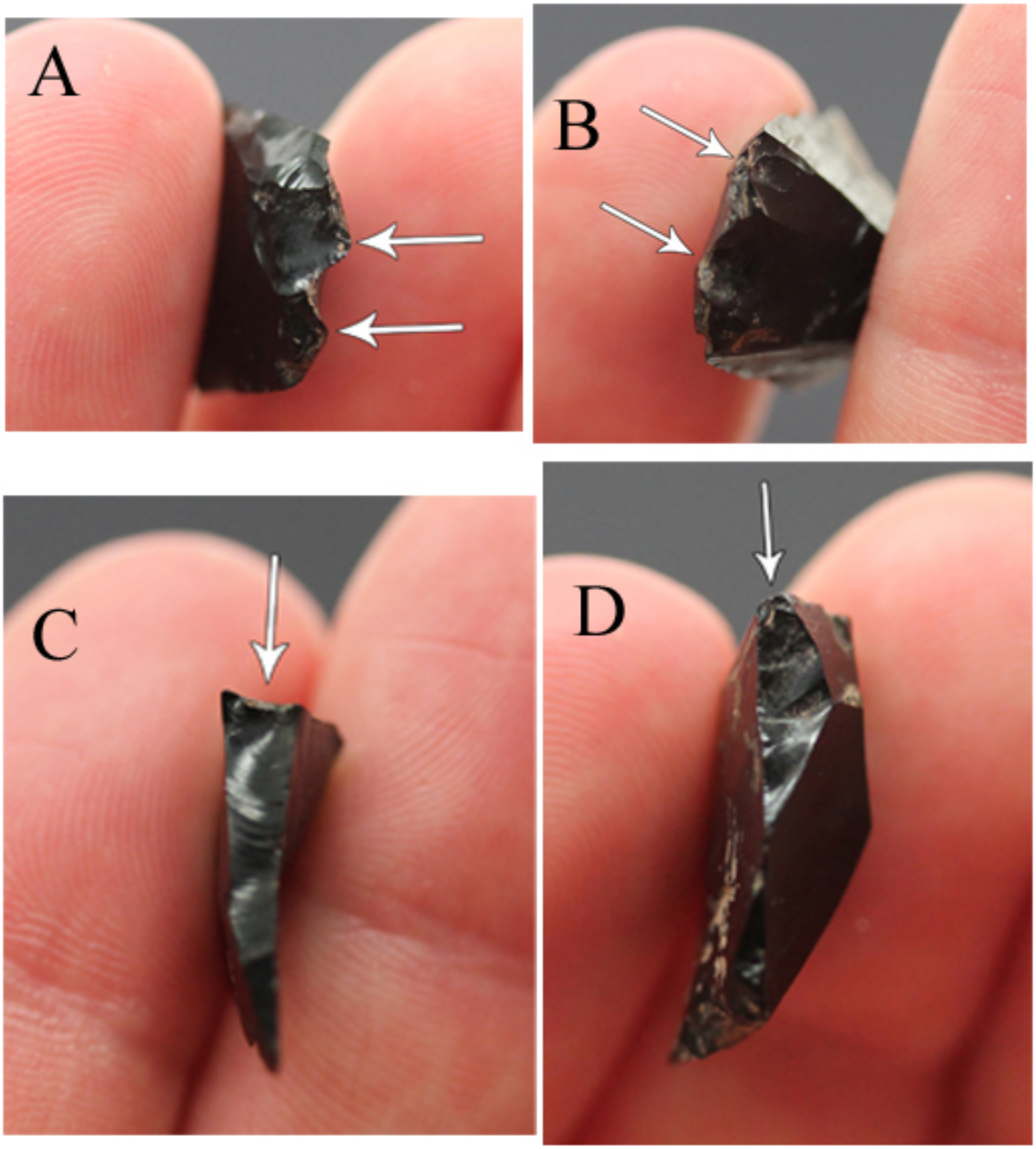

Figure 5.11. Tools from DBL horizon at Enkapune Ya Muto. (A-B) Bec (#33364) created from blows, indicated by arrows, on alternate sides; (C-D) two burins struck on lateral flake edges (C, #33404; D, #33402).

Figure 5.12. Blade technology from DBL horizon at Enkapune Ya Muto. (A) Tabular or truncated faceted core (#33405); (B) unmodified flake blank (#33323); (C) unmodified blade blank (#33397); (D-F) backed microliths (#33401, #33372, #33361).

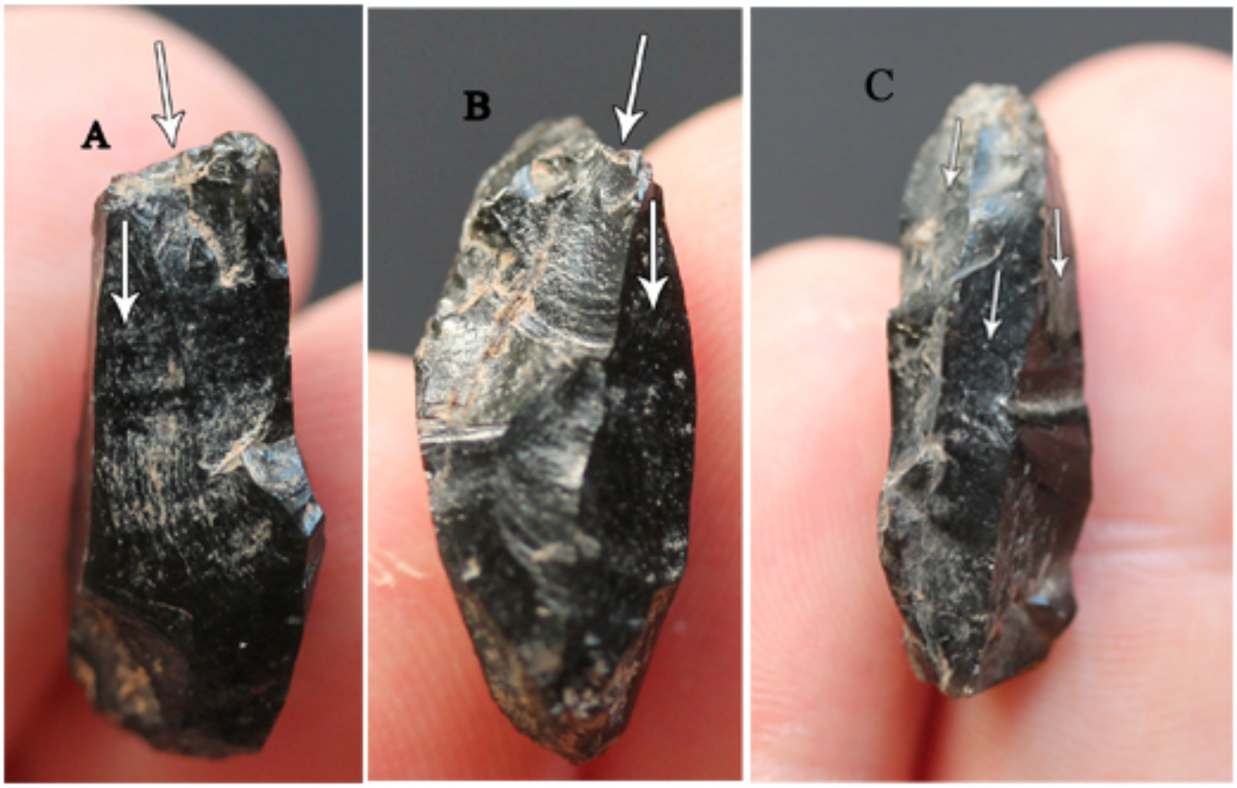

Figure 5.13. Exhausted bipolar cores or *batonettes* from the GG 1 horizon. (A-B) Two sides of the same piece (#33993); (C) #33994. Arrows indicate striking direction of visible scars.

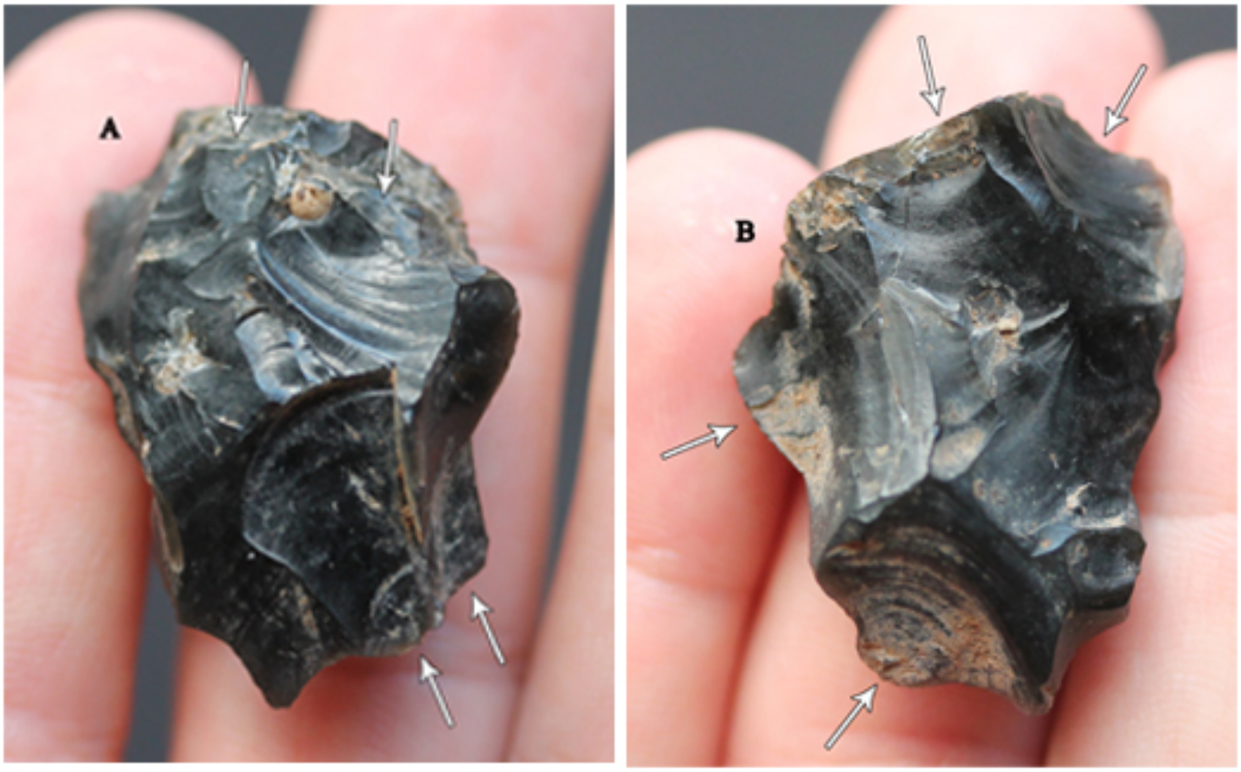

Figure 5.14. Exhausted radial core from the GG 1 horizon. (A-B) Two sides of the same piece (#33996). Arrows indicate striking direction of visible scars.

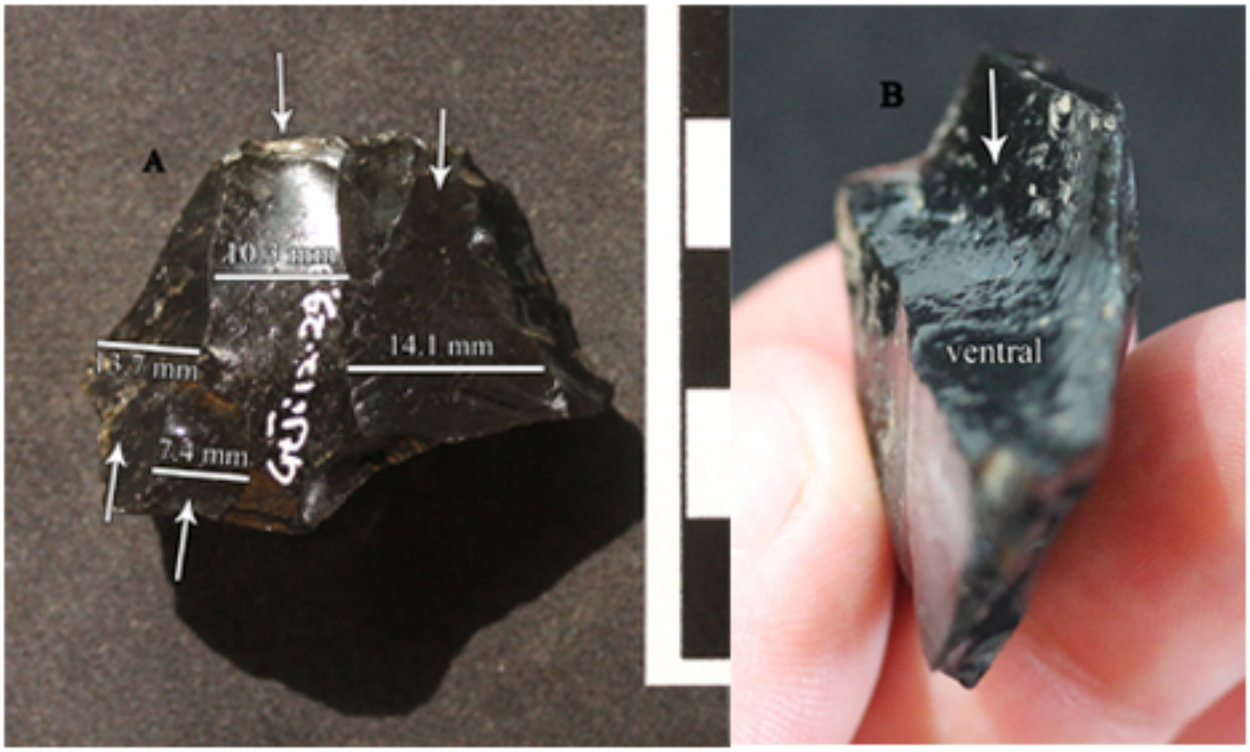

Figure 5.15. Photo of and overstruck distal blade fragment (#33995) that retains the striking platform from the opposed end of the tabular blade core from which it was struck. (A) Dorsal face with arrows indicating direction of scars. Bars with measurements are widths of negative removals. (B) ventral face with arrow pointing to the overstruck distal end.

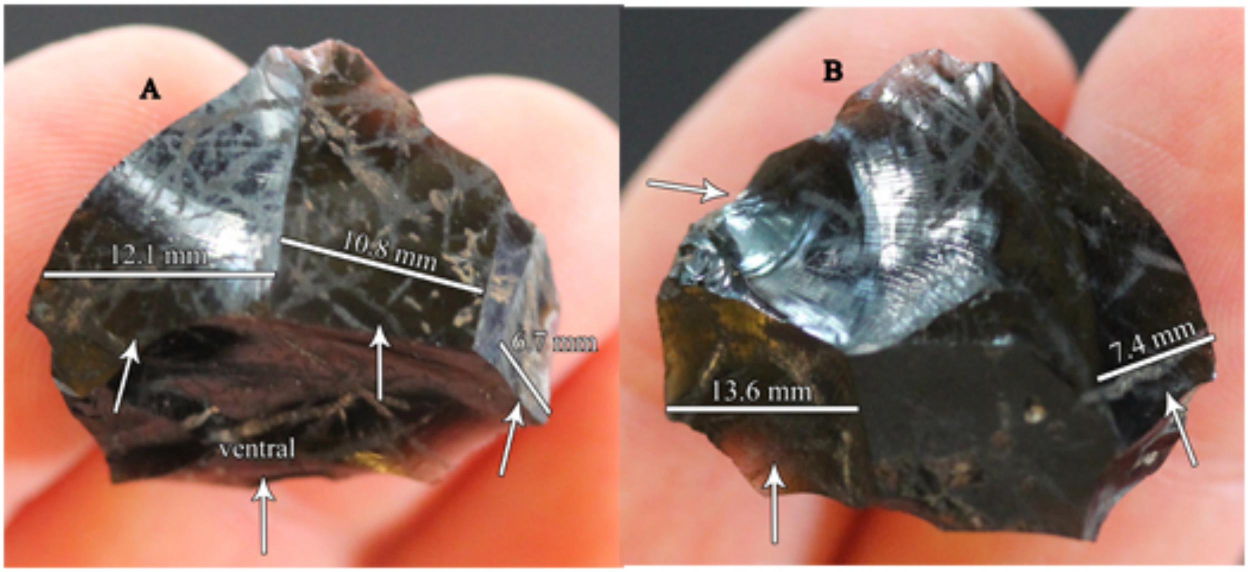

Figure 5.16. Photo of an overstruck distal blade fragment (#34069) that retains at least five negative blade scars from the core that this piece was struck from. (A) The ventral face is labeled on bottom part of the piece. Arrows indicate directions of previous scars and bars with measurements are widths of those negative removals. (B) The dorsal face with two measured negative scars and retouched edge (top left of the piece). Because the piece is broken the full length of the scars cannot be determined, however, based on the parallel arêtes and consistent widths the scars most likely represent blade, not flake, removals.

Figure 5.17. Photo of a refit blade core platform rejuvenation flake (#34126). The distal end is to the right in both images and the proximal end is missing. Arrows indicate six negative blade scars that were removed from this platform, and the bars with measurements show the minimum width of the blades that were removed from the core.

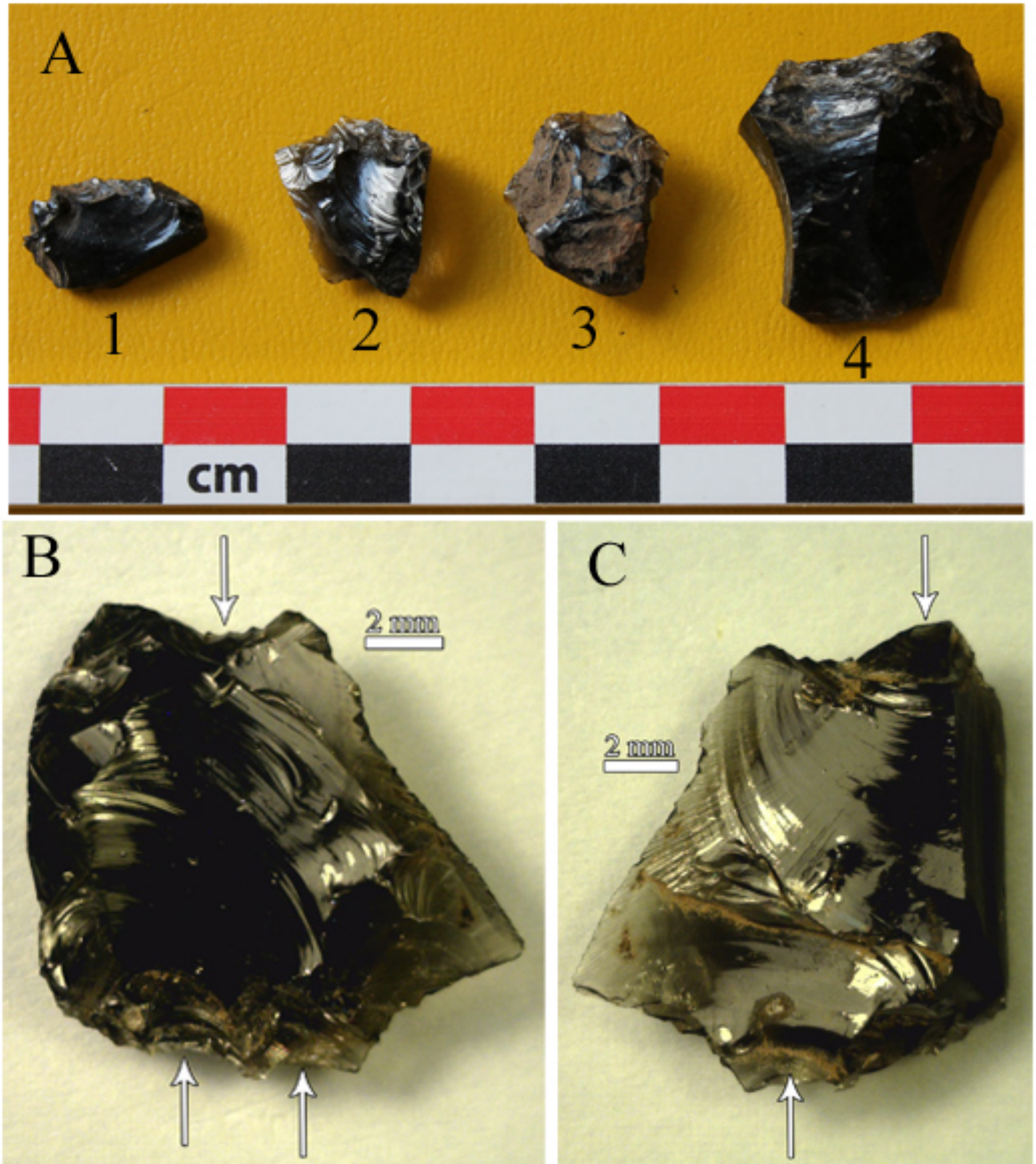

Figure 5.18. (A) Photo of outil écaillés (#33900, #33901, #33902, #33903) from the GG 1 horizon; (B-C) different faces of #33901 with arrows indicating stepped and scaled flake scars removed from opposite directions.

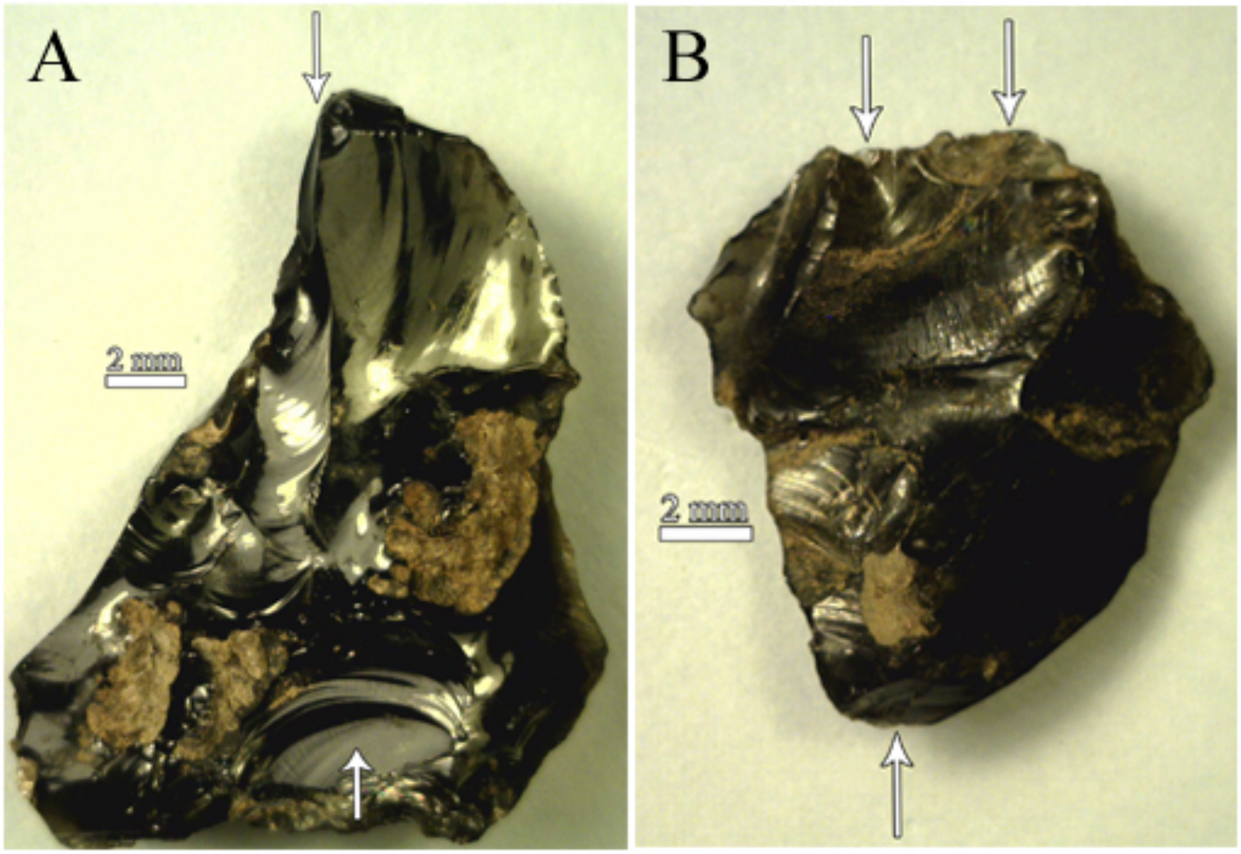

Figure 5.19. Outil écaillés from the GG 1 horizon. (A) #34000; (B) the other face of #33902 (see figure 5.18). Arrows indicate opposed points of impact.

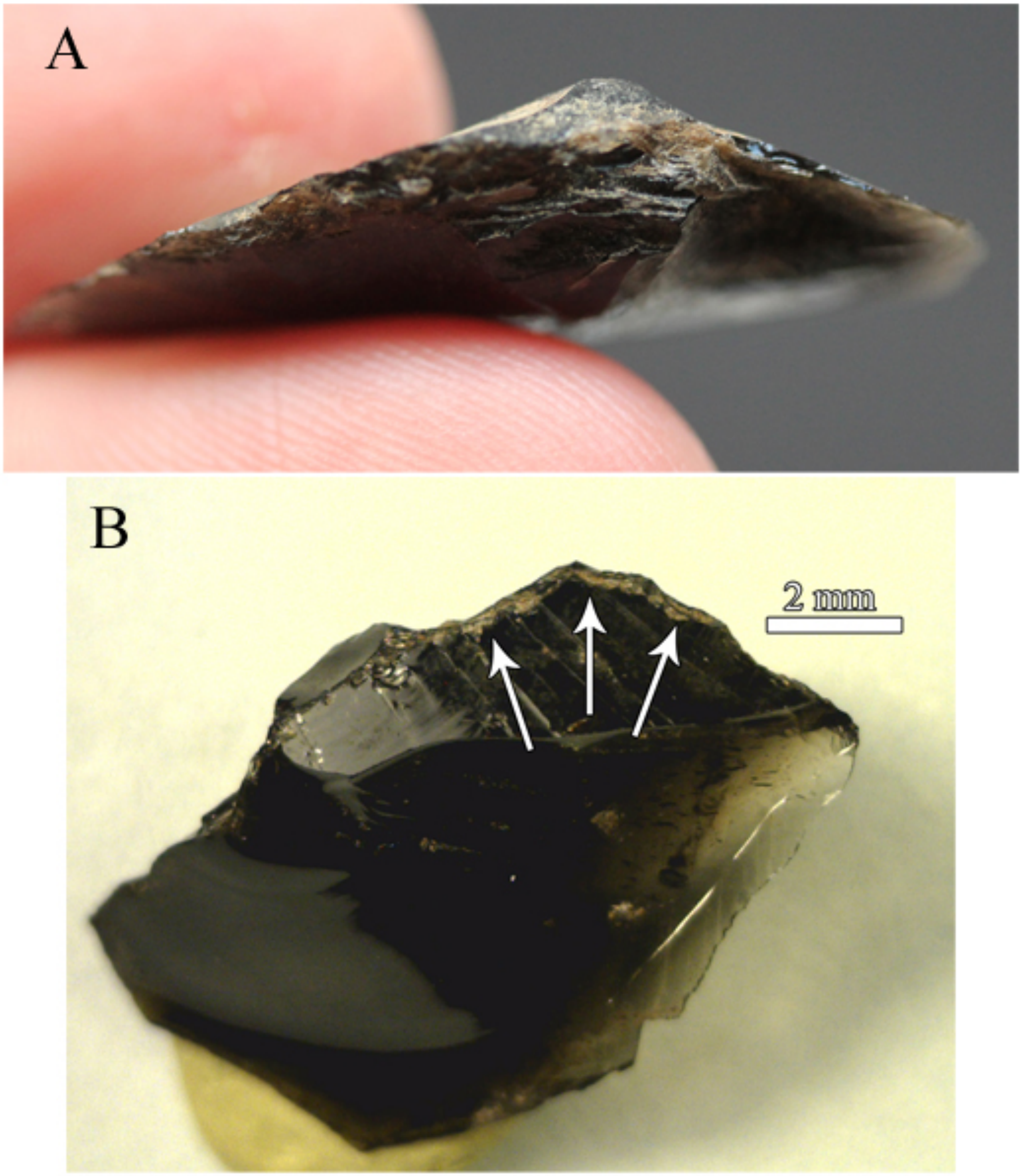

Figure 5.20. Small retouch flakes from the GG 1 horizon. (A) Plain platform with stepped scarring (#34144); (B) wide and thick plain platform with edge rounding and stepped scars on the dorsal proximal area (indicated by arrows (#33961).

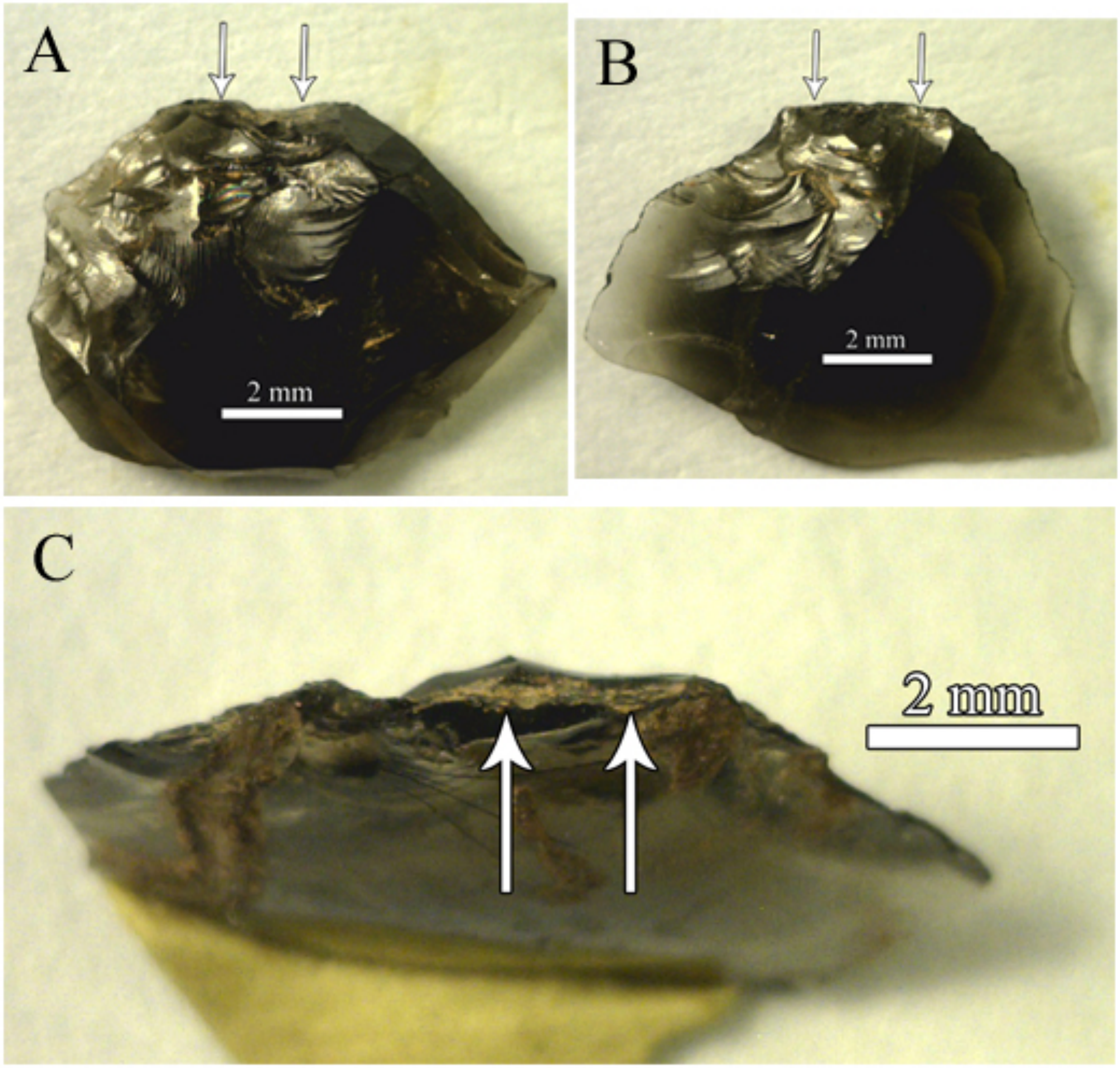

Figure 5.21. Small retouch flakes from the GG 1 horizon. Arrows indicate direction of removal (onto the dorsal face) for use-wear scars. (A) #33925; (B) #33926; (C) #33916.

Figure 5.22. Lipped biface retouch flake (#33864) from the GG 1 horizon. The large arrow indicates the point of percussion and the smaller arrows indicate other small retouch scars initiated from the edge of the bifacially retouched piece this flake was removed from.

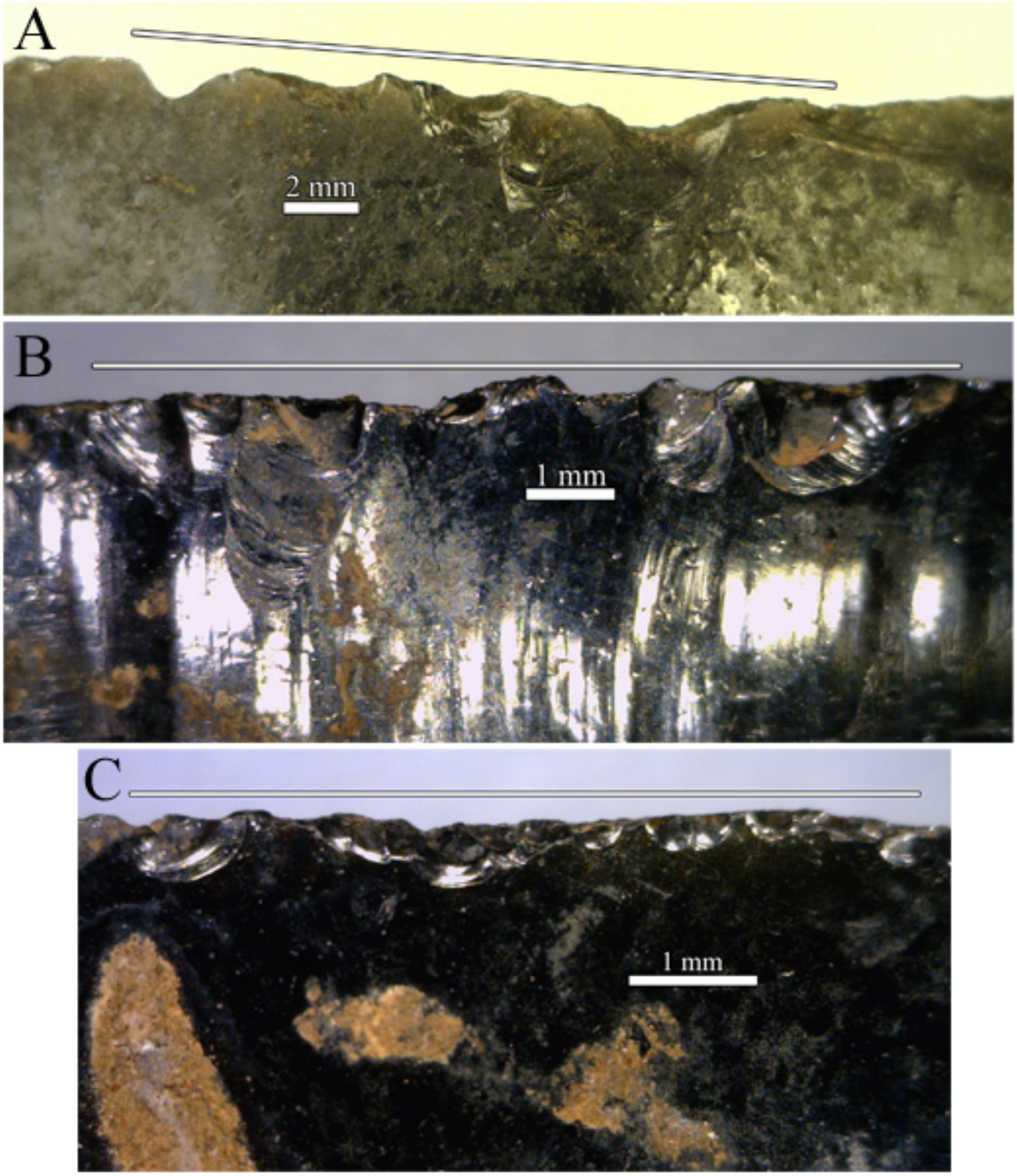

Figure 5.23. Utilized blade edges from the GG 1 horizon. (A) #33834; (B-C) #33832.

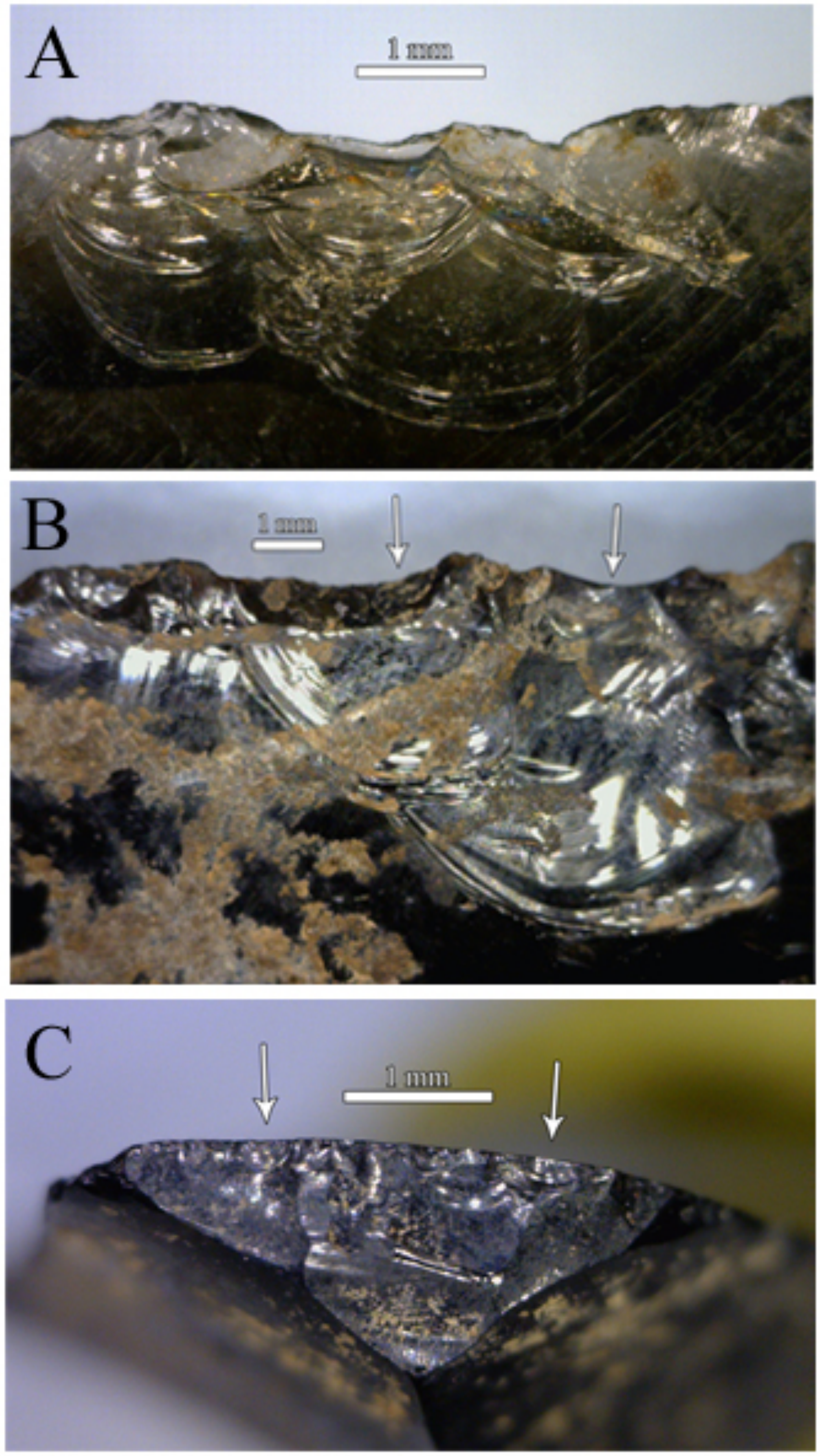

Figure 5.24. Retouched blade edges from the GG 1 horizon. (A) Denticulate, #33848; (B) denticulate, #33841; (C) casual retouch, #34177.

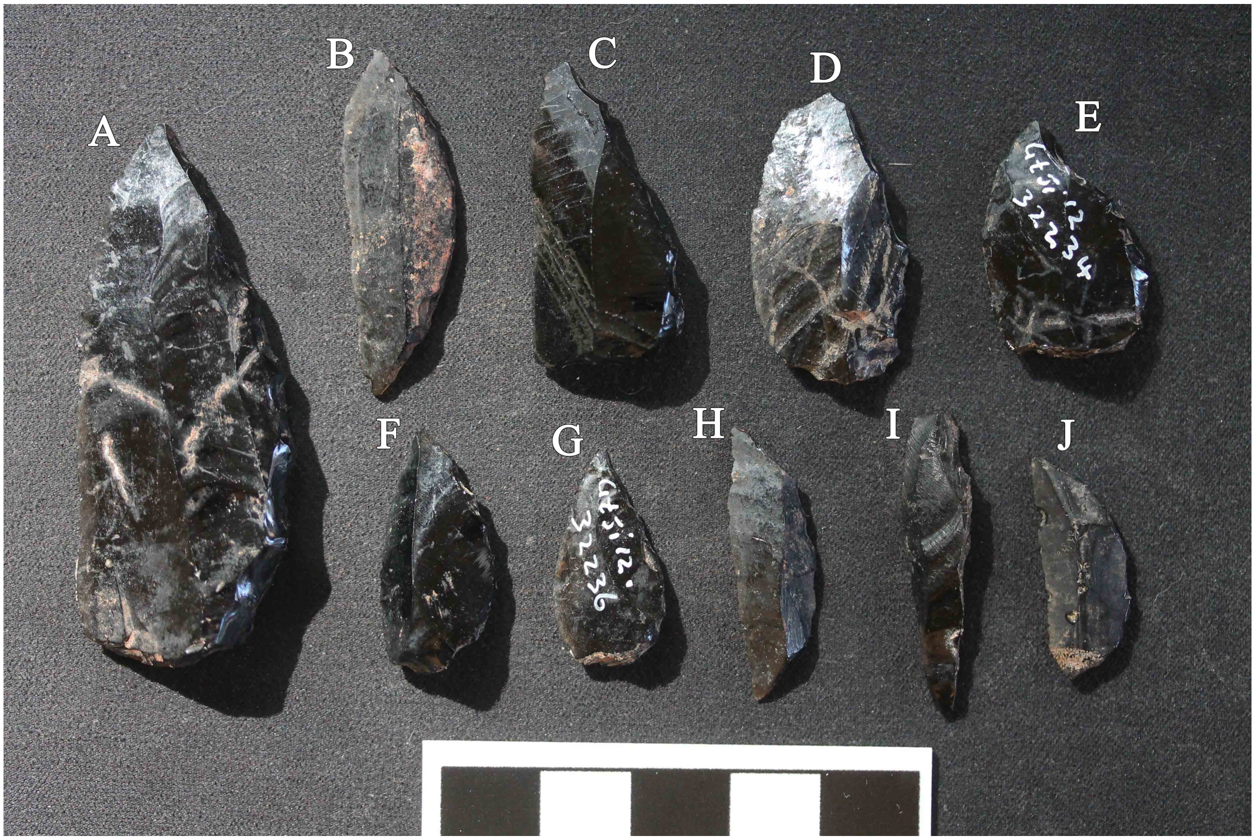

Figure 5.25. Backed microliths from the GG 1 horizon. (A) Orthogonal backed, #32237; (B) crescent with red ochre staining, #32230; (C) orthogonal backed, #32238; (D) oblique backed, #32235; (E) curved backed, #32234; (F) curved backed, #32233; (G) oblique backed, #32236; (H) crescent, #32231; (I) straight backed, #33886; (J) trapeze, #32232.

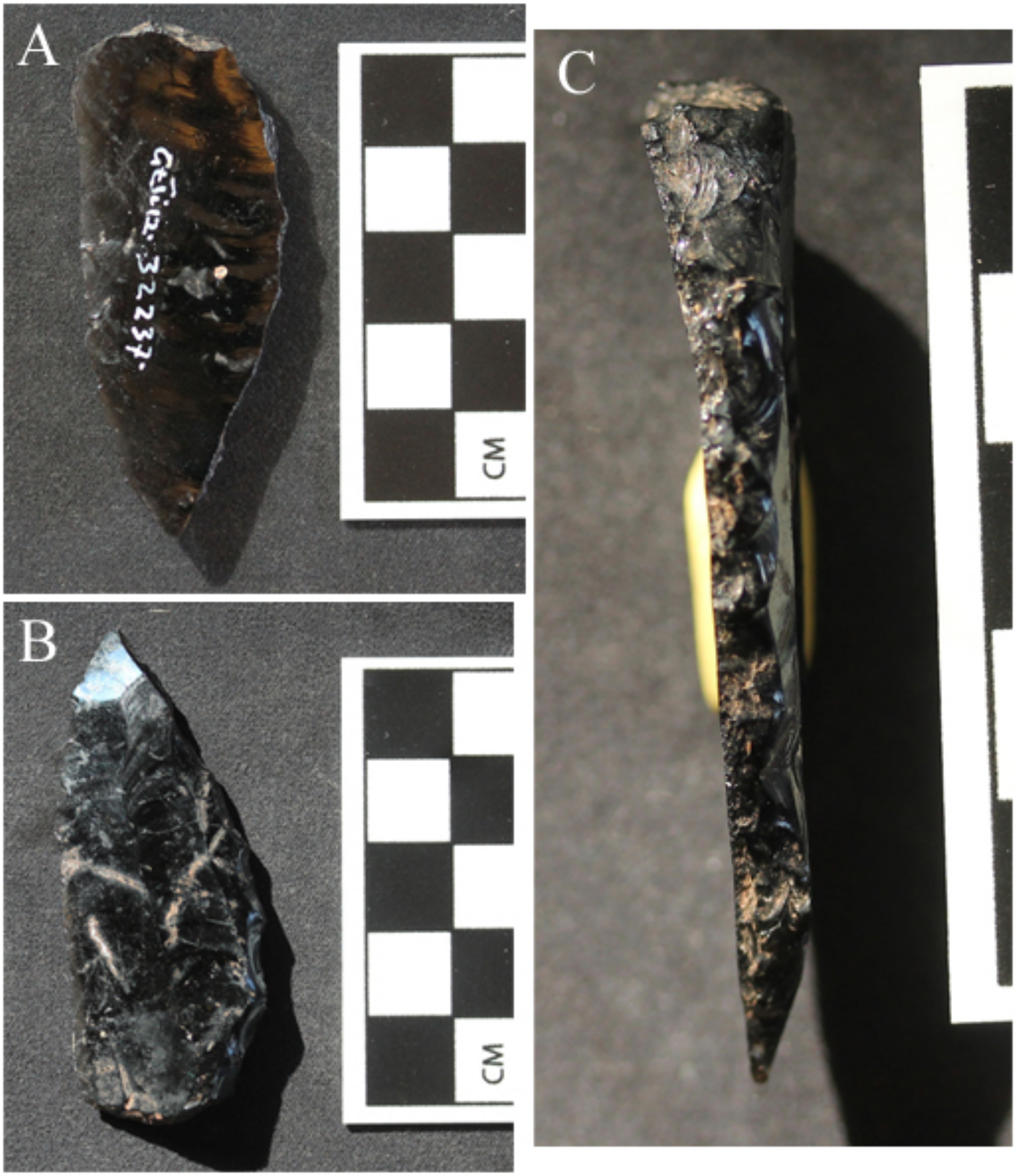

Figure 5.26. Large orthogonal backed microlith (#32237) from the GG 1 horizon. (A) Ventral; (B) dorsal face; (C) backed edge.

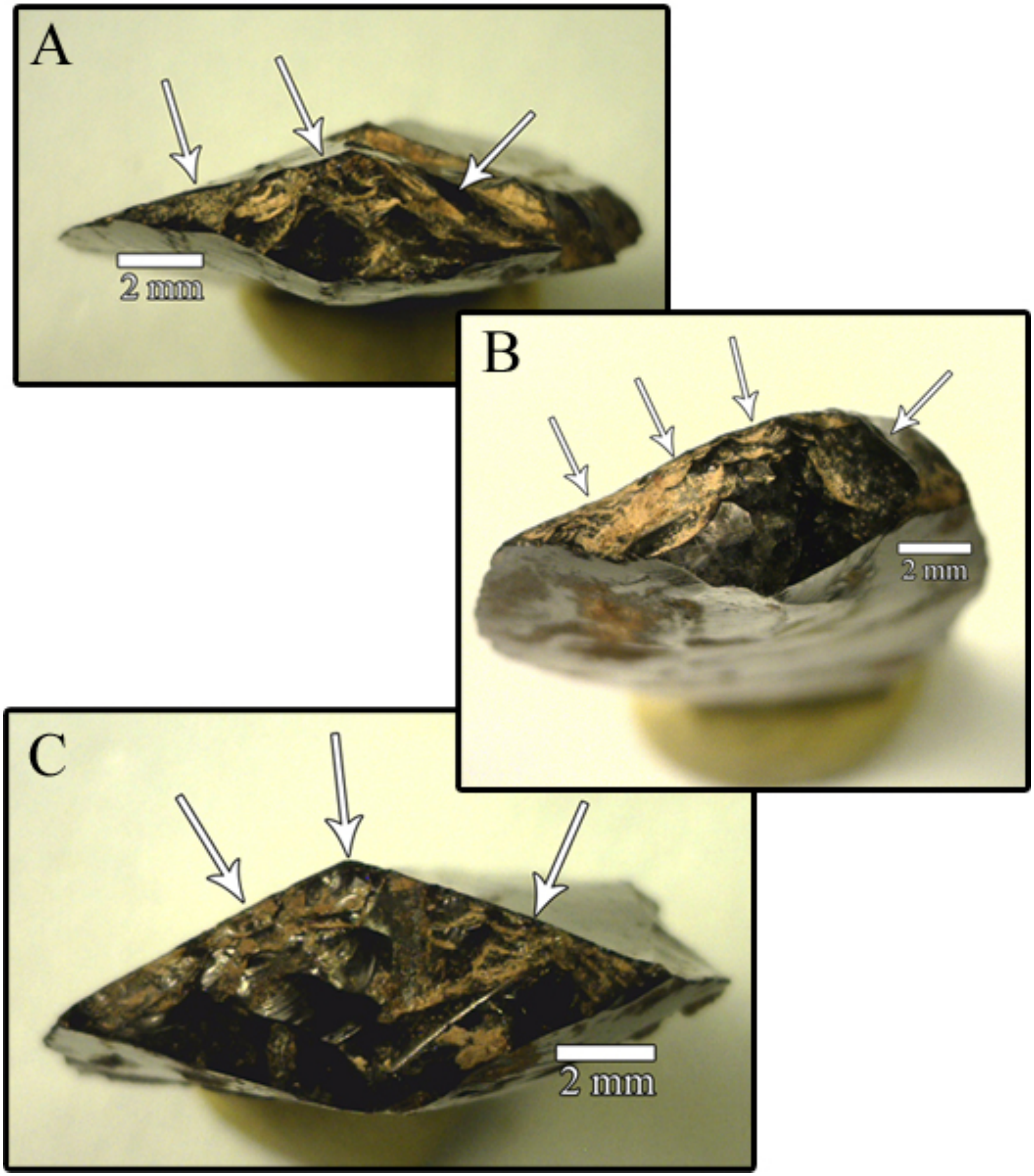

Figure 5.27. Faceted platforms on microliths from the GG 1 horizon. Arrows indicate direction of retouch on the platform, initiated from the dorsal face. (A) Oblique backed, #32235; (B) oblique backed, #32236; (C) curved backed, #32234.

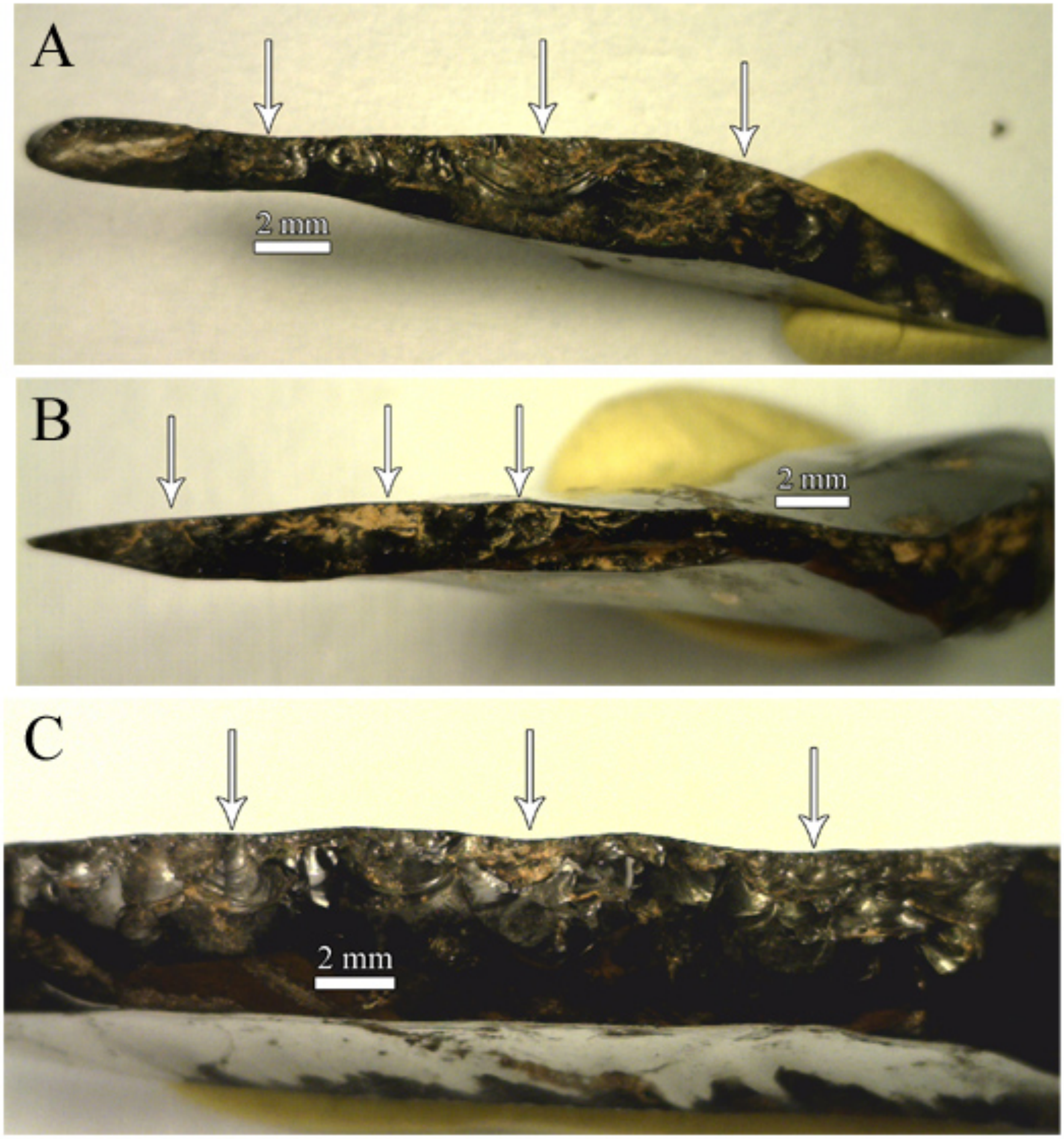

Figure 5.28. Microlith backed edges with arrows indicating direction of retouch. The majority of GG 1 microliths were retouched from the ventral face down onto the dorsal face. A) Straight backed, #33886; (B) oblique backed, #32236; (C) orthogonal backed, #32237.

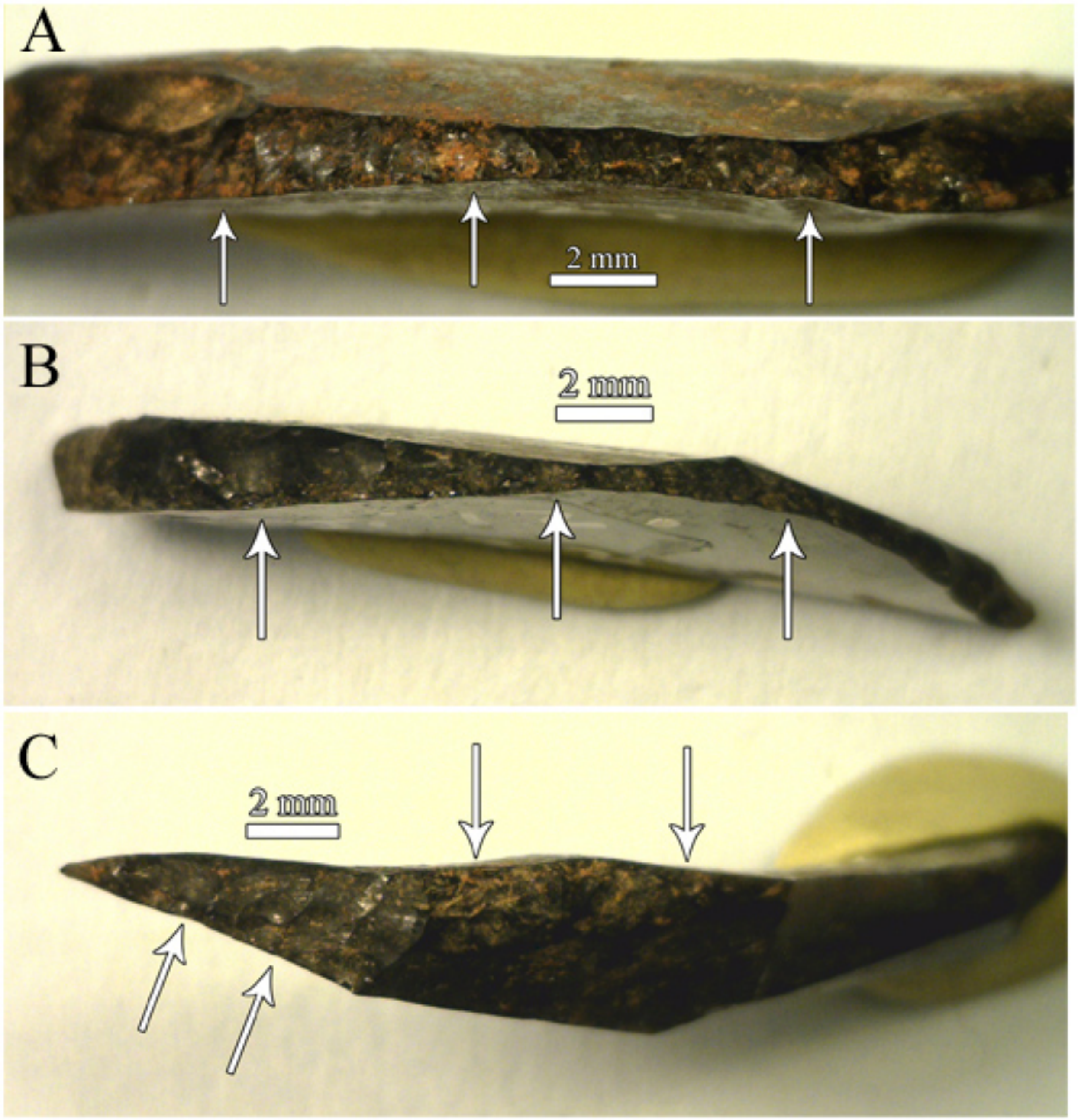

Figure 5.29. Microlith backed edges with arrows indicating direction of retouch. (A) Crescent with red ochre staining, #32230; (B) trapeze, #32232; (C) crescent with alternate backing, #32231.

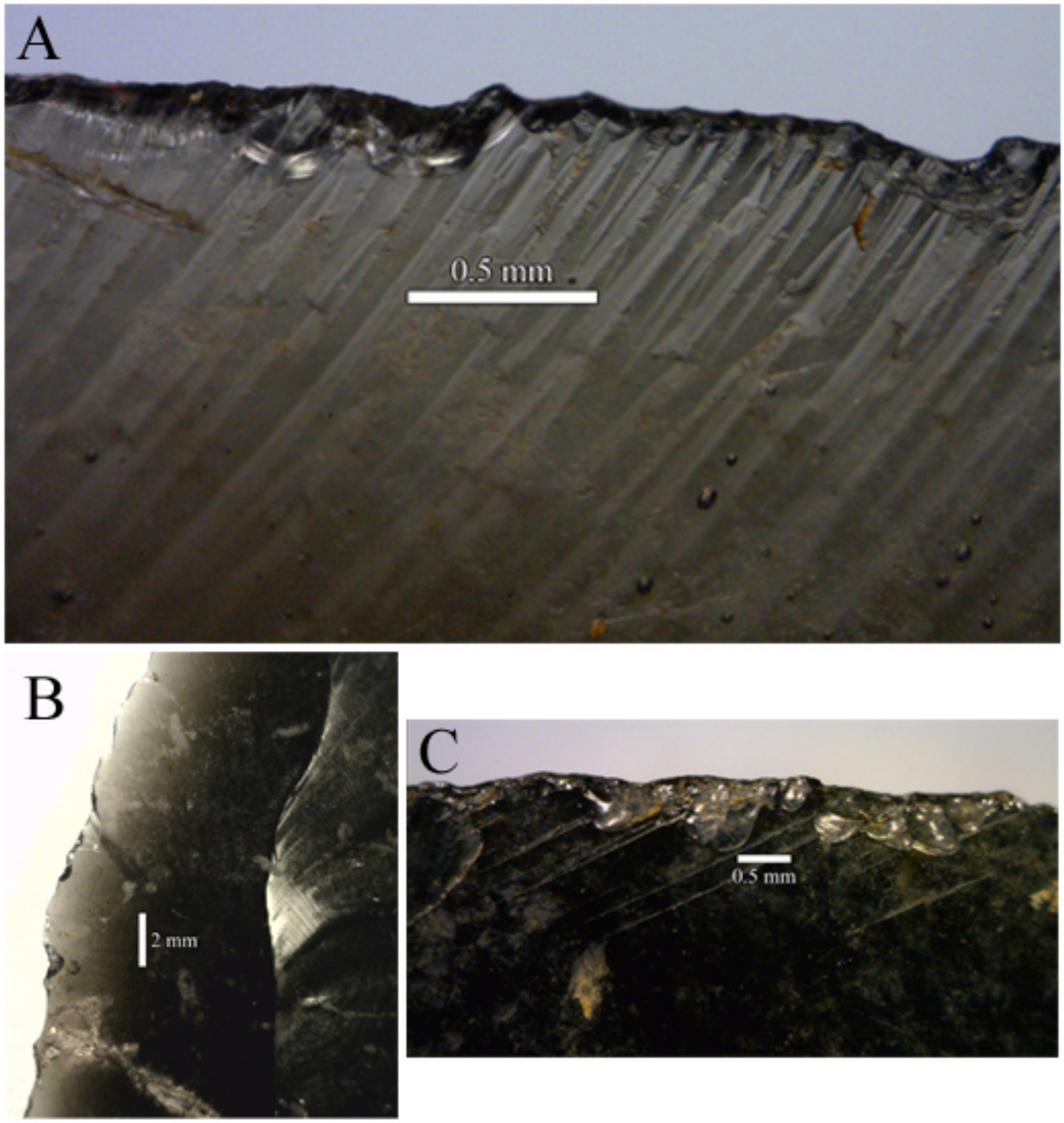

Figure 5.30. Utilization damage on the unmodified edges of microliths from the GG 1 horizon.

(A-B) Orthogonal backed, #32237; (C) curved backed, #32233.

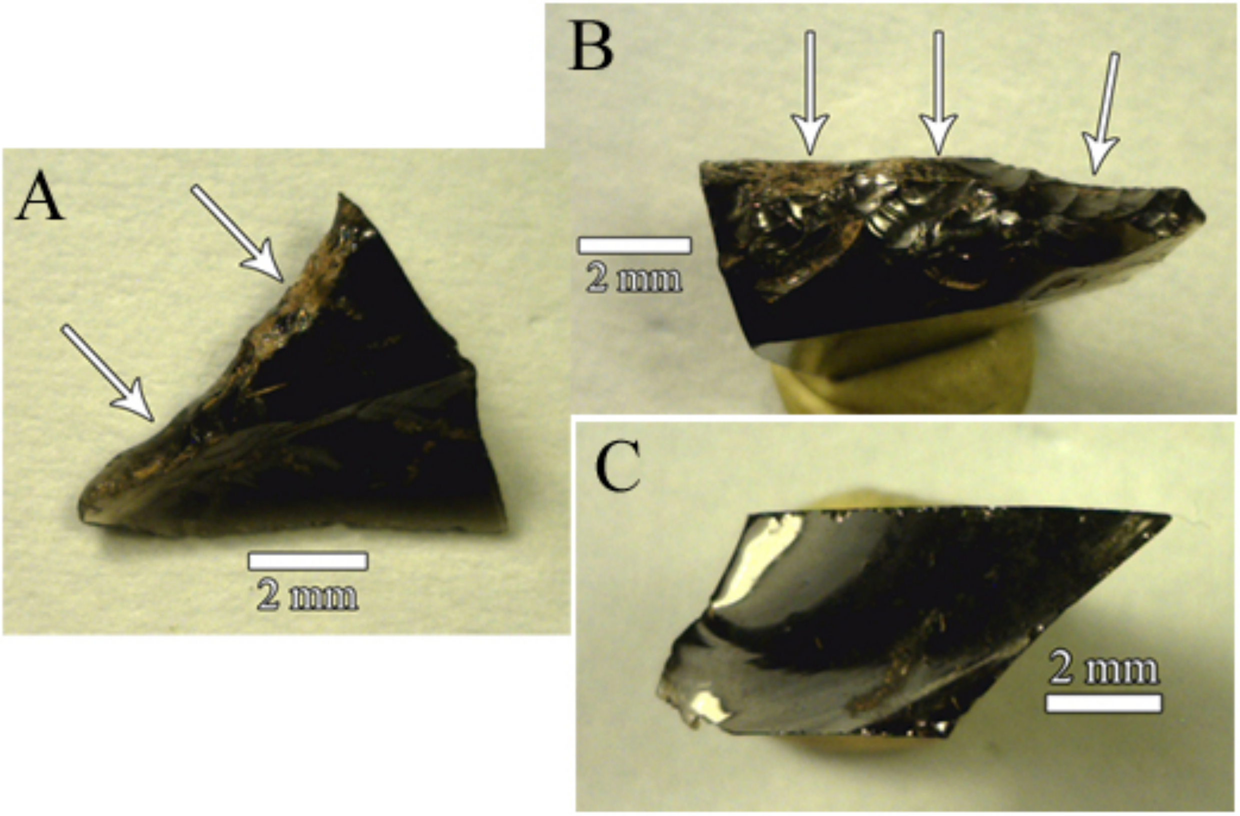

Figure 5.31. Broken microlith fragment (#33884) from the GG 1 horizon. (A) Dorsal face with arrows indicating backed edge; (B) backed edge with arrows indicating direction of retouch; (C) broken, snapped edge.

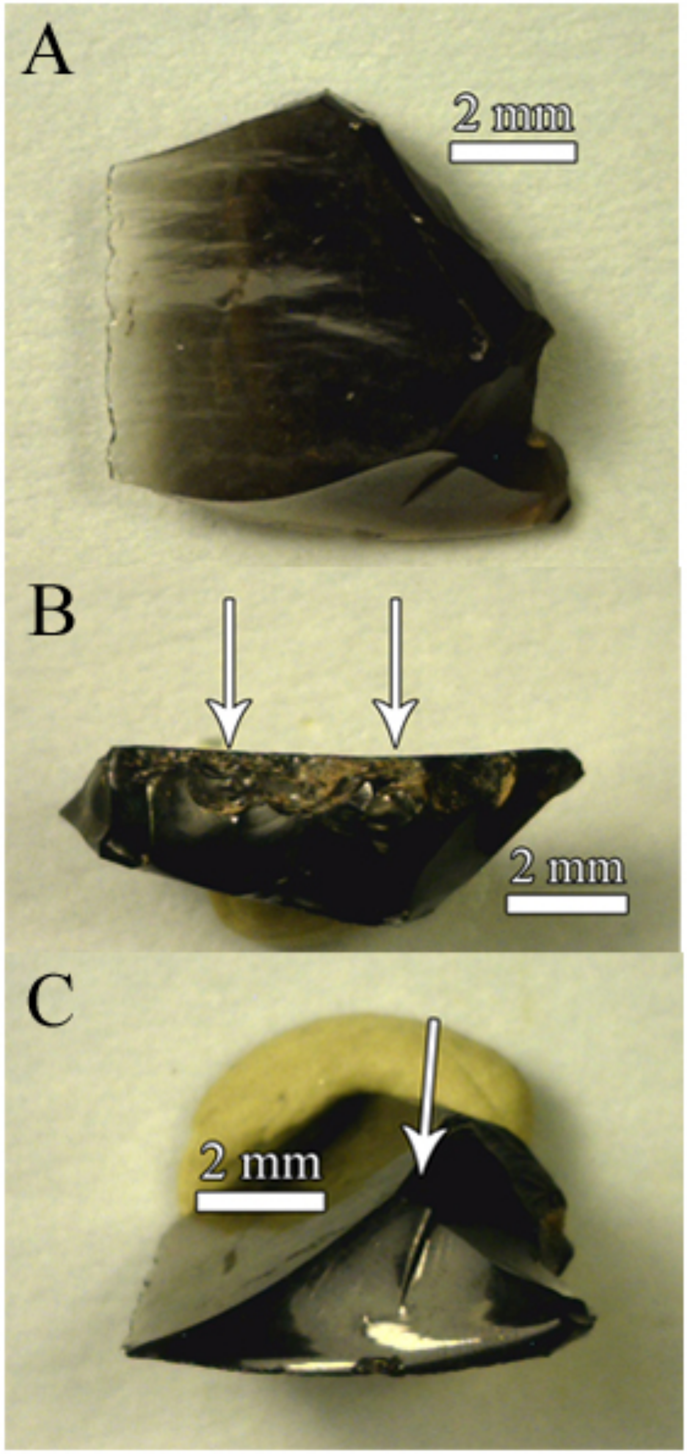

Figure 5.32. Segmented and partially backed blade fragment (#33883) from the GG 1 horizon. (A) Dorsal face; (B) backed edge with arrows indicating direction of retouch; (C) segmented edge with arrow indicating direct percussion segmentation (DPS) bulb.

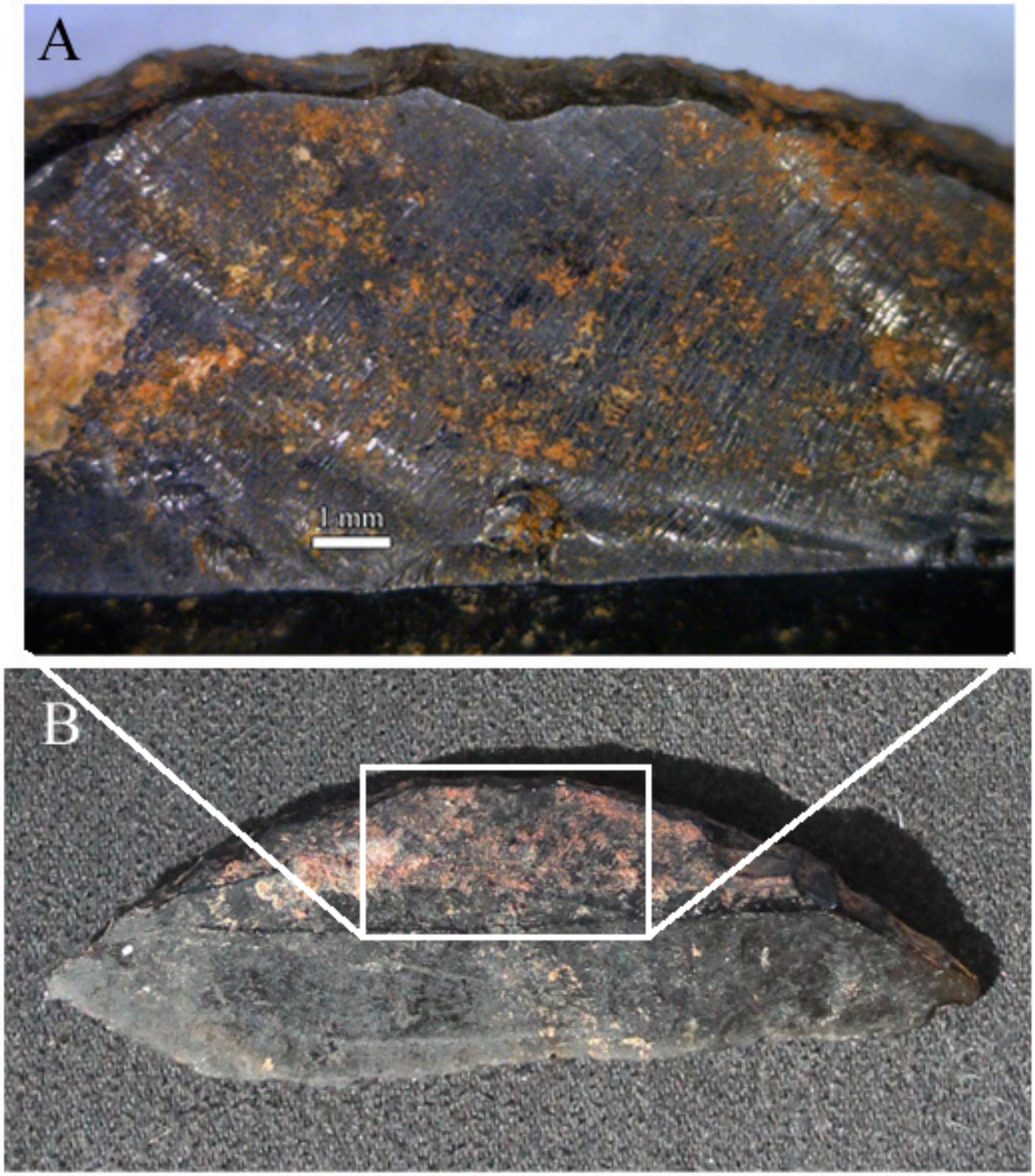

Figure 5.33. Backed microlith crescent (#32230) with red ochre staining on the dorsal face and backed edge.

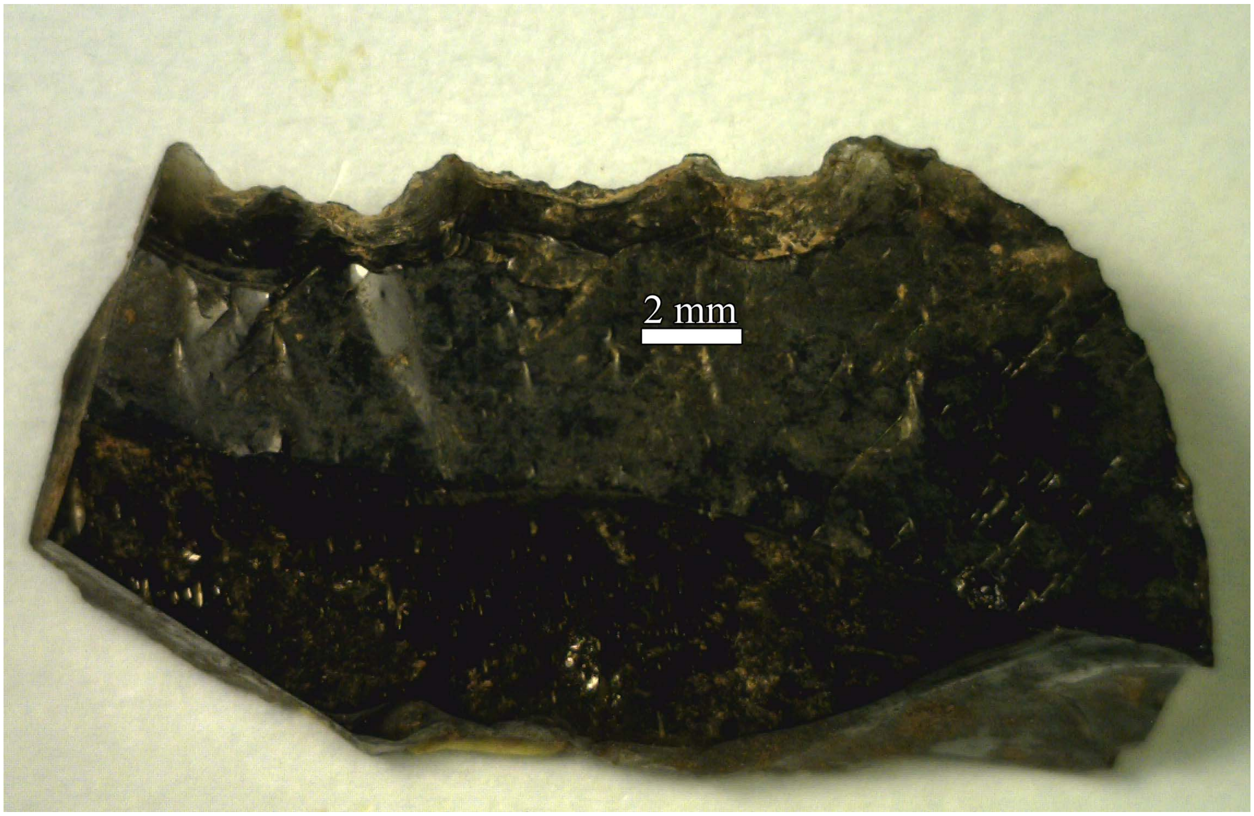

Figure 5.34. Denticulate retouched edge (#33856) from the GG 1 horizon.

Figure 5.35. Notched piece (#34068) from the GG 1 horizon. Arrows indicate direction of retouch.

Figure 5.36. Large blade tool blanks from the GG 1 horizon. (A) Utilized on left side, #33832; (B) broken twice with one glued refit, #33848; (C) casual retouch on left side, #34135; (D) Utilized on distal end, #34181.

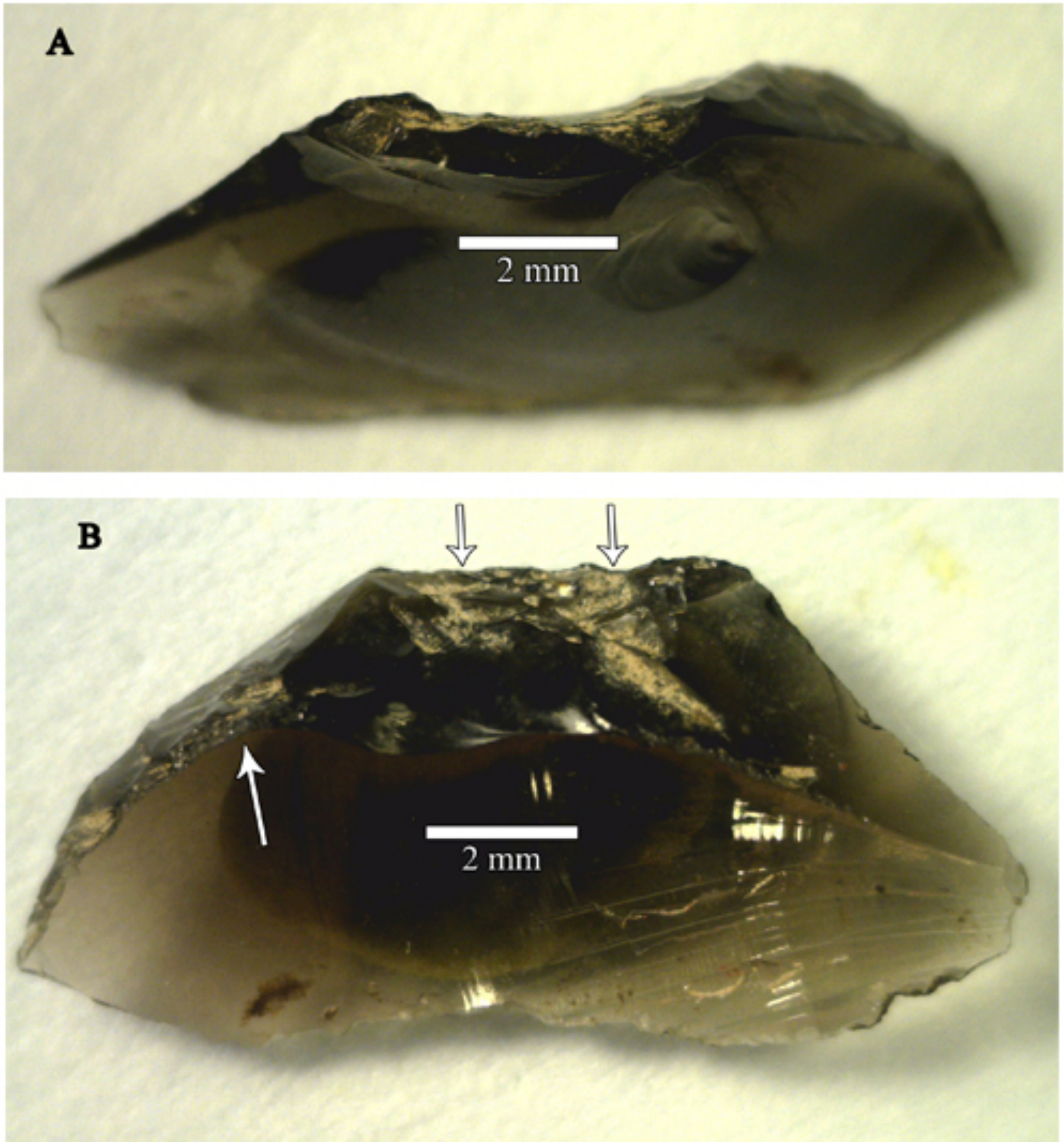

Figure 5.37. Backing retouch flake (#33950) from the GG 1 horizon. (A) Plain striking platform is visible above the scale; (B) dorsal face with arrows indicting earlier retouch strikes.

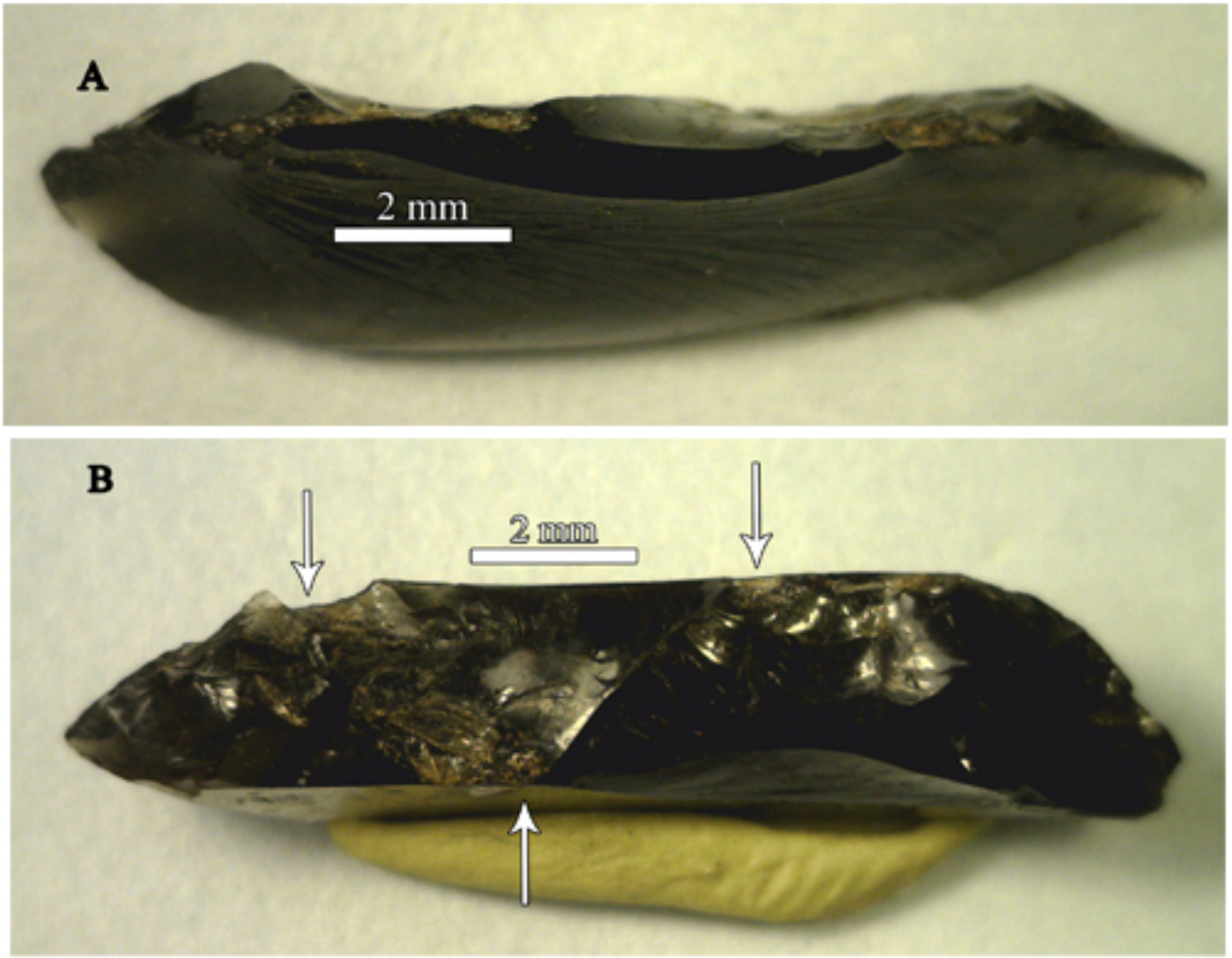

Figure 5.38. Backing retouch flake (#33941) from the GG 1 horizon. (A) Wide, plain striking platform is visible above the scale; (B) dorsal face with arrows indicting earlier, possibly bipolar retouch strikes.

Chapter 6

Lithic Technological Organization at Ol Tepesi

This chapter comprises a full description of the Ol Tepesi rockshelter (GsJi53) site geography, stratigraphy, excavation history, and lithic technology from spit 17. This level contains an LSA blade-based microlithic industry dating to ~19 ka, and thus to the last glacial maximum (MIS 2). Excavations at the site were conducted in 1991 and 2002, directed by Stanley Ambrose. All materials recovered from the site are stored at the National Museum in Nairobi.

Geography

The site is located in a deep box canyon on the southern slope of Mt. Eburu in the northwest corner of the Lake Naivasha basin in Nakuru County of the Rift Valley Province of Kenya. It is about 4 km north of the Ndabibi ADC ranch (Marmonet Drift [MD] is about 1 km west of Ndabibi) in the Eburu forest preserve at an elevation of 2180 m above sea level. The GPS coordinates are 0° 41' 30.3" South 36° 12' 25.8" East. It lies within the lower boundary of the Eburu forest reserve, and should be protected from deforestation. However, many trees have been burned for charcoal, farms have been established around the site, and homestead construction, and bushfires have contributed to forest degradation. Prior to occupation of this area by farmers during the 20th century, the site would have been close to or within the lower edge of the montane forest. The ecotone with grassy woodlands and wooded grasslands of the Rift floor begins less than 1 km south of the site. Its broader ecological context is thus similar to those of Enkapune Ya Muto (EYM) and MD before intensification of agricultural land use. Its southern exposure and box canyon setting renders this sheltered valley heavily shaded and perpetually cold and humid, Conversely MD and EYM, lie on sunny, relatively warm east-facing slopes. The slopes and floor of the valley in front of Ol Tepesi also supports a dense cover of tall, extremely potent stinging nettles. This small box canyon joins the larger Kiteko Valley 300 m downstream, where a semi-permanent stream and waterhole provide fresh water.

The rockshelter is situated at the base of a 30-meter-high wall composed of hard, brittle highly welded tuff with large jointed columns and horizontal cracks on weakly welded layers within the ignimbrite. The cliff hosts several beehives and a community of rock hyraxes. Giant forest hog, buffalo, bushbuck, colobus monkeys and other forest species were also recently common in this area. The cliff is centered beneath a seasonal drainage on the south slope of Mt. Eburu. During torrential rains the cliff becomes a temporary waterfall, eroding deposits beyond the drip line. The ignimbrite overlies more than six meters of softer unwelded ashy tuffs (base not exposed) that erodes comparatively rapidly, undercutting the dense ignimbrite to form the rockshelter overhang. The rockshelter floor is ~45-meter wide with up to 9 meters from the drip line to the rear wall (figure 6.1). This would have provided prehistoric inhabitants with a large and well-protected dry habitable area. Low quality obsidian crops out in thin seams in the ignimbrite above the site, and small chunks also occur in the lower levels of the underlying tuff. Coarse-grained obsidian pebbles and cobbles derived from sources higher on Mt. Eburu also occur in secondary fluvial deposits upstream in the Kiteko Valley.

Excavation History, Stratigraphy and Chronology

Ol Tepesi (OT) was discovered in 1987, and excavated twice under the direction of Stanley Ambrose; first in 1991 and second in 2002. The original excavations were carried out as part of Ambrose's broader research project investigating the transition from hunting and gathering to food production in Kenya's Rift Valley, the ultimate objective of which was to investigate changes in human settlement and subsistence patterns in response to climate change throughout the Holocene. This was a continuation of the same project Ambrose initiated in the 1980's with the excavations at EYM. The primary research goal in 1991 was to sample archaeological horizons dating to the middle Holocene, in order to further test a model of shifts in the zone of preferred settlement by Eburran hunter-gatherers associated with the middle Holocene dry phase, and to obtain evidence for the earliest stages of the introduction of agriculture and pottery to the central Rift Valley (Ambrose, 1998a, 2001b). Excavations at OT revealed rich archaeological deposits spanning this transition, reinforcing the pattern observed at EYM. The second field season's primary objective was to determine whether deeper levels in this site contained Pleistocene MSA archaeological horizons and early LSA horizons that spanned the gap within the LSA sequence in the central Rift between 14,000 and 35,000 BP.

The primary source of information on the excavations at OT is a 1992 research report written by Ambrose for the National Museums of Kenya Archaeology Division and field notes from the 1991 and 2001 excavation. Before digging commenced, a datum nail was hammered into the rear wall and given an arbitrary meter grid position of North 25.00, East 21.44. All excavation depths and level thicknesses were measured relative to this nail, which was 106 cm above the original ground surface at that point. Deposits slope steeply to the west at a rate of 12-25 cm per m horizontal distance on this grid. The site was excavated in 1991 to a depth of 4.78 m below datum in 36 spits, each about 10 cm thick. The 2002 excavations were laid out close to the drip line where rockfall densities and the sizes of rockfall blocks increased rapidly. Excavations reached a depth of 6.2 m below datum in 19 spits. The spit numbers and associated depths are not consistent between seasons, but stratigraphic control was maintained by matching major strata boundaries with previous excavations. In most levels thicker excavation units were excavated because of the thickness of rockfall layers in that part of the site.

In 1991 a 2x3 m trench (6 m^2) was excavated, plus a 1m wide, 1m deep step square on the west side of the main pit, which was used for bulk soil sampling and to facilitate access to the main pit when it became too deep. In 2002 the excavation was extended by 1 m on the south and west sides of the 1991 trench, adding seven square meters (including lower levels of the 1991 step) to the original excavation for a total excavated area of 13 square meters.

Seven radiocarbon dates were obtained between the two seasons and provide a firm chronology for the stratigraphic sequence (table 6.1). Six major archaeological horizons were identified, They include (with uncalibrated radiocarbon ages):

1) Recent/Later Iron Age (<1400 bp);

2) Elmenteitan Neolithic interstratified with late Eburran Phase 5a above a one-meter thick rockfall horizon with volcanic ash (1400-3000 bp);

3) Eburran phase 4/5a with pottery and a few domestic caprines (3000-5000 bp);

4) Eburran Phase 2 below an erosional unconformity and sterile sediments (9760 bp);

5) Microblade LSA beneath an erosional unconformity and sterile sediments (14,100 bp);

6) LSA blade Kiteko Industry (15,700 bp) conformably beneath the microblade industry.

Table 6.1 summarizes these separate horizons and their associated uncalibrated and calibrated radiocarbon dates. The Stratum 15 microblade industry has not yet been named, pending comparison with a possibly similar contemporary microblade industry in Section T at Nderit Drift, which is located 22 km north of Ol Tepesi, in the southern Lake Nakuru basin (Bower et al., 1978; Merrick, 1975).

Table 6.1: Radiocarbon dates from Ol Tepesi

Lab and Sample #	*Stratum*	*Depth Below Surface (cm)*	*Archaeological Horizon*	*Industry or Phase*	*Uncalibrated Age (bp)*	*Age (cal BP)*
ISGS 2321	3	70-75	Horizon 2	Elmenteitan Neol.	1390 ± 70	1346 ± 339
ISGS 2389	6	90-95a	Horizon 2	Eburran 5a LSA	3120 ± 70	3316 ± 461
ISGS 6018	6	90-95b	Horizon 3	Eburran 5a LSA	3960 ± 100	4430 ± 281
ISGS 2318	8	120-125	Horizon 3	Eburran 5a LSA	4560 ± 80	5270 ± 599
ISGS 2317	14	135-140	Horizon 4	Eburran 2/3 LSA	9760 ± 100	11076 ± 658
OxA 3716	15	165-170	Horizon 5	LSA microblade	14135 ± 105	17192 ± 669
ISGS 6020	17	170-175	Horizon 6	LSA Kiteko	15730 ± 180	19060 ± 826

Note: Dates were acquired from the Illinois State Geological Survey (ISGS#) and Oxford Radiocarbon Accelerator Unit (OxA#). All dates were calibrated using *OxCal 4.2* with the 'INTCAL13' dataset (University of Oxford).

Extremely high densities of artifacts and hearths in the middle Holocene dry phase Eburran levels suggest that this ecotone was a preferred environment for hunter-gatherers between 5270 and 3300 cal BP. During the early Holocene wet phase, when the ecotone had likely shifted to lower elevations, this site was totally abandoned, with the exception of a brief period of ephemeral occupation around 11 ka. During the more arid late Pleistocene, the pre-Eburran LSA deposits are incredibly dense, implying that this ecotone preference likely extended back to earlier Pleistocene LSA hunter-gatherers. This settlement model may also explain differences in the pattern of high intensity occupation during DBL1 and low intensity occupation during GG1 at EYM. Periods of high intensity MSA occupation at MD and other MSA sites in the central Rift Valley may also fit the ecotone settlement preference model (Ambrose, 2001b).

Lithic Technology: Raw Materials

Obsidian is the dominant raw material type for all horizons at OT, averaging >99% of lithic artifacts in all levels, with lava, chert, quartzite and quartz forming the remainder. Because OT is in such close proximity to MD and EYM, the availability of raw material outcrops for all of the site's occupants would have been essentially the same. High quality sources nearby that were used at other sites in this study include Sonachi/Mundui (west Naivasha, 11-13 km south of OTP), Masai Gorge, Ol Orengenai, Waterloo Ridge and Ilkek sources (north Naivasha basin, 12 – 20 km east) and Upper Eburu sources (8 – 8.5 km northeast). As a result, it is unlikely that lithic raw material would have ever been in short supply and, therefore, knappers would not have been under pressure to conserve stone during tool production or maintenance. Lava sources are ubiquitous in the Rift Valley, including in the rock shelter formation. Some chert could have come from hydrothermal deposits on Mt. Eburu and elsewhere in the central Rift, the Magadi basin or elsewhere. Quartz must have come from outcrops at least 77 km away, and reflect either long distance travel or exchange by OT occupants with other groups.

Spit 17: LSA Backed Blade Industry

The total excavated lithic assemblage for the lowest LSA horizon (spits 16-19; ~80 cm thick) at OT is approximately 68,940 pieces, reflecting an intense occupation of the site at this time. This industry represents the (currently) oldest and deepest LSA horizon in the OT sequence. Although it is at least 15,000 years younger than the Sakutiek LSA industry at EYM it is close enough that it can provide insights into technological changes from the early to middle LSA. Consistent with the sampling strategy at MD and EYM, only obsidian artifacts were selected for analysis. Spit 17 (23 cm thick) has a total of 35,390 flaked stone artifacts across the six square meter excavation. Raw material frequencies for Spit 17 are 99.56% obsidian, 0.38% chert, 0.05% lava, and <0.01% quartz. I analyzed a total of 3696 artifacts, which equates to 10.4% of the assemblage from this level. Bulk bags from two squares in spit 17 were selected: #7856 from square N26 E22 and #7928 from square N28 E22 (table 6.2). The complete typological composition of this sample is presented in table 6.3. Together, flaking debitage comprise 82.4% of all artifacts: 76.4% primary reduction and 11.0% secondary retouch. Cores represent 1.73%. Combined tools total 10.8%, with 3.6% informal and 7.2% formal.

Table 6.2: Total count and weight of obsidian artifacts sampled for analysis from Ol Tepesi spit 17

Bag Catalog #	**Artifact Count**	**Weight (g)**	**Wt/Piece (g)**
7856	1943	1792.6	0.92
7928	1753	1478.9	0.84
Total	*3696*	*3271.5*	*0.89*

	Site ID and Level	
Artifact Type	**OT (N)**	**OT (%)**
Backed Piece	103	2.79
Scraper	34	0.92
Notch	29	0.78
Bec	5	0.14
Outil Écaillé	7	0.19
Point	0	0.00
Knife	0	0.00
Burin	66	1.79
Combination Tools	22	0.60
Total Shaped Tools	***266***	***7.20***
Total Unshaped Tools	134	3.63
Total Tools	***400***	***10.82***
Whole/Prox Flake	385	10.42
Whole/Prox Blade	575	15.56
MFF/DFF Flake	1120	30.30
MFF/DFF Blade	668	18.07
MFF/DFF DPS Blade	51	1.38
Split Flake	7	0.19
Eraillure Flake	15	0.41
Potlid Flake	4	0.11
Total Primary Debitage	***2825***	***76.43***
PRF	49	1.33
Burin Spall	14	0.38
Microburin	75	2.03
Derived Segment	60	1.62
Bipolar Flake	3	0.08
Trimming Retouch Flake	178	4.82
Tool Edge Fragment	28	0.76
Total Secondary Debitage	***407***	***11.01***
Total Debitage	***3232***	***87.45***
Utilized Debitage	***154***	***0.04***
Blade	20	0.54
Flake	12	0.32
Radial	0	0.00
Tabular	7	0.19
Opposed Platform	0	0.00
Bipolar	3	0.08
Informal	8	0.22
Fragment	14	0.38
Total Cores	***64***	***1.73***
Total Flaked Obsidian	***3696***	***100.00***

Table 6.3. Complete typological composition of the OT sample.

Artifact preservation for this horizon is remarkable, with very little weathering or trampling damage on artifacts. Surfaces and edges are extremely fresh and sharp and there is no evidence for water-related size sorting on flaking debris; tiny retouch debitage ($\leq$0.5 cm) all the way to large ($\geq$50 mm) flakes and cores are present. Fauna is also plentiful and well preserved, though highly fragmented, with many medium and small mammals, including rodents. Together these observations suggest that water movement of artifacts was not a major factor in site formation, and that there was a fast rate of sediment deposition and burial. Evidence for carcass processing (i.e. stone tool cut-marks) and burning (i.e. cooking) is also present and suggests that site occupants were bringing back animal remains for processing and consumption (Zimmermann, 2014, personal communication). The high density of artifacts and fauna, along with the location and impressive size of the site, suggest that it was repeatedly and intensively occupied by LSA people over thousands of years during the terminal stages of the Pleistocene.

Primary debitage. The most notable observation regarding primary flaking debitage is the overwhelming focus on blade production. True blades and blade fragments account for 46.1% of all primary debitage and informal tools indicating that controlled blade production was the most important technological goal of site occupants at this time. The typological distinction between flakes and blades is decisively supported by size dimensions (table 6.4), which show that all recorded measurements are significantly different for blades compared to flakes. Overall, blades have smaller platforms, higher EPAs, and are longer, narrower, and thinner than flakes. These data fit well with the traditional definition of blades being (at least) twice as long as they are wide.

Table 6.4. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for flakes and blades in Ol Tepesi Spit 17 sample

Attribute	**Flakes (n=314)**					**Blades (n=456)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	94	15	16.0	55	133	101	13	12.9	68	138	-7.44[#]
PW (mm)	4.3	4.4	102.3	0.1	35.1	2.5	2.7	108.0	0.1	17.7	6.40[#]
PT (mm)	1.5	1.5	100.0	0.1	11.3	0.9	1.0	111.1	0.1	7.4	6.62[#]
L[a] (mm)	18.1	8.0	44.2	4.7	45.9	24.5	9.4	38.4	5.3	52.3	-6.45[#]
W (mm)	13.9	7.9	56.8	3.6	72.6	9.9	3.8	38.4	2.5	31.2	8.39[#]
Th (mm)	3.5	1.9	54.3	1.0	14.3	2.9	1.3	44.8	0.8	12.2	4.81[#]
PT/PW	0.35	0.33	94.3	0.08	2.14	0.36	0.32	88.9	0.08	1.50	n/a
PW/W	0.31	0.29	93.5	0.00	2.34	0.25	0.23	92.0	0.01	2.08	n/a
PT/Th	0.43	0.32	74.4	0.01	1.10	0.31	0.25	80.6	0.02	1.21	n/a
W/L	0.77	0.39	50.6	0.15	2.08	0.40	0.15	37.5	0.13	1.57	n/a
W/Th	3.97	1.83	46.1	0.27	11.89	3.41	1.17	34.3	0.98	8.58	n/a
L/Th	5.17	2.44	47.2	0.97	16.57	8.45	3.72	44.0	3.30	28.00	n/a

[a] Sample sizes for length are 155 for flakes and 156 for blades.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

Dorsal scars on blades typically show one or two arêtes from previous removals and are almost always parallel to the long axis. This pattern indicates that blades were most often removed sequentially from specialized cores with prepared platforms, using arêtes from previous removals as a guide for each new blade. Knappers appear to have invested time and effort up-front in core preparation and were later compensated with a systematic pattern of blade removal. Because of the up-front preparation blades had consistent sizes and shapes, evinced by low CVs for length and width that were helpful for producing standardized formal tool forms.

Table 6.5: Platform preferences for all measured primary debitage and informal tools

Platform Type	Combined (N)	%	Flakes (N)	%	Blades (N)	%
Plain	467	52.9	170	45.9	297	58.0
Faceted	124	14.1	84	22.7	40	7.8
Point	265	30.0	98	26.5	167	32.6
Cortical	26	2.9	18	4.9	8	1.6
Total	*882*	*100.0*	*370*	*100.0*	*512*	*100.0*

Data on platform type and preparation for all primary debitage, and flakes and blades separately are presented in tables 6.5-6.8. Note that in these tables counts include informal unshaped tools as well as primary debitage. Unshaped tools were included because the vast majority of these pieces are simply primary debitage with minor use-wear or casual retouch. Medial and distal fragments were included when calculating the total percent of blades in the sample. Together, these tables show that blades overwhelmingly have either plain or point platforms (combined 90.6%), and almost three-quarters display dorsal proximal faceting ([DPF] figures 6.2 – 6.3). The DPF abrasion technique isolates and strengthens a platform, both of which are important factors for flake production in general, and blades in particular because knappers typically try to conserve the overall volume and carefully prepared platforms on cores to produce thin blades with small platforms. As shown in table 6.4, blade platform width (PW) and platform thickness (PT) average only 2.5 x 0.9 mm, which are both significantly smaller than those of flake platforms. Ratios of PW/W (25% vs. 31%) and PT/T (31% vs. 43%) are also smaller for blades compared to flakes, indicating that platforms are proportionally smaller relative to the blade/flake body as well. Finally, plain platforms are the dominant type for flakes (approaching 50%) with smaller, relatively equal percentages of faceted and point platforms. Notably, DPF is present on only 37% of these pieces, which suggests that knappers were not preparing flake platforms as regularly as they were for blades.

Table 6.6: Platform preparation for all measured primary debitage and informal tools

Platform Type	Dorsal Proximal Faceting		Percent DPF (%)
	No	Yes	
Plain	174	293	62.7
Faceted	94	30	24.2
Point	80	185	69.8
Cortical	23	3	11.5
Total	*371*	*511*	*57.9*

Table 6.7: Platform preparation for all measured primary debitage flakes and informal flake tools

Platform Type	Dorsal Proximal Faceting		Percent DPF (%)
	No	Yes	
Plain	104	66	38.8
Faceted	70	14	16.7
Point	42	56	57.1
Cortical	17	1	5.6
Total	*233*	*137*	*37.0*

Table 6.8: Platform preparation for all measured primary debitage blades and informal blade tools.

Platform Type	Dorsal Proximal Faceting		Percent DPF (%)
	No	Yes	
Plain	70	227	76.4
Faceted	24	16	40.0
Point	38	129	77.2
Cortical	6	2	25.0
Total	*138*	*374*	*73.0*

Cores. A total of 64 cores were identified in the OT sample. Blade cores represent the most common type (31.3%), with various forms of flake cores combining to make up 42.2%, and bipolar cores being quite rare (4.7%). The remaining 21.2% is made up of core fragments, which retain no striking platform and were excluded from measurement analyses. Table 6.9 presents size dimensions for all measured cores (combined) as well as separated dimensions for blade and flake cores. Notably, the length of blade cores is 27% longer than flake cores while width and thickness are essentially the same. This mirrors the data for primary debitage blades, which are 35% longer than primary debitage flakes.

Table 6.9. Core size dimensions and standard deviation and coefficient of variation statistics for Ol Tepesi Spit 17

	Combined (n=50)					***Flake (n=30)***					***Blade (n=20)***				
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
L	28.8	9.8	34.0	9.7	50.9	25.5	10.6	41.6	9.7	50.9	32.5	6.9	21.2	18.7	44.3
W	21.3	7.0	32.9	10.9	44.0	21.6	7.9	36.6	10.9	44.0	20.8	5.7	27.4	11.7	32.6
Th	16.2	8.4	51.9	3.4	38.8	16.6	9.8	59.0	3.4	38.8	15.5	6.1	39.4	4.9	25.9
Wt [a]	9.3	14.5	155.9	0.7	107.5	11.1	20.3	182.9	0.8	107.5	9.5	5.6	58.9	1.4	23.6

[a] Sample sizes for weight include fragmented cores. They are 64 for Combined, 44 for Flake and 20 for Blade.

Rather than core size or shape, the primary striking platform's area and angle appear to have been the most important qualities to knappers for producing blades. A large platform provides space for continuous removals and a flat surface provides a good contact point for the hammer to strike as well as a desirable flake release angle (i.e. EPA on the detached piece). From the platform, a blade is released down a flat or slightly convex face, ideally all the way to the distal end of the core. Blades in spit 17 were most often removed from the same platform one next to the other, or in some cases, alternating between opposed platforms. This is evinced by the dorsal scar patterns on the cores themselves, as well as those on the blade debitage.

Blade cores are most often either a pyramidal or tabular form (figure 6.4) with either a single, or two flat opposed platforms. Notably, the platforms on these discarded cores all retain DPF and a high EPA (above 90°), reflecting the morphology seen on primary debitage blades. The sequential removal from only one or two platforms produced visually distinct cores with long, thin and parallel arêtes. Most of these cores can be considered exhausted, with little to no remaining volume or platform suitable for producing blades. These pieces likely started off with length and width measurements similar to their discarded forms, but were much thicker. As blades were removed, only the core thickness was reduced.

The recovery of overstruck blades (figure 6.5) and step-removal flakes (figure 6.6) testify to the fact that OT knappers, despite an overall astounding level of skill, still made mistakes. The overstruck pieces are examples of blades that accidentally removed the distal portion of the core, thereby reducing its length and total volume. Some of the overstruck blades even retain another platform on their distal end, the second from an opposed platform core. Step-removal flakes represent cases where knappers had a blade terminate in the middle of the core with a hinge or step fracture. However, rather than striking in the same platform spot again (or just to the side) and risking another hinge, they rotated the core and struck perpendicular to the flaking axis to remove the hinge and salvage the core. This special category of waste, the hinge removal flake, has not been reported previously in archeological assemblages. Subtypes of hinge removal flakes are defined in Appendix A.

Finally, examples of platform removal or rejuvenation flakes, crested blades (figure 6.7) as well as cortical flakes (figure 6.8) demonstrate stages of core shaping and rejuvenation. Cortex is present on 12.9% of primary debitage and indicates that at least some raw, or lightly worked, nodules were being brought to the site. Platform rejuvenation flakes (tablette de ravivage) and crested blades (lame à crête) vary quite a bit in size (n=43; mean length 28.2 mm; min 10.8 mm; max 62.2 mm) and show that cores were re-prepared as needed in order to maintain effective striking platforms.

Secondary debitage. Retouch flakes, microburins, derived segments and burin spalls comprise the secondary debitage class. The majority of retouch flakes (77%) are simple casual trim, with scraper trim (20.8%) as the second most common. Only two retouch flakes with faceted platforms were identified, indicating that retouch was primarily carried out on the dorsal faces of unifacial pieces. Casual trim retouch flakes have two probable origins; first, as larger retouch flakes from tool edges (the explicit definition of this category), and second, as "fine" retouch to prepare core platforms, such as the dorsal proximal area on the blade release face.

Table 6.10 presents size dimensions for combined primary and secondary debitage classes, with clear support for the typological distinction. The mean EPA, length, width and thickness of trimming flakes were all significantly smaller than those of primary flaking debris using an Independent Samples t-test ($p<0.008$). Despite being significantly smaller, the secondary debitage EPA is still relatively steep, and suggests that many pieces from the simple 'casual trim' category are the result of core platform preparation rather than retouch on thin blade tools. Scraper retouch flakes would also fit with this steep-edged retouch. Finally, the relatively short and wide morphology (flake W/L ratio is 54% for primary and 101% for secondary) is noteworthy for the fact that the mean width for secondary debitage is nearly the same as that of the primary, but that they are shorter and thinner suggesting a more controlled setting and a finer touch (or softer hammer) on the part of the knapper. Preparation of core platforms, scraper retouch, or backing of microliths exemplify such situations where that care may take place.

Table 6.10. Mean platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all debitage in Ol Tepesi Spit 17 sample

Attribute	**Primary (n=770)**					**Secondary (n=178)**					*t-test of means*
	Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	
EPA (°)	98	14	14.3	55	138	82	14	17.0	56	120	13.48[#]
PW (mm)	3.3	3.6	109.0	0.1	35.1	3.5	3.2	91.4	0.1	17.4	-0.84
PT (mm)	1.2	1.2	100.0	0.1	11.3	1.1	1.0	90.9	0.1	7.3	0.21
L[a] (mm)	21.3	9.5	44.6	4.7	52.5	9.8	5.2	53.1	0.7	40.6	17.35[#]
W (mm)	11.5	6.2	53.9	2.5	72.6	9.9	4.5	45.5	1.1	25.7	4.12[#]
Th (mm)	3.1	1.6	51.6	0.8	14.3	2.3	1.5	65.2	0.7	11.5	5.81[#]
PT/PW	0.36	0.33	91.7	0.08	2.14	0.31	0.29	93.5	0.10	1.00	n/a
PW/W	0.29	0.26	89.7	0.00	2.34	0.35	0.43	122.9	0.00	3.35	n/a
PT/Th	0.39	0.29	74.4	0.01	1.21	0.48	0.35	72.9	0.01	1.83	n/a
W/L	0.54	0.38	70.4	0.13	2.08	1.01	1.21	119.8	0.14	12.71	n/a
W/Th	3.71	1.52	41.0	0.27	11.89	4.30	2.48	57.7	0.14	15.30	n/a
L/Th	6.87	3.82	55.6	0.97	28.00	4.26	2.70	63.4	0.56	13.25	n/a

[a] Sample sizes for length are 311 for primary and 157 for secondary.

[#] *p<0.008*, which is the adjusted value for statistical significance using the Bonferonni correction.

Microburins (figure 6.9-6.10) and derived segments (figure 6.11) attest to the segmentation of blades and production of microliths. Microburins start off as a complete blade, are notched and then struck on the opposite side of the notch to break the piece into segments that can be further modified by backing to create a microlith. Sometimes the act of making the notch itself can be enough to segment the blade. Derived segments are evidence of a quicker method for segmenting a blade, where the piece is placed on an anvil and struck in a bipolar fashion that breaks it into segments. Derived segments may also be produced incidentally during microlith backing. Both were identified in the sample, though microburins (n=75) outnumber derived segments (n=60). Both distal and proximal microburins are present, indicating that knappers used this technique at both ends of blades and likely did not back blade segments without first segmenting them. The average width and thickness of microburins are nearly the same as primary blade debitage while length is shorter, which is unsurprisingly considering microburins are segmented (i.e. shortened) blades (table 6.11).

Table 6.11: Mean platform and flake size dimensions for primary blade debitage and microburins (plus standard deviation and coefficient of variation statistics) at Ol Tepesi

Attribute	**Primary Blade Debitage (n=456)**	**Microburins (n=75)**				
		Mean	*SD*	*CV*	*Min*	*Max*
EPA (°)	101	106	8	0.08	94	135
PW (mm)	2.5	1.3	1.3	100.0	0.1	4.7
PT (mm)	0.9	0.5	0.4	0.80	0.1	1.6
L[a] (mm)	24.5	20.0	6.8	0.34	8.6	35.8
W (mm)	9.9	9.3	2.7	0.29	3.6	16.9
Th (mm)	2.9	3.3	1.0	0.30	1.6	6.2

[a] Sample size for blade length is 156. All 75 microburins were measured for length.

Informal unshaped tools. Unshaped casually retouched tools form 3.6% (n=134) of the OT sample. The distribution of retouched flakes (52.4%) vs. blades (47.6%) is close to even, and suggests that there was no obvious preference for one morphology over another for expedient tool production.

Formal shaped tools. This category comprises 7.2% (n=266) of all identified pieces in the OT sample. A total of seven distinct formal tool types were identified in the sample as well as combination tools (table 6.3). Microlith, the largest category, actually includes six different subtypes that substantially increase the overall typological diversity of the assemblage. The SID value is 0.755 if all of the microliths are combined but 0.871 if the subtypes are calculated separately, an extremely high value.

Microliths are by far the most common formal type at OT, representing 38.7% of all formal tools. They include six different subtypes: curved, oblique, orthogonal, longitudinal, and straight backed pieces, as well as geometric crescents (table 6.12; figure 6.12). Microlith production appears to have been the primary technological goal in this horizon, with different backing morphologies suggesting a multitude of hafting options. For example, oblique backed pieces tend to be wider than other varieties and are only partially backed, leaving unmodified edges on both sides of the piece (figure 6.13). In contrast, longitudinal and curved backed pieces tend to be longer and narrower, with a completely backed edge opposed to an unmodified one (figure 6.14). Many of these also terminate in a slender and pointed awl-type bit, which is quite different than the perpendicular square ends seen on oblique and orthogonal backed pieces. Crescents are the only geometric form identified in the sample; there are no triangles or trapezes. The crescents come in a range of sizes, but always with the backed edge forming an arc opposite from the unmodified edge (figure 6.15).

Size dimensions for the microlith sample fit well with those presented above for microburins and primary blade debitage. It is likely that the shortest and narrowest microburins are byproducts of crescents or straight and longitudinal backed pieces, while wider ones are byproducts of oblique backed pieces. Unmodified blade ‘blanks’ were also identified in the sample (figure 6.16). Such pieces have a similar size and morphology to microburins and microliths and, along with the cores and the rest of the primary flaking debitage, indicate that microlith production was being carried out on site.

Table 6.12. Size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all microlith subtypes

Microlith Sub-Type	*N*	***Length (mm)***					***Width (mm)***					***Thickness (mm)***					***W/L***	***SD***
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*		
Crescent	27	23.2	8.9	38.4	7.5	41.6	7.8	1.9	24.4	5.6	14.1	2.8	1.1	37.5	1.6	6.3	0.39	0.19
Curved	34	27.1	9.3	34.2	11.7	47.2	8.3	2.1	25.3	3.9	12.8	3.1	1.0	32.8	1.5	5.6	0.33	0.11
Oblique	17	23.9	7.8	32.5	13.9	40.4	10.2	3.2	31.4	5.3	17.0	3.1	1.1	36.5	1.9	5.4	0.44	0.11
Orthogonal	3	20.5	6.9	33.7	13.7	27.5	9.2	2.1	22.8	7.5	11.6	2.9	0.5	15.4	2.5	3.4	0.47	0.13
Longitudinal	8	28.6	13.4	46.9	13.4	51.2	8.1	1.8	22.2	5.2	9.6	2.8	1.0	36.3	1.3	4.4	0.33	0.13
Straight	14	23.7	9.0	37.8	11.6	42.5	8.0	2.6	32.5	4.3	14.6	3.2	0.8	24.0	2.1	4.6	0.37	0.13
Combined	*103*	*25.4*	*9.3*	*36.5*	*7.5*	*51.2*	*8.5*	*2.4*	*28.2*	*3.9*	*17.0*	*3.1*	*1.0*	*32.5*	*1.3*	*6.3*	*0.37*	*0.14*

Burins represent the second most common type making up 24.8% of all formal tools, and they are also a major component of combination tools (22.7%). Two forms predominate: single bits with multiple spalls on thick blades (figure 6.12, s-t), and transverse or plàn blows across thinner blades (figure 6.17). The proliferation of burins in the sample suggests this type played an important role in the OT toolkit, while the two distinct forms imply distinct functions. The thinner transverse bits are more suitable for slicing or cutting while the thicker bits are better suited for piercing, boring or drilling.

Scrapers and notches represent the third and fourth most common types making up a combined 23.7% of all formal tools and 31.8% of combination tool components. These types are pooled together for discussion due to the morphological gradation of retouch between concave scrapers and notches. Concave scrapers are the least common form found in the sample but this may be a consequence of overlapping morphology and classification as notches rather than concave scrapers. Complete scrapers were most often made on distal ends of larger, thicker blades with convex and steep-edged bits (figure 6.18; table 6.13). The largest blank in figure 6.16 (B9), if it was not broken, presents an ideal starting form. Despite the high probability of being made on long blades, many scrapers were recovered with a short and stubby form, which suggests that they had been extensively retouched (i.e. curated). This premise is supported by the nature of secondary debitage described above, which is dominated by short and wide retouch flakes with steep EPAs. Table 6.14 shows that, in terms of size, scrapers and notches are quite similar, with only thickness considered significantly different (scrapers are thicker) using an Independent Samples t-test ($p<0.017$).

Table 6.13: Retouch characteristics for scrapers in Ol Tepesi sample (n=34)

Edge Location %	*End*	*Side*	*Fragment*	*Total*
	41.2	17.6	41.2	100.0
Edge Shape %	*Convex*	*Straight*	*Concave*	*Total*
	52.0	32.0	16.0	100.0
Edge Angle %	*Shallow*	*Intermediate*	*Steep*	*Total*
	4.6	31.8	63.6	100.0

Table 6.14: Mean size dimensions for scrapers and notches in the Ol Tepesi sample

Attribute	*Scrapers (n=34)*	*Notches (n=29)*	*t-test of means*
Length (mm)	23.6	24.6	-0.34
Width (mm)	18.4	14.3	2.06
Thickness (mm)	6.7	4.1	4.39[#]

[#] $p<0.017$ is the adjusted value for statistical significance using the Bonferonni correction.

Small numbers of outils écaillés, becs and combination tools round out the formal tool category. Bipolar percussion does not appear to have been an important strategy for knappers; together, bipolar cores, bipolar flakes and outils écaillés make up only 0.35% (n=13) of the entire sample. Finally, combination tools were most often composed of a scraper or burin component that was combined with casual retouch on a completely different edge.

Use-wear analysis. During classification and measurement, microlith edges were observed under low magnification with a 10x eye loop or with the Dino-Lite digital microscope. The vast majority did not have any visible damage on their edges. Based on these observations three possibilities seem reasonable: first, that they were unused and represent future replacement components; second, that they were used with less force and/or on softer materials; and third, that they were replaced so quickly that they did not acquire edge damage. The third possibility seems unlikely, as the primary reason for tool replacement is that the edge or bit is damaged and no longer functions at the same level as when it was first made. The first and second possibilities seem more realistic. It is plausible to think that many microliths were used on materials too soft to generate substantial edge damage especially considering that two artifacts from my own blind tests that I did not detect wear on were actually used intensively. In short, the absence of use-wear on the majority of the microliths in this sample does not necessarily constitute a lack of use. Ultimately, a small sample of tools with seemingly more obvious examples of use-wear damage was subjected to high magnification SEM analysis. Five microliths, one scraper and one notched piece were observed, the results of which are presented in table 6.15.

Table 6.15: Artifact sample from OT Spit 17 subjected to SEM use-wear analysis

Catalog #	*Classification*	*Microflake Scars*	*Striations*	*Functional Interpretation*	*Worked Material Hardness*
9698	Microlith	Small, bi-directional, angled	None	Light slicing or sawing	Soft
9707	Microlith	Bi-directional, angled with edge snap	None	Sawing	Medium/hard
9714	Microlith	Edge snaps, rounding, shallow and perpendicular	Rare, parallel to unmodified edge	Sawing and/or scraping	Soft
9732	Microlith	Shallow and feather-terminating; angled and perpendicular	None	Slicing	Soft/medium
9736	Notch	None	None	Unused	N/A
10706	Microlith	None	None	Unused	N/A
10731	Convex endscraper	Edge rounding, perpendicular to the bit-end	Perpendicular to the bit-end	Scraping	Soft with grit

Artifact #9698 is a curved backed microlith made on a non-truncated blade, and retains its plain platform with DPF. This piece appears to have been made on a complete blade (no DPS or microburin segmentation) as the extreme distal portion has a slight curve that indicates it terminated just beyond the backing. Microflake scars on the unmodified edge are bidirectional, angled, extremely small and are relatively consistent along the edge (figure 6.19). There are no large snaps or striations. Together these data suggest that this piece was used for light slicing or sawing, probably on a soft material.

Artifact #9707 is a curved backed microlith made on a non-truncated and nearly complete blade. Based on the ventral ripple arcs the proximal end is very close to the bulb of percussion while the distal end has a curve similar to that of #9698, indicating that the original complete piece terminated just beyond the backing. There is clear macroscopic damage along the unmodified edge, and SEM images show that these are primarily angled, bidirectional microflake scars with both feather and step terminations (figure 6.20). Rare snaps are also present. There are no striations. These data suggest this edge was used in a sawing use-action on a medium to hard material.

Artifact #9714 is an oblique backed microlith. This piece was made on a DPS blade and the snap was left untouched (i.e. not backed). Backing was confined to one lateral and oblique edge of the blade. SEM images of the unmodified edge show snaps, rounding, perpendicular striations and shallow feather terminating scars (figure 6.21). Images from the medial portion show surface abrasion and crushing on the primary arête, as well as two dark blobs that may be residues of a hafting adhesive (figure 6.21, image F). Together, these data suggest the tool was hafted and used for sawing and/or scraping on a soft material.

Artifact #9732 is straight backed microlith made on a double DPS blade (proximal and distal ends), with both broken faces left untouched in a similar fashion to #9714. SEM images of the unmodified edge show shallow and feather-terminating microflake scars either perpendicular or angled in only a single direction (figure 6.22). There are no striations. It appears that this piece was used for slicing a material of soft or medium hardness.

Artifact #9736 is a notched piece made on a snapped blade that retains a plain platform with DPF. This piece resembles a microburin but was not struck transversely to segment it, and therefore was classified as a retouched notch. SEM images show that, beyond the intentional retouch, there is little evidence for utilization inside the notch. Stepped scars are visible down and away from the ventral face, but are consistent with hard hammer abrasion rather than a functional activity (figure 6.23). The retouched area on this piece does not appear to have been used, and this may simply be a broken microburin.

Artifact #10706 is a curved backed blade that was segmented and backed on the proximal end and one lateral edge. The distal end has a slight curve and becomes extremely thin indicating that it is the original blade termination. SEM images show zero use-wear traces on the unmodified edge and no hafting traces, such as abrasion or crushing, on the backed edge (figure 6.24). This piece appears to have been discarded without being used, which is consistent with its thinness and edge curvature.

Artifact #10731 is a convex endscraper on a complete blade. It retains the typical plain platform with DPF and represents the longest scraper found in the OT sample at 54.1 mm This piece clearly was discarded before the end of its effective use-life; if the bit-end had continued to be retouched the piece's thickness and width would have almost no change and the same morphology could have been used for a long period of time. SEM imaging shows rare longitudinal microflake scars initiating at the bit and extending back into the piece along with edge rounding and striations (figure 6.25). Notably there are no traces that would suggest this piece was hafted, as the proximal 75% of the piece has only minor casual retouch (or nothing) on the still sharp and thin edges. Together these data suggest that this piece was used as a hand-held tool for scraping a soft material with some gritty particles.

Four of the five microliths observed with the SEM display light use-wear traces on their unmodified edges consistent with slicing/sawing. One may have been used to scrape as well. Microlith #9714 retains two small blobs of a dark residue and crushing/abrasion that suggest it was hafted during use. These four pieces all appear to have been discarded after relatively short bouts of use. Microlith #10706 does not appear to have been used at all, however, as I mentioned earlier this may be a factor of light pressure or a very soft material rather than non-use. Many of the traces on clearly utilized edges are subtle as well. The notch/concave scraper has no evidence for use, and may actually be a segmented or broken microburin. The convex end scraper was clearly used for scraping a soft material, though it was discarded relatively early in its life and could have been effectively retouched for another 20-30 mm of its length. Notably, this piece does not appear to have been hafted and was instead used in a hand-held manner.

Technological organization. The lithic artifact sample from OT's spit 17 shows that knappers were primarily focused on producing small to medium sized blades as blanks for making a diverse range of formalized tool types, including backed microliths, burins, and scrapers. Blades account for 46.1% of all primary debitage and informally retouched tools. All microliths and most scrapers and burins were also made on blades meaning that the true percentage of blades in the assemblage is greater than 50%. Considering that there is also evidence for early stage core shaping and platform preparation it is clear that knappers were single-minded in their production goal. Secondary debitage byproducts show that the entire tool production sequence was carried out on site.

Blade cores represent 40% of all complete (non-fragmented) cores. These typically have one or two (always opposed) platforms with either a pyramidal or tabular shape. The blades they produced were relatively small, averaging about 25 mm long and 10 mm wide, and standardized, with CVs for length and width both less than 40. Primary debitage flakes were also small, but significantly shorter and wider (18 mm long and 14 mm wide), and with higher CVs on length and width (>44) than blades. Blade platforms also differ from those of flakes in terms of the ratio of types and DPF preparation. Blades overwhelmingly have plain or point (crushed or heavily abraded) platforms with DPF and EPAs over 100° while flakes have a more even distribution of plain, faceted, and point platforms with significantly lower EPAs and about half as many pieces with DPF. These differences can probably be attributed to the flakes being byproducts of blade core shaping and platform preparation, while the blades were the desired product. Based on the primary debitage and core samples, it appears that OT knappers were bringing lightly worked obsidian nodules to the site, shaping and preparing platforms, and then producing a high volume of blade tool blanks.

Blade blanks were most often transformed into different microlith forms through segmentation and backing. A large portion of the secondary debitage sample is made up of microburins and derived segments, which attest to the modification of blades for tool production. Similar sizes of blade blanks (table 6.4), microburins (table 6.11), and microliths (table 6.12) as well as dorsal scars patterns indicate that many blades produced on site were directly transformed into microliths, providing a nearly complete *chaîne opératoire*. I identified a total of six different microlith subtypes using Nelson's (1973) classification scheme. These come in two general forms, long and narrow (e.g. curved, straight, and longitudinal backed) or short and wide (e.g. oblique and orthogonal backed). The similarity of form but different sub-type classification is a factor of how the backed edges intersect (or do not intersect) the unmodified edges. Variability in backing morphology, as well as size and shape, suggest that different subtypes were hafted in different positions or angles and may have been used for different functions such as sharp edges that fit into grooves or notches on shafts to act as spears (or arrows), knives, or other cutting or sawing actions. Their production in relatively standardized shapes and sizes (table 6.12) would have also allowed knappers to effectively replace broken or damaged components without modifying the haft.

Notably, zero microliths were resharpened after their edges became damaged from use; instead, they appear to have been discarded and replaced. Very few broken or snapped microliths were recovered. Many also appear unused, and may represent ready-made components to replace those that became damaged during use. It is also possible that some of those were lightly used or on soft materials that did not generate use-wear damage. Overall, use-wear analysis provides strong evidence for the short use-life of microliths, and for their use in delicate and precise functions that require thin, sharp, and unmodified edges.

Burins and scrapers are the other two major tool forms in the OT sample. Both of these types were also typically made on blades, although burin blows also appear to have been made opportunistically on thicker flakes. Long blades, especially those that are snapped, provide a relatively easy platform with which to create a burin. OT knappers took full advantage of this, often striking several long burin spalls off of snapped blade facets to create robust bits. Alternatively, they struck perpendicular to the blade's long axis across the ventral face creating a thin sharp edge more suitable for fine cutting and slicing. Scrapers represent the only formal tool class that was intensively curated in the assemblage. Small retouch flakes most often retain thick plain (ventral face) platforms, steep EPAs and use-wear on the dorsal proximal area such as edge rounding and stepped microflake scars. These features are consistent with the resharpening of scraper bits. Thinner forms of these small flakes may also be derived from platform preparation on blade cores or backing retouch on microliths. Because retouch debitage accounts for less than 5% of the assemblage artifact curation likely played a relatively small, but specific, role in the technological organization strategy of OT toolmakers.

The OT spit 17 assemblage contains a diverse range of formal tool types including, geometric and non-geometric backed microliths, two different burin types, and end scrapers. It also contains the microburin technique that characterizes the Holocene LSA Eburran Industry, which is found throughout the central Rift (Ambrose, 1985). Sizes and shapes of formal tools, particularly microliths, are similar to the Eburran as well. However, in the Eburran, blade core platform preparation is characterized by abrasion from the core face up onto and across the platform resulting in wide and thick micro-faceted platforms on blades (Ambrose, 2002). These flakes typically lack DPF. Conversely, in the OT spit 17 assemblage, core platforms were prepared by drawing the abrader/hammerstone in the opposite direction, from the platform over the edge and down onto the core face, resulting in proportionately small plain platforms with DPF. This platform preparation type is characteristic of the younger Elmenteitan Neolithic industry (Ambrose, 2002).

The differences in platform preparation and the resulting differences in platform size between the Eburran and the OT spit 17 (and Elmenteitan) industries likely reflect an isochrestic (Sackett, 1982) culturally determined style in habitual flaking strategies (habitus). Therefore, the

OT assemblage is distinct from other lithic industries known from this region, and should be given a new local industry name. In accordance with the recommendations for definition of industries in African archaeology (Clark et al., 1966) Slater and Ambrose (2015) have proposed to name this the Kiteko Industry after a local Maasai place name for the valley and ridge to the west of the Ol Tepesi rock shelter. Whether this industry is widespread remains to be determined by excavation of other obsidian-based lithic assemblages dating to the last glacial maximum in this region. Comparisons with contemporary assemblages outside of the Kenya Rift, for example those from Lukenya Hill (Gramly, 1976; Kusimba, 2001; Tryon, 2015) may be complicated by differences related to mechanical properties of locally available raw materials, which are predominantly chert, quartz, and lava.

To conclude, the location, size, and ecological context of Ol Tepesi rock shelter would have made it a highly desirable and well-protected home base for Stone Age hunter-gatherers of any era. The dates and high density of lithic artifacts and fauna indicate that this was certainly the case for the terminal Pleistocene. Thus, the entire OT sequence, and especially the lowest levels described here, are significant for our understanding of the variation in technological organization strategies and human behavior in Kenya's Rift Valley over the past 20,000 years. The next chapter examines long-term changes in technological organization strategies in the Kenya Rift Valley using assemblages from MD (MSA), EYM (early LSA), and OT (LSA).

Figures

Figure 6.1. Ol Tepesi (OT) Rockshelter. The rear wall is ~30 meters high and the floor is ~45 meters wide. This is a very large and well-protected location.

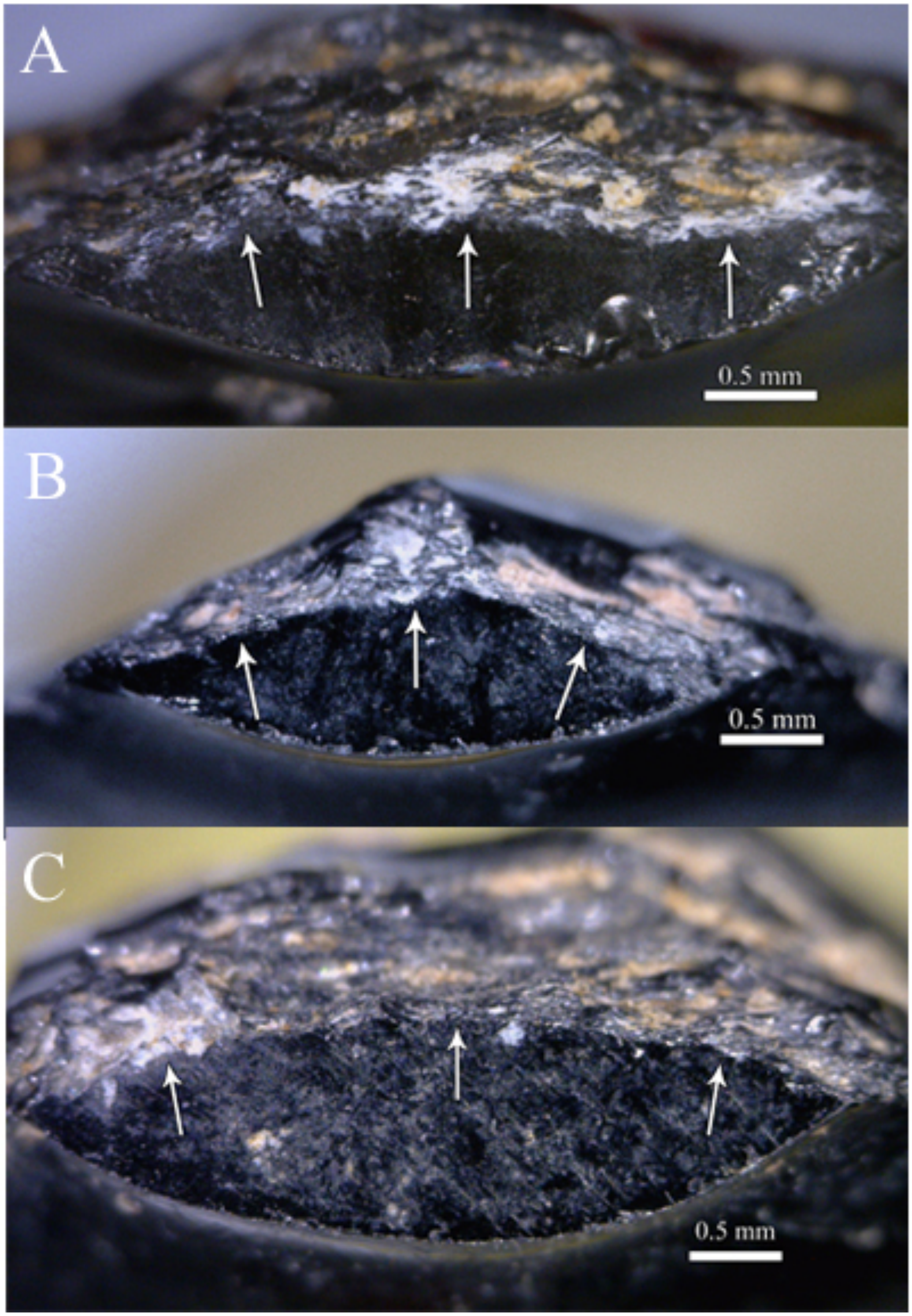

Figure 6.2. OT blade platforms. Note the plain platforms and dorsal proximal faceting (DPF), which is indicated by arrows. This combination is the predominant platform preparation technique used in the Kiteko Industry. (A) #9191; (B) #9210; (C) #10352.

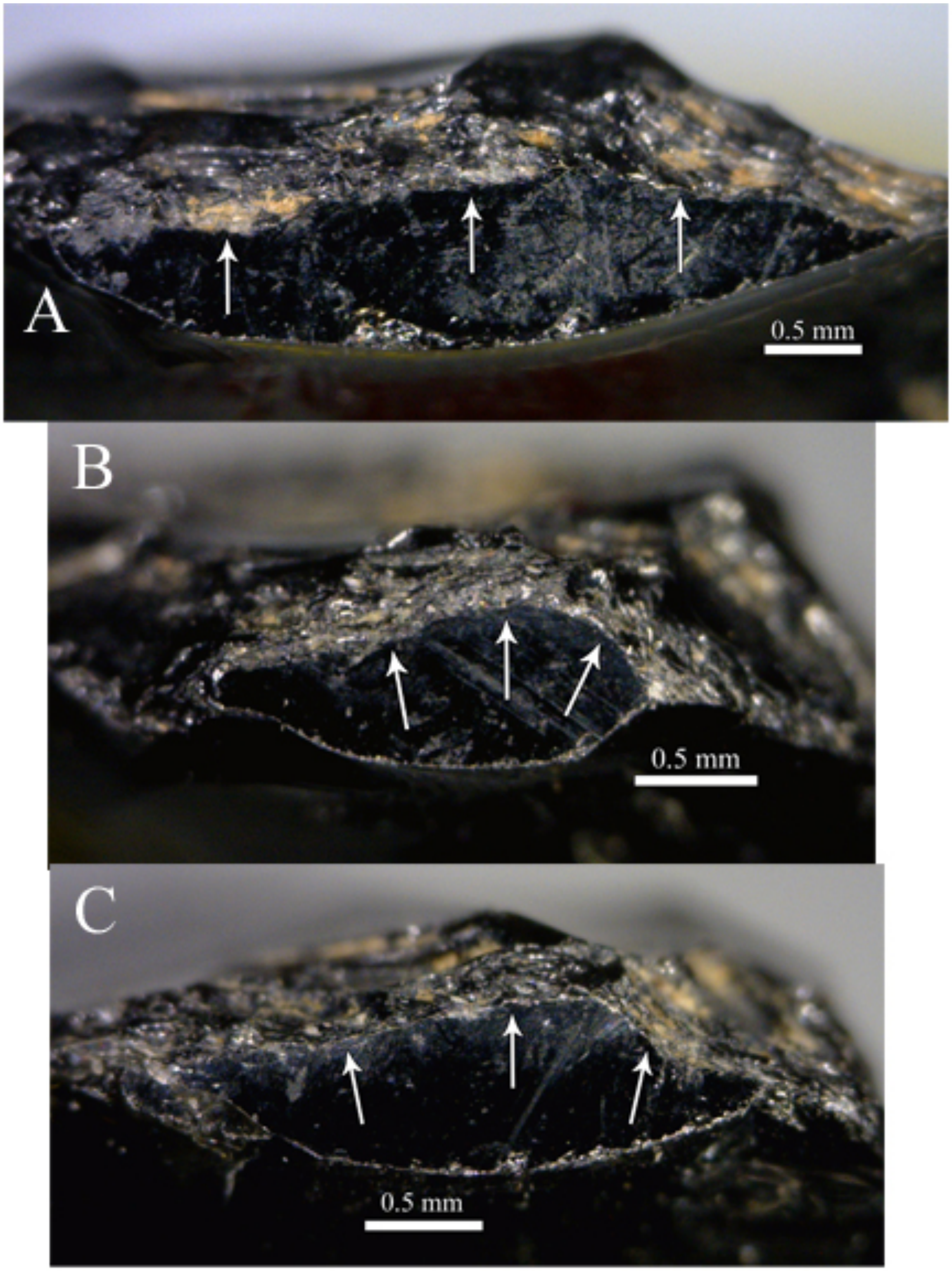

Figure 6.3. More plain platforms with DPF from OT. (A) #10353; (B) #10358; (C) #10361.

Figure 6.4. Tabular (A, #10031) and pyramidal (B-E, #10032-10035) blade cores from OT.

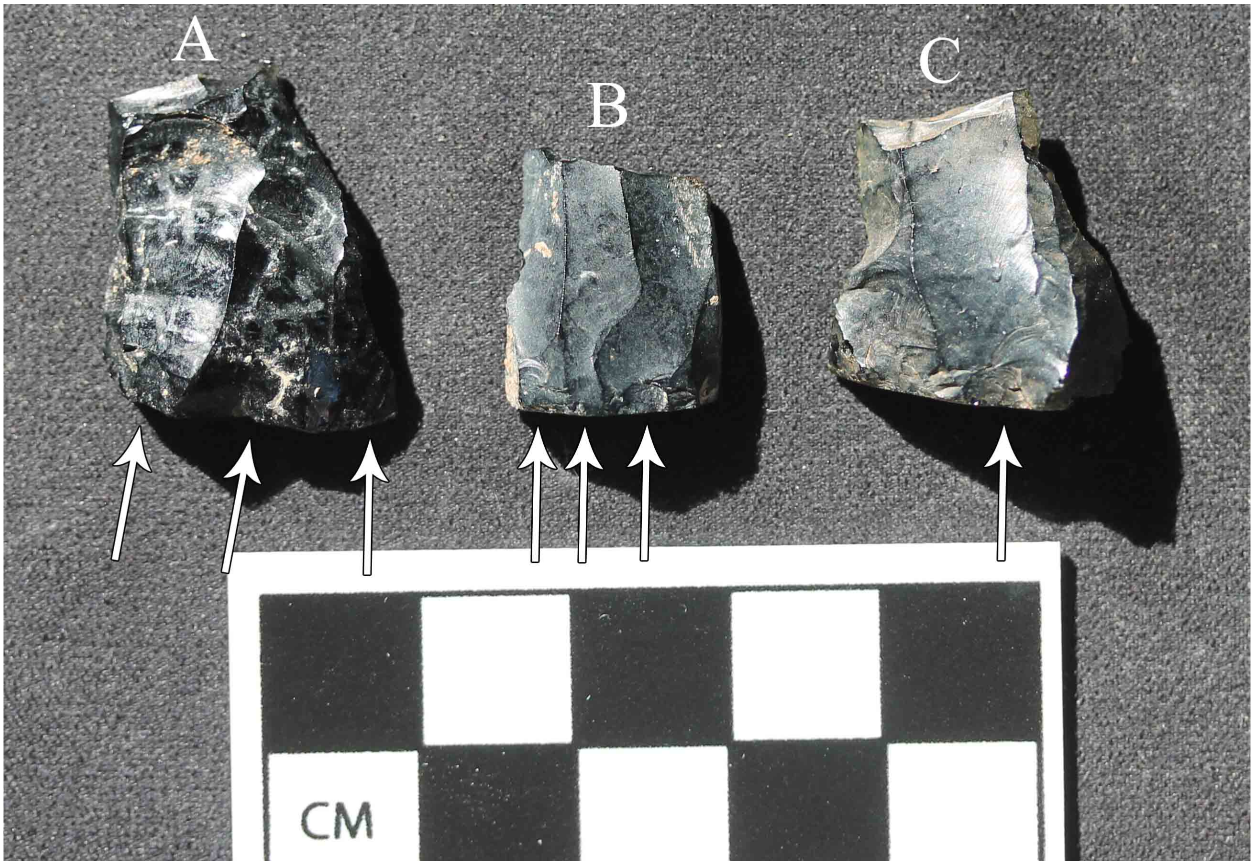

Figure 6.5. Broken overstruck blades with distal ends down from OT. These pieces removed the opposite platform of the core from which they were struck. Arrows indicate previous removal scars from those distal platforms.

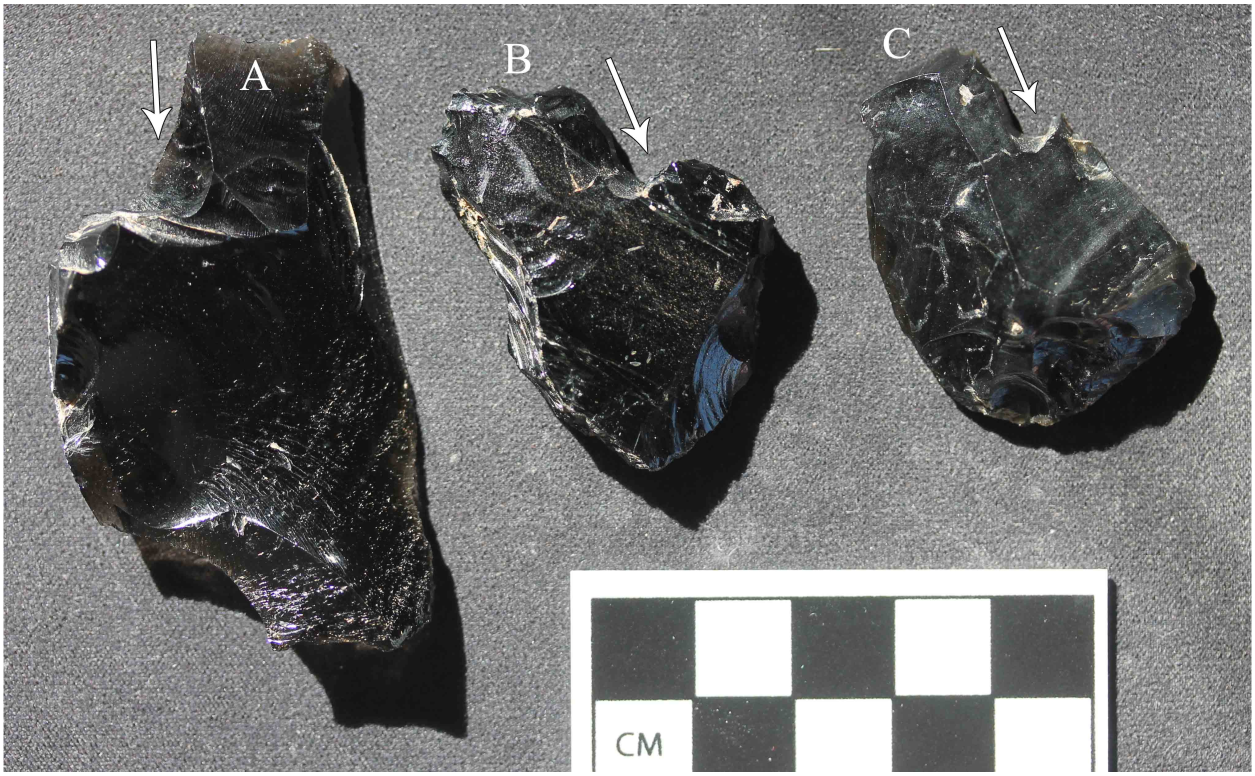

Figure 6.6. Three examples of step-removal flakes from OT: (A) #9188; (B) #9857; (C) #9154. These flakes are orientated with platforms on the left side. The arrows indicate the step and orientation of the flaking axis of the core. Because the step removal flake axis is orthogonal to the core axis of percussion these step removal flakes are the lateral sub-type.

Figure 6.7. Core platform rejuvenation flake from OT showing flat plain platform (facing down) and proximal portions of negative scars.

Figure 6.8. Flakes with four different types of cortex from OT. (A) Thin and banded cortex with rare surface inclusions (#9568); (B) smooth and glassy cortex (#9330); (C) thin cortex with a fine sandpaper roughness (#9409); (D) thin, banded and smooth cortex (#9447).

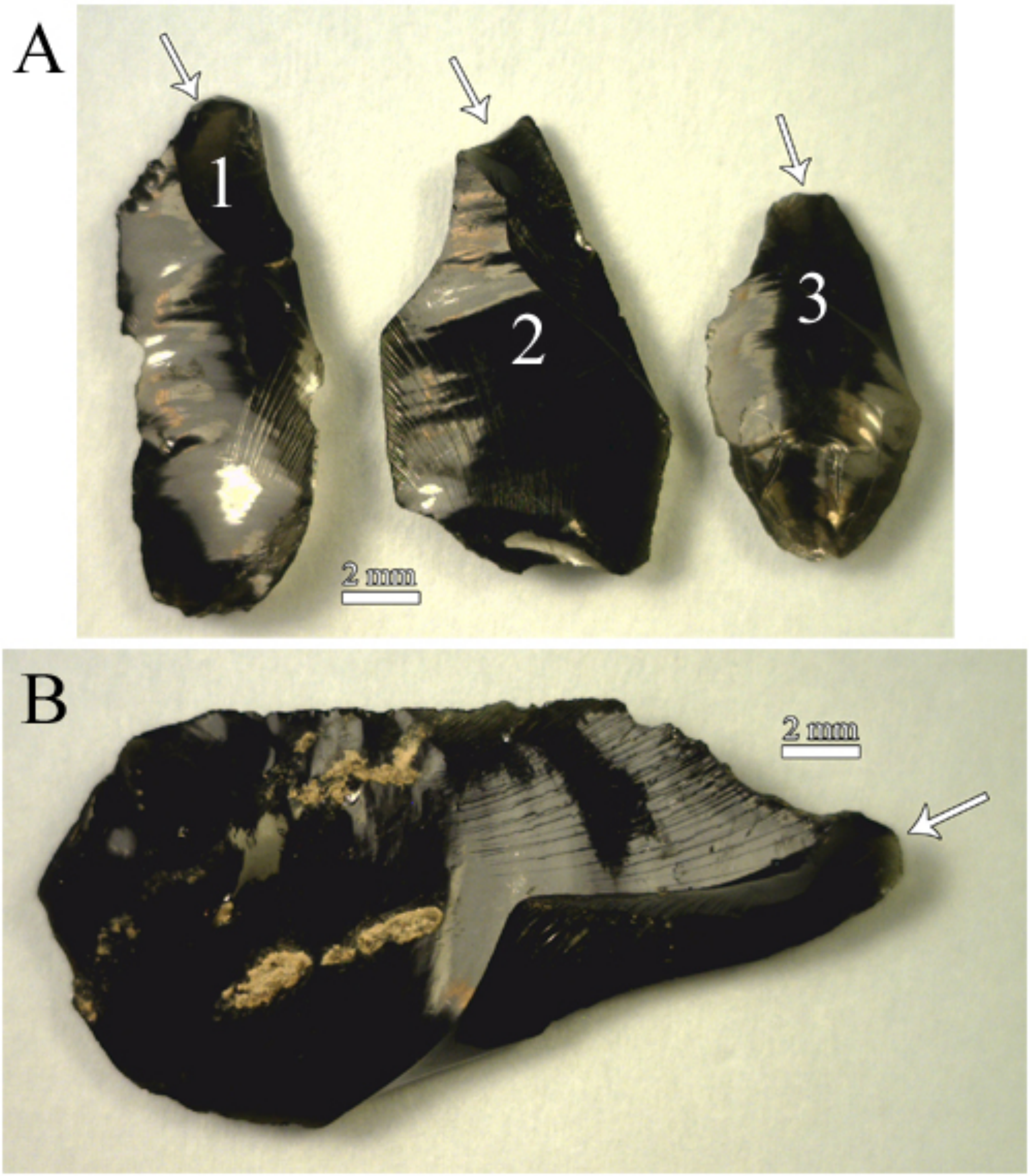

Figure 6.9. Microburins from OT. Arrows indicate direction of transverse blow to segment blade.

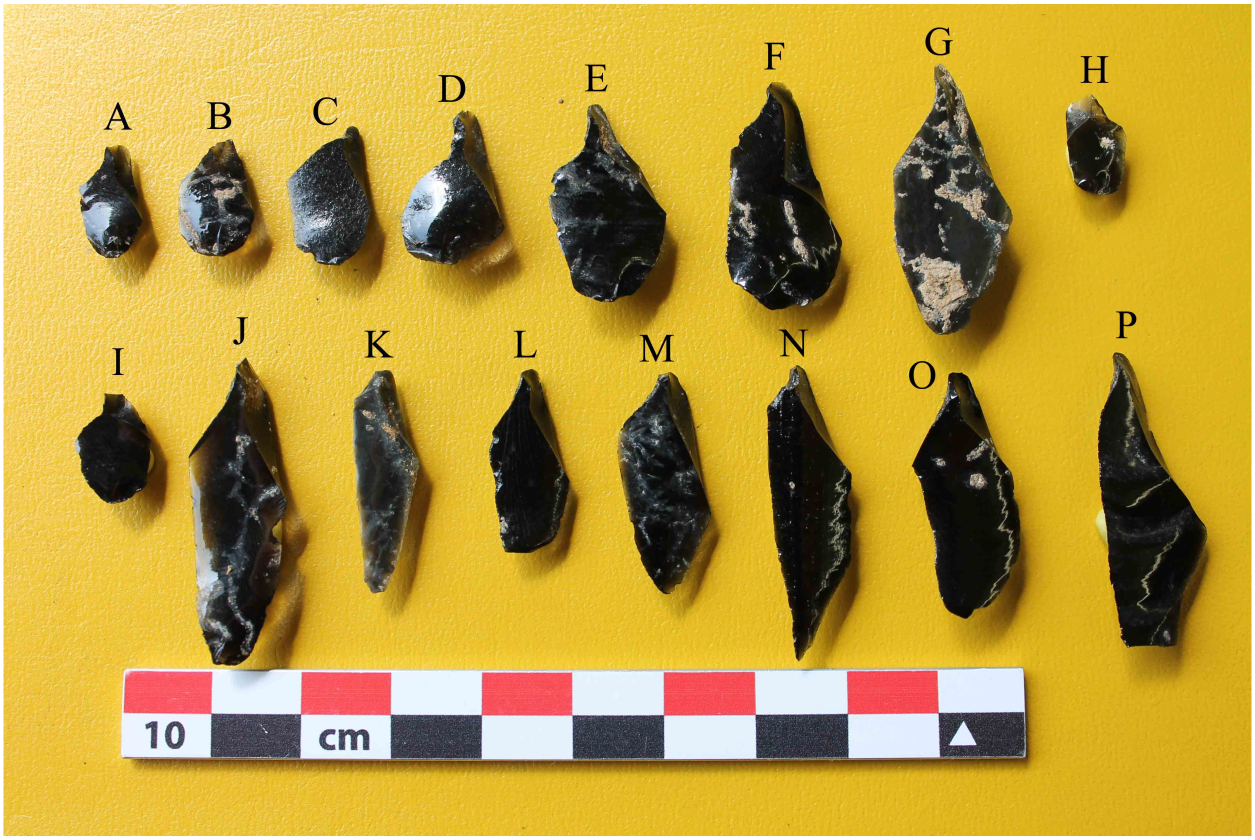

Figure 6.10. Bulk microburins from OT. (A-J) Proximal; (K-O) distal.

Figure 6.11. Sample of derived segments from OT produced during direct percussion segmentation (DPS) of blades.

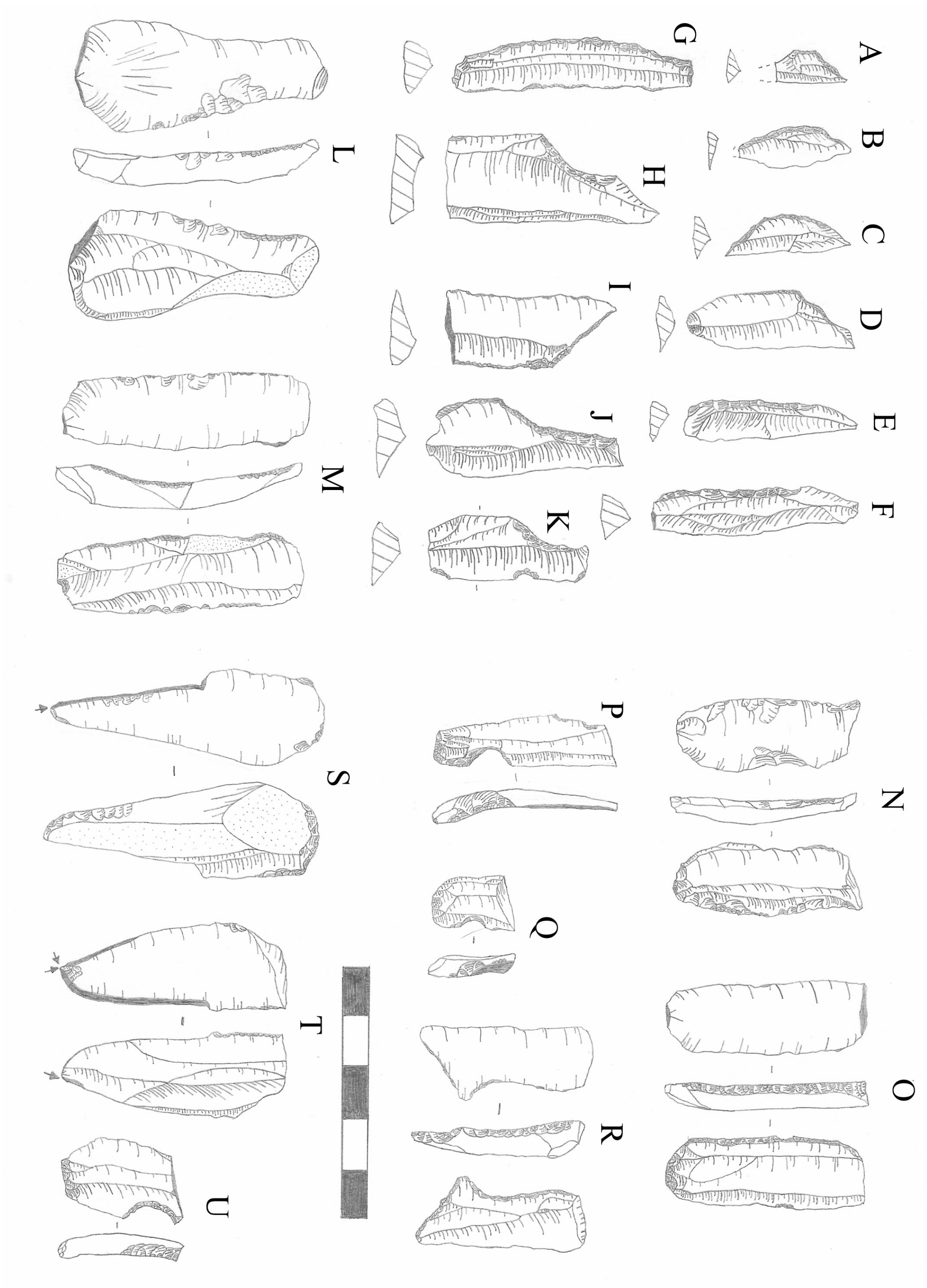

Figure 6.12. Tools from OT: (a-k) Microliths, (l-o, r) casually retouched blades, notches (p-q, u) and (s-t) burins.

Figure 6.13. Sample of concave oblique partially backed microliths from OT (A, #9716; B, #9713; C, #9715). Arrows indicate backed edges; note that they are only partially backed, and that there are two parallel unmodified edges.

Figure 6.14. Sample of straight and longitudinal backed microliths from OT.

Figure 6.15. Sample of backed microlith crescents (A-M) from OT.

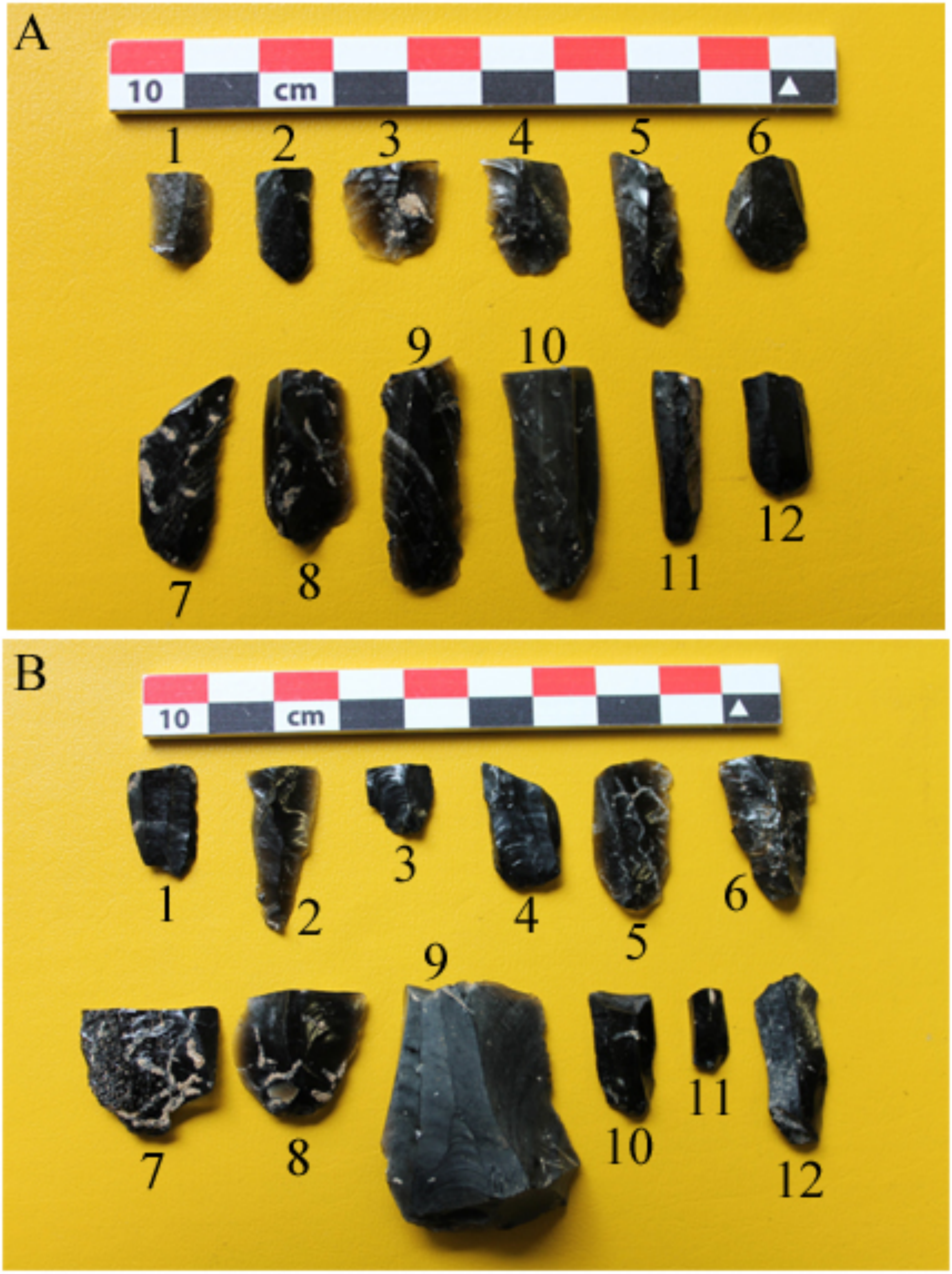

Figure 6.16. Two samples of blade tool 'blanks' from OT. Whole blades (A 4-5, 7; B 4); proximal blade fragments (A 1-3, 6, 8-12; B 1, 3, 5-12); distal blade fragments (B 2).

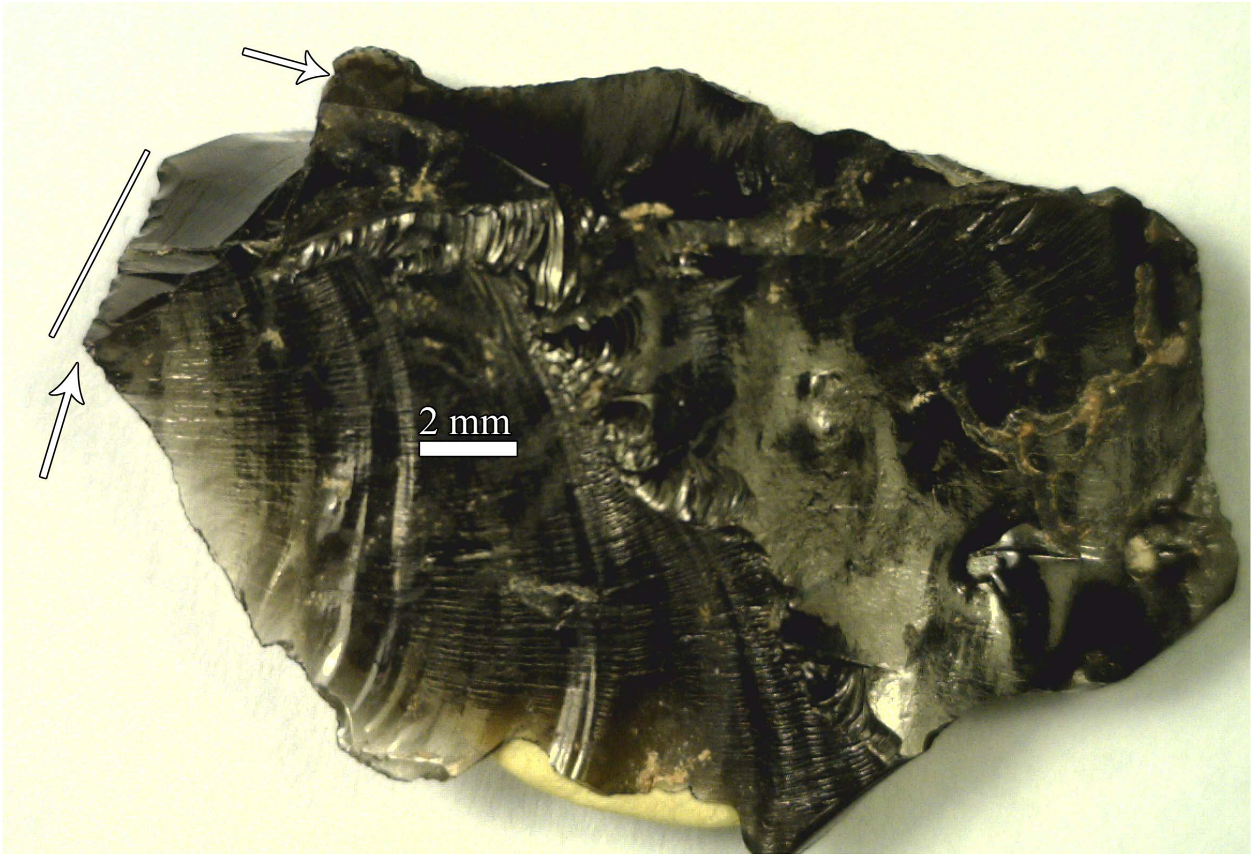

Figure 6.17. Burin plàn (#9743) from OT. Arrows indicate two different burin blows and the bar indicates a utilized edge.

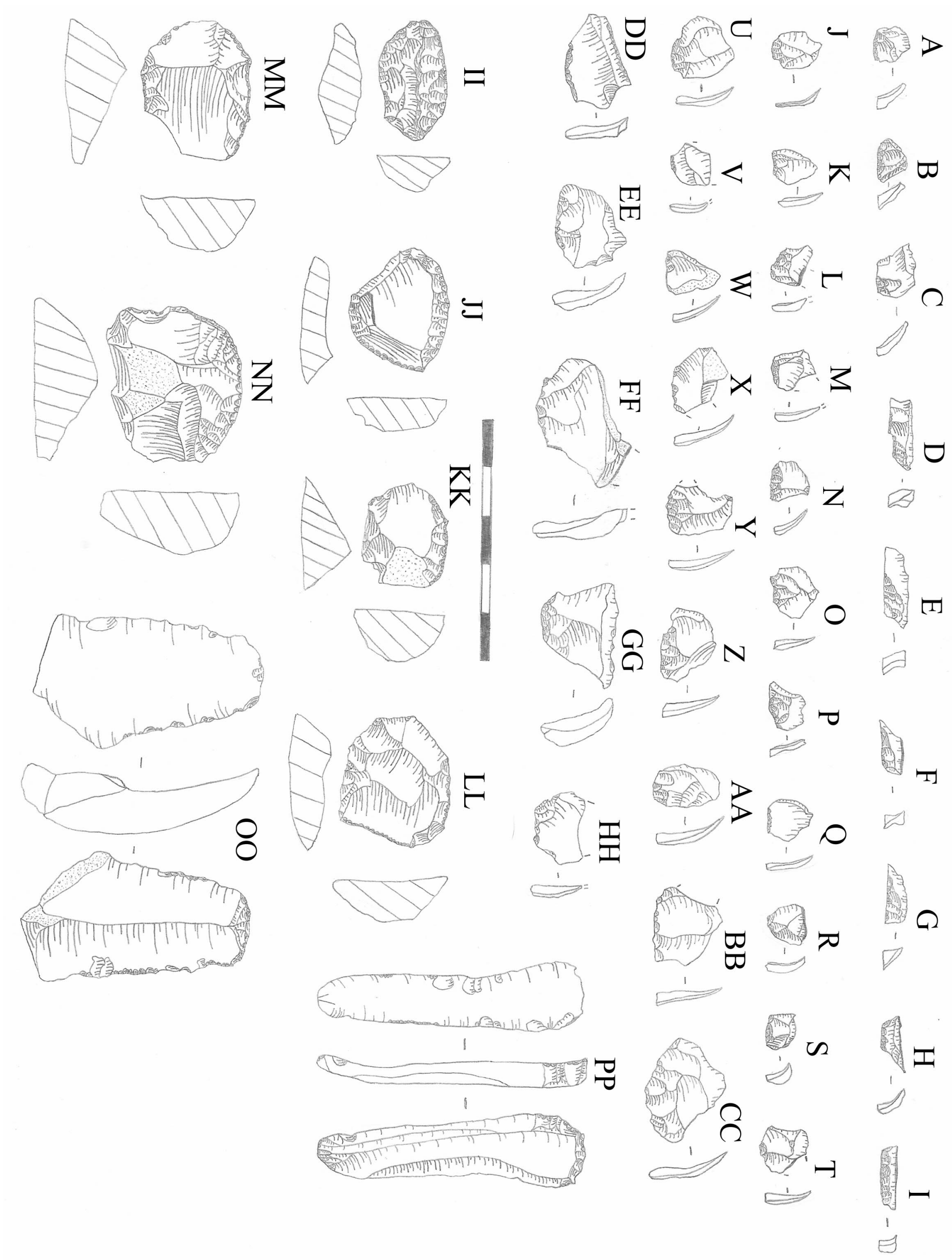

Figure 6.18. Retouch flakes and scrapers from OT: (A-I, L-T) Scraper retouch flakes; (J-K, U-HH) unifacial trimming flakes; (II) #9739, convex end and side or circular scraper; (JJ) #9740, convex end scraper; (KK) #10732, convex end scraper; (LL) #10733, double end scraper; (MM) #9742, convex end scraper; (NN) #10735, convex end and double side scraper; (OO) #10734, convex end scraper (on proximal) and side denticulate; (PP) #10731, convex end scraper on whole blade.

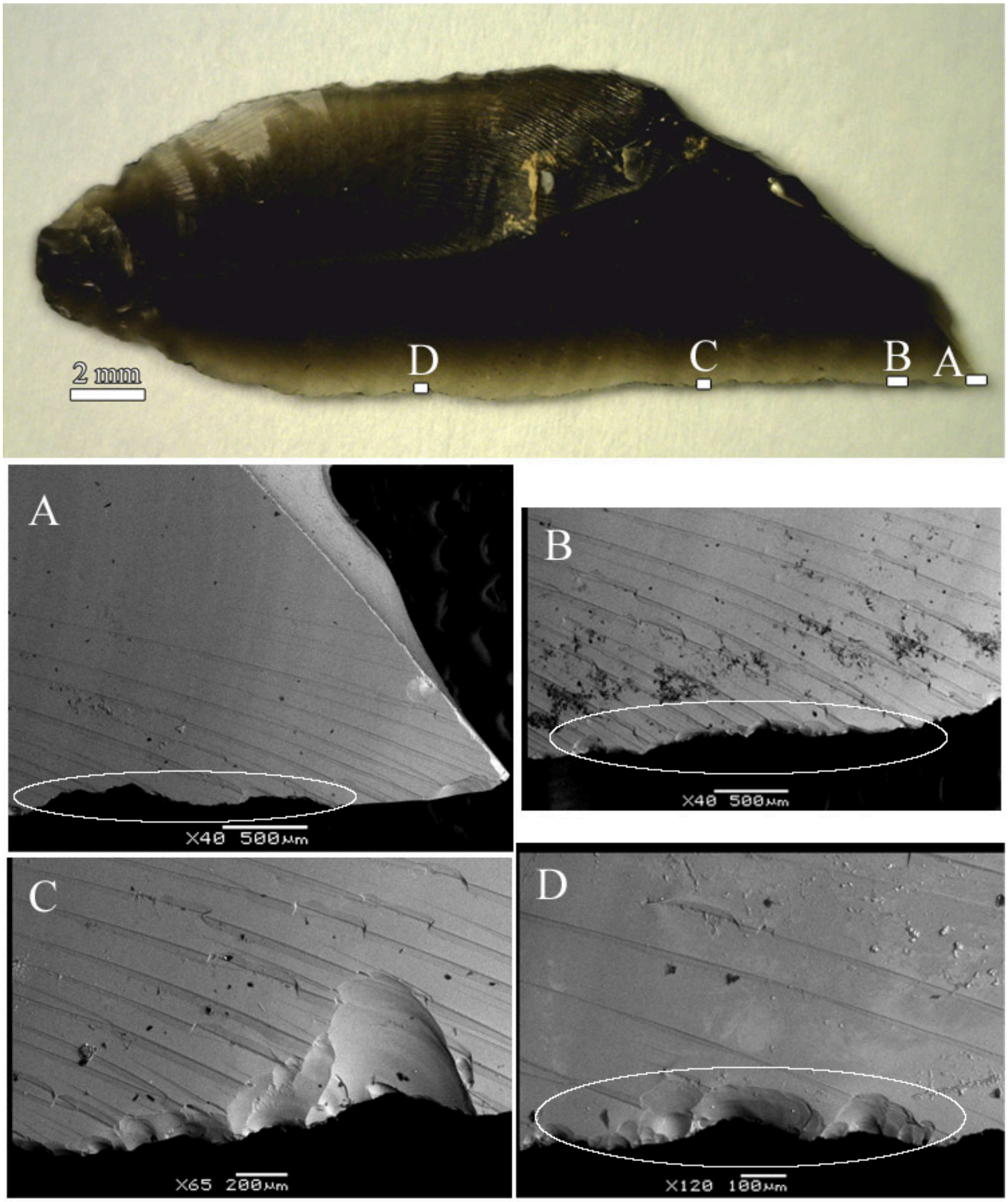

Figure 6.19. Photo of a curved backed microlith (#9698) from OT. (A) SEM micrograph of the truncated edge meeting the unmodified edge; (B) small angled microflake scars with feather terminations. Scars are consistent along unmodified edge and suggest slicing of a soft material.

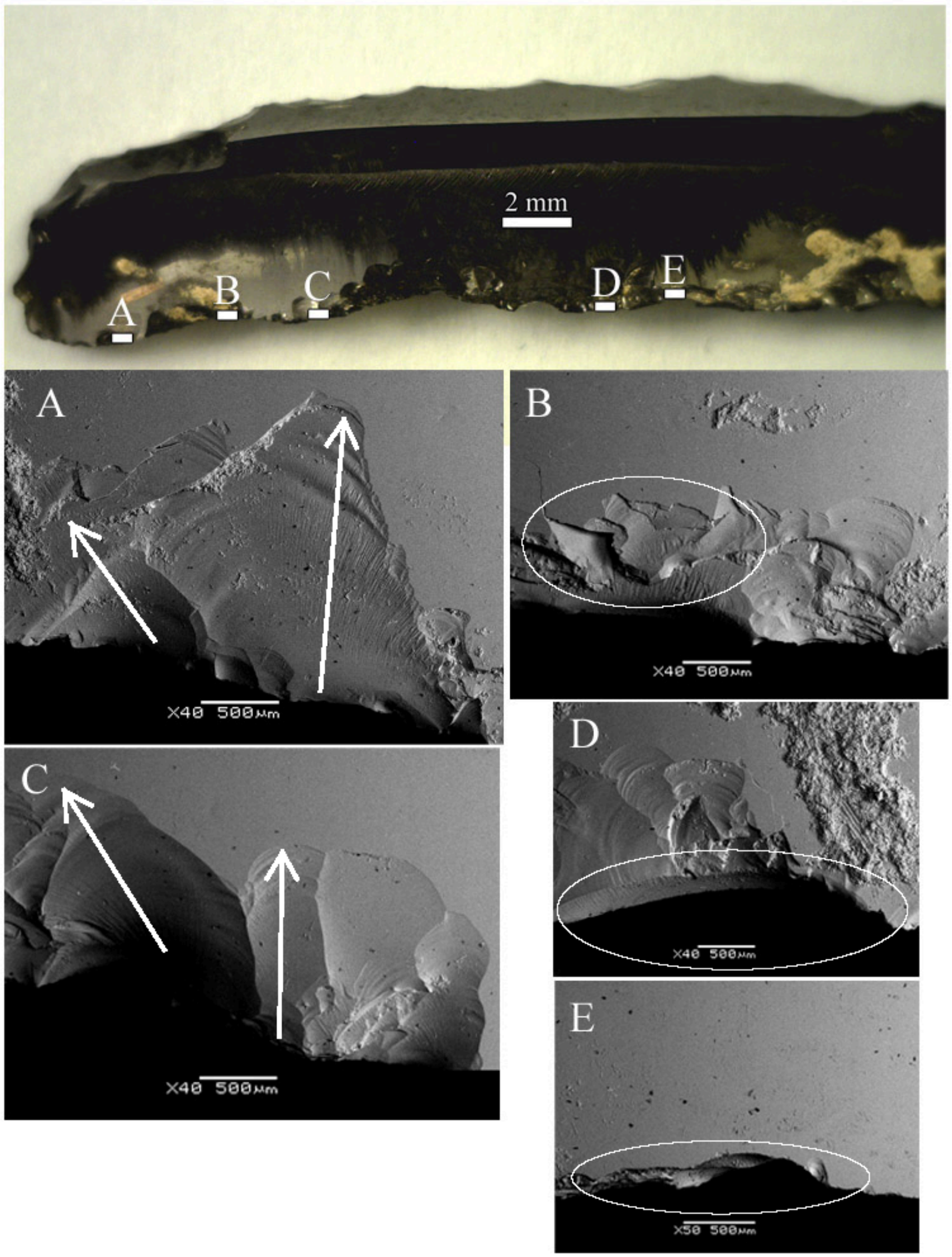

Figure 6.20. Photo of a curved backed microlith (#9707) from OT. (A, C) SEM micrograph of angled and bidirectional microflake scars with feather terminations on the unmodified edge; (B) stepped terminations on microflake scars are more rare; (D-E) wide and shallow half-moon breaks or edge snaps. Together, these features suggest sawing on a hard material.

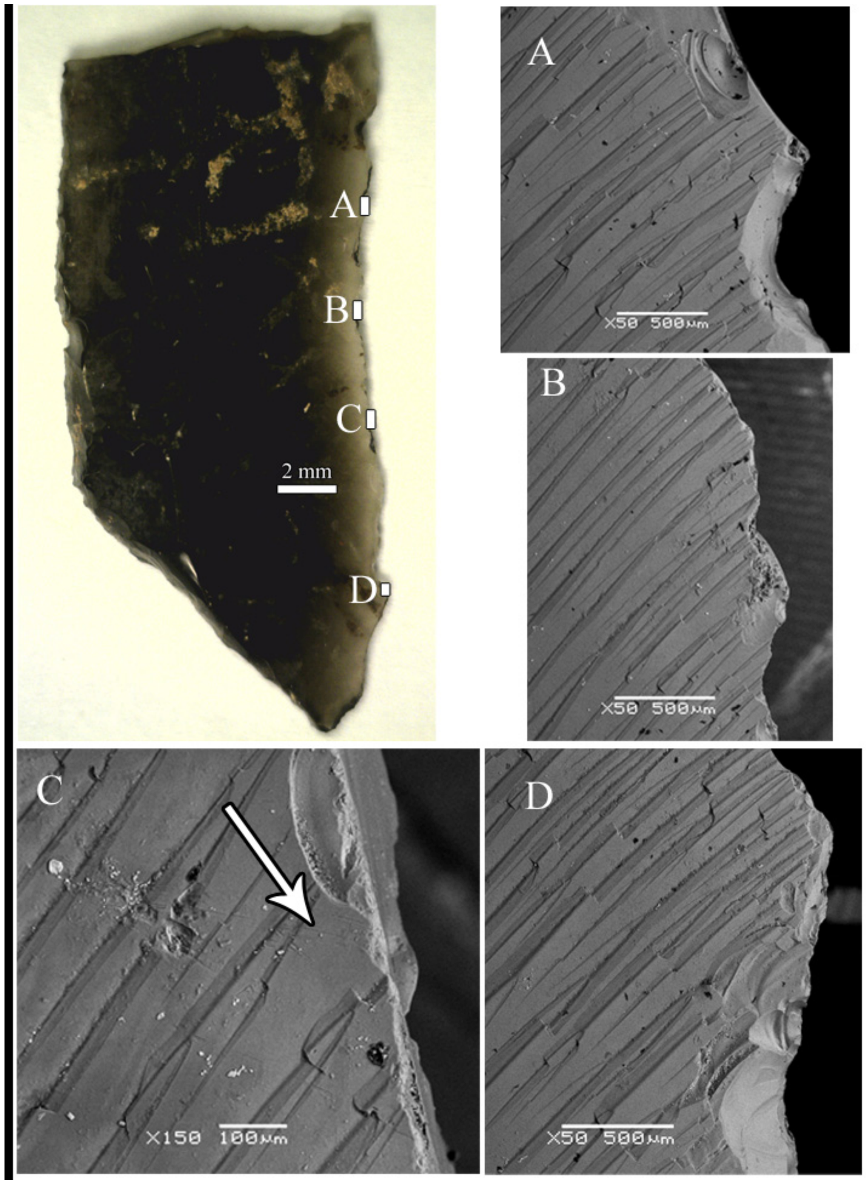

Figure 6.21. Photo of an oblique backed microlith (#9714) from OT. (A) SEM micrograph of a half-moon snap on the unmodified edge; (B, D) edge rounding and marginal stepped microflake scars; (C) small striations perpendicular to the worked edge; (E, G) small microflake scars initiating from arêtes near the backed edge, which suggests rubbing, not percussion; (F) two dark splotches stuck to the artifact surface that may be an adhesive residue. Images E-G show use-wear features that suggest this microlith was hafted while images A-D suggests that the worked edge was used for scraping a soft material.

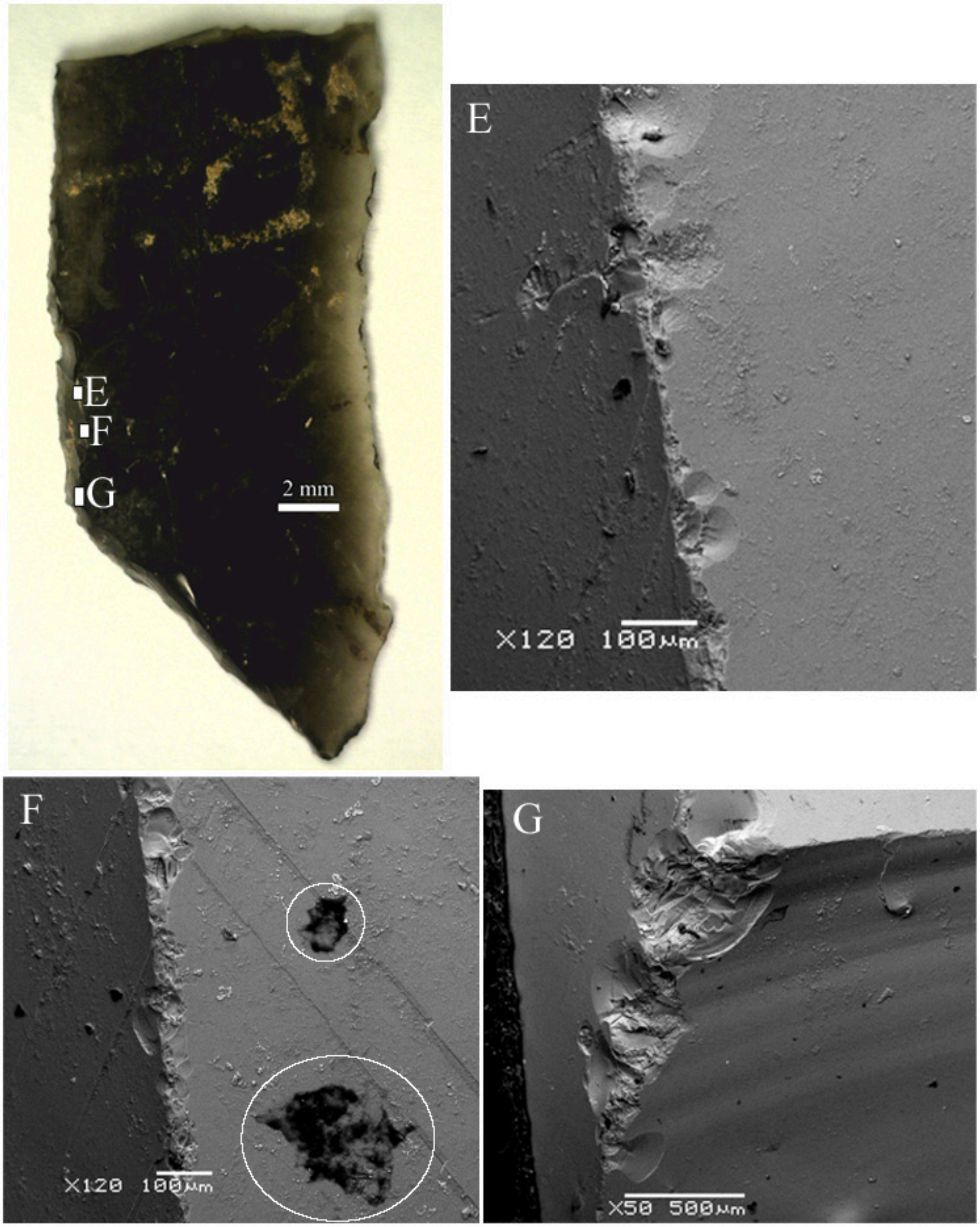

Figure 6.21 continued.

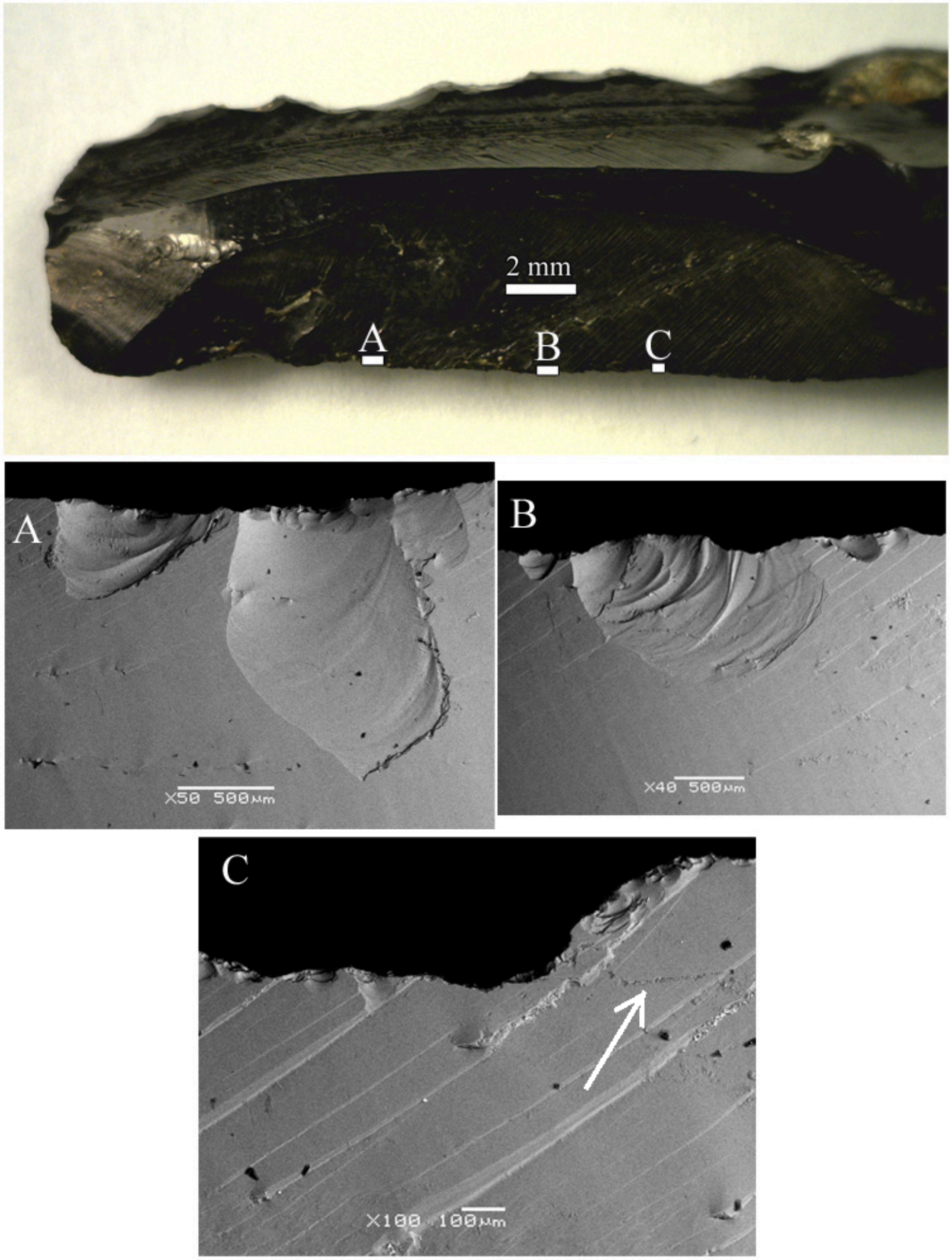

Figure 6.22. Photo of a straight backed microlith (#9732) from OT. (A-B) SEM micrographs of a few large, angled and feather terminating microflake scars on the unmodified edge; (C) marginal utilization and one striation. The light use-wear features suggest slicing of a soft material.

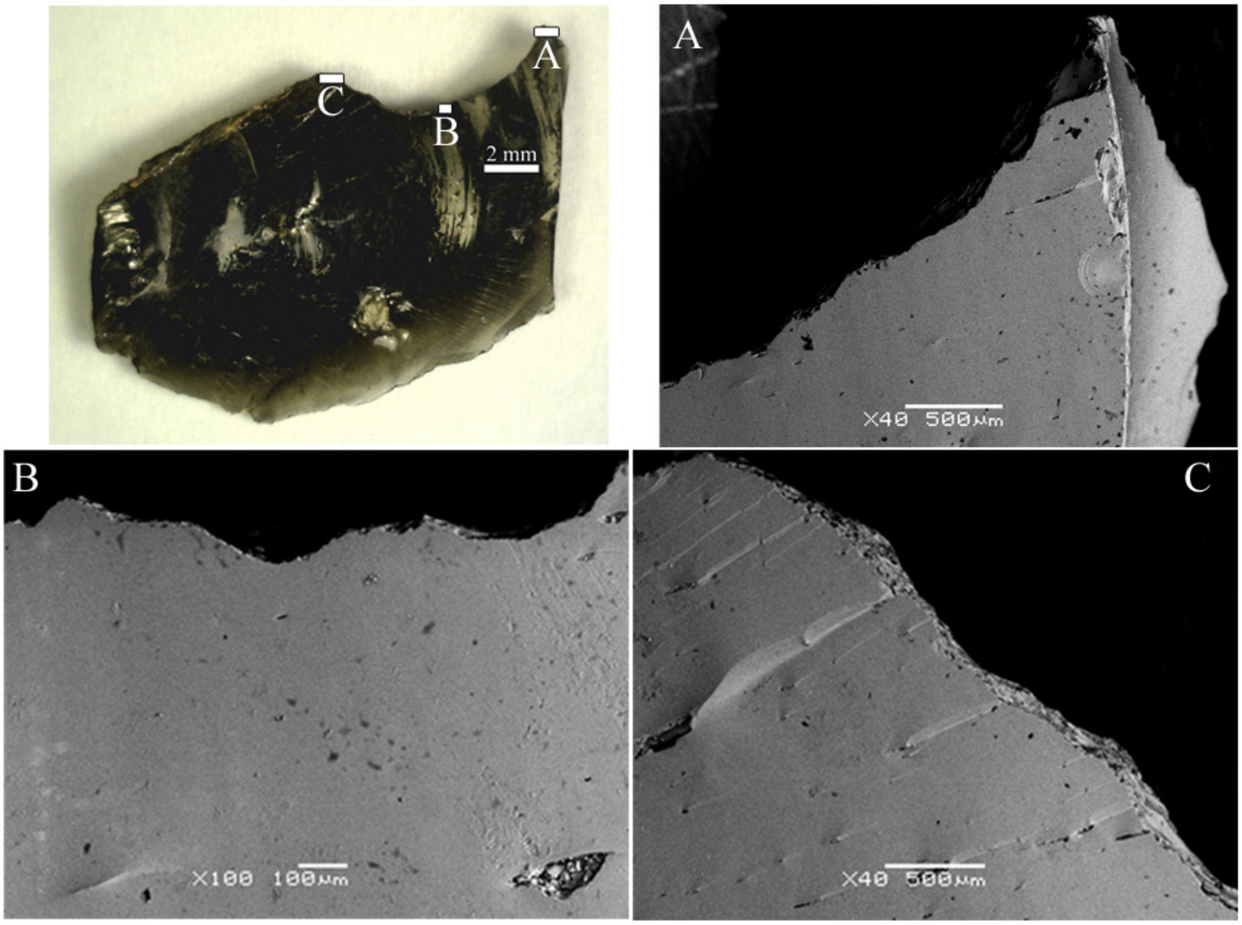

Figure 6.23. Photo of a notched piece on a truncated blade (#9736) from OT. (A) SEM micrograph of the meeting point between the truncated edge and notch; (B) the medial portion of the notch showing no major use-wear features; (C) edge rounding on the inside of the notch. The edge rounding suggests that this piece was used to scrape or rub a hard material or simply a hard hammer.

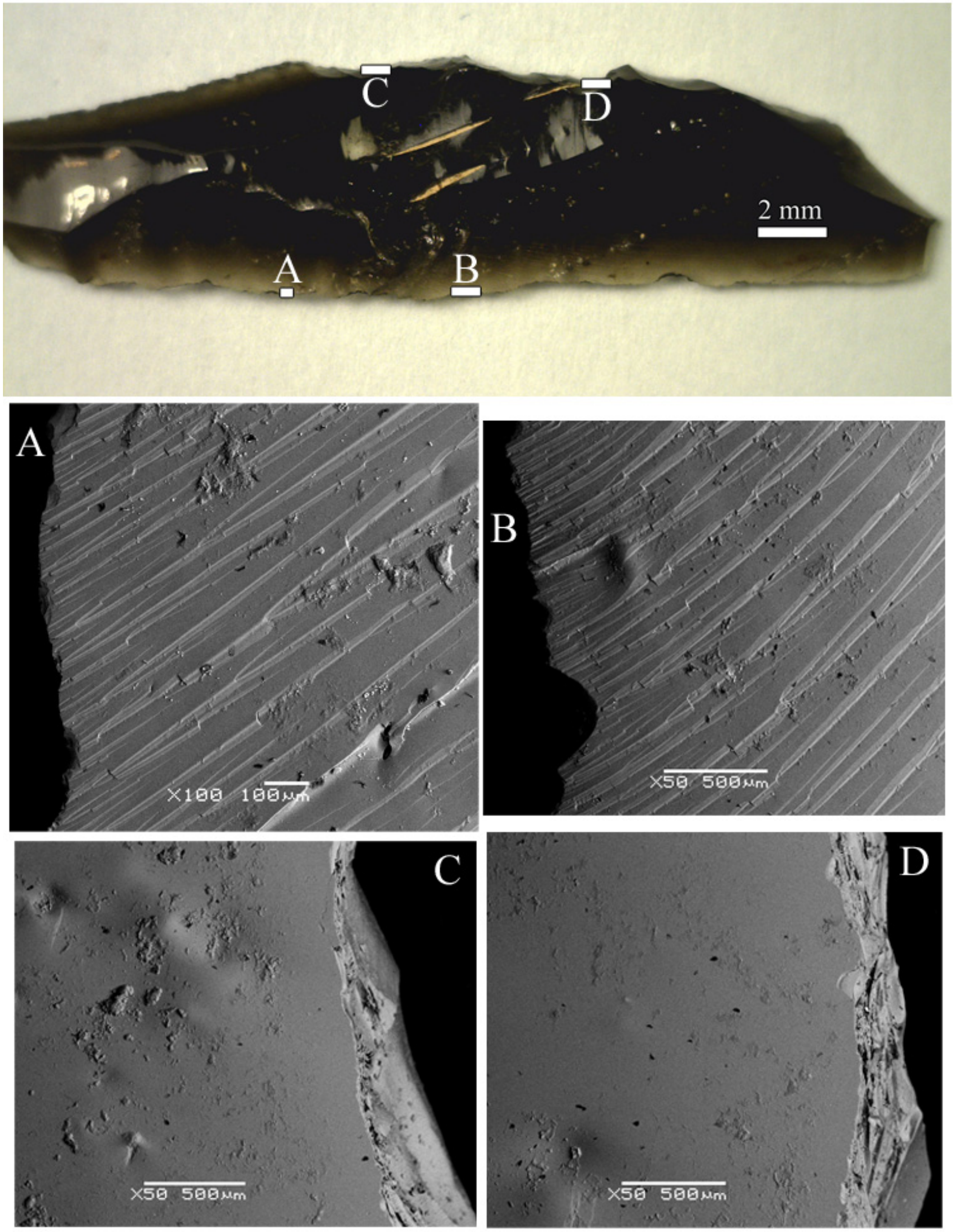

Figure 6.24. Photo of a curved backed microlith (#10706) from OT. (A-B) SEM micrographs of the unmodified edge with no visible use-wear features; (C-D) edge rounding and stepped scarring on the backed edge. This piece does not appear to have been used or hafted.

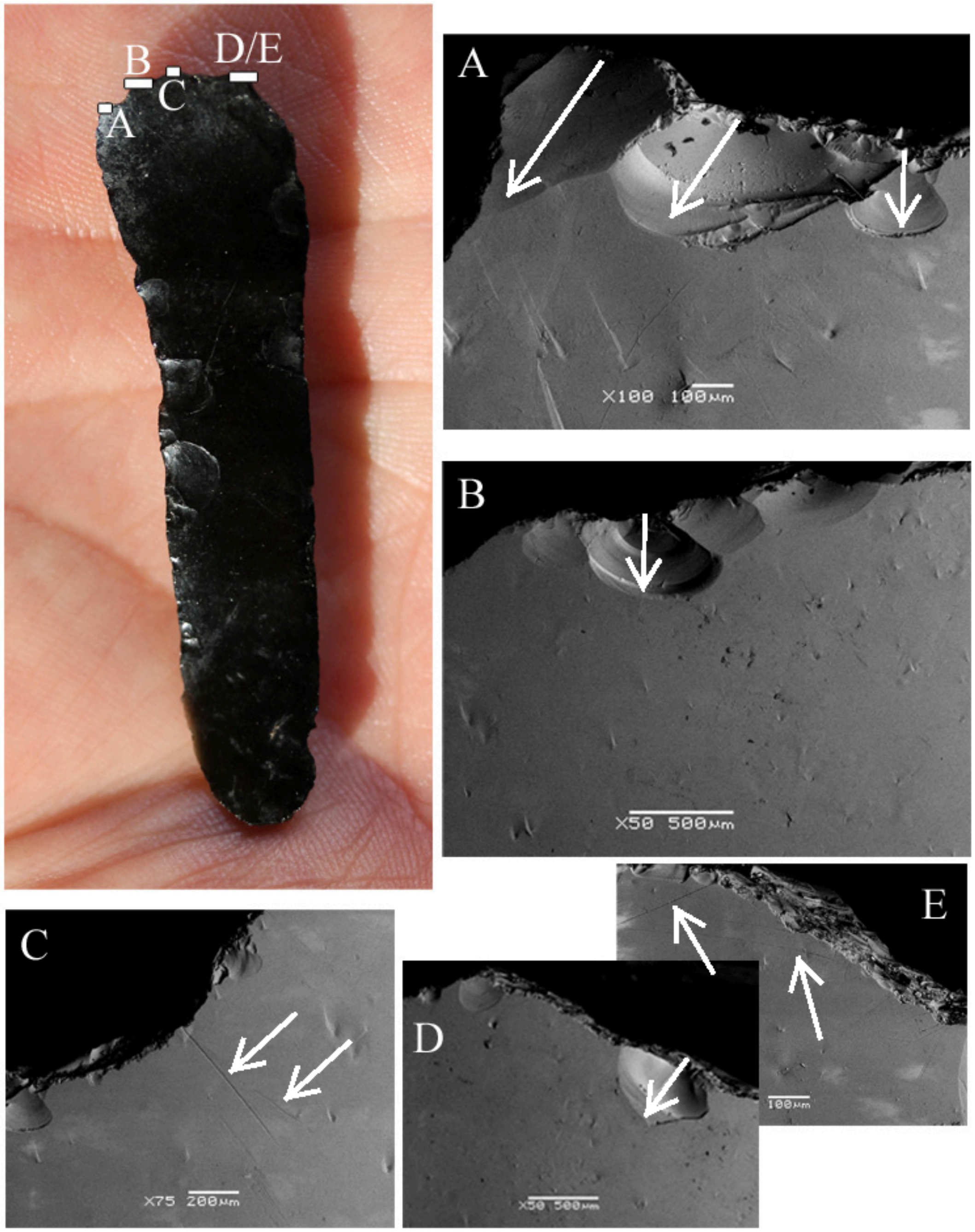

Figure 6.25. Photo of a convex endscraper on a complete blade (#10731) from OT. (A-B) SEM micrographs of microflake scars removed perpendicular to the retouched edge; (C) striations diagonal to the retouched edge; (D) edge rounding and a perpendicular microflake scar (E) high magnification image of the edge rounding in image D. Striations are also visible (arrows). Together, these features suggest this piece was used for scraping a soft material.

Chapter 7

Middle and Later Stone Age Technological Organization Strategies

The purpose of this chapter is to answer the two major questions that I proposed in Chapter 1: first, to investigate how lithic technological organization (TO) strategies change from the Middle (MSA) to Later (LSA) Stone Age, and second, whether LSA industries represent enhanced technological planning compared to the preceding MSA. To answer these questions I developed three hypotheses and nine test predictions based on theoretical expectations for planned and unplanned Stone Age toolkits (see Chapter 2) derived from technological organization theory (Torrence, 1983, 1989; Bleed, 1986; Shott, 1989, 1996; Nelson, 1991; Kuhn, 1992a, 1994; Carr and Bradbury, 2011). In this chapter I will test these hypotheses using data generated from a multifaceted technological analysis (Chapter 3) on three lithic artifact assemblages from the MSA (Chapter 4) and three from the LSA (Chapters 5 and 6).

Marmonet Drift (MD) contains three MSA occurences that are dated from greater than 110 ka to ~94 ka. Enkapune Ya Muto (EYM) contains two early LSA horizons that are dated to 55 – 35 ka. Ol Tepesi (OT) rockshelter has one LSA horizon that is dated to ~19 ka. These three sites represent key points in time that will allow me to assess long-term diachronic change in lithic TO strategies spanning the MSA/LSA technological transition. In order to investigate change over such a long time period it was necessary to combine artifact assemblages from different horizons at MD and EYM. Table 7.1 presents the typological composition of each site's aggregate analyzed assemblage. Detailed justification for the horizon combination comes in the next section, followed by the results of all tested hypotheses. I conclude with a discussion of the implications of these results for the role of technological planning in modern human behavioral evolution.

	Site ID and Level					
Artifact Type	**MD (N)**	**MD (%)**	**EYM (N)**	**EYM (%)**	**OT (N)**	**OT (%)**
Backed Piece	0	0.00	22	0.69	103	2.79
Scraper	26	0.32	9	0.28	34	0.92
Notch	5	0.06	11	0.35	29	0.78
Bec	5	0.06	1	0.03	5	0.14
Outil Écaillé	2	0.02	8	0.25	7	0.19
Point	19	0.24	0	0.00	0	0.00
Knife	28	0.35	0	0.00	0	0.00
Burin	57	0.71	4	0.13	66	1.79
Combination Tools	20	0.25	3	0.09	22	0.60
Total Shaped Tools	*162*	*2.02*	*58*	*1.83*	*266*	*7.20*
Total Unshaped Tools	*77*	*0.96*	*77*	*2.43*	134	3.63
Total Tools	***239***	***2.99***	***135***	***4.25***	***400***	***10.82***
Whole/Prox Flake	1454	18.17	628	19.79	385	10.42
Whole/Prox Blade	9	0.11	131	4.13	575	15.56
MFF/DFF Flake	4835	60.41	1496	47.15	1120	30.30
MFF/DFF Blade	0	0.00	403	12.70	668	18.07
MFF/DFF DPS Blade	0	0.00	11	0.35	51	1.38
Split Flake	6	0.07	8	0.25	7	0.19
Eraillure Flake	7	0.09	18	0.57	15	0.41
Potlid Flake	1	0.01	1	0.03	4	0.11
Total Primary Debitage	***6312***	***78.86***	***2696***	***84.97***	***2825***	***76.43***
PRF	80	1.00	15	0.47	49	1.33
Burin Spall	11	0.14	2	0.06	14	0.38
Microburin	0	0.00	0	0.00	75	2.03
Derived Segment	0	0.00	18	0.57	60	1.62
Bipolar Flake	9	0.11	11	0.35	3	0.08
Trimming Retouch Flake	1227	15.33	265	8.35	178	4.82
Tool Edge Fragment	63	0.79	6	0.19	28	0.76
Total Secondary Debitage	***1390***	***17.37***	***317***	***9.99***	***407***	***11.01***
Total Debitage	***7702***	***96.23***	***3013***	***94.96***	***3232***	***87.45***
Utilized Debitage	156	***0.02***	72	***0.02***	***154***	***0.04***
Blade	1	0.01	5	0.16	20	0.54
Flake	8	0.10	2	0.06	12	0.32
Radial	7	0.09	0	0.00	0	0.00
Tabular	6	0.07	2	0.06	7	0.19
Opposed Platform	3	0.04	0	0.00	0	0.00
Bipolar	2	0.02	4	0.13	3	0.08
Informal	5	0.06	5	0.16	8	0.22
Fragment	31	0.39	7	0.22	14	0.38
Total Cores	***63***	***0.79***	***25***	***0.79***	***64***	***1.73***
Total Flaked Obsidian	***8004***	***100.00***	***3173***	***100.00***	***3696***	***100.00***

Table 7.1. Aggregate typological compositions of the analyzed MD, EYM, and OT assemblages**.**

Comparative Analysis of MD and EYM Horizons

Because I am investigating technological change over a >100,000 year period, the analysis in this chapter necessitates observation on a large timescale. To achieve this it is necessary to combine individual horizons from MD and EYM that are separated by shorter time intervals (≤20,000 years). The three horizons at MD all contain conventional MSA flake-based assemblages and are dated to >110-94 ka. The two horizons from EYM contain two of the earliest LSA microlithic industries in Africa and date to 55-35 ka. Chapters 4 and 5 provide in-depth comparisons between artifact assemblages from the different horizons at each of these sites. Those comparisons did reveal some differences between horizons in terms of typological composition and artifact size but found that, overall, assemblages at each site reflect similar strategies of tool production and use. The differences, while important at the smaller scales within each site's sequence, are negligible at the larger scale and for the purposes of this chapter's analysis.

Further support for combination of MD and EYM horizons comes from statistical comparisons of size measurements for all analyzed artifacts. Table 7.2 presents the results of multiple one-way ANOVAs whereby artifact size dimensions (one attribute in each cell) are compared across horizons within a site (Columns titled *MD* and *EYM*) and across all three sites (*All Sites*). Even though the F-statistics may be significant for within site measurements, the F-statistics are substantially larger in the *All Sites* than the F-statistics in either MD or EYM. The magnitude of that difference is measureable by comparing the eta-squared values in the bottom row of each cell. Eta-squared ((η^2)) reflects the proportion of variance explained by belonging to a group within the ANOVA model. The larger the number, the more variance in a size dimension is explained by the site or horizon to which an artifact belongs. For example, the eta-squared for

All Sites under the measurement of EPA is 32.84%, and only 1.69% for MD. This means that 33% of the variance in EPA is accounted for by the site from which a tool originates whereas only 1.69% of the variance in EPA is accounted for by the horizon from which a tool originates within the MD site, suggesting artifacts are more similar within this site than to the other sites.

Table 7.2. Results of multiple one-way ANOVAs for platform and flake size dimensions of all artifacts compared across horizons within *MD* and *EYM* and across *All Sites*.

	EPA			**PW**			**PT**		
	All Sites	*MD*	*EYM*	*All Sites*	*MD*	*EYM*	*All Sites*	*MD*	*EYM*
F	712.82	7.42	1.38	304.71	53.63	0.37	204.02	33.32	2.25
Sig.	0.000	0.001	0.241	0.000	0.000	0.541	0.000	0.000	0.134
Df (between, within)	2, 2915	2, 861	1, 921	2, 2911	2, 859	1, 921	2, 2911	2, 859	1, 921
Eta-squared	32.84%	1.69%	0.15%	17.31%	11.10%	0.04	12.29%	7.20%	0.24%
	Length			**Width**			**Thickness**		
	All Sites	*MD*	*EYM*	*All Sites*	*MD*	*EYM*	*All Sites*	*MD*	*EYM*
F	76.90	18.81	32.45	212.71	20.32	45.77	36.87	17.44	40.29
Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Df (between, within)	2, 2801	2, 872	1, 729	2, 4121	2, 1194	1, 1139	2, 4121	2, 1194	1, 1139
Eta-squared (η^2)	5.20%	4.14%	4.26%	9.36%	3.29%	3.86%	1.76%	2.84%	3.42%

A notable point about these tests is that they show artifact platform dimensions to be the most distinctive feature among sites. This makes sense when you consider the different tool production techniques (i.e. flake vs. blade) and the associated strategies of platform preparation on cores or curation (if present) of retouched tools. Figure 7.1 provides a panel of bar graphs of means for each dimension for each horizon and shows that assemblages within each site are more similar to each other than to those from other sites. The next section of this chapter will further explore the differences in TO strategies among the three sites, including artifact production, morphometrics, and curation.

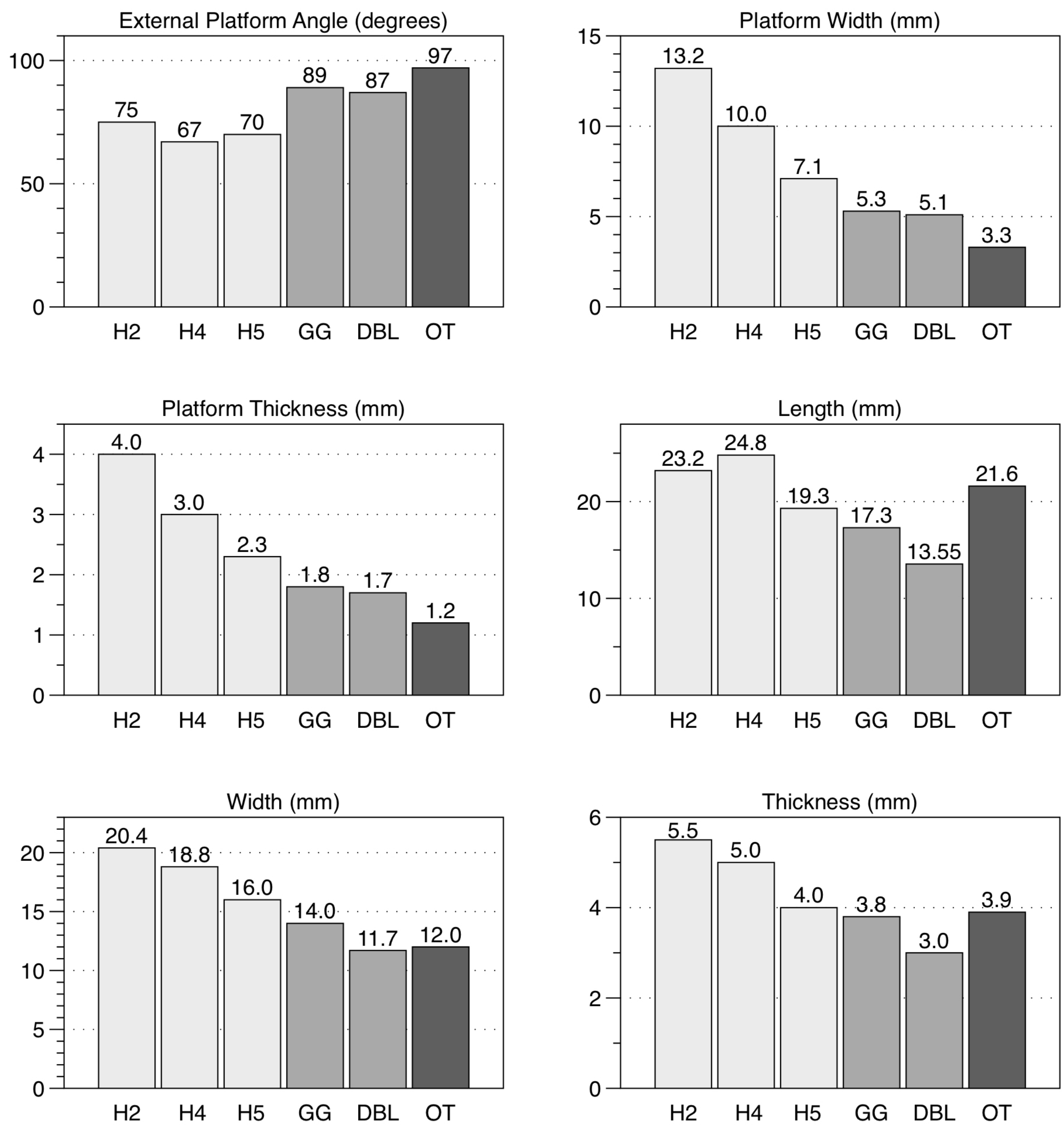

Figure 7.1. Means for platform and flake size dimensions of all measured pieces in each horizon and each site. H2, H4 and H5 are the three horizons from MD. GG1 and DBL1.3 are the two horizons from EYM. OT has only one horizon.

Hypothesis One: Artifact Morphometrics

Hypothesis one focuses on the size and shape (i.e. morphometrics) of artifacts: if LSA industries used information sharing networks to better plan their TO strategies with mechanically efficient tool designs while MSA TO strategies relied upon versatile and flexible tools then I expect artifact (debitage and tools) size to be smaller in the LSA. This expectation is based on TO theory, which assumes that large thick flakes and shaped artifacts have greater potential than thin flakes or blades for reuse and morphological transformation. Such tools reduce the risk of technological failure during opportunistic (i.e. unplanned) foraging because they can be reshaped and/or resharpened quickly, even providing small flakes for expedient tasks (Kelly, 1988; Morrow, 1996). In contrast, tools made for planned activities can be specially designed and mechanically efficient (Torrence, 1983; Bleed, 1986). Because the most mechanically efficient stone tool edges for cutting are small, thin and sharp blades (Ambrose, 2002; Eren et al., 2008), it follows that blade-based LSA industries should have smaller artifact sizes than MSA industries.

The first test prediction for this hypothesis was that MSA debitage would have significantly larger overall size than the LSA debitage. The second test prediction was that MSA debitage would have significantly larger average platform sizes than the LSA debitage. These predictions were based on the greater potential for retouch (and increased versatility and flexibility) for flakes compared to blades (Eren et al., 2008), and the demonstrated relationship between flake platform thickness and flake mass (i.e. size) (Dibble and Whittaker, 1981; Dibble and Pelcin, 1995; Braun et al. 2008; Dibble and Rezek, 2009; Clarkson and Hiscock, 2011). Both predictions were confirmed for both primary and secondary debitage samples (tables 7.3-7.4).

Data on artifact size and shape, including linear dimensions and ratios, for all primary debitage, blade debitage (EYM and OT only), and secondary debitage for all three sites are presented in tables 7.3 – 7.5. One-way analysis of variance (ANOVA) tests confirm that means for primary debitage platform width and thickness, and flake width and thickness decrease significantly from MD to EYM to OT (table 7.6). More specifically, the average platform width for MD debitage is nearly three times that of OT, while thickness is more than twice as large. Platform EPA also changes significantly though time: younger assemblages have a larger external platform angle, up to almost 100° for OT. This trend is directly related to differences in platform preparation techniques because the OT assemblage has more than five times as many primary debitage pieces with dorsal proximal faceting (DPF) than either MD or EYM (table 7.7). More plain and point but fewer faceted platforms accompany this increase in DPF for OT. Faceted platforms are much more common for both MD and EYM but only about 10% of all primary debitage retains DPF for either of these sites. The primary platform preparation technique shifted from faceting on the platforms themselves (MD and EYM) with little DPF to one where plain platforms were heavily abraded prior to flake removal. This abrasion was intense, as the OT platforms average 98° EPA and point platforms (pieces where the platform was completely abraded away) are about twice as common as for MD or EYM.

Table 7.3. Artifact platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all primary debitage from MD, EYM, and OT

Site	*N*	**External Platform Angle (EPA°)**					**Platform Width (PW)**					**Platform Thickness (PT)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	390	81	13	0.16	37	124	9.3	6.90	0.75	0.1	34.6	2.8	2.16	0.77	0.1	13.7
EYM	599	89	13	0.14	54	136	5.1	4.17	0.81	0.1	34.1	1.8	1.39	0.78	0.1	11.7
OT	770	98	14	0.14	55	138	3.3	3.58	1.10	0.1	35.1	1.2	1.22	1.06	0.1	11.3

Site	*N*	**Length[a] (L)**					**Width (W)**					**Thickness (Th)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	390	20.2	12.5	0.62	4.9	99.7	17.6	8.35	0.47	2.6	50.2	4.2	2.24	0.54	0.6	13.7
EYM	599	16.4	7.69	0.47	5.1	47.6	12.9	5.70	0.44	4.7	52.1	3.1	1.62	0.52	0.7	12.0
OT	770	21.3	9.47	0.44	4.7	52.5	11.5	6.19	0.54	2.5	72.6	3.1	1.63	0.52	0.8	14.3

Site	*N*	**PT/PW**					**PW/W**					**PT/Th**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	390	0.39	0.24	0.61	0.10	1.0	0.51	0.29	0.56	.004	1.1	0.65	0.31	0.48	0.02	1.4
EYM	599	0.46	0.26	0.57	0.08	2.3	0.40	0.26	0.65	.004	1.0	0.56	0.30	0.53	0.02	1.1
OT	770	0.56	0.33	0.58	0.08	2.1	0.28	0.26	0.94	.002	2.3	0.36	0.29	0.80	0.01	1.2

Site	*N*	**W/L[a]**					**W/Th**					**L/Th[a]**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	390	0.91	0.42	0.47	0.23	3.4	4.65	1.63	0.35	1.61	11.0	5.67	2.90	0.51	0.94	18.4
EYM	599	0.86	0.43	0.50	0.26	3.8	4.55	1.65	0.36	1.21	11.6	5.63	2.34	0.42	1.19	14.9
OT	770	0.63	0.38	0.60	0.13	2.1	3.99	1.52	0.38	0.27	11.9	7.47	3.82	0.51	0.97	28.0

[a]Sample sizes for Length, W/L, and L/Th are 184 for MD, 241 for EYM and 311 for OT.

Table 7.4. Artifact platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for primary debitage blades from EYM and OT

Site	*N*	**External Platform Angle (EPA°)**					**Platform Width (PW)**					**Platform Thickness (PT)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
EYM	121	92	12.3	13.4	55	136	4.4	3.2	72.8	0.1	18.3	1.6	1.1	66.8	0.1	5.2
OT	456	102	12.5	12.4	68	138	2.5	2.7	106.0	0.1	17.7	0.9	1.0	107.3	0.1	7.4
Site	*N*	**Length[a] (L)**					**Width (W)**					**Thickness (Th)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
EYM	121	23.3	8.4	36.2	11.0	47.6	12.1	4.7	38.7	4.8	32.4	3.3	1.5	45.8	1.1	9.9
OT	456	24.5	9.4	38.5	5.3	52.3	9.9	3.8	38.7	2.5	31.2	2.9	1.3	45.3	0.8	12.2
Site	*N*	**PT/PW**					**PW/W**					**PT/Th**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
EYM	121	0.49	0.30	0.60	0.2	2.3	0.36	0.23	0.64	0.01	0.91	0.50	0.29	0.57	0.03	1.06
OT	456	0.57	0.32	0.56	0.1	1.5	0.25	0.23	0.95	0.01	2.08	0.31	0.25	0.82	0.02	1.21
Site	*N*	**W/L[a]**					**W/Th**					**L/Th[a]**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
EYM	121	0.42	0.07	0.17	0.26	0.51	4.00	1.47	0.37	1.45	8.92	7.83	2.61	0.33	2.98	14.88
OT	456	0.39	0.15	0.39	0.13	1.57	3.71	1.17	0.32	0.98	8.58	9.76	3.72	0.38	3.30	28.00

[a]Sample sizes for Length, W/L, and L/Th are 47 for EYM and 156 for OT.

Table 7.5. Artifact platform and flake size dimensions, shape ratios, and standard deviation and coefficient of variation statistics for all secondary retouch debitage from MD, EYM, and OT

Site	*N*	**External Platform Angle (EPA°)**					**Platform Width (PW)**					**Platform Thickness (PT)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	378	55	13	0.23	19	109	7.3	5.17	0.70	0.1	35.1	2.2	1.83	0.83	0.1	19.0
EYM	265	84	16	0.19	35	126	4.6	3.72	0.83	0.1	20.3	1.3	1.11	0.84	0.1	7.1
OT	178	82	14	0.17	56	120	3.5	3.18	0.90	0.1	17.4	1.1	0.97	0.86	0.1	7.3

Site	*N*	**Length[a] (L)**					**Width (W)**					**Thickness (Th)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	378	14.3	6.82	0.48	3.4	47.9	12.9	6.03	0.47	3.7	41.4	2.6	1.46	0.57	0.2	13.8
EYM	265	9.6	3.84	0.40	3.1	26.7	11.0	4.16	0.38	1.3	32.6	2.4	1.14	0.49	0.9	7.1
OT	178	9.8	5.22	0.53	1.7	40.6	9.9	4.54	0.46	1.1	25.7	2.3	1.51	0.66	0.7	11.5

Site	*N*	**PT/PW**					**PW/W**					**PT/Th**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	378	0.34	0.19	0.55	0.11	1.26	0.59	0.34	0.58	0.00	2.39	0.89	0.73	0.83	0.02	11.63
EYM	265	0.43	0.27	0.62	0.10	1.00	0.45	0.71	1.59	0.01	10.67	0.57	0.33	0.58	0.02	2.16
OT	178	0.49	0.29	0.59	0.10	1.00	0.46	0.57	1.23	0.00	3.35	0.53	0.35	0.66	0.01	1.83

Site	*N*	**W/L[a]**					**W/Th**					**L/Th[a]**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
MD	378	1.01	0.49	0.48	0.24	4.06	5.57	3.02	0.54	0.84	52.25	6.50	4.50	0.69	0.43	66.65
EYM	265	1.24	0.52	0.42	0.05	3.61	5.10	1.66	0.33	0.25	13.27	4.55	1.72	0.38	0.82	9.89
OT	178	1.25	1.21	.97	0.14	12.71	5.34	2.48	0.46	0.14	15.30	4.97	2.70	0.54	0.56	13.25

[a]Sample sizes for Length, W/L, and L/Th are 293 for MD, 249 for EYM and 157 for OT.

Table 7.6. ANOVA comparison of mean size dimensions for all measured primary debitage

Attribute	*MD (n=390)*	*EYM (n=599)*	*OT (n=770)*	*F-statistic*
EPA (°)	81_l	89_m	98_n	241.06***
PW (mm)	9.3_l	5.1_m	3.3_n	212.08***
PT (mm)	2.8_l	1.8_m	1.2_n	151.77***
L[a] (mm)	20.2_l	16.4_m	21.3_l	18.43***
W (mm)	17.6_l	12.9_m	11.5_n	116.01***
Th (mm)	4.2_l	3.1_m	3.1_m	52.41***

[a] Sample sizes for length are 184 for MD, 241 for EYM and 311 for OT.

***p<.001

Means in the same row that do not share subscripts differ at $p<0.008$ in the Bonferonni comparison.

Notably, mean length is largest for primary debitage from OT despite it having the smallest mean width and thickness. This reflects the increased production of relatively long, but narrow and thin, blades compared to EYM and MD (table 7.8). OT blades also have significantly smaller platforms and higher EPA than those of EYM using an Independent Samples t-test ($p<0.008$, table 7.9).

Table 7.7. Primary debitage platform types and DPF identified for each site

Platform type %	MD (n=651)	EYM (n=668)	OT (n=882)
Plain	41.2	47.0	52.9
Faceted	40.9	36.2	14.1
Point	17.7	13.6	30.0
Cortical	0.3	3.1	2.9
DPF	9.5	10.8	57.9

Table 7.8. Percentage of primary debitage classified as 'blade'

Site	*Blade %*
Marmonet Drift	0.1
Enkapune Ya Muto GG1	29.7
Enkapune Ya Muto DBL	13.9
Enkapune Ya Muto combined	*20.6*
Ol Tepesi	45.1

Further evidence for size reduction over time is also reflected in ratios of PW/W and PT/Th for primary debitage. Figure 7.2 shows three things: first, that mean platform size reduces from MD to EYM to OT; second, that within the primary debitage class blades have relatively small platforms; and third, that platforms are proportionally smaller through time. Finally, one-way analysis of variance (ANOVA) tests show that cores, which produced at least a portion of the primary debitage samples, are also significantly longer and wider for MD than those of EYM and OT (table 7.10). Core thickness is not significantly different between MD and OT. In general, MD and EYM cores are quite blocky as width is about 90% of the length, whereas OT core width is only 75% of the length, and translates to a slightly longer, narrower form.

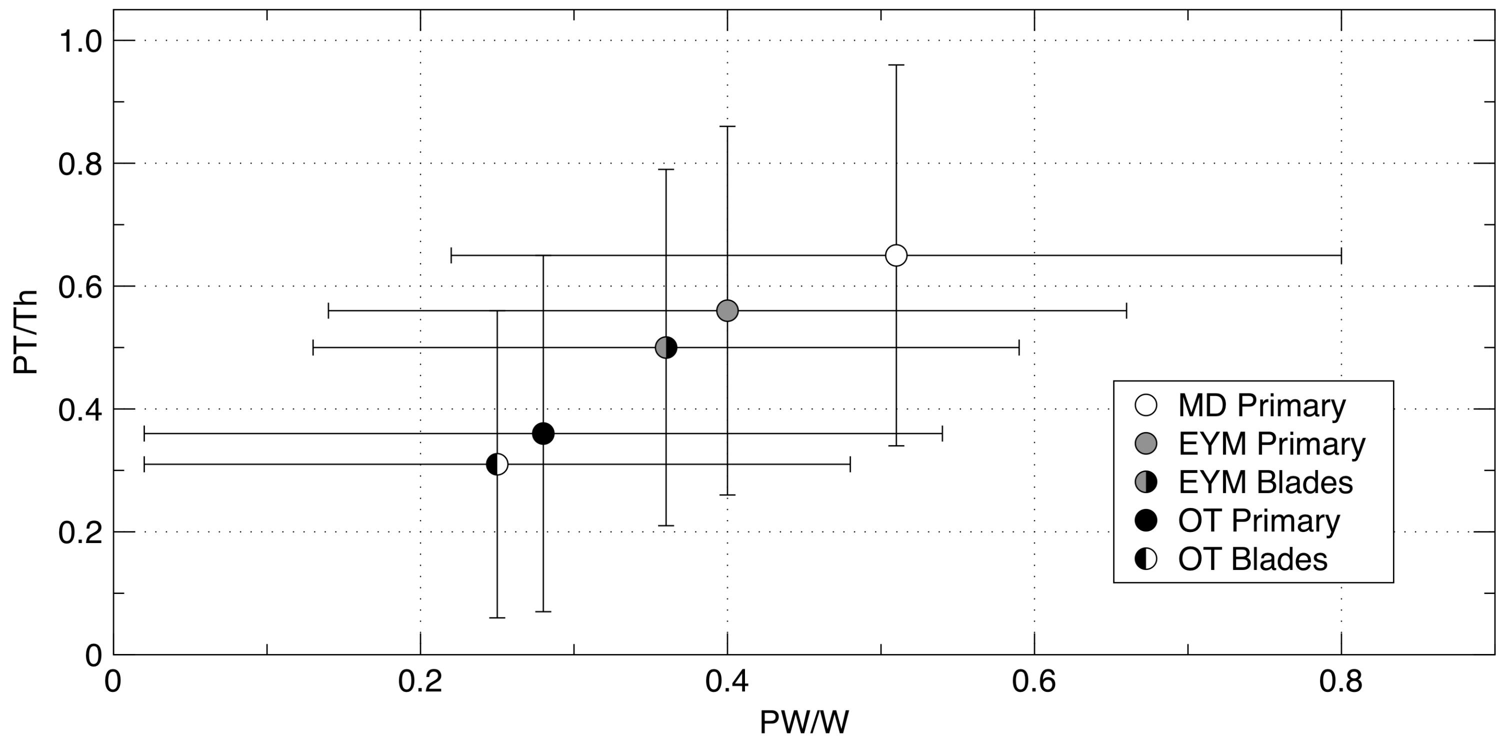

Figure 7.2. Plot of platform width/flake width vs. platform thickness/flake thickness for all primary debitage and blade samples from all three site assemblages. Note that ratios decrease from MD to EYM to OT and that blade from EYM and OT have reduced ratios compared to primary debitage samples.

Table 7.9. T-tests of mean primary debitage blade platform and blade size dimensions for EYM and OT

Attribute	EYM (n=121)	OT (n=456)	t-test of means
EPA (°)	92	102	-7.51[#]
PW (mm)	4.4	2.5	6.01[#]
PT (mm)	1.6	0.9	6.90[#]
L[a] (mm)	23.3	24.5	-0.82
W (mm)	12.1	9.9	4.98[#]
Th (mm)	3.3	2.9	3.26[#]

[a] Sample sizes for length are 47 for EYM and 156 for OT.

[#] $p<0.008$, which is the adjusted value for statistical significance using the Bonferonni correction.

Table 7.10. ANOVA comparison of mean size dimensions for all whole[*] cores from all sites

Attribute	MD (n=28)	EYM (n=19)	OT (n=48)	F-statistic
Length (mm)	34.6_{l}	19.9_{m}	28.4_{n}	14.65***
Width (mm)	31.3_{l}	17.9_{m}	21.3_{m}	17.52***
Thickness (mm)	13.4_{l}	9.7_{lm}	16.2_{ln}	5.80**

[*]Core fragments are not included in this table. Only cores with at least one complete platform.

Means in the same row that do not share subscripts differ at $p<0.017$ in the Bonferonni comparison.

***$p<.001$ ** $p<.01$

One-way analysis of variance (ANOVA) tests also confirm that means for secondary retouch debitage platform width and thickness, and flake length and width are significantly larger for MD compared to EYM and OT (table 7.11). Flake thickness is also larger, but not significantly so. EYM and OT retouch flakes are not significantly different from each other in any size dimension. The most notable dissimilarity is for EPA: MD EPA averages only 55°, a very low angle compared to 84° and 82° for EYM and OT. This reflects a critical difference among sites in the edge morphology of the retouched pieces that these flakes were removed from. Low EPA indicates that the edges of the majority of MD's retouched tools were thin, while EYM and OT tool edges were much steeper. This is consistent with the preponderance of thin unifacial and parti-bifacial invasively flaked points and knives for MD H4 and H5.

Table 7.11. ANOVA comparison of platform and flake size dimensions for all measured secondary retouch flakes from all sites

Attribute	MD (n=378)	EYM (n=265)	OT (n=178)	F-statistic
EPA (°)	55_l	84_m	82_m	382.25***
PW (mm)	7.3_l	4.6_m	3.5_m	54.40***
PT (mm)	2.2_l	1.3_m	1.1_m	41.03***
L[a] (mm)	14.3_l	9.6_m	9.8_m	60.62***
W (mm)	12.9_l	11.0_m	9.9_m	23.42***
Th (mm)	2.6	2.4	2.3	3.01

[a]Sample sizes for length are 293 for MD, 249 for EYM and 157 for OT.

***p<.001

Means in the same row that do not share subscripts differ at $p<0.008$ in the Bonferonni comparison.

Exploring flake size further, MD retouch flakes are, on average, almost 5 mm longer than those of EYM and OT. Combined with the low EPA° this suggests that the MD retouch flakes were being driven off far into the retouched piece (i.e. invasively), and thus from larger blanks. This focus on invasive retouch serves to create (or maintain) sharp and thin edges as well as reduce thickness in the artifact overall. Fragments of thin retouched tool edges and the morphology of the majority of MD's formal types (invasively flaked points) support this as well. In contrast, the EYM and OT samples have larger average widths than lengths (though still smaller than MD in both dimensions) and, combined with their steep EPA, were most likely confined to marginal edges of long and thin blade tools such as scrapers or the backed edges of microliths. The difference in retouch flake size and shape among site assemblages appears to be a function of the abundance, or lack thereof, of invasively flaked tool types.

The third test prediction for hypothesis 1 was that MSA formal tools would have significantly larger average sizes than LSA types. This prediction was confirmed. Table 7.12 presents the results of one-way analysis of variance (ANOVA) tests for mean length, width, and thickness dimensions of all formal tools showing that MD tools were significantly larger in each recorded size dimensions. Similar to size dimensions for primary and secondary debitage, OT tools were significantly longer than those of EYM, but still narrower and thinner. This pattern is confirmed when size dimensions are analyzed by specific tool types (tables 7.13 – 7.18).

Table 7.12. Mean (with ANOVA) flake size dimensions and standard deviation and coefficient of variation statistics for all formal tools from each site

Statistic	*Attribute*	*MD (n=162)*	*EYM (n=58)*	*OT (n=266)*	**F-statistic**
Mean	*L*	30.7_l	21.7_m	26.3_n	15.93***
	W	22.6_l	13.6_m	12.8_m	89.10***
	Th	6.8_l	4.8_m	4.5_m	36.52***
SD	*L*	13.4	9.3	10.5	
	W	8.8	5.3	6.9	
	Th	2.9	2.0	2.5	
CV	*L*	43.6	43.7	39.7	
	W	39.1	38.9	53.5	
	Th	43.5	41.4	56.1	

Means in the same row that do not share subscripts differ at $p<0.017$ in the Bonferonni comparison.

***$p<.001$

Table 7.13. Mean platform and size dimensions, and standard deviation and coefficient of variation statistics of the five most common formal tool types at MD

Type	*N*	**External Platform Angle (EPA°)**					**Platform Width (PW)**					**Platform Thickness (PT)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Burin	5	88	21	23.9	62	108	10.5	7.71	73.3	0.1	21.8	2.2	2.66	122	0.1	6.6
Knife	4	83	3	3.6	79	87	9.2	1.72	18.7	7.6	10.8	3.0	1.24	40.8	1.2	3.8
Scraper	11	81	15	18.5	49	101	15.0	7.62	51.0	1.8	24.3	7.3	5.14	70.5	0.8	18.6
Point	4	91	16	17.6	78	114	17.1	2.95	17.2	13.5	20.3	5.5	1.43	26.0	4.4	7.6
Combination	5	85	8	9.4	75	93	14.6	6.91	47.3	10.0	26.9	4.9	1.96	40.0	2.2	7.6
Site	*N*	**Length (L)**					**Width (W)**					**Thickness (Th)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Burin	57	22.4	10.1	45.2	7.5	49.1	17.4	9.30	53.4	2.6	48.1	5.4	2.62	48.4	2.3	13.2
Knife	28	35.1	11.6	33.1	13.7	68.5	24.9	5.70	22.9	15.1	43.9	6.0	1.97	33.1	2.7	10.9
Scraper	26	30.1	12.6	41.8	7.2	56.5	24.7	9.50	38.5	7.9	43.5	9.0	3.30	36.8	3.5	18.6
Point	19	37.7	10.3	27.2	23.9	68.9	26.3	6.30	24.0	17.2	45.6	7.3	1.92	26.3	4.8	12.0
Combination	20	39.7	10.5	26.3	23.0	59.3	27.4	3.80	13.9	22.1	36.9	8.3	3.11	37.3	5.2	15.8

Table 7.14. Artifact shape ratios and standard deviation and coefficient of variation statistics for the five most common formal tool types at MD

Type	*N*	PT/PW					PW/W					PT/Th				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Burin	5	0.34	0.38	111	0.02	1.00	0.40	0.32	80.0	0.00	0.84	0.28	0.28	100	0.02	0.63
Knife	4	0.33	0.13	39.4	0.16	0.48	0.37	0.02	5.4%	0.34	0.39	0.50	0.17	34.0	0.26	0.63
Scraper	11	0.46	0.13	28.3	0.30	0.76	0.57	0.35	61.4	0.07	1.32	0.71	0.33	46.5	0.11	1.10
Point	4	0.33	0.08	24.2	0.22	0.41	0.67	0.08	11.9	0.57	0.74	0.70	0.09	12.9	0.63	0.83
Combination	5	0.39	0.24	61.5	0.18	0.77	0.52	0.21	40.4	0.39	0.90	0.73	0.30	41.1	0.26	1.00

Site	*N*	W/L					W/Th					L/Th				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Burin	57	0.81	0.40	49.4	0.21	2.26	3.36	1.38	41.1	1.00	6.51	4.55	1.76	38.7	1.62	10.3
Knife	28	0.80	0.38	47.5	0.37	1.84	4.52	1.56	34.5	2.56	9.85	6.24	2.41	38.6	2.63	15.2
Scraper	26	0.92	0.53	57.6	0.38	3.12	2.93	1.17	39.9	0.94	5.32	3.62	1.67	46.1	0.98	7.45
Point	19	0.71	0.09	12.7	0.58	0.88	3.65	0.55	15.1	2.42	4.51	5.24	0.95	18.1	3.55	6.63
Combination	20	0.73	0.20	27.4	0.43	1.00	3.56	0.88	24.7	1.85	5.45	5.04	1.53	30.4	2.52	7.92

Table 7.15. Mean platform and size dimensions, and standard deviation and coefficient of variation statistics of the five most common formal tool types at EYM

Type	*N*	**External Platform Angle (EPA°)**					**Platform Width (PW)**					**Platform Thickness (PT)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	1	88	-	-	-	-	11.3	-	-	-	-	3.3	-	-	-	-
Notch	4	103	9	8.7	92	111	8.7	2.70	30.9	5.0	11.2	3.2	1.03	32.4	2.1	4.5
Scraper	1	80	-	-	-	-	15.2	-	-	-	-	7.2	-	-	-	-
Outil écaillé	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burin	1	73	-	-	-	-	7.6	-	-	-	-	3.8	-	-	-	-
Site	*N*	**Length (L)**					**Width (W)**					**Thickness (Th)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	22	24.7	10.3	41.6	7.6	57.6	11.0	4.50	40.9	4.9	23.6	3.9	1.48	37.8	1.5	8.5
Notch	11	16.5	10.3	62.6	6.1	35.6	14.7	5.30	36.1	8.5	23.2	4.8	1.74	36.0	2.3	7.9
Scraper	9	21.2	8.93	42.1	13.3	41.4	16.3	6.20	38.0	8.4	26.4	6.5	3.00	46.2	2.5	12.2
Outil écaillé	8	17.6	5.87	33.4	9.3	27.8	17.0	4.60	27.1	10.6	22.5	5.2	1.29	24.9	2.9	6.9
Burin	4	18.9	2.38	12.6	17.0	22.1	12.5	4.10	32.8	8.9	16.0	4.2	0.78	18.4	3.5	5.0

Table 7.16. Artifact shape ratios and standard deviation and coefficient of variation statistics for the five most common formal tool types at EYM

Type	*N*	**PT/PW**					**PW/W**					**PT/Th**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	1	0.29	-	-	-	-	0.83	-	-	-	-	0.85	-	-	-	-
Notch	4	0.38	0.12	31.6	0.24	0.54	0.45	0.06	13.3	0.36	0.51	0.56	0.08	14.3	0.49	0.68
Scraper	1	0.47	-	-	-	-	0.58	-	-	-	-	0.88	-	-	-	-
Outil écaillé	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burin	1	0.50	-	-	-	-	0.48	-	-	-	-	0.79	-	-	-	-
Site	*N*	**W/L**					**W/Th**					**L/Th**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	22	0.48	0.20	41.7	0.24	1.01	2.84	0.70	24.6	1.44	4.15	6.59	2.32	35.2	2.40	11.4
Notch	11	1.07	0.39	36.4	0.54	1.71	3.15	0.87	27.6	2.07	4.60	3.37	1.43	42.4	1.21	5.08
Scraper	9	0.85	0.46	54.1	0.39	1.98	2.68	0.79	29.5	1.81	4.20	3.68	1.92	52.2	1.62	8.88
Outil écaillé	8	1.01	0.29	28.7	0.77	1.62	3.36	0.92	27.4	2.29	5.21	3.38	0.67	19.8	2.66	4.88
Burin	4	0.66	0.21	31.8	0.46	0.93	3.03	1.13	37.3	1.80	4.44	4.53	0.45	9.9%	3.88	4.86

Table 7.17. Mean platform and size dimensions, and standard deviation and coefficient of variation statistics of the five most common formal tool types at OT

Type	*N*	**External Platform Angle (EPA°)**					**Platform Width (PW)**					**Platform Thickness (PT)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	1	113	-	-	-	-	0.1	-	-	-	-	0.1	-	-	-	-
Burin	16	104	19	18.3	69	131	4.6	3.90	84.8	0.9	16.6	1.9	1.36	70.5	0.4	4.4
Scraper	5	109	21	19.3	72	127	7.2	7.93	110	2.1	21.1	2.8	3.97	140	0.6	9.9
Notch	10	103	12	11.7	84	125	5.1	4.12	80.8	0.1	11.5	1.8	1.45	80.6	0.1	3.9
Combination	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site	*N*	**Length (L)**					**Width (W)**					**Thickness (Th)**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	103	25.4	9.28	36.5	7.5	51.2	8.5	2.40	28.2	3.9	17.0	3.1	0.99	32.5	1.3	6.3
Burin	66	29.1	10.6	36.5	9.7	53.0	13.9	5.70	41.0	5.2	29.4	5.3	2.74	51.5	1.6	16.0
Scraper	34	23.6	11.3	48.0	5.3	54.1	18.4	9.40	51.1	4.6	48.4	6.7	2.98	44.8	2.6	13.4
Notch	29	24.6	11.4	46.1	7.3	45.3	14.3	6.10	42.7	6.0	34.6	4.1	1.52	37.3	2.0	8.6
Combination	22	30.0	10.9	36.3	14.7	52.6	18.6	7.70	41.4	6.3	34.1	6.3	2.79	44.2	2.5	12.7

Table 7.18. Artifact shape ratios and standard deviation and coefficient of variation statistics for the five most common formal tool types at OT

Type	*N*	PT/PW					PW/W					PT/Th				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	1	1.00	-	-	-	-	0.01	-	-	-	-	0.04	-	-	-	-
Burin	16	0.47	0.20	42.6	0.22	0.89	0.31	0.17	54.8	0.09	0.67	0.31	0.15	48.4	0.08	0.59
Scraper	5	0.35	0.14	40.0	0.21	0.52	0.33	0.24	72.7	0.04	0.69	0.35	0.32	91.4	0.10	0.89
Notch	10	0.49	0.28	57.1	0.25	1.00	0.34	0.24	70.6	0.01	0.64	0.47	0.37	78.7	0.03	1.00
Combination	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site	*N*	**W/L**					**W/Th**					**L/Th**				
		Mean	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*	*Mean*	*SD*	*CV*	*Min*	*Max*
Microlith	103	0.37	0.14	37.8	0.15	1.04	2.92	0.74	25.3	1.40	4.77	8.57	2.58	30.1	2.46	15.4
Burin	66	0.54	0.29	53.7	0.24	1.55	2.98	1.42	47.7	0.87	8.33	6.12	2.42	39.5	2.43	11.0
Scraper	34	0.95	0.71	74.7	0.23	3.92	2.92	1.20	41.1	0.96	6.50	3.98	2.28	57.3	1.59	11.3
Notch	29	0.66	0.42	63.6	0.27	1.83	3.63	1.18	32.5	1.56	6.03	6.09	2.60	42.7	2.20	11.3
Combination	22	0.65	0.22	33.8	0.23	1.01	3.12	0.93	29.8	1.41	4.78	5.21	1.87	35.9	2.50	10.4

Platforms on formal tools are also much larger for MD than for EYM and OT reflecting the likely larger starting size of flake blanks compared to blade blanks. Notably, the average sizes of platforms on MD and OT tool types are equal to or larger than those of their respective primary debitage samples. This suggests that knappers at both sites were preferentially selecting the largest flakes or blades as blanks for making tools.

Figure 7.3 provides a visual representation of tool size and shape, showing ratios of tool width/length plotted against thickness for the five most common formal types in each assemblage. Also shown is the mean ± SD for all formal tools combined. Two major points should be noted. First, most tool types from EYM and OT are significantly thinner than those of MD, the notable exception being scrapers. Second, OT types have smaller W/L ratios than EYM types reflecting their narrow blade-like morphologies. The notable exception is EYM microliths, which plot near the microliths of OT. Despite their visual proximity, EYM microliths are still significantly wider and thicker than those of OT using an Independent Samples t-test ($p<0.017$; table 7.19).

Table 7.19. Mean size dimensions for all microlith types from EYM and OT.

Attribute	*EYM (n=22)*	*OT (n=108)*	*t-test*
Length	24.7	25.4	-0.33
Width	11.0	8.5	2.50[#]
Thickness	3.9	3.1	3.43[#]

[#]$p<0.017$ is the adjusted value for statistical significance using the Bonferonni correction.

Confirmation of all three test predictions supports my hypothesis that the shift to microlithic toolkits was accompanied by a reduction in artifact size from the MSA to LSA. Notably, the tendency of OT blades and backed microliths to be longer and narrower than those of EYM suggests that, despite an overall reduction in artifact size between the assemblages, OT knappers appear to have preferred longer blades.

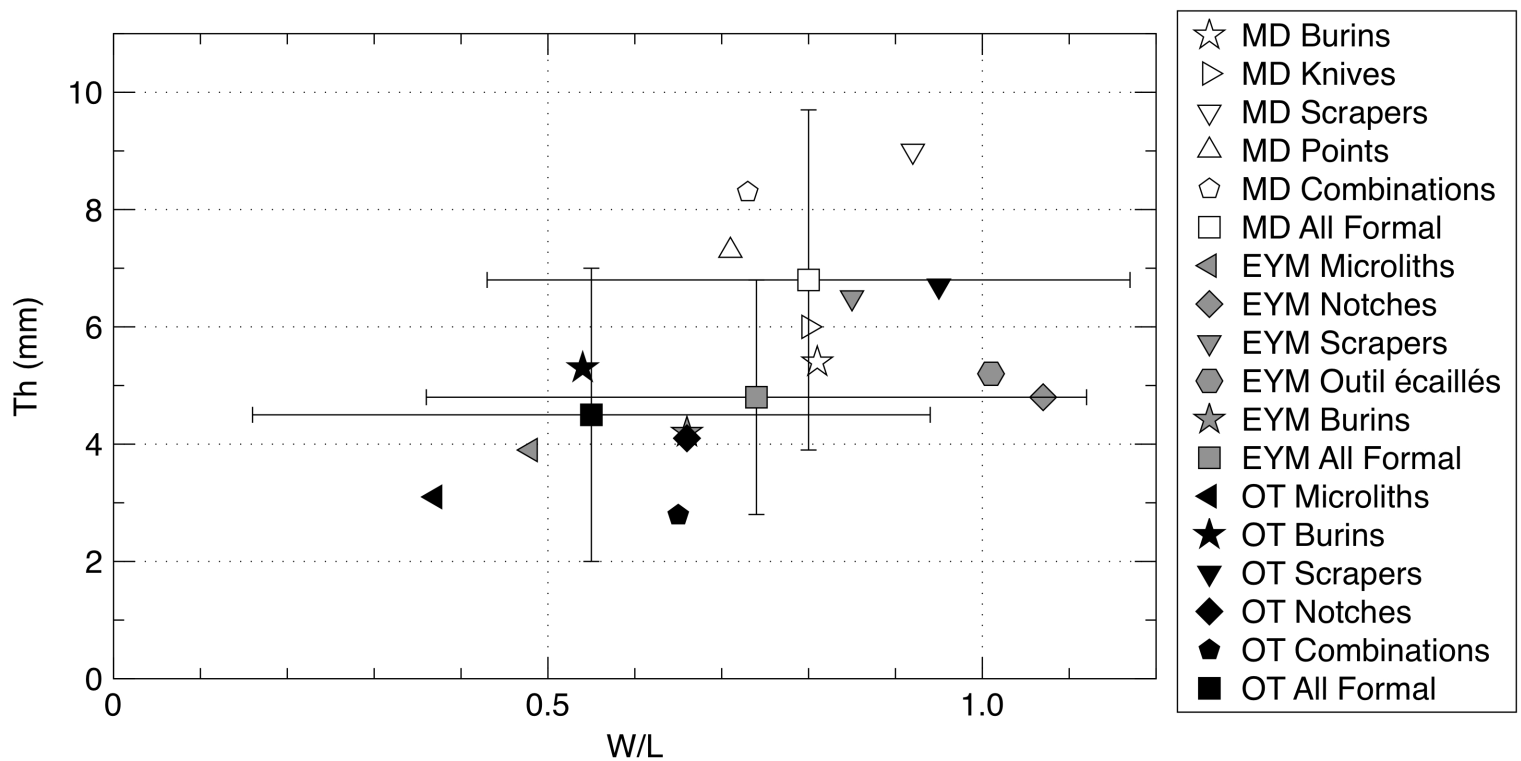

Figure 7.3. Plot of width/length against thickness for the five most common formal types in each assemblage. The mean for all tools combined is represented by the square symbol and the error bars are the standard deviations. Note how EYM and OT tools have similar thicknesses but OT types have reduced W/L ratios meaning that they are generally narrower, except for EYM microliths.

Hypothesis Two: Tool Production

Hypothesis two focuses on tool production: if LSA industries utilized a technological system with a variety of specialized and replaceable mass-produced microlithic tool components while MSA industries produced larger and more morphologically flexible tools individually, then I expect there to be an increase in the diversity of tool types and the degree of tool standardization in the LSA. This expectation is based on the fact that because microliths cannot be substantially reshaped they must be made in the "right" shape (most efficient edge angle and shape) for a given task from the outset, meaning that several different shapes (types) would be required to complete different tasks. Additionally, because microlithic tools are made on inherently fragile blades they need to be made in large quantities (mass-produced) of the same shape (standardized) ahead of time so that replacements can be carried in case of breakage (Bleed, 1986; Hiscock, 2006). Such a tool production strategy is most effective when people have specific knowledge of upcoming tasks because they can produce and carry the most efficient types for those tasks rather than either a large diversity of types for all possible tasks or a few generalized but less efficient types.

The first testable prediction for this hypothesis is that LSA assemblages will have greater formal tool diversity, determined using Simpson's Index of Diversity (SID), than MSA assemblages. Calculations of SID for each site assemblage are presented in two ways: first, with all microlith subtypes combined as a single type (table 7.20) and, second, with microlith subtypes separated (table 7.21). When subtypes are combined SID values drop from MD (0.794) to EYM (0.783) to OT (0.755) indicating a decrease in typological diversity over time. However, when microlith subtypes are calculated separately the trend reverses: the younger EYM (0.881) and OT (0.871) have higher SID values and increased typological diversity compared to MD.

Because MD does not have backed microliths its SID value does not change. The difference between EYM and OT SID values in this second calculation is negligible, but both are much higher than that of MD.

It is clear that backed microliths became the increasingly dominant formal tool type in LSA assemblages, and the analyst's choice of whether or not to combine subtypes impacts the confirmation (or rejection) of this test. In terms of typology, microlith subtypes reflect variation in the way that backed edges intersect with unmodified edges and, presumably, how those pieces were hafted for use. The variety of shapes suggests a diversity of hafting options (e.g. lateral vs. distal inserts) and likely a difference in their functions as well, with certain forms better suited as spear/arrow tips and others for drilling, boring, cutting, etc. Ultimately, the increase in SID values from MD to EYM and OT does appear to reflect a meaningful increase in the diversity of toolkits from MSA to LSA industries, which confirms this test prediction.

Table 7.20. Simpson's Index of Diversity (SID) for formal tool samples from MD, EYM, and OT lithic assemblages with all microlith subtypes combined.

Tool Type	MD		EYM		OT	
	Count	**n(n-1)**	**Count**	**n(n-1)**	**Count**	**n(n-1)**
Microlith[a]	0	0	22	22(21) = 462	103	103(102) = 10506
Scraper	26	26(25) = 650	9	9(8) = 72	34	34(33) = 1122
Notch	5	5(4) = 20	11	11(10) = 110	29	29(28) = 812
Bec	5	5(4) = 20	1	1(0) = 0	5	5(4) = 20
Outil Écaillé	2	2(1)= 2	8	8(7) = 56	7	7(6) = 42
Point	19	19(18) = 342	0	0	0	0
Knife	28	28(27) = 756	0	0	0	0
Burin	57	57(56) = 3192	4	4(3) = 12	66	66(65) = 4290
Combination	20	20(19) = 380	3	3(2) = 6	22	22(21) = 462
Total (N)	162	162(161) = 26082	58	58(57) = 3306	266	266(265) = 70490
1-(Σn(n-1)/N(N-1))	1 – (5362 / 26082)		1 – (718 / 3306)		1 – (17524 / 70490)	
SID Value	0.794		0.783		0.755	

[a]Note that for SID calculations in this table all microlith subtypes combined.

Table 7.21. Simpson's Index of Diversity (SID) for formal tool samples from MD, EYM, and OT lithic assemblages with all microlith subtypes separated.

Tool Type	MD		EYM		OT	
	Count	**n(n-1)**	**Count**	**n(n-1)**	**Count**	**n(n-1)**
Microlith: Crescent	0	0	5	5(4) = 20	27	27(26) = 702
Microlith: Curved backed	0	0	11	11(10) = 110	34	34(33) = 1122
Microlith: Oblique backed	0	0	2	2(1) = 2	17	17(16) = 272
Microlith: Orthogonal backed	0	0	2	2(1) = 2	3	3(2) = 6
Microlith: Longitudinal backed	0	0	0	0	8	8(7) = 56
Microlith: Straight backed	0	0	2	2(1) = 2	14	14(13) = 182
Scraper	26	26(25) = 650	9	9(8) = 72	34	34(33) = 1122
Notch	5	5(4) = 20	11	11(10) = 110	29	29(28) = 812
Bec	5	5(4) = 20	1	1(0) = 0	5	5(4) = 20
Outil Écaillé	2	2(1)= 2	8	8(7) = 56	7	7(6) = 42
Point	19	19(18) = 342	0	0	0	0
Knife	28	28(27) = 756	0	0	0	0
Burin	57	57(56) = 3192	4	4(3) = 12	66	66(65) = 4290
Combination	20	20(19) = 380	3	3(2) = 6	22	22(21) = 462
Total (N)	162	162(161) = 26082	58	58(57) = 3306	266	266(265) = 70490
1-(Σn(n-1)/N(N-1))	1 – (5362 / 26082)		1 – (392 / 3306)		1 – (9088 / 70490)	
SID	0.794		0.881		0.871	

The second test prediction for this hypothesis was that primary debitage and formal tools from LSA assemblages will be more standardized, meaning less variable in size, than those of MSA assemblages. Data on primary and secondary debitage, blades, and formal tool size dimensions, standard deviations, and coefficients of variation (CV) for all assemblages are presented in tables 7.3 – 7.5 and 7.13 – 7.18. For primary debitage platforms, CV values for platform width (PW) and platform thickness (PT) are lowest for MD (74.6-77.2%) and highest (106-110%) for OT. The large CVs for OT are a factor of the consistent abrasion on the platforms of OT blades, which often manifests itself as point platforms (measured as 0.1 mm W and 0.1 mm PT) on detached pieces. The preponderance of point platforms in OT debitage makes the mean very low so that even when small non-point platforms are incorporated the result is a low mean with a very high SD and CV. Due to the lack of point platforms in EYM primary debitage, platform CVs are more similar to those of MD. This same pattern is observed for EYM and OT blades when they are calculated separately.

In terms of flake size, the CV value for length is ≥14.8% greater for MD primary debitage compared to either EYM or OT (61.8 vs. <0.47%), while CV values for width and thickness are within 7% of each other among all three sites. MD primary debitage clearly has greater variability in length, but is quite similar for width and thickness variability. When CV values are calculated separately for EYM and OT blades, they drop substantially across all three dimensions by an average of 10.1% for both sites, indicating that both site's blade sub-samples have greater standardization than the primary debitage samples as a whole. Notably, differences in CV values for EYM and OT blade size dimensions are less than a 2.5% for all but PW and PT. This means that, despite statistically significant differences in means, the younger OT blades are no more size standardized than EYM blades, but both are more standardized than MD debitage.

Formal tools present a murkier picture of standardization, with each site assemblage containing some types with high CV values (>45%) for length, width, and thickness, while other types have low CV values (<35%) for those dimensions (tables 7.13 – 7.18). For MD, point CV values are all ≤27.2% and indicate that this is the most standardized type; qualitative observations of retouch, such as order of removal, support this conclusion. CV values for knives are also all quite low (<33.1%) while burins have the highest CV for length, width, and thickness. For EYM, burins and outils écaillés both have CV values ≤33.4% for all three dimensions, while microliths and scrapers, types that are typically associated with more distinct standardized forms, have all CV values between 37.8-46.2%. For OT, microliths have the lowest CV values, ≤36.5% for all linear dimensions; this is lower than any CV for EYM microliths and indicates greater standardization in the younger OT assemblage for this type. Beyond microliths, no other type in the OT assemblage has more than one linear dimension with a CV lower than 40%. This is significant point because it suggests that there is actually equal or greater morphological standardization in the older EYM and MD formal tool samples.

Ultimately, this second test prediction is partially confirmed. Primary flaking debitage from MD had the highest CV for flake length and relatively equal values to EYM and OT for width and thickness. However, when blades were calculated separately the two younger LSA assemblages had much lower CVs (by about 10%) and are clearly more standardized. For formal tool types CVs are collectively lowest for MD types, and points in particular, suggesting equal or greater size standardization to the LSA assemblages.

For the second hypothesis, test prediction number one was confirmed but number two was rejected. Both of the LSA assemblages had greater typological diversity than the older MSA assemblage at MD. However, despite greater standardization of primary debitage (blades in particular) in both LSA assemblages, formal tools in the youngest LSA assemblage (OT) displayed equal or less standardization than those of the older EYM and MD. Ultimately, these tests partially confirm my hypothesis that there would be an increase in overall typological diversity and the degree of tool morphological standardization in the LSA compared to the MSA.

Hypothesis Three: Tool Curation

Hypothesis three focuses on formal tool maintenance and discard (i.e. curation): if MSA industries are more highly curated than LSA industries, then I expect less tools, more retouch flakes, and tools with longer use-lives in MSA assemblages, while LSA assemblages should have the contrast. This is because larger and thicker tools can be used, resharpened, and/or modified expediently for different functions. Due to their larger volume and potential for resharpening assemblages relying on these types of tools should contain large amounts of retouch debitage. Such tools should also have a high intensity and large diversity of use-wear traces from their long use-lives. This expectation is based on TO theory regarding the curation of large, flexible, and versatile tools buffers against the risk of technological failure in situations of opportunistic (i.e. unplanned) foraging. In contrast, microlithic industries primarily contain thin-edged blade tools, which are fragile and have little potential for resharpening or transformation. Such tools act as disposable components and large quantities should be produced ahead of time for replacing dull or broken ones. Assemblages relying on these types of tools should have low percentages of retouch debitage. Finally, due to their short use-lives microlithic tools should have a low diversity and low intensity of use-wear traces.

The first test prediction for this hypothesis was that MSA assemblages would have fewer formal tools than LSA assemblages. This prediction was partially confirmed because the total percentage of shaped formal tools is actually lower for EYM (1.8%) than MD (2.0%), however both have less then one-third of that in the OT assemblage (7.3%). Burins, knives, scrapers, and points characterize the MD assemblage. These types were primarily made on medium to large flakes and shaped with invasive soft-hammer retouch. Burins are the overall most common type, however, these are also the most morphologically variable, likely a factor of the versatility of the burin blow for producing a tool bit/edge that may serve a wide variety of cutting, boring, scraping, grooving and incising functions, as shown by Cahen et al. (1979) at Meer. The sample of points in H5 represents the most obvious attempt by knappers to create a specific tool design, with a thinned bulb of percussion, low and wide shoulders (i.e. base or butt) and a wide or transverse bit. In H4, samples of oval scrapers (bit shape, edge angle, and the overall artifact plan shape) and Helwan backed knives (consistent retouch technique and location, and edge morphology) also display remarkable uniformity in their morphologies. Together, these three types suggest that MD knappers were focused on creating and maintaining consistent typological forms for certain tools.

For EYM, backed microliths, notches, scrapers, and outils écaillés characterize the assemblage. Backed microliths are primarily geometric crescents and curved-backed forms. These have a relatively large size range with a 50 mm difference in length between the smallest and largest complete pieces. Some of the microliths from GG1 retain traces of red ochre on their backed edges and medial surfaces, which was presumably used in conjunction with hafting adhesives. Notches and scrapers, despite being made primarily on blades (determined by arête and retouch patterns) only have mean W/L ratios of 1.07 and 0.85 respectively, meaning that they were segmented and/or retouched extensively along their flaking axis. For comparison, microliths have a W/L ratio of 0.48. Finally, based on the identification of outils écaillés, bipolar cores, and bipolar flakes, some of which were utilized, bipolar reduction must be considered an important technological strategy.

In the OT assemblage, formal tool types are overwhelmingly made on blades, including microliths, burins, scrapers, and notches. Remarkably, there is a greater percentage of microliths in the OT assemblage (2.8%) than EYM (1.8%) and MD (2.0%) have when all tools are combined. These come in a variety of subtypes of which curved backed and geometric crescents are the most common. Burins are the next most common type and have two variations: a traditional burin blow on a blade snap that creates a thick, robust bit, and a transverse or plàn blow across the ventral face of a thinner blade. Finally, convex end scrapers and notches similar to concave scrapers are also common types. Similar to those of EYM the convex end scrapers have a mean W/L ratio of 0.95, meaning that they have been retouched extensively before discard.

On a related note, the percentage of informal casually retouched tools increases over time from MD (0.96%) to EYM (2.4%) to OT (3.6%). It is important, however, to consider the physical context of the three sites as a possible cause for this increase; both EYM and OT are rockshelters whereas MD is open-air. The DBL1.3 level at EYM and spit 17 at OT have extremely high artifact densities, fragmented and burned bone, and in the case of OT, burned obsidian. The constrained area for occupation in both rockshelters could have increased the potential for trampling damage on artifacts and generated confusion with intentional retouch. In contrast, Marmonet Drift is an open-air site, with no obvious physical features to constrain activities to a small area. High densities of artifacts in H4 and H5 across nearly 100 meters of the outcrop show that this area was regularly occupied and hosted a diverse, spatially structured suite of activities. The larger occupation area could have reduced the intensity of artifact trampling. In order to conclude trampling as the primary cause for the increase in casually retouched pieces, however, further analysis is required: if more casually retouched artifacts at EYM and OT were the result of trampling than at MD, then there should be higher frequencies of randomly distributed edge damage on such pieces.

The second test prediction for this hypothesis was that MSA assemblages would have higher ratios of retouch debitage to tools than LSA assemblages. This prediction was confirmed. First, a chi-square test of independence shows that the proportion of retouch flakes relative to the total analyzed sample is significantly larger for MD compared to both EYM and OT ($\chi^2_{(2)}$ = 313.9, p<.001). Second, the ratios of retouch flakes to formal tools dramatically reduce from MD (7.6:1) to EYM (4.6:1) to OT (0.7:1). Based on these data, it is clear that MD knappers were retouching their tools to a significantly greater extent than at either EYM or OT.

Beyond the straightforward amounts of retouch debitage, the distribution of retouch flake subtypes is also quite different among the three sites (table 7.22). For example, MD has a wide variety of distinct retouch types, including: general retouch, edge removal, bulbar trim, biface trim, and scraper trim. In contrast, EYM and OT retouch flake samples are both dominated by general retouch and scraper trim subtypes. Additionally, over 44% of MD retouch flakes retain lipped platforms indicating consistent use of a soft-hammer such as bone, wood or horn. Biface retouch is also extremely common at MD (10.4%). Both of these features are almost completely absent in the EYM and OT samples indicating less focus on tool shaping and maintenance, and fewer bifacial tools.

Table 7.22. Distribution of retouch flake subtypes

Retouch Sub-Type	MD		EYM		OT	
	N	%	N	%	N	%
General retouch	981	80.0	247	93.2	139	78.1
Edge removal	87	7.1	0	0.0	0	0.0
Bulb trim	23	1.9	0	0.0	0	0.0
Scraper trim	8	0.7	16	1.3	37	20.8
Biface trim	128	10.4	2	0.8	2	1.1
Total	*1227*	*100.0*	*265*	*100.0*	*178*	*100.0*

The third test prediction for this hypothesis was that MSA formal tools would have greater intensity (multiple use sessions) and diversity (multiple functions) of use-wear traces than LSA formal tools. MD tools subjected to use-wear analysis included points, scrapers, knives, and casually retouched pieces. A large variety of different use-wear features were observed, including: edge rounding, striations, abrasion, and microflaking, which also had multiple termination types, directions, and invasiveness. The assortment of features observed suggests that MD tools were, collectively, used in a multitude of ways such as sawing, slicing, scraping, piercing, and as projectiles. Notably, evidence for two or more functions on a single tool was not observed in the analyzed sample and certain types appear to have played specific functional roles. For example, the proximal ends (base) of points overwhelmingly displayed evidence for hafting while distal ends (bit or point) preserved use-wear features indicative of piercing as thrown or thrust projectile, including impact fractures, and/or cutting. A similar pattern was observed for scrapers, where the proximal ends typically have lateral striations and surface abrasion suggesting that they were hafted while the distal ends have edge rounding and longitudinal striations consistent with use as scrapers on soft worked materials.

Evidence for the longevity of MD tool use-lives was reflected in the high density of striations and microflaking on the ventral faces of artifacts, which indicate that most went through several stages of use and maintenance. Dorsal surfaces typically had fewer use-wear features because earlier edges had been removed by retouch. Put another way, ventral faces accumulated use traces throughout the tool's entire life history, while the dorsal surface preserved traces that accumulated only since the previous bout of retouch. Overall, these results suggest that MD (MSA) tools had long use-lives and that specific types, particularly knives, scrapers, and points were used for specific functions.

Tools subjected to use-wear analysis from OT included backed microliths, one scraper, and one notch. The most notable observation for microliths was that they typically had very little, if any, visible damage on their unmodified edges even under low magnification (≤10x). However, this does not necessarily constitute a lack of use. Considering that two artifacts used on soft materials from my own blind tests did not generate visible edge damage it is plausible that some of these archaeological pieces were used but did not generate use-wear traces. I selected five microliths with more obvious damage for high magnification SEM analysis, and concluded that four (80%) had been used for slicing or sawing actions. One piece retained two dark residue blobs and crushing on an arête that suggest it was hafted. No microlith edges were retouched suggesting that they had relatively short use lives. The end scraper observed with SEM was clearly used for scraping a soft material with some gritty particles. The intense vertical stepped microflaking and edge rounding present on its distal (bit) end was also visible on several other scrapers in the OT sample, suggesting that they had been used in a similar fashion. Many of these scrapers were recovered as small stubby forms (see figure 6.18) despite having been made on blades and so they had likely been used and resharpened along their entire length meaning that they had long use lives.

To conclude, all MD tool types were found to have a high intensity of use-wear features and appear to have been used and retouched several times. For OT, different types appear to have been designed for different use durations; scrapers were used and retouched for as long as their length allowed while backed microliths were never retouched and likely were replaced with a new component when they became dull. Notably, individual tools from MD did not have a greater diversity of traces than those from OT; instead tools from both sites only displayed traces from one function. It is possible that tools from either site were used on more than one material or for more than one function, but I was not able to identify it. Ultimately, this test prediction was partially confirmed because use-wear diversity was found not to have decreased from MD to OT, but that all MD types were used and retouched for multiple use sessions while only scrapers were for OT.

For the third hypothesis, test predictions numbers one and three were partially confirmed, and the second was confirmed. The percentage of tools jumped dramatically in the OT assemblage (~7%) while MD and EYM were essentially the same (~2%). Retouch debitage was a significantly higher percentage of the MD assemblage and ratios of retouch flakes to formal tools dropped continuously from MD to EYM to OT. Use-wear analysis of formal tools showed that, except for scrapers, the length of artifact use life decreased from the MSA to LSA. However, tool types from all three sites appear to have been used for specific functions and the diversity of use-wear traces was not higher on individual MD tool types. Ultimately, these tests lend moderate to strong support for my hypothesis that tool curation would decrease in the LSA compared to the MSA.

Discussion: Technological Organization Strategies and Planning

The three hypotheses that I tested in this chapter were designed to identify quantitative and qualitative differences between MSA and LSA lithic TO strategies in order to determine whether LSA stone tool industries represent enhanced technological planning compared to the preceding MSA. Based on my analyses of artifact assemblages from the MD, EYM and OT archaeological sites there are three main areas that encompass those differences: artifact size and shape, tool production techniques, and tool curation strategies.

The most obvious physical trends observed across these three assemblages were the reduction of artifact size and adoption of blade-based toolkits. The size of debitage and tools decreased significantly from MD to EYM, specifically becoming shorter, narrower, and thinner. These size and shape changes reflect the transition from flake-based to blade-based toolkits at the beginning of the LSA. The size reduction trend was also observed within EYM itself; debitage and tools from the older GG1 horizon are larger than those of the younger DBL1. Debitage from OT showed a substantial increase in the overall production of blades, from about 20% in EYM to 45% in OT, confirming the transition to a fully blade-based industry during the LSA. This increased production rate of blades at OT was accompanied by a reduction in primary debitage width and a slight increase in length.

Many of the observed differences in artifact size and the transition from flake (MD) to blade-based (EYM and OT) industries are a function of fundamental changes in how knappers shaped cores to produce 'blanks' for formal retouched tools. At the most basic level the size, shape, number, and location of platforms on a core influence the size, shape, and number of tool blanks that can be produced from it. For MD, blocky radial or tabular cores with multiple platforms were preferred by knappers for producing medium to large flakes, which had a high potential for curation and physical transformation over a long use-life. Production of new tool blanks may have been done individually (on-demand) and as needed to replace old worn out tools, or several large blanks may have been produced at the quarry or on-site from large cores, but replaced less often due to their greater potential resharpening lifespan (Eren et al., 2008).

MD knappers then shaped these flake blanks into consistent formalized types, including points, knives, and scrapers. Typically the initial blank had a large (thick and wide) platform that was thinned and a body, or edge(s), which was shaped with invasive retouch. Over 44% of small retouch flakes in the MD assemblage retain a lipped platform indicating the use of soft-hammers while the mean EPA is less than 60° indicating that existing retouched edges were already thin. Furthermore, the combination of a low percentage of formal tools, a high ratio of retouch flakes to formal tools, and the high density of use-wear traces on the ventral faces of artifacts substantiate the claim of a TO strategy focused on the curation of few, large, and long-lived tools. This technique of retouch/shaping eventually resulted in relatively standardized tool forms that are a function of their long use-lives and several resharpening bouts, rather than derivation from standardized flake blanks from cores. Overall, the flexibility and versatility of this kind of toolkit is high and suggests low levels of planning, but high adaptability, for future tool use activities by MD knappers. Kuhn (2011) proposed the concept of "planning for the unplanned" for this large flake-based strategy in the European Middle Paleolithic where the manufacture of large, flexible, and versatile tools could be used for a variety of unanticipated activities.

For EYM and OT, tool production strategies focused on using standardized blades as blanks for formal tools. EYM blade cores were most often made on truncated tabular flakes with a single faceted platform from which several blade blanks were removed. This technique is quite different from that of OT blade cores, which were typically prepared with either a single large facet (i.e. plain platform) or two opposed platforms from which consistently sized blades were removed. These core platform edges were heavily abraded between each blade removal, resulting in plain or point platforms with substantial DPF and extremely steep EPAs, averaging over 100°. For both EYM and OT blade cores, opposed platforms are also common, providing knappers with more platform area to exploit arêtes from previous removals. In effect, many blades can be produced in rapid succession after one initial stage of core platform and arête preparation. Notably, the heavy reliance on blade DPF abrasion and point platforms by OT knappers, compared to EYM's larger faceted platforms, may represent a small-scale improvement in production by further reducing platform waste (more core platform remains for subsequent removals) and allowing knappers to obtain even more blades from a single core. Such a production strategy is especially useful for quickly producing large numbers of standardized blade blanks that were then shaped into various formal tool types, such as microliths and scrapers. Notably, it appears that blanks were differentially selected for making different types based on their size, shape, and potential for retouch. Scrapers were typically made on larger, thicker blades while smaller, thinner blades were used for microliths

As a general rule, blades must be made in large quantities because they are relatively (compared to flakes) thin and fragile, and have a low potential for retouch. This combination of high production rate, standardization, and fragility means that blade tools lend themselves to being made, used, and replaced more quickly than flake tools. Use-wear analysis of OT microliths certainly supports this, showing that they were either lightly used and discarded or not used at all and held for future use. End scrapers represent the primary curated tool type in both the EYM and OT assemblages. This is evinced by the secondary debitage retouch flakes, which are typically short, wide, have a steep EPA, and retain use-wear on the platform and dorsal proximal area. Scrapers from both EYM and OT are overwhelmingly made on blades, but relative to other blade tools such as microliths are wider and thicker, suggesting differential blank selection for formal types and highly planned production sequences. Scrapers were retouched almost exclusively along their maximum dimension (i.e. length) because there is so little volume to exploit in terms of their width and thickness (Eren et al., 2008; Shott and Weedman, 2007). Technically, backing on microliths counts as width or thickness retouch, however, because its purpose is to dull an edge, rather than resharpen, it does not serve to extend the use-life of the piece. Therefore, the widths and thicknesses of blade tools are much less likely to dramatically change during their use-lives.

Retouch on the blade's long axis, however, can continue until it is too short for its haft. For example, if a fresh end scraper on a blade is 40 mm long and retouch flakes 1-2 mm thick are removed from the bit-end then there should be about ten resharpening sessions available before the length is reduced to 20 mm and the piece is discarded (20 mm is slightly less than the average length of discarded scrapers at OT). Such a reduction pattern was observed ethnographically by Shott and Weedman (2007: 1023) with the Gamo of Ethiopia. Notably, they found that retouch flake sizes from individual resharpening sessions differed depending on when in the sequence they were removed. Earlier resharpening sessions reduced blade/scraper length by ~4 mm while later ones reduced length by 2-2.5 mm. Width was found to change only during the initial stage of production when the scrapers were retouched laterally to fit a haft. Maximum thickness never changed, while distal thickness at the bit increased as the piece was shortened towards the slightly thicker proximal end of the blade.

This allometric pattern of morphological change due to retouch certainly differs from what is observed at MD, where tool morphology changes in a more uniform fashion because retouch flakes are long and driven of far across the piece. This invasive flaking technique executed by the MD knappers reduces the thickness of the tool as well as length and/or width, and when pieces are retouched around the entire perimeter. Many MD points, scrapers, and knives were reduced in three dimensions simultaneously. Notably, over many stages of retouch, this retouch technique has the effect of size standardizing the discarded forms, as shown by similar CV values for MD points and EYM/OT microliths, because they are reduced to small and stubby forms. However, standardization of flake tools through extensive retouch is not necessarily an intentional goal on the part of the knapper but a factor of the longevity of use-life. In contrast, blade production is organized from the outset to produce standardized blanks that are only minimally retouched and so the standardization that I observed with EYM and OT blades can be considered intentional. This suggests that the adoption of blade-based toolkits and the associated TO strategy of the LSA represent enhanced planning relative to the earlier flake-based industries of the MSA.

In conclusion, it is apparent that lithic TO strategies changed dramatically over time from the MSA to LSA in aspects of artifact morphology, production, and curation. Collectively, these changes represent an overall increase in the level of technological planning on the part of LSA toolmakers providing a “yes” answer to my second research question. Ultimately, the transition from an ‘on demand’ strategy of flake-based blank production to a more systematic blade-based production strategy allowed LSA knappers to better organize and plan their use of technology as a whole, and in particular to create standardized tool blanks for specific tool forms in advance of, presumably, known tasks.

Chapter 8

Summary and Conclusions

Fossil and genetic evidence indicate that anatomically and behaviorally modern humans evolved in Africa during the Middle Stone Age (MSA) sometime after 200 ka (Harpending et al., 1993; McDougall et al., 2005; Shea et al., 2007; Behar et al., 2008). There is a firm consensus that these African populations are the direct ancestors of all humans on Earth today (Endicott et al., 2010; Blum et al., 2011; Veeramah and Hammer, 2014). Three broad questions that remain unresolved by archaeological evidence are when, how, and why these biologically modern people began to behave in fully modern ways. Archaeological evidence indicates that many of the behaviors that paleoanthropologists cite as characteristic of fully modern humans emerged piecemeal across Africa during the mid-late MSA and early Later Stone Age (LSA) (Clark, 1992; McBrearty and Brooks, 2000; McBrearty, 2013), rather than as a 'behavioral revolution' at a single point in time (Mellars and Stringer, 1989; Klein, 2008). The transition from 'archaic' to 'modern' human behavior (MHB) includes significant changes in lithic technological organization (TO) strategies (Ambrose, 2002; Lombard, 2012; Porraz et al., 2013; McCall, 2007; Mackay et al., 2014), socio-territorial organization (Clark, 1988; Ambrose and Lorenz, 1990), faunal exploitation patterns (Klein, 2001; Weaver et al., 2011), and cognitive capabilities, especially related to symbolism and planning (Ambrose 2001, 2010; Henshilwood and Marean, 2003; Watts, 2010; Texier et al., 2013; Henshilwood et al., 2014).

This dissertation examined one aspect of the modern human behavioral transition, the evolution of lithic TO strategies from the MSA to LSA and the implications of those strategies for human planning capacities during that time period. The significance of the relationship between planning and technology for human behavioral evolution was originally proposed by Binford (1989) and later expanded by Ambrose (2002, 2010) and, most recently, McCall (2007; McCall and Thomas, 2012). The main thrust of these arguments is that humans make decisions about what tools they will need for future situations based on the type, quality, and timeliness of information that is available to them. With more specific and reliable information they can make better decisions and plans, and reduce the risk of failure to achieve planned objectives. This is fairly straightforward but also extremely important for understanding how humans organize their technology. Humans are habitual tool users, and carry tools that may be useful for whatever activities are encountered, regardless of whether they are planned or unplanned. The hand-held Acheulean handaxe may be the ultimate tool for all seasons because it has large sharp heavy-duty cutting edges and can serve as a core for smaller flake tools. This versatile and flexible but bulky all-purpose toolkit was replaced by a variety of smaller, lighter flake-based hafted tools in the MSA and LSA (Ambrose, 2001a). However, mobile foragers cannot carry their entire toolkit around with them and so they must make strategic decisions regarding toolkit composition in order to balance the goals of minimizing time, energy expenditure (Torrence, 1983, 1989; Eren et al., 2013), toolkit weight and size (Kelly, 1988; Kuhn, 1994; Morrow, 1996), and risk of failure (Bamforth and Bleed, 1997; Bousman, 2005; McCall, 2007). To reduce the risk of technological failure, such as having the wrong size, shape or kind of tool to complete a task, humans use the information available to them to plan ahead and to bring the appropriate tool(s) for the situation.

As a modern day example, if you are packing for a vacation to the Arctic Circle to go whale watching in November you will plan for cold and wet weather by bringing waterproof boots, a parka, gloves, hat, and other cold-weather or waterproof gear. If, for some reason, you were going on vacation but did not know where you were going you would have to pack clothes for a variety of hot/cold/wet/dry weather conditions in order to be prepared. You might bring pants with zip-off legs or many thin shirts that could be worn individually in hot conditions or layered together in cold conditions. The point of this example is that for an unplanned future you need to account for all possible events by bringing a large, adaptable, and transformable toolkit (or suitcase). In a situation where you know where you are going and what you are going to do then you can plan accordingly by bringing tools that are purposely designed for a specific task.

Continuing with the topic of technological planning in prehistory, Ambrose (2002, 2010) proposed that late MSA and LSA modern humans were better able to plan the use of their technology compared to their earlier MSA ancestors. This proposition is predicated on the notion that at some point after ~100 ka modern humans developed enhanced intergroup social information-sharing networks among dispersed hunter-gatherer groups. These networks are thought to have integrated local groups into a cooperative social landscape that permitted accurate and up-to-date information to be shared among dispersed hunter-gatherer groups (Ambrose and Lorenz, 1990; Gamble, 1998; Ambrose, 2002; McCall, 2007; McCall and Thomas, 2012; Mackay et al., 2014). The sharing of up-to-date information about resource availability and environmental conditions is thought to have facilitated more strategic planning of tool-using activities with mechanically efficient tools designed for specific tasks (Torrence, 1983; Bleed, 1986; Ambrose, 2010; McCall and Thomas, 2012). If this is true, then late MSA and LSA sites should contain lithic assemblages that reflect increased levels of technological planning compared to older MSA sites. In this dissertation I addressed the evolution of planning and technology with two research questions:

1. How did lithic TO strategies change from the MSA to LSA?

2. And do LSA TO strategies represent enhanced technological planning relative to the preceding MSA?

I answered these two research questions by first examining the current state of knowledge regarding the modern human behavioral transition in general and, more specifically, the technological transition between the MSA to LSA. Second, I analyzed lithic artifact assemblages from three archaeological sites in Kenya's central Rift Valley that date from >110 – 19 ka and span the MSA/LSA boundary. The sites are: Marmonet Drift (MD), dated to the MSA between >110 and ~94 ka; Enkapune Ya Muto (EYM), dated to the early LSA between ~55 ka and <40 ka; and Ol Tepesi (OT), dated to the middle LSA ~19 ka. Finally, third, I tested three hypotheses using data from my analyses concerning long-term changes in artifact morphometrics, production, and curation (i.e. TO strategies) as reflections of planning from the MSA to LSA.

In order to determine whether one artifact assemblage reflected a higher or lower level of planning than another it was necessary to understand what planned and unplanned toolkits look like. To do that I used the theoretical framework of technological organization, which attempts to explain what, how, and why stone toolmakers use different strategies (a.k.a. lithic TO strategies) in different situations. Planning, based on the availability and timeliness of information, is a critical part of technological choices. For the Stone Age technological planning can be thought of in terms of opportunistic vs. scheduled foraging. Humans who are opportunistically foraging should be simultaneously prepared for several contingencies in order minimize the risk of failure. In essence they are planning for the unknown, which TO theory suggests favors a flexible toolkit that can be modified for several contingencies (Nelson, 1991; Morrow, 1996; Hiscock, 2006; Ambrose, 2010). Large and thick tools, such as most of the points, knives, and scrapers found in the MD site assemblage have great potential be modified through retouch to produce different edge angles and shapes (Shott, 1989; Nelson, 1991; Eren et al., 2008; Andrews et al., 2015). A high percentage of small retouch debitage found in the MD assemblage (>15%) confirms that these long-lived tools were being intensively maintained.

It is notable that, despite their large overall size and intense retouch, MD points and to a lesser degree scrapers were highly standardized in terms of both quantitative and qualitative features and functions. Standardized qualitative features of points include a thinned bulb of percussion, low and wide shoulders (i.e. base or butt), and a wide or transverse bit. This type also had coefficient of variation (CV) values for length, width, and thickness dimensions that were lower (more standardized) than those of LSA microliths from EYM and OT. Despite having greater size variability than points, oval scrapers and Helwan backed knives also displayed remarkable uniformity in their qualitative morphologies, including retouched bit/edge shape and angle, retouch technique, and overall artifact shape. Use-wear analysis of these different types also showed that each type was used for a different function. Together, these data indicate that mid-late MSA knappers were capable of creating distinct formal tool designs for specific functions, while still retaining flexible and versatile forms.

A TO strategy of few formal tools and technological versatility and flexibility characterizes most MSA industries across Africa and those of Middle Paleolithic (MP) Eurasian Neanderthals (Kuhn, 1992a, 2011; Uthmeier, 2005; Tryon et al., 2006; White et al., 2011). These industries typically contain few tools, unmodified blanks, or cores, but have many small retouch flakes indicating high levels of artifact maintenance, long use-lives, and potential for adaptability to unplanned events. Retouched points, considered to be the *fossils directeurs* of the MSA/MP, are found in almost all assemblages after 150 ka, and show regional variability that suggests the development of distinct cultural traditions during the late MSA (Brooks et al., 2006; McBrearty, 2013).

The appearance of such distinct cultural traditions is often recognized as a key event in the evolution of modern human social behavior (Clark, 1988; Gamble, 1998; McBrearty and Brooks, 2000; Henshilwood and Dubreuil, 2011) and stylistic designs of technology could have provided a useful mechanism for creating and reinforcing social identities, to both members and outsiders of a group (Wiessner, 1985; Wobst, 1999). Many MSA industries, including the Aterian (Scerri, 2013), Nubian (Van Peer and Vermeersch, 2007; Rose et al., 2011; Usik et al. 2013), Still Bay (Wadley, 2007; Villa et al., 2009; Lombard et al., 2010), Howiesons Poort (Villa et al., 2010; Henshilwood and Dubreuil, 2011), Emireh (Marks and Kaufman, 1983; Copeland, 2001), and Sibudan (Conard et al., 2012) among others, are synonymous with their consistent production techniques and morphologies of their points and are considered distinct cultural entities. This is significant in the context of the Marmonet Drift H5 assemblage because of the apparent repetitive design of points and their associated debitage. Ultimately, this assemblage appears to represent a previously undocumented style of points in the region, and may represent the particular style of a social group. Excavations at similarly dated sites in this region are needed to determine if this represents a larger regional and temporally restricted stylistic zone or Tradition. Regardless, at this time the H5 assemblage is distinctive enough to warrant naming a new local industry, the Marmonet H5 Industry, within the MSA of East Africa.

The Marmonet Drift H4 assemblage is also notable, but for its convex end scrapers and Helwan backed knives, both of which have samples of morphologically and stylistically distinct forms. The scrapers are unique based on their oval-shape with convex retouched bits. Use-wear evidence on a sample of four suggests that they were hafted and used for scraping the same soft material, possibly hides. The knives are also unique based on their specialized type of Helwan "backed" retouch. This feature has not been reported in other MSA industries. Similar to H5 this assemblage represents two previously undocumented artifact morphologies in this region, and may represent the particular style of a social group. Excavations at similarly dated sites in this region are needed to determine the possible temporal and geographic range. Ultimately, it is distinctive enough to warrant naming a new local industry, the Marmonet H4 Industry, within the MSA of East Africa.

My analyses of LSA industries from EYM and OT show a dramatically different TO strategy from that of the MSA at MD. First, there was a significant reduction in the size of debitage and tools from MD to EYM/OT that accompanied the shift from a flake-based to blade-based production sequence. The size reduction is important because it means that tools were generally smaller, with less potential for retouch or transformation. Smaller tools, especially blades, are better suited for short use-lives and replacement after use rather than resharpening (Eren et al., 2008). Due to their low potential for retouch and transformation they are considered to reflect production for specific planned tasks (Bleed, 1986; Ambrose, 2002).

Second, both industries at EYM contained less blade related debitage (29.7% for GG1 and 13.9% for DBL) than OT (45%) and show continued production, particularly in DBL, of more intensively retouched tools such as large outils écaillés and bifacially retouched knives (Ambrose, 1998a). Blades and microliths from both EYM industries were also significantly wider and thicker than those of OT suggesting that there may have been a shift in size preference for tool blanks as toolkits changed in response to available information. It is not surprising, considering their medial age, that the EYM industries contain combinations of MSA and LSA technological features. Other regional industries or sites in East Africa that date to this same period between roughly 55 and 35 ka, such as those in Tanzania (Mumba, Nasera), Ethiopia (Mochena Borago, Goda Buticha), or Kenya (Ntumot, Lukenya Hill, Prospect Farm, Prolonged Drift), also contain similar combinations of technologies that suggest substantial inter and intra-regional variability in the timing and adoption of LSA microlithic industries (Merrick, 1975; Gramly, 1976; Anthony, 1978; Mehlman, 1989; Ambrose, 2002; Diez-Martin et al., 2009; Brandt et al., 2012; Pleurdeau et al., 2014; Tryon et al., 2015). It is notable that the earliest microlithic industry in South Africa, the Howiesons Poort (HP), occurs during the late MSA from 72-60 ka (Brown et al., 2012) but is replaced by more conventional non-blade MSA after 60 ka (Wadley and Jacobs, 2006; Conard, 2012). It is not until after ~25 ka with the Robberg industry that the MSA/LSA technological transition to blade-based LSA technology actually occurred, much later than in East Africa.

Third, differences in the production techniques for blade and flake tools in MSA and LSA industries account for observations regarding standardization of tools. For example, distinct formal types are clearly recognizable in many MSA industries and, in the case of MD points, even show similar degrees of size standardization as LSA microliths from EYM and OT. However, standardization of MD tools is derived from long use-lives and extensive retouch rather than the production sequence of tool blanks that are not repeatedly retouched, as is the case for blade-based tools other than end scrapers. Additionally, the higher production rate of blades contrasts with the slower paced production of radial or Levallois core flake blanks observed at MD, and for the MSA in general (Bleed, 1986; Bar Yosef and Kuhn, 1999; Belfer-Cohen and Hovers, 2010). It is likely that the ability to quickly produce standardized blank forms and resulting tool components made microlithic industries an attractive technological adaptation in the context of planned foraging tasks, which has been proposed for the late MSA and LSA.

The mass-production and standardization of small microlithic components would have allowed LSA humans to quickly replace the most brittle components of composite tools, the sharp stone edges, and suggests that they were designed for use as disposable inserts in composite tools (Ambrose, 2002; Hiscock, 2006; Eren et al., 2008; McCall and Thomas, 2012).

Fourth, differences in blank production and artifact size clearly influenced TO strategies of tool maintenance and curation in the MSA and LSA. For MD and other MSA industries, toolkits are characterized by low levels of tool blank production and high levels of tool curation whereas high levels of blank production and low levels of tool curation characterize LSA assemblages. Put simply, more tools were produced in LSA assemblages but they were used for shorter durations. End scrapers made on blades are an important exception to this. My use-wear analysis of various MD tools and LSA microliths supports this distinction. Almost all MD tools had extensive use-wear and retouch around their edges indicating intense use-lives with several sessions of use and resharpening. Although the relatively large size of most formal tools at MD made them potentially useful for multiple functions, most appear to have been used for one function suggesting that, to a certain degree, they were planning their use of tools.

For microliths I only found evidence for light cutting and sawing activities but many pieces did not retain observable use-wear traces at all suggesting that they were either being saved for later use or had been used lightly, in ways that did not generate damage. Low frequencies of use damage are consistent with a TO strategy of frequent edge replacement. It is notable that there are many different microlith subtypes, defined by differences in segmentation techniques, backing styles, overall shape, and intersections of backed and unmodified edges (Nelson, 1973; Mehlman, 1989). These subtypes may be differentially suited for tasks depending on their morphology (Lombard, 2011; Leplongeon, 2014), however these subtypes do reflect classification strategies of archaeologists based on technical attributes and may not have actual functional significance.

Despite their limited size and potential for retouch, microliths as a tool class may actually represent an adaptable tool design because they can be individually shaped and hafted onto handles or shafts in many ways (Bar-Yosef and Kuhn, 1999). Due to their mass-production and standardization they fulfill a technological role as replaceable components for different composite tools within a larger system (Hiscock, 2006; Hiscock et al., 2011). For example, they can operate as barbs on spears, backed knives, awls, woodworking implements, and tips for hunting weapons in a similar manner as MSA points. The considerable reduction in size and weight of hafted microliths compared to larger MSA points would have enhanced already existing projectile weapon systems by increasing the distance from the thrower to the target, thereby reducing the risk of close contact with prey animals (Brooks et al., 2006; Shea and Sisk, 2010; McBrearty, 2013). Together, these features indicate that LSA microlithic industries were highly planned and organized technological systems with many different components that required up-front time investment but created reliable and mechanically efficient tools (Torrence, 1983; Bleed, 1986; Bar-Yosef and Kuhn, 1999; Lombard and Haidle, 2012).

The long archaeological sequence in Kenya's central Rift valley described in this dissertation provides a useful model for future researchers investigating the technological transition from the African MSA to LSA and how modern human planning capacities changed over that same time period. Bringing all the evidence together, it appears that earlier MSA humans reacted to opportunities they encountered in their environments by relying on flexible and transformable toolkits to buffer against both expected and unexpected events. However, evidence from Horizons 4 and 5 at MD for strongly correlated morphological, typological, and functional differentiation of formal artifact types suggests greater levels of planned TO than I had anticipated for the mid-late MSA during MIS 5 between 110 and 94 ka. Based on this, and similar technological evidence from the Aterian and Nubian Industries of northern Africa, and the Stillbay-HP-Sibudan industrial sequence of southern Africa (76-58 ka), it seems plausible that there may have been an increase in planned, task-specific behavior during MIS 5-4. It is also possible that this proposed increase in technological planning facilitated the range expansion by MSA humans into the Arabian Peninsula during MIS 5. That there is evidence for the long-distance movement of lithic raw materials after 100 ka (Merrick and Brown, 1984a, 1984b; Merrick et al., 1994) suggests that cooperative intergroup information-sharing social networks were being developed by this time and so the enhanced technological flexibility and organization observed at MD, and with the Aterian, Nubian, and Stillbay-HP-Sibudan sequence may represent early technological adaptations by humans during MIS 5 and MIS 4 to greater levels of current information regarding resource availability, predictability, and distribution.

LSA humans during MIS 3 and MIS 2 (55 ka to 19 ka) appear to have anticipated and strategically planned for tool-using activities with specialized toolkits more systematically and to a far greater degree than MSA humans. Cooperative information-sharing social networks that were first developed during the interglacial MIS 5 likely expanded in size and significance during the highly variable MIS 3 and consistently cold MIS 2 when current information and a social safety net would have been at even higher premiums. Information acquired through these social networks is proposed to be the foundation for enhanced levels of planning (Kuhn, 1992a; Ambrose, 2002; 2010; McCall, 2007; McCall and Thomas, 2012; Mackay et al., 2014) observed in the organization of LSA lithic technology at sites such as Mumba, EYM, and OT (Mehlman, 1989; Ambrose, 1998, 2002; chapter 6 this dissertation). Ultimately, the growth of cooperative networks may represent a *social* adaptation for reducing risk (Mitchell, 2000; Ambrose, 2002), while the invention of LSA microlithic technology may represent a complimentary *technological* adaptation (Ambrose, 2010; Hiscock et al., 2011; McCall and Thomas, 2012; Eren et al., 2013). These fundamental shifts in social and technological behavior mark an important stage in the transition to fully modern human behavior and may represent key differences between the socio-territorial organization of Neanderthals and modern humans; differences that eventually facilitated our species' expansion out of Africa and replacement of Neanderthals and other archaic species of *Homo* across the world.

To conclude, the evolution of technology and behavior documented in this dissertation illustrates the versatility and innovative abilities of modern humans as a species. The technology that we use in daily activities, both in the past and present, co-evolved with our cognitive capacities for planning and organization. These skills are extremely valuable for survival whether you are in central Kenya 50,000 years ago or downtown Chicago in 2016. We may live in very different environments today than our MSA and LSA ancestors, but we still make, plan, and organize our technology using socially acquired information in similar ways.

Appendix A: Definitions of Retouch Attributes and Artifact Types

As discussed in Chapter 3, definitions of technological and typological attributes of flaked stone tools are largely based on Nelson (1973, 1982), Clark and Kleindienst (1974), and Inizan et al. (1999). Mehlman (1989, chapter 5) provides a useful comparison of typologies used by Nelson (1973), Merrick (1975) and Clark and Kleindienst (1974). Other sources are referenced where relevant.

Retouch Attributes and Definitions

A. *Location*: describes the position of the retouched edge relative to the flaking axis, defined with the artifact oriented with the proximal end down, or the base down for heavily retouched artifacts that have a clear long axis, such as bifacially retouched points.
   a. Proximal: the end of a tool with the striking platform.
   b. Distal: the end of a tool with the termination.
   c. Left: the left edge of a tool.
   d. Right: the right edge of a tool.

B. *Direction*: describes how many and which surface (face) of the tool was retouched.
   a. Normal: retouch is observed only on the dorsal surface of flake.
   b. Inverse: retouch is observed only on the ventral surface of flake.
   c. Bifacial: retouch is observed on both faces of a tool. The ventral and dorsal faces may still be discernable, or both faces may be completely flaked.
   d. Alternating: one edge with partial normal and partial inverse retouch.

e. Burin: longitudinal or transverse removal of a narrow flake struck from a corner, platform, snap or truncation, *parallel* to the flake thickness.

f. Burin plan: longitudinal or transverse removal of a narrow flake struck from a corner, platform, snap or truncation, *oblique* to the flake thickness.

C. *Edge angle*: the angle between the unifacial or bifacial retouched edge and opposite side.

a. Shallow: between 0° and 40°

b. Intermediate: between 40° and 70°

c. Steep: between 70° and 90°

d. Vertical (Abrupt)/Obtuse: 90° or greater.

D. *Invasiveness*: relative distance of retouch from the edge across the artifact's dorsal or ventral surface.

a. Marginal: ≤15%.

b. Semi-Invasive: 15-50%.

c. Invasive: ≥50%.

E. *Edge shape*: plan form shape (viewed from above) of a retouched edge.

a. Straight.

b. Convex.

c. Concave.

d. Concavo-Convex: alternating (undulating) concave and convex portions.

F. *Regularity of retouch*: the pattern or consistency of retouch along an edge.

a. Continuous or smooth: overlapping small removals with no edge irregularities.

b. Denticulate: continuous retouch comprised of adjacent notches and protrusions. Their spacing may be regular (as in pressure-flaking) or irregular.

c. Casual: groups or individual small negative flake scars separated by unretouched sections of an edge.

d. Utilized: Any edge with very small (≤ 2 mm), marginal, non-randomly distributed micro-flaking, crushing, etc., that does not alter the shape of the edge. Edge damage that may be continuous or irregular.

e. Trampled: pieces with micro-damage distributed randomly on all edges.

Primary and Secondary Debitage

Primary debitage includes all flaked stone artifacts without retouch that are produced during the reduction of a core. This category includes flakes, flake fragments, chunks, platform removal flakes, and step removal flakes. Secondary debitage includes all flaked artifacts without retouch that are interpreted as products of retouch to modify the shape of a flake blank or an edge. Secondary debitage has two subdivisions: 1) special categories of waste, such as burin spalls, microburins, and derived segments, and 2) secondary retouch flakes. All debitage types described below can also be classified as Casually retouched, Casually trimmed, Utilized, or Trampled. Finally, any 'old' artifact that was picked up from the surface and re-flaked at a much later time (thousands of years) is additionally classified as a *piece rétrouvée*. These are identified by the presence of fresh flake removals on a piece with otherwise patinated surfaces. It is an attribute that is notable for its implications for recycling and economizing of raw materials. For example, at Ntumot (Ntuka River 3, GvJh11) MSA flakes were sometimes recycled into LSA microblade cores (Ambrose, 2002).

Primary Debitage Types

A. *Whole flake*: an artifact with identifiable dorsal and ventral faces, and a complete platform, lateral margins and distal end termination. Distal terminations may be hinged, feathered or overstruck, but they are not tallied as a separate class. Whole flakes include *step removal flakes* (SRF), which were identified in the Ol Tepesi sample analysis. These are flakes that remove all, or a portion, of a step termination on a core. Core faces with stepped/hinged negative flake scars impede further removals from that part of the core face. Roux and David (2005) describe the strategy of step removal used by skilled flint knappers to repair blade cores in Cambay (Gujarat, India) stone jewelry workshops, but they do not explicitly define this type. Three subtypes are defined here: 1) striking once from a platform turned 90° from the flake axis of the step produces a "lateral SRF"; 2) striking from the opposite end of the core (180° rotation) in the same axis as the stepped flake scar makes one or more "opposed SRF"; 3) striking two or more flakes from the same platform as the step to remove successive portions of the step is termed "normal SRF".

   a. Attributes recorded:

      i. Platform type:

         1. Plain platform: single negative facet.
         2. Dihedral platform: two negative flake facets.
         3. Faceted platform: three or more negative flake facets.
         4. Micro-faceted platform: a core edge preparation technique where the hammer stone abrasion is up and onto the platform resulting in ‘micro’ facets.
         5. Point platform: The point of percussion is identifiable on the ventral face at the apex of the bulb of percussion. However the platform is absent or too

small to measure because it is crushed, shattered, abraded or spalled.

6. Ground platform: Scratches and abrasion by rubbing the hammer stone across the core top toward the flake release face. Often accompanied by crushed platform edge and dorsal proximal faceting.
7. Cortical platform: whole or partial cortex.
8. Lipped platform: the presence of a 'lip' on the striking platform. The lip is formed by a bending fracture, producing a broad, diffuse bulb of percussion lacking a distinct point of percussion. This is typically produced with soft hammer flaking.

ii. Dorsal Proximal Faceting (DPF): core edge preparation technique where the abrasion is down and away from the platform. Microflake scars are present on the dorsal proximal face of the flake. This is usually the result of hammer stone abrasion of the platform before removing the flake.

iii. Blade: flakes that are at least twice as long as they are wide, with elongated and parallel negative flake scars on the dorsal face, and more or less parallel edges.

iv. Cortex: the presence or absence of cortex on the platform or dorsal surface of primary and secondary debitage

v. Segmentary blades: blade fragments that appear to be snapped, but have a bulb of percussion originating from the center of the dorsal and/or ventral surface. These blade segments are produced by Direct Percussion Segmentation (DPS) on an anvil (Nelson, 1980; Ambrose 1985). This is also called side-blow blade flaking (Inizan et al., 1999: 86).

b. Measurements recorded:

i. External Platform Angle (EPA): an artifact's platform is held parallel to a goniometer's upper bar and the second arm is parallel to the dorsal face of the artifact.

ii. Platform width (PW): maximum width of an artifact's platform.

iii. Platform thickness (PT): maximum thickness of an artifact's platform.

iv. Length (L): the technical length of the artifact; the longest dimension along the 'flaking axis'. For artifacts with a platform they are measured from the platform to the distal end perpendicular to the platform. Tools not made on whole flakes were measured using the 'tool axis'.

v. Width (W): the maximum width of the artifact. Appropriate orientation is measured perpendicular to the 'flake axis' or 'tool axis' length.

vi. Thickness (Th): maximum thickness of the artifact.

vii. Weight (measured in grams).

B. *Proximal Flake Fragment (PFF)*: an artifact with a complete platform but missing a distal termination.

a. Attributes recorded:

i. Platform type:

1. Plain.
2. Dihedral.
3. Faceted.
4. Point.
5. Cortical.
6. Lipped.

ii. DPF.

iii. Blade.

iv. Proximal DPS or snap.

v. Cortex.

b. Measurements recorded:

i. EPA.

ii. PW.

iii. PT.

iv. W.

v. Th.

vi. Weight.

C. *Medial Flake Fragment (MFF)*: artifact with identifiable dorsal and ventral surfaces but no platform or distal termination.

a. Attributes recorded:

i. Snapped blade: a MFF determined to have come from a blade core based on its dorsal flake scar pattern and relatively parallel edges.

ii. DPS blade: (Medial Segmentary Blade): medial blade fragment that has been intentionally segmented with a direct blow to the dorsal ridge, resulting in a bulb of percussion on the proximal and/or distal end of the piece. This type overlaps with derived segments (defined as a secondary debitage class below), and is distinguished by having a L/W ratio ≥1.

b. Measurements recorded:

i. Number per excavation unit (N).

ii. Weight.

D. *Distal Flake Fragment (DFF)*: artifact without a platform but with identifiable dorsal and ventral surfaces and distal termination.

a. Attributes recorded:

i. Snapped blade: same as MFF snapped blade but with a distal termination.

ii. DPS blade: same as medial DPS blade but with a distal termination.

b. Measurements recorded:

i. Number per excavation unit (N).

ii. Weight.

E. *Split flake*: a flake split through the striking platform, bisecting the bulb of percussion. These platforms were not measured.

a. Measurements recorded:

i. Number per excavation unit (N).

ii. Weight.

F. *Eraillure flake*: flake originating from the middle of the bulb of percussion on the ventral face of a flake. It is a thin curved or flat whole flake (whole because it has feathered termination on all edges) with a convex dorsal surface formed by the bulb, and a flat ventral face lacking a bulb and point of percussion.

a. Measurements recorded:

i. Number per excavation unit (N).

ii. Weight.

G. *Chunks*: Flake fragments lacking identifiable landmarks including platform, distal terminations, and whose dorsal and ventral surfaces cannot be identified.

a. Measurements recorded:

   i. Number per excavation unit (N).

   ii. Weight.

H. *Weathered Waste*: Extremely battered, rounded, trampled, weathered, patinated and/or unflaked fragments of obsidian. Their absolute and relative frequencies can provide information on site formation processes, particularly sediment deposition rates. High frequencies are associated with low deposition rates and low frequencies of fresh artifacts (Ambrose, 1985).

   a. Measurements recorded:

      i. Number per excavation unit (N)

      ii. Weight.

Secondary Debitage Types: Special Categories of Waste

A. *Platform Removal Flake (PRF)*: flake that retains at least one negative flake scar on its dorsal surface.

   a. Subtypes recorded:

      i. Lateral: from a core with one or more platforms at right angles to that of the flake's axis of percussion, including "naturally backed knives", and *éclats débordants* struck from radial and Levallois cores (Debénath and Dibble, 1990).

      ii. Distal: overstruck flake from an opposed platform or radial core.

      iii. Core crest flake (crested blade or *lame à crète*): has a longitudinal dorsal ridge with proximal parts of negative flake scars at right angles to the flake axis.

Striking this flake from a prepared blade core creates long parallel arêtes that guide subsequent blade removals.

iv. Core top rejuvenation (*tablette de ravivage*): removes the entire platform of a narrow, usually cylindrical or pyramidal blade core.

B. *Burin spall*: small, narrow elongated bladelet with steep lateral edge angles, produced by striking the corner of a blank at right angles to the flake thickness, parallel or transverse to the long axis. The first spall struck from the lateral margin or distal of an unretouched flake is typically elongated and triangular in cross section. Subsequent spalls from the same platform are quadrilateral in cross-section and retain earlier burin facets (negative flake scars) on their dorsal side. The dorsal ridge may also be a backed edge, or a retouched scraper edge; these differ from platform removal flakes because they remove retouched tool edges rather than core platforms. The striking platform may be a snap or DPS facet, a flake platform, a burin facet (from a dihedral burin) or a steeply retouched truncation.

a. Burin spall plàn: burin spall struck from the corner of a blank that removes an edge parallel or transverse to the long axis at a shallow (oblique) angle relative to the flake thickness. Corner-thinned blades (Nishiaki, 1990) are shaped by burin spall plàn removals.

C. *Microburin*: primarily associated with the production of backed microliths from blades. This technique removes the irregular, thick or thin proximal or distal ends of blades by notching with abrupt (steep backing) retouch on an anvil with a ridge until the blade fractures in the notch. The resulting microburin spall often has an oblique twisted triangular bit or *piquant-trièdre* (Inizan et al., 1999: 83). On its dorsal face it retains a portion of the steeply retouched notch and adjacent backed edge.

D. *Derived segment*: byproduct of blade segmentation that most often is created during DPS when a blade breaks apart from the dorsal strike. A small medial flake fragment, often triangular in plan form, preserving one lateral margin, or rectangular, preserving left and right edges. This type has all the attributes of medial DPS blades, but has a L/W ratio <1.

E. *Tool edge fragment*: a portion of a bifacial or unifacial retouched tool edge with a curved bending fracture snap surface lacking a bulb and point of percussion. The fracture face is concave with a distal feather terminating edge that extends like a tongue (languette fracture). This bending fracture refits to a "half-moon" break on the broken edge of another artifact. See edge fragment *GtJi15.2157*, which refits to point *GtJi15.2145*.

F. Measurements recorded:

   a. Number per excavation unit (N)

   b. Weight.

Secondary Debitage Types: Secondary Retouch

G. *Bipolar flake*: a flake with opposed flattened (sheared) bulbs of percussion, usually point platform, crushed edges, and thin, flat, stepped negative flake scars on the dorsal and sometimes ventral faces.

H. *General Shaping and Trimming Retouch*: small flakes interpreted as having been removed during various stages of artifact reduction or maintenance. This category includes plano-clinal marginal retouch flakes from steep scraper edges, and plano-clinal and bi-clinal invasive shaping, thinning and resharpening flakes from lower angle edges of knives and points.

a. Unifacial trimming flake (UTF): a broad category of unifacial retouch flakes with plano-clinal platforms formed by the ventral face of the retouched flake. There are four subtypes:

   i. Shallow invasive unifacial trimming flake (SIUTF): these have at least two of the following features: 1) an acute EPA that is usually less than 70°; 2) a plain striking platform; 3) a lipped striking platform; 4) a broad, diffuse bulb of percussion; 5) very thin relative to their length and/or width; 6) an irregular pattern of shallow negative flake scars on the dorsal face; 7) an irregular quadrilateral plan form shape.

   ii. Edge removal flake (ERF): a special category of soft hammer retouch flake where the platform retains the parent flake's ventral surface, is extremely wide, and runs along (nearly) the entire *length* of the flake. This platform is almost always lipped, with an extremely low (≤50°) EPA, and resembles a languette fracture (see *GtJi15.2106*). They result from striking the edge of a parent flake at an oblique angle, which drives the long axis of the retouch flake along the edge, removing part of the parent flake's ventral face as the ERFs platform. This is similar to an overstruck uniface or biface trimming flake.

   iii. Bulbar trimming flake (BuTF): another special category of retouch that removes the ventral surface of a flake (inverse retouch). The dorsal face has the convex ventral surface of the bulb of percussion of the parent flake, often with an eraillure scar. These flakes result from thinning the bulb of percussion (proximal ventral area) of a flake blank.

   iv. Scraper retouch flake (SRF): a category of retouch specific to scraper resharpening. They typically have: 1) a thick platform, 2) a steep or vertical EPA, often approaching 90°, and 3) visible use-wear on dorsal proximal area, usually stepped microflake scars and/or rounding (Frison, 1968: 150).

b. Biface trimming flake (BiTF): same attributes as 'SIUTF' but with a microfaceted platform because it is struck from a bifacially retouched edge.
c. Measurements recorded:
    i. EPA.
    ii. PW.
    iii. PT.
    iv. L.
    v. W.
    vi. Th.
    vii. Weight.

Tools

A broad category of artifact types that display deliberate or intentional retouch on one or more edges. The retouch can modify an edge's shape and/or angle. This category includes formal shaped tools and informal/unshaped tools (Nelson, 1973). Formal shaped tools have retouch that systematically modifies the outline or overall morphology. Specific types are created and named when several artifacts from an assemblage share the same combination of retouch or edge morphology attributes. Informal or unshaped tools have retouch that does not systematically modify the full or partial length of an edge or intersection of two edges. In Nelson's (1973: 137-140) typology these are included in 'Miscellaneous' tools. In the classification system used for this analysis any debris type exhibiting casual retouch is classified as informal/unshaped tools.

Formal Shaped Tools

I. *Microlith*: includes all blade segments that have been truncated and 'backed' on one or more edges. Backing is defined as continuous steep or vertical retouching (often on an anvil) to blunt one side, opposed to or lateral to an acute-angled sharp unretouched edge. The term microlith itself is somewhat of a misnomer, as size ranges are not typically used for classification (Casey, 1993; Ambrose, 2002). Instead the most important feature for identifying and classifying microliths is the presence and nature of backing. A diverse range of geometric forms on medial blade segments, and non-geometric types on whole, proximal and distal flake and blade fragments have been defined based on the number and orientation of backed edges and the relationship between backed and non-backed sharp edges. Backed artifact types are divided into two main groups of subtypes.

   a. Geometric: Medial flake or blade segments characterized by a single unmodified edge, which intersects (i.e. is truncated by) backed edges at the proximal and distal ends or left and right sides. The first three primary geometric forms are common in East African sites.

      i. Crescent: a single convex backed edge that intersects an unmodified edge at both ends of the piece. If the width at right angles to the unmodified edge is greater than length then it is classified as a deep crescent.

      ii. Triangle: two backed edges that intersect to form a single point perpendicular to the unmodified edge.

      iii. Trapeze: two or three backed edges; two are oblique to the unmodified edge and one is parallel. The parallel edge may be unmodified.

iv. Rectangle: two or three backed edges; two are orthogonal to the unmodified edge and one is parallel. The parallel edge may be unmodified.

v. Tranchet: triangle, trapeze, rectangle or U-shaped deep crescent whose width at right angles to the unmodified edge is greater than length.

b. Non-geometric truncated: a diverse group of microliths that truncate (remove) either the proximal or distal end of a blade or flake.

i. Curved-backed: backing that forms a convex truncation of the proximal or distal end of a flake or blade.

ii. Oblique truncation: convex, straight or concave backing that is oblique to the unmodified edge. The edge parallel to the unmodified edge may be backed or unmodified.

iii. Orthogonal truncation: backing on a truncated edge that is perpendicular to the flake axis and removes its proximal or distal end.

iv. Longitudinal truncation: the backed edge is straight and the unmodified margin of the blade or flake curves to intersect the straight backing at the distal end.

v. Straight-backed: the backed edge does not intersect the opposite margin of blade.

vi. Double-backed: backing on left and right sides. If backed edges converge at proximal and/or distal end they are often classified as points; those with rotational abrasion are classified as borers.

J. *Scraper*: a group of tool types characterized by continuous unifacial retouch on the ventral or flat surface of a blank, creating negative flake scars on the dorsal surface (a plano-clinal edge). Edge angle is generally steep (60°-90°). Major subtypes are defined by retouched edge position and plan form shape, and include:

c. End scraper: the retouched edge is perpendicular to the blank's flaking axis, at either the proximal or distal end. The plan shape be convex, straight, concave, concavo-convex (shouldered or nosed) or notched. This can be a single end scraper (one retouched end) or double end scraper (proximal and distal ends retouched), if the retouched end width is greater than the length on the flaking axis (L/W<1) then it is classified by Bordes (1961) as a transverse scraper. However, a low L/W ratio may also reflect repeated resharpening.
d. Side scraper: the retouched edge is in-line with the blank's flaking axis, on either the left or right side. This can be single or double.
e. End and side scraper: two retouched edges one on an end and one on a side. The retouched edges may intersect.
f. Convergent (déjeté): an end and side scraper where the two retouched edges converge at an acute angle. Double side scrapers whose edges converge at the proximal or distal end of the blank are also classified as convergent scrapers.
g. Alternate: a double scraper that has one retouched edge on the dorsal face and the other, opposite edge, retouched on the ventral face.
h. Concave: the retouched edge is concave and typically on a side. If the concavity itself is narrower than 2 cm the tool is considered a notch, not a scraper.
i. Convex: the retouched edge is parallel to the flake axis at one end, and transverse at the other, covering 50-75% of the perimeter of the artifact.
j. Circular: the same as a convex scraper but with 75% or more of the artifact's perimeter being retouched.

k. Concavo-convex: alternating portions of concave and convex continuous scraper retouch along a single edge. This is not the same as a denticulate edge, which has retouch comprised of multiple smaller notches and protrusions.

l. Attributes recorded:

   i. Location(s).

   ii. Direction.

   iii. Edge angle.

   iv. Edge shape(s).

K. *Notch*: a small 'hollowed' out concavity made with a single large blow or multiple smaller blows on the edge of a flake or blade. If the notch itself is wider than 2 cm the tool is considered a concave scraper.

L. *Bec*: a point or 'beak' formed by two contiguous small notches or a notch adjacent to a corner or snap (Debénath and Dibble, 1994).

M. *Perçoir*: a pointed tip (drill) formed through convergence of two retouched edges.

N. *Outil écaillé*: flake or flake fragment bifacially flaked tool with strong bipolar rippling and steep scaled or stepped retouch and crushed and battered edges. Single edges may be scaled and battered. Two opposed edges are most common, but three or four edges may exhibit these attributes. If flakes are removed preferentially from lateral margins they may be narrow, becoming batonnettes (also known as multi-faceted spikes). These are considered tools because the dorsal and ventral sides of the flake primary form can be identified. Batonnettes can intergrade with bipolar cores, and with opposed platform cylindrical blade cores, if they are thick and have prominent negative flake scars on all faces.

O. *Point*: a tool retouched to a relatively acute convergent tip (<90°) with a generally triangular to teardrop plan form, and semi to fully-invasive bifacial and/or unifacial retouch on all or part of one or more sides, and sometimes the end (usually proximal). Retouched edge angles are typically low (<60°). In accordance with Bordes's type system, unretouched triangular Levallois flakes (with faceted platforms) whose sides converge at the distal end are also classified as points. Points are considered *fossiles directeurs* of the African MSA. Several points from the upper levels of GtJi15 have wide rounded tips or tranchét tips, which makes this assemblage typologically or stylistically distinct from other MSA assemblages. Point subtypes include:

   m. Unifacial: made on a flake or blade with retouch restricted to the dorsal face (normal retouch).

   n. Unifacial with trimmed bulb: a unifacial point with invasive shallow inverse retouch that removes the bulb of percussion. Bulbar thinning may have facilitated hafting.

   o. Parti-bifacial: one or both normally retouched edges have inverse retouch on all or part of the edge.

   p. Bifacial: normal and inverse retouch on the same edge on both sides of the piece.

P. *Knife:* Continuous shallow semi-invasive to invasive retouch on one or more edges that do not converge to form an acute or rounded point. Edge angle is generally intermediate or shallow. Retouch may be unifacial or bifacial.

   q. Helwan retouch knife (crescent knife): Marginal steep bifacial edge retouch on one convex lateral margin opposite a straight, convex or concave unretouched or utilized edge with acute edge angle. A microlithic version of this type occurs in the early Natufian (Belfer-Cohen, 1991).

r. Attributes recorded:

   i. Location.

   ii. Direction.

   iii. Edge angle.

   iv. Invasiveness.

   v. Edge shape.

   vi. Regularity of retouch.

Q. *Burin*: a chisel-like 'bit' in the plane of the thickness of the blank (e.g. at right angles to the dorsal and ventral sides) formed by the intersection of at least one burin facet with any edge or surface that is suitable for a striking platform, including a snap, segmented blade fracture face, flake platform, truncation or a negative burin scar. Burin direction may be parallel or transverse (angle burin) or oblique relative to the flake axis. Burin subtypes are defined by the following attributes:

s. Direction:

   i. Normal.

   ii. Transverse.

   iii. Oblique.

t. Number of burin bits:

   i. Single.

   ii. Double.

   iii. Triple.

   iv. Multiple (>3 bits).

u. Platform type. The burin blow originates from a steep edge formed by a:

i. Retouched truncation.

ii. Snap or segment fracture face.

iii. Platform, or any other steep face of a blank, including dorsal cortex.

v. Dihedral: burin facets that remove adjacent edges to create a bit. One negative burin facet is the platform for the other burin removal. Bit orientation may be:

i. Normal: one facet parallel to the blank's long axis and the other transverse.

ii. Oblique, with two defined subtypes:

1. Two oblique facets converging symmetrically on the midline like a point tip (*dièdre droit*).

2. One facet parallel to the long axis and the other oblique (*dièdre déjèté*).

w. Nucleaform: a core-like burin made on a thick flake blank that has wider burin facets that grade into microblade facets.

R. *Burin plàn*: burin spall struck from the corner of a blank that removes a steep edge parallel to or transverse to the long axis at a shallow (oblique) angle relative to the flake thickness. These are called corner-thinned blades by Nishiaki (1990); they are also common in the Elmenteitan Neolithic Industry in Kenya (Ambrose, 1985; Nelson, 1980).

S. *Combination tool*: any tool that displays attributes of two or more types. The types are listed individually and attributes are recorded as per normal classification.

T. *Transformed tool*: any tool that has attributes of two or more types, where the retouch for one type is partially removed by modifications with attributes of the second type.

U. Measurements recorded for all formal tools:

x. EPA

y. PW

z. PT

aa. L

bb. W

cc. Th

dd. Weight

Informal Unshaped Tools

V. *Casual retouch*: an edge with intentional marginal flake scars ≤ 4 mm, sporadically distributed, and often interspersed with utilization. The edge plan form is not appreciably altered. Any type of flake, flake fragment and chunk can be casually retouched.

W. *Casual Trimming*: an edge with intentional flake scars ≥ 4 mm and interspersed with utilization and casual retouch. Casually trimmed edges tend to be irregular and/or somewhat altered in plan form.

X. Retouched snap: a natural break of an artifact exhibiting casual retouch or trimming.

Y. Retouched corner: a corner of an artifact exhibiting casual retouch or trimming.

Cores

A core is any piece of stone raw material from which flakes or blades have been struck that are large enough to be blanks for shaped tool manufacture. The core must have at least one identifiable platform and associated negative flake scars. Orientation of platforms and shapes of flake scars define major classes of cores.

A. *Blade*: Negative flake scars are elongated and sub-parallel to parallel.

a. Attributes recorded:

i. Number of platforms: 1, 2, 3, etc.

ii. Orientation of platforms (if 2 or more): opposed on same face or opposite face, or at right angles.

B. *Flake*: negative flake scars are wider and convergent to irregular.

a. Attributes recorded:

i. Number of platforms

ii. Orientation of platforms: opposed or at right angles.

C. *Radial*: flakes are struck around the perimeter of the core towards the center on both upper and lower faces from the same edge around the perimeter of the platform. These are also known as recurrent centripetal cores. Flakes struck from radial and Levallois cores have faceted platforms formed by the proximal ends of negative flake scars. The upper face is typically flatter. Negative flake scars are typically quadrilateral to triangular. Radial core subtypes form a continuum from:

a. Conic (high backed) and bi-conic: with thickest cross-section

b. Radial: with intermediate cross-section thickness.

c. Discoidal: with thinner, flatter cross-section.

D. *Levallois*: a core with two asymmetrical convex surfaces. The surface with higher convexity is considered the striking platform surface. Flakes struck from this platform prepare the core surface (preparation phase) for the removal of a single large flake blank (exploitation phase). The flake release surface typically requires re-preparation between flake products (White et al., 2011). Subtypes are defined by preparation patterns on the upper surface, and include:

a. Radial: negative flake scars originate from several points around the core perimeter (tortoise core).

b. Bilateral: negative flake scars originate predominantly from both of the lateral margins of an elongated upper core face, also known as Nubian Type 2 (Van Peer 1991, figure 3).

c. Convergent unipolar point: flakes are struck predominantly from one end of a core to generate arêtes that prepare the core face for striking a large, often elongated, triangular pointed flake (Levallois point core). The preparation phase flakes include platform removal flakes that remove the left or right lateral platforms of the core; these PRFs are called naturally backed knives (*éclats débordantes*).

d. Convergent opposed platform points: flakes are struck from opposed ends of a core to generate arêtes that prepare the core face for striking a large, often elongated, triangular pointed flake. This is the Nubian type 1 point core (Van Peer, 1991). Nubian Type 1 preparation also produces naturally backed knives (Usik et al., 2013).

E. *Tabular*: a large, thick flake or flake fragment truncated with inverse retouch transverse to the long axis. The truncation surface becomes the platform for the removal of flakes or blades. In LSA assemblages these are commonly called cores on flakes, tabular cores, *nucleus sur éclats*, or sinew frayers (Leakey, 1931; Dibble and McPherron, 2007). In MSA and Middle Paleolithic assemblages they are also called truncated faceted pieces (Dibble and McPherron, 2007).

F. *Bipolar*: a core with crushed, battered, stepped, scaled, bidirectional (biclinal) opposed platforms. The biclinal platform edges may be sinuous. They are typically sub-rectangular and pillow-shaped, with a bi-convex cross-section. Narrower bipolar cores grade into multifaceted spikes (*batonettes*). This type differs from the o*util écaillé* because bipolar core faces are entirely negative flake scars rather than dorsal and ventral surfaces of a flake.

G. *Informal*: a core with one or more platforms from which three or fewer flakes have been removed.

H. *Fragment*: They have either no striking platform but retain distal ends of negative flake scars on all or most faces, or have platforms, but lack distal ends of negative flake scars. Flake scar patterns can provide evidence for core type.

I. Measurements recorded:

   a. L: measured from the primary striking platform.

   b. W

   c. Th

   d. Weight

Ground Stone

Ground stone is a category of stone tools shaped by pecking, grinding, or polishing one stone against another. They may first be flaked with direct percussion to roughly shape but are finished by pecking away with a harder hammer stone or stone pick, and sometimes smoothed or polished with sand, using water as a lubricant. This category also includes hammer stones. Ground stone tools are usually made with coarse-grained, macro-crystalline igneous or metamorphic rocks. The number, orientation, and morphology of battered ends, ground bits, and grinding facets define major classes of ground stone tools.

A. Hammer: any object used to strike off flakes from a core. Typically these are not ground or polished, but are cobbles or chunks with concentrations of peck-marks, battering and abrasion. A hammer can be made of any material that is harder than the type of stone being worked and are divided into two subtypes:

a. Hard hammer: any hammer made of a natural mineral or stone.

b. Soft hammer: natural materials such as bone, antler, wood, horn, or ivory.

B. Grindstone: ground stone slabs composed of two parts:

a. Upper: a handheld grindstone, usually rounded or convex shape to fit into the lower grinding slab. Also known as a pestle.

b. Lower: an immobile grindstone slab, usually with a concave upper surface that fits a rounded handheld grindstone. Also known as a mortar or whetstone.

C. Stone bowl: a ground stone bowl. These are unknown in the MSA and early LSA.

D. Pitted or dimpled anvil: a cobble, block or slab with one or more discrete pecked and/or battered small concavities on a relatively flat face of the artifact.

E. Bored stone: a ground, perforated doughnut-shaped to spheroidal ring (Mehlman, 1989). These are often classified as digging stick weights. This rare type is found in the early LSA in southern, central and eastern Africa. None have been recovered in Pleistocene sites in the central Rift Valley.

F. Manuport: an unmodified object, such as a block of stone or water-rolled cobble that has been moved from its original context and discarded at the site.

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