Interpreting Variability Through Multiple Methodologies: The Interplay of Form and Function in Epipalaeolithic Microliths

by

Danielle Aviva Macdonald

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Department of Anthropology
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Abstract

The reason and significance of variation in material culture is one of the most fundamental debates in archaeological studies. These debates factor strongly into Levantine Epipalaeolithic research, where the morphological variability of microlithic tools has been interpreted to represent distinct cultural or ethnic communities. This dissertation addresses microlith variability during the Middle Epipalaeolithic (≈17,500 – 14,600 cal BP) through the analysis of lithic assemblages from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV (Jordan). Although regionally disparate, the lithic assemblages are characterized by the same geometric microlith type: the trapeze-rectangle. The integration of typological, technological, morphometric, and use-wear analyses allows for the subtleties in material culture to be explored among these sites. In addition to these analyses, new methods for use-wear quantification are presented.

This dissertation sets out to test several hypotheses in regards to the microlith assemblages: 1) microliths will have overlapping functions, indicating that function does not drive form; and 2) microliths will show differences in technological style. These hypotheses relate back to current debates in Epipalaeolithic research about the nature of microlith variability. Is variation in microlith morphology the product of different technological sequences of production or microlith function? Or is variability the result of different cultural practices? This material culture variability is explored through the lens of the *chaîne opératoire*, where I advocate for the inclusion of functional analysis into our study of lithic assemblages. Through the integration of multiple methods, I suggest there is not a direct correlation between microlith form and function.

Instead, the variability we witness in microliths during the Middle Epipalaeolithic is the result of local expressions within different communities.

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Table of Contents

List of Tables

List of Figures

Chapter 1
Introduction

1.1 Introduction

The driving force behind variability in lithic form has long been a topic of debate among archaeologists (e.g., Binford and Binford, 1969, Bisson, 2000, Bordes, 1961, Dibble and Rolland, 1992, Dibble, 1984). Scholars have hypothesized that tool form is the result of ethnic identity (Bordes, 1961, Bordes and de Sonneville-Bordes, 1970), functional requirements (Binford and Binford, 1969), or technological sequences of production (Dibble and Rolland, 1992). These debates factor strongly into Levantine Epipalaeolithic (23 000-11 600 cal BP) research, where the chronological and regional morphological variability of microlithic tools have been interpreted to represent distinct cultural or ethnic communities (e.g., Bar-Yosef, 1970, Goring-Morris, 1987, Henry, 1995). This interpretation has been critiqued by other researchers who hypothesize that microlith variability is the result of technological sequences of production (Neeley and Barton, 1994). This critique has sparked controversy, causing strong reactions in the archaeological community as people defended the cultural hypothesis for Epipalaeolithic lithic variability (see Chapter 2, section 2.7). Although technological evidence was brought into this discussion by Neeley and Barton (1994), functional evidence has rarely informed this debate (but see Richter, 2007). Exploring the functional and technological aspects of microlith variability will greatly contribute to our understanding of how microlithic tools acted as both utilitarian artifacts and carriers of cultural information during the Epipalaeolithic.

This dissertation addresses the underlying meaning of microlith variability during the Epipalaeolithic through the use of multiple techniques to analyze variation in lithic tools at the Middle Epipalaeolithic (Geometric Kebaran) sites of Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV. Addressing variability in morphology, technological production, and function, the primary hypotheses driving this research are:

1. Different forms of geometric microliths will have overlapping functions, as function is not the driving force behind variation in form.

2. Microliths from each site will show differences in 'technological style' at each stage of the tool's life history, suggesting that these tools were manufactured and used in distinct communities.

3. The microliths functioned as sickle inserts, indicating a deep time depth for the use of the microliths as cereal-harvesting tools.

The question of why Epipalaeolithic microlith form changes across time and space links into larger discussions of how people interact with material culture. The people of the Epipalaeolithic were modern humans practicing a hunting-gathering subsistence pattern. Because this period precedes the Neolithic, many studies examine features of the Epipalaeolithic looking for initial signs of Neolithic behaviours (Bar-Yosef and Belfer-Cohen, 1989, Grosman and Belfer-Cohen, 1999, Hillman, 2000, Verhoeven, 2004). Thus, the Epipalaeolithic is often viewed as a step towards agriculture. However, this teleological framework suggests that the Epipalaeolithic people were actively pushing themselves towards domestication. In contrast to viewing it as a 'transitional' period, the Epipalaeolithic needs to be viewed on its own merit (e.g., Boyd, 2006) with increasing diversity a dominant feature of the Epipalaeolithic. Understanding this diversity and change in material culture, not as an evolutionary step towards agriculture, but as a feature of modern human behaviour, is an important step towards understanding interactions between people and objects.

1.2 Material Culture Variability

Archaeologists have approached material culture variability in numerous ways. This variability often relates to the material properties of the artifact that are highly visible and easily compared between objects. As archaeologists, we often equate this variability to 'style'. The concept of style has been used by archaeologist to organize material culture both temporally and regionally, and has been attributed to processes at the individual, group, and 'cultural' levels (Conkey and Hastorf, 1990:1). As noted above, groupings and interpretations of Epipalaeolithic cultures are based on the morphological style of microliths. This constructs an archaeological narrative hinged on our interpretations of material culture variability. This section will review archaeological literature on style, dichotomized between 'communicative' style and 'technological' style in an effort to problematize our current understanding of Epipalaeolithic material culture and highlight ways of interpreting variability witnessed in the archaeological record.

1.2.1 Communicative Style

Wobst defined style as an active form of communication in his seminal paper (1977). He highlighted that style had previously been defined as elements of material culture that are ‘non-functional’. This created a dichotomy between function and style that permeated archaeological thought for decades. In contrast, he defines style as “the part of formal variability in material culture that can be related to the participation of artifacts in processes of information exchange” (1977: 321). Thus, he ascribed a communicative function to style, subtly breaking down the distinction between style and function. However, this did not extend to the ‘everyday’ functioning of the artifact; style is functional only in that it has a purpose to communicate. For style to be an effective communicator, it needs to have a specific target audience that can decode the message. Archaeologically, this ‘communicative’ style is often interpreted as a message of group solidarity, both within the group and to create social boundaries between groups. Artifacts that carry messages of group affiliation need to have public visibility, signaling to members within and outside the community.

Wiessner (1983) further elaborated on Wobst’s definition of style, stating that style is “formal variation in material culture that transmits information about personal and social identity” (Wiessner, 1983: 256). Her definition highlights the integration of identity with the concept of style, suggesting that style broadcasts group or individual identities to other communities. Through her work with Kalahari San populations, Wiessner defined two types of style. The first is ‘emblemic style’, which communicates conscious identity (or affiliation) to a specific audience. This style is predicated on the presence of social boundaries between groups; there needs to be an ‘other’ to which the style is communicating. The second type is ‘assertive style’, which communicates information about individual identity; the personalization of style by individuals (Wiessner, 1983). This style is more mutable than emblemic style, as it does not have a specific referent at which the communication is aimed.

Her conceptualization of style is best illustrated through her ethnographic research. Analysis of Kalahari San metal arrowheads showed clear variability among individual hunter’s arrows, but there were no clear differences in variability at the band level in terms of size, tip shape, and base shape (Wiessner, 1983). The variability at the individual level can be considered assertive style. Despite there being no difference at the band level, there were striking differences seen between different language groups, suggesting that material culture boundaries are not as permeable between language groups as they are between different bands. This suggests that, for this ethnographic case study, patterns of regional variation in metal arrowheads marked boundaries between different linguistic groups. San informants approached the other groups point's with trepidation, acknowledging the differences in style and the unknown qualities of points not from their language group. Furthermore, there appeared to be little fusing of style between these groups, despite contact during seasonal rounds (Wiessner, 1983). Through this, Wiessner suggests that San arrowheads represent emblemic style, actively distinguishing between different linguistic groups.

1.2.2 Technological Style

In contrast to communicative style, technological interpretations of style are the expression of variability in material culture without a communicative function. Elements of technological style can be incorporated into the action of tool production, tool use, or tool form. Technological style can include an agent's embodied experience within their community, creating technical acts within a framework of cultural acts (Dobres, 2000). Thereby, the action of creating also becomes an active communication within a group, but without the conscious desire to communicate.

Early work by Mauss (1935) studied movements of the body, highlighting that techniques and ways of acting are culturally situated. These ideas were further expanded by other anthropologists studying technology, looking at material culture variability as an expression of different techniques or technological 'choice'. To understand this technological choice, Lemonnier has suggested that anthropological inquiry into technical systems should "investigate whether some technological choices are arbitrary from a *technological* point of view" (1992:18). Thus, technological style results from choices that are not constrained by the utilitarian function of the object. Through this perspective, style can be considered as entering all aspects of the technological process, including the choice of raw material, how a tool is manufactured, and how it is used. Does the 'style' we witness in material culture – from raw material, to manufacture, to use – fall outside the constraints of function? This perspective does not divorce style from function, but highlights how style is an integral part of all elements of technology.

Writing at the same time as Wobst, Sackett (1977) suggested that artifacts are objects of action being made and used in daily life, as part of a cultural system. How the object interacts in economic and social realms is the artifact's function. Sackett also argues that artifacts can be viewed as having 'style'; the properties that place them in a cultural-historic framework. Linking into concepts from the anthropology of technology, style in this context is the *choice* that groups make for the aspects of material culture for which there could be multiple avenues to the same (utilitarian) function (Sackett, 1977). Thus, because choice is socially transmitted, style is historically unique to a specific time and place. Artifact variability relates to these two modes, style and function, which are both elements of material culture. This perspective brought the concept of style to everyday objects in archaeology, placing them into the social realm without removing their utilitarian purposes.

Sackett further elaborates on this concept of style, creating a dichotomized system, iconological and isochrestic style, that have passive and active elements (Sackett, 1982). His 'iconological' style is similar to Wiessner's emblemic style or Wobst's definition of style. Here, style is a purposeful signaling of social information regarding the boundaries between human groups. However, his major contribution to archaeological discussions of style lies in his definition of 'isochrestic variation'. This highlights the different choices made in tool production that result in the same end product, particularly the same functional end (Sackett, 1982). For Sackett, this is a passive process of enculturation, where the available choice is unconsciously made based on cultural context (Sackett, 1990). In lithic technology, these choices can lie in the raw materials chosen for manufacture, the knapping technique used, and the sequence of flake removals, among other technological actions. Choices are learned through interaction with a community, through the historical context of the group. Therefore, through understanding isochrestic variation in material culture, insights can be gained into the differences and boundaries between communities. This theory suggests that function and style result in all formal variation in material culture, giving equal weight to the function of objects in how they are designed. Through the lens of isochrestic variation, style is the unconscious choice made by a group or individual that results from traditions or norms within culture. Thus, it is assumed that similarities in material production are the result of interaction and shared learning among people while they are creating that material culture.

Using the framework of isochrestic style, Sackett commented on Wiessner’s seminal paper defining emblemic and assertive style (Wiessner, 1983), suggesting that variability in material culture might not be an active process of ethnic signaling (Sackett, 1985). He does not hesitate to agree with the observation that different language groups are manufacturing different ‘styles’ of arrows, but challenges the interpretation that this style is a conscious process of ethnic differentiation. Instead, he suggests that the style witnessed in the Kalahari San arrowheads is better described as isochrestic style, where variability is part of a passive process and the result of enculturation in social groups. Wiessner (1985) contests this by stating that style should only be considered as an active process, not something that is acquired through routine. She highlights the communicative nature of style, where the craftsperson intentionally imbues an artifact with style to convey a specific message. Revisiting the material, there appear to be elements of both active and technological style found in the material culture of the San people. This debate suggests that artifacts can be situated between active and technological style, and that this dichotomy is not divided by a fixed boundary.

Some archaeologists have attempted to bridge active, or communicative, and passive elements of style. Dietler and Herbich (1998) argue that material culture is often separated into three categories: 'style', 'technology', and 'function', the former of which is often thought to be the key to understanding the social realm in the archaeological record. These authors equate the differences in active and passive style to the differences in structure and agency; passive style is controlled by cultural organization and overarching structure, while active style is a choice of communication and symbols that can be manipulated to articulate different meanings. Dietler and Herbich use Bourdieu’s theory of practice and *habitus* to bridge these two different conceptions of style. In their framework, *habitus* generates patterned actions, and techniques are formed within these patterns. These are called 'tendencies' by the authors, which limit the range of possible choice within the cultural framework. Material culture is thus situated in social life, where style is not 'added' to materials, but grows in tandem with the formation of social identity through the enactment of techniques. Based on ethnographic examples from the Luo, the authors show how situated learning can result in 'micro-styles' of pottery production which permeate all aspects of the material culture during the manufacturing stages (Dietler and Herbich, 1998). This micro-style is developed within a group of potters as they learn within that particular community. In this context, style is the result of different choices made by the artisans while performing similar stages of the technological process (Dietler and Herbich, 1989). This allows for the artisans to make individual modifications (active style) within a range of cultural choices (passive style).

1.2.3 *Chaîne Opératoire*

The discussion of technological style brings us to the concept of the *chaîne opératoire*. A term originally coined by André Leroi-Gourhan (1964), the concept of the *chaîne opératoire* was first introduced into archaeological interpretation to situate technology in social contexts. In this scheme, the '*connaissance'* (knowledge) of the task is enacted through the '*savoir-faire'* (skill) of the craftsperson. Thus, the *chaîne opératoire* is the combination of both the sequence of technical actions and conception behind these actions, creating a *pattern* (Chazan, 2009:471). This pattern has linear and non-linear elements, where the sequence of actions is performed in order (…bladelet removed from core, bladelet ends snapped, bladelets retouched…), while the concepts behind this sequence are non-linear (configuration of bladelet hafting, concept of tool shape etc.). In the context of lithic analysis, the *chaîne opératoire* includes all processes that a lithic undergoes, including raw material collection, manufacture, use, and discard (Inizan, et al., 1992:12). However, the *chaîne opératoire* has primarily been used to reconstruct methods of manufacture (e.g., Bar-Yosef and Van Peer, 2009, Davidzon and Goring-Morris, 2003, Sellet, 1993).

Through the lens of the *chaîne opératoire,* lithics are incorporated into the general context of human societies where every tool is a product of a technological system, rooted in a societal or cultural context. Each stone tool is part of a lithic sub-system that interacts with other material sub-systems such as bone and wood to create technologies used in everyday actions (Soressi and Geneste, 2011). Thus, no artifact is isolated but is part of a larger technological system. These conceptual schemes are physically realized through operational sequences. In lithic analysis, this concept is accessed through several different methods including refitting, experimental flintknapping, and technological attribute analysis (e.g., Bar-Yosef and Van Peer, 2009). Although much of archaeological literature has focused on a linear progression from one stage to another, these sequences are often iterative, repeating stages of manufacture, hafting, use, and re-tooling prior to discarding the artifact.

Two different foci have been identified for discussing the *chaîne opératoire* (Conneller, 2011:17). The first of these is the sequence of material transformations, prioritizing the process of materials through different actions. This includes the transformation of a core, through reductive flintknapping, into one or more finished tools. The second is the physical enactment of the sequence, highlighting the people involved with the material culture. This focuses on the gestures and behaviours of past peoples imprinted onto objects. Technological analysis of debitage and finished tools allows us to reconstruct transformative processes while lithic use-wear analysis allows us to focus on the second description of the *chaîne opératoire*, reconstructing human behaviours through traces and remnants left on stone tool surfaces.

Recently Knappett (2011) argued that the *chaîne opératoire* provides a lens through which we can evaluate material culture in both a local and regional context. Often the *chaîne opératoire* is used as a *prescriptive* method of analysis, to create generalized models or schematics by amalgamating techniques into an idealized 'norm'. However, it can also be used as a *descriptive* method, documenting fluctuations and variations in material culture. Thus, the *chaîne opératoire* allows us to move between different scales of analysis, between the variation witnessed between single artifacts and variations between assemblages at the regional level (Knappett, 2011).

The *chaîne opératoire* has often been contrasted with the North American approach of reduction analysis. It has been suggested that the former focuses on cognition rather than purely reductive sequencing, as advocated by proponents of the latter technique (Bleed, 2001, Shott, 2003, Tostevin, 2011). The strength of the *chaîne opératoire* is that it illuminates past processes through objects, making it an ideal method for evaluating past human-material interactions. This interaction is guided by knowledge and the skill of the artisan (Chazan, 2009). Thus, the focus of the *chaîne opératoire* is on gestures and techniques, integrating the human element into our understanding of material culture. However, as mentioned previously, the *chaîne opératoire* is rarely used to understand the processes beyond manufacturing. This is where we turn to behavioral archaeology to integrate function into the life-history of material culture.

1.2.4 Behavioural Archaeology

When initially conceptualized, behavioural archaeology set out to develop a method to study the relationships between human behaviour and material culture (Reid, et al., 1975). This early definition has been subsequently refined, acknowledging that human behaviour is artifact based and therefore cannot be easily separated from materials (Schiffer, 2010). It looks to understand human-technology interactions at every scale from within a 'life-history' perspective (Hollenback and Schiffer, 2010). In this context, life history is defined as a sequence of interactions and activities that an artifact goes through during its lifetime (LaMotta and Schiffer, 2001:21). Life-history analyses not only incorporate tool manufacturing, but also explore the conception, use, recycling, and discard of objects (Hollenback and Schiffer, 2010).

Behavioral archaeology maps the movements of material culture from a behavioral or systemic state to an archaeological state (S-A process). Materials can also undergo 'successive system states' where they pass through a series of processes prior to deposition in the archaeological record. Artifacts can move back to a systemic state through modern behaviours such as excavation, looting, and collection (A-S process). Finally, the transformation of materials without human interaction, such as post-depositional processes, is termed the A-A process (Schiffer, 1976). Thus, behavioral analysis continues past manufacturing, where the *chaîne opératoire* approach often terminates.

Behavioral archaeology is based on four strategies which form the basis for questions this analysis asks about the relationship between people and material culture. These four strategies are (as outlined in Schiffer, 1976):

1. Using **past** (archaeological) material culture to answer questions about **past** behaviours. Inferences made through this strategy are based on the application of laws to archaeological interpretation.

2. Evaluating **present** material culture to make inferences about **past** behaviour. These results tend to be general questions because they are not temporally or geographically restricted.

3. The study of **past** materials to derive behavioural laws, applicable to both **past** and **present** behaviors. This constructs general rules about human behaviour that is not linked to time or space constraints.

4. Using **present** material culture to explain **present** behaviours.

In constructing a behavioral analysis, a 'behavioral chain' is built which maps out the sequence of actions that took place during the life history of an object (Hollenback and Schiffer, 2010). A behavioural chain is the sequence of all activities in which an element participates during its systemic context (Schiffer, 1976:49). The proponents of this technique admit that it is often difficult to construct a complete chain, therefore usually only segments are created. These chains are depicted as tables which organize the activities of an object against contextual information such as time, location, and interacting elements. The systemic portion of the life-history can also be modeled as a flow chart moving through the stages of procurement, manufacture, use, recycling, and discard (Schiffer, 1976).

The four strategies outlined above illuminate the deeply embedded processual goals of behavioral archaeology, including the application of general laws to the archaeological record. This method of analysis separates the object from the techniques and gestures of people interacting with material culture, essentializing the technology to a generalized schematic such as behavioural chains and flow charts. Thus, behavioural archaeology does not have the same ability as the *chaîne opératoire* to integrate individuals and gestures into analysis because it is focused on making generalized laws and theories applicable only at ‘zoomed-out’ scales.

1.3 Summary

Much of the current archaeological literature has focused on sequences of manufacture in the *chaîne opératoire* (e.g., Bar-Yosef and Van Peer, 2009), thus deprioritizing tool function in favour of understanding the manufacturing process. In contrast, behavioral archaeology incorporates the full life-history of the tool. However, in doing so it removes the human element of gestures and techniques and loses the ability to approach materials from a multi-scalar perspective. I would like to advocate the reintegration of function into our understanding of the *chaîne opératoire* and integrate a life-history approach (Kopytoff, 1986, Schiffer, 1976, 2010) into these methods. This recognizes that objects undergo complex processes after manufacture and before discard that are integral to our understanding of the interaction between people and objects (Gosden and Marshall, 1999). Function and use are essential elements in understanding an object’s life history and use-wear analysis is uniquely suited to address tool use and behaviours in the past. Furthermore, by moving the *chaîne opératoire* into the microscopic scale of analysis, we can evaluate material properties in new ways, illuminating traces of past processes and behaviours otherwise invisible in the archaeological record.

Research by Olivier Gosselain (Gosselain, 1992, Gosselain, 1999, 2000) marries the concept of technological style with the *chaîne opératoire,* looking for how social boundaries and identity are expressed at different stages of the *chaîne opératoire*. He articulates the importance of understanding subtle aspects of material culture for identifying social boundaries. Using ethnographic examples from West and Sub-Saharan Africa, he shows that different facets of identity are woven into each stage of the *chaîne opératoire*. This is because different stages of the *chaîne opératoire* involve different types of social interactions, which can result in different levels of technical fluidity. Technologically malleable and highly visible stages are more susceptible to variability and change as they are taught and learned among individuals (Gosselain, 2000). In the context of lithic analysis, I suggest that the form of tools and their use falls within these categories; form is a highly visible aspect of lithic technology and is easily malleable through retouching to change the shape. However, the use of a tool is the most visible element of technology. Although not always a performance, tool use often takes place within communities where multiple individuals are present. Furthermore, the gestures used in the performance of tasks such as hunting, butchering, and harvesting, are usually expressive and include social interaction. Manufacturing details that are not visible in the final product, such as core preparation and retouching technique, are influenced only by a small handful of people: the teachers and other knappers. Thus, form and use are both highly flexible and easily shared (or identified) across social boundaries, while technological production is more restricted and locally based.

Highly visible elements of material culture can communicate social boundaries, as in Wiessner's emblemic style (1983), or they can be easily transmitted between groups. Technological diffusion happens with material culture that is easily borrowed or imitated without the need for migration (Gosselain, 2000). Thus, these 'diffuse technologies' can be transmitted through limited interactions, resulting in shared technologies with little self-identification of a common social group. I suggest that the trapeze-rectangle microliths, characteristic of the Middle Epipalaeolithic, are a technologically malleable and highly visible technology that is widespread as a result of technological diffusion and not limited to functional characteristics. Through the *chaîne opératoire*, I will explore the less visible elements of technological production and the more visible elements of tool shape and use. Variability seen between the sites of Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV suggests that the Geometric Kebaran is not a homogenized ‘culture’ with a cohesive identity, but represents a composition of communities through which technological ideas were shared and adapted to specific community needs.

1.4 Outline of Thesis

This dissertation presents a detailed analysis of three Middle Epipalaeolithic microlith assemblages from the sites of Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV to understand variability in lithic technology. Using an approach combining elements of the chaîne opératoire and life-history, this variability is explored through typological classification, technological analysis, morphometric analysis, and use-wear analysis.

Chapter 2 begins with a history of Epipalaeolithic research in the southern Levant. Following is a discussion of the Epipalaeolithic, highlighting the differences between commonly used culture distinctions in the Early, Middle, and Late Epipalaeolithic. This chapter focuses on how archaeologists currently differentiate between groups and how they define these differences on the basis of the lithic assemblages. Recent debates surrounding the interpretation of Epipalaeolithic culture groups are also presented to situate the study in current issues.

The following chapter, Chapter 3, introduces the three sites chosen for analysis, Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV. These three sites date to the Middle Epipalaeolithic period. They each contain very different cultural features and are situated in three different regions of Jordan. Comparison of site features and stratigraphy is presented in order to set the stage for the detailed analysis of the microlith assemblages.

The next chapter, Chapter 4, presents the results of the typological and technological analysis of the three lithic assemblages. Basic reduction strategies are discussed, typological classifications of tool assemblages, and raw material choice. Emphasis is placed on the microlith assemblages, both the non-geometric and geometric microliths, as these tools are used as cultural indicators for the Geometric Kebaran.

The morphology of the geometric microliths is more fully explored in Chapter 5. This chapter uses geometric morphometrics to evaluate the differences in trapeze-rectangle form among the three sites. This work highlights both intra- and inter-site variability in the geometric microliths.

Several experiments were conducted to generate a reference collection for lithic use-wear analysis. Descriptions of these experiments are in Chapter 6. In addition, this chapter presents my experiences using hafted microlithic tools on a variety of materials. This takes an experiential approach to understanding microlith function, further informing our conception of how these tools may have been used.

Both low- and high-powered use-wear analyses were undertaken to look for traces of use on the microliths. Chapter 7 presents the methods and the results of this use-wear analysis. For this analysis a sample of non-geometric and geometric microliths were analyzed. The results of each site are presented separately and then compared to understand patterns in function between different forms of microliths.

Chapter 8 presents a new quantitative method of use-wear analysis. Although this analysis was not used on an archaeological sample for this dissertation, it has the potential to contribute to our understanding of tool function through the refinement of the identification of contact material. This is evidenced through the analysis of the experimental collection presented in Chapter 6.

Finally, a synthesis of the results from the typology, morphological, and functional analyses is presented in Chapter 9. This chapter highlights the similarities and differences among the three sites, identifying patterns within the microlith variability. How does the variability of microliths help us understand the meaning of variability in material culture during the Epipalaeolithic and our definition of the Geometric Kebaran?

Chapter 2
The Epipalaeolithic of the Southern Levant

2 Introduction

This chapter outlines the background to the Epipalaeolithic in the Southern Levant, setting the stage for the analysis of three Middle Epipalaeolithic lithic assemblages. The chapter begins with a history of Epipalaeolithic research in the Levant, followed by a summary overview of the general chronological sequence of the Epipalaeolithic, beginning with the Early, then the Middle, and the Late Epipalaeolithic periods. Within each of these periods, the general culture history is focused on how archaeologists have divided and defined cultures from the archaeological material culture record. Finally, I will present recent and topical debates in Epipalaeolithic research oriented around how we interpret material culture variability.

The Epipalaeolithic is often discussed as a prelude to the origins of agriculture. Epipalaeolithic culture groups have been placed in contrast to the Neolithic, identifying traces and developments from hunting and gathering towards agricultural development. Thus, archaeologists have focused on the final stages of the Epipalaeolithic, the Natufian, to find the origins of agriculture. However, the earlier Epipalaeolithic periods exhibit behavioural variability and innovations linked to economic, technological, and social changes also witnessed in the Natufian and Neolithic (Maher, et al., 2012a), suggesting a long-term trajectory. Current Epipalaeolithic literature does not focus enough attention on these earlier phases, thereby ignoring complex human relationships with material culture and the environment.

2.1 The Epipalaeolithic

The Epipalaeolithic period took place during the transition from the Late Pleistocene to the Early Holocene in Southwest Asia and North Africa. It is divided into three main periods, the Early (23 000-17 500 cal BP), the Middle (17 500-14 600 cal BP) and the Late (14 600-11 600 cal BP). Each of these periods are defined from their lithic assemblages, with the Early Epipalaeolithic characterized by non-geometric microliths, the Middle Epipalaeolithic characterized by trapeze-rectangle geometric microliths, and the Late Epipalaeolithic characterized by lunates (Figure 1). Early and Middle Epipalaeolithic sites are traditionally understood as ephemeral hunter-gatherers sites, although recent evidence for built habitations, deep cultural deposits, and cemeteries is challenging this interpretation (e.g., Maher, et al., 2011a, Maher, et al., 2012b, Nadel, 2006, Nadel, et al., 2004). The long-term Epipalaeolithic trend indicates a move towards more sedentary communities and from non-geometric forms to geometric microliths in Southwest Asia. During the Late Epipalaeolithic, we find the first evidence of wide spread stone architecture that has been interpreted as evidence of increasing sedentism in comparison to previous periods (Bar-Yosef, 1998). However, at the end of the Late Epipalaeolithic period, stone architecture is abandoned for more ephemeral shelters and increased mobility.

The Early, Middle, and Late Epipalaeolithic periods are subdivided into cultural entities based on characteristics of the lithic tool assemblages. There is considerable debate about the scale of these groups and how they should be divided. Some archaeologists advocate for numerous named entities, highlighting assemblage variability (e.g. Henry, 1995), while others lump together groups to emphasize cultural continuity (e.g. Olszewski, 2001, Olszewski, 2006). The commonly used typology of Epipalaeolithic groups is outlined in Table 1 and the microliths appear in Figure 2. Henry (1995) identified several new cultural phases unique to Southern Jordan, named the Qalkhan, Hamran, and Madamaghan. These terms have not been widely adopted and subsequent researchers have suggested these entities should be classified as more commonly used cultural names, as the definitions of Henry's groups are similar or identical to current definitions (Olszewski, 2006, 2011). Because of this, the Epipalaeolithic cultural entities discussed by Henry are not included in the summary of the Epipalaeolithic periods.

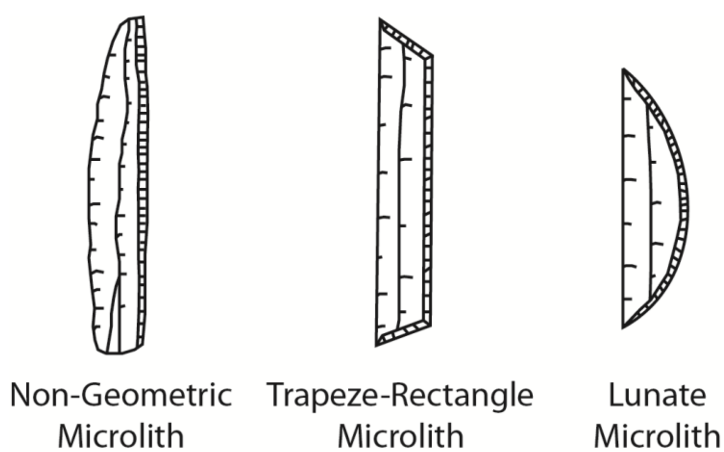


Figure 1: Schematic of non-geometric, trapeze-rectangle, and lunate microliths from the Early, Middle, and Late Epipalaeolithic.

Table 1: Epipalaeolithic Culture Groups of the Southern Levant.

Dates (cal BP)	Mediterranean Zone	Steppe and Desert Zone	Dominant Microlith Type
		EARLY EPIPALAEOLITHIC	
23 000-17 500		Nebekian	narrow curved bladelets with the microburin technique
	Masraqan	Masraqan	microliths with Ouchtata retouch and backed bladelets
	Kebaran	Kebaran	backed bladelets and micropoints, Kebara points
	Nizzanan	Nizzanan	microburin technique
		MIDDLE EPIPALAEOLITHIC	
17 500-14 600	Geometric Kebaran	Geometric Kebaran	trapeze-rectangles
		Mushabian	La Mouillah points made with the microburin technique
		Early Ramonian	Ramon Point (obliquely truncated bladelet with concave backing)
		LATE EPIPALAEOLITHIC	
14 600-12 900	Early Natufian		large lunates with Helwan retouch
		Terminal Ramonian	Ramon Point (obliquely truncated bladelet with concave backing)
12 900-11 600	Late Natufian	Late Natufian	small lunates with bipolar retouch
	Final Natufian		
		Harifian	Harif projectile points

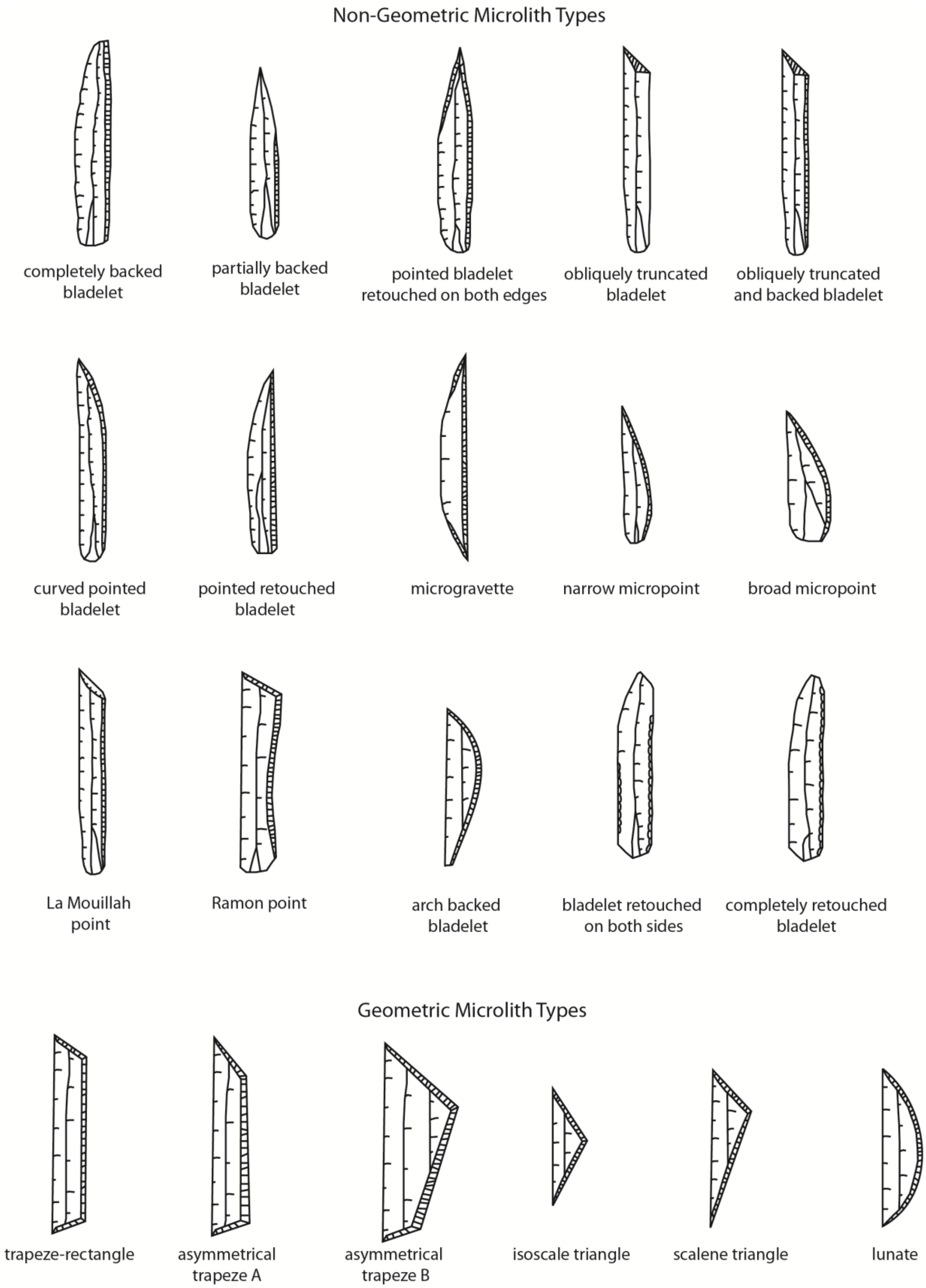


Figure 2: Epipalaeolithic microlith types (adapted from Bar-Yosef 1970).

2.2 History of Epipalaeolithic Research in the Southern Levant

The Epipalaeolithic was first identified in the Southern Levant by Dorothy Garrod, who uncovered Late Epipalaeolithic deposits from several sites, including Shukba and el-Wad caves in Israel (Garrod, 1932). Garrod describes the most abundant microliths at Shukba as being "small lunate with blunted back' (1932: 258). She describes the microliths from el-Wad as similar to these lunates, with backing that had been "trimmed from both surfaces, the result being to make it sharp instead of blunt" (1932: 261), suggesting they were backed with Helwan retouch. Both sites contain several burials from the microlith bearing deposits and have an abundance of worked bone tools. Garrod labeled these sites as Mesolithic based on European comparisons and not as Epipalaeolithic, but coined the term 'Natufian' to describe the local cultural complex (Garrod, 1932). Other early research in the region included the excavations of Kebara Cave (then termed Mugharet el-Kebarah). These excavations uncovered remarkable worked bone material including carved sickle handles and fish hooks (Turville-Petre, 1932).

Following these initial excavations, Perrot and colleagues began excavations in 1955 at the Natufian site 'Ain Mallaha, located in northern Israel (Perrot, 1966). These excavations resulted in the discovery of several round stone structures, bone, and lithic artifacts. The most remarkable find from this site was the discovery of a human burial containing the skeleton of a 3-5 month old puppy (Davis and Valla, 1978). The individual's hand rested on the body of the puppy, who was buried close to the individual's head, leading the investigators to speculate that the domesticated dog emerged during the Natufian.

Meanwhile, on the other side of the Jordan Valley, Diana Kirkbride was surveying southern Jordan. With the help of local populations she located two Epipalaeolithic sites, the Early Epipalaeolithic site Wadi Madamagh (Kirkbride, 1958) and the Late Epipalaeolithic/Neolithic site of Beidha (Kirkbride, 1966). The rockshelter Wadi Madamagh contained several hearths and rich cultural material, making it an important Early Epipalaeolithic site east of the Jordan Valley. Beidha became a significant excavation for Kirkbride and she continued to excavate at the site until 1983.

The first large systematic exploration of the Levantine Epipalaeolithic was undertaken in the 1960's during Ofer Bar-Yosef's dissertation research (1970). In this work, Bar-Yosef created the first Epipalaeolithic type list specific to the Levant (derived from North African typologies developed by Tixier (1963)). Although other researchers have expanded on this typology (e.g., Byrd, 1989, Goring-Morris, 1987, Henry, 1989, 1995, Hours, 1974), Bar-Yosef's typology is still widely used today. His dissertation presented the lithic assemblages from eight excavated Epipalaeolithic sites and 23 surface scatters, classifying them into cultural groups based on the proportion of microlith types present in the assemblage. This work focused on Epipalaeolithic assemblages to the west of the Rift Valley, in Israel and Palestine. Sites discussed by Bar-Yosef in this work include the Early Epipalaeolithic site of Ein Gev I, which had evidence for a hut structure and a human burial, both rarely discovered at Early Epipalaeolithic sites.

During the period the excavations at Hayonim Cave began, directed by Bar-Yosef, Arensburg, and Tchernov (Bar-Yosef, 1991). They began work in 1965 and their initial goal was to establish the cultural sequence and classify the lithic assemblage using Bordes' methods. The excavations revealed stratified Late Epipalaeolithic, Early Epipalaeolithic, Upper, and Middle Palaeolithic deposits. In early seasons the directors identified cultural remains on the terrace outside the cave, and excavations were conducted there during the 1970's by Henry revealing further Epipalaeolithic material.

Moving south, the Negev and the Sinai also became a focus of research in the late 1970's and early 1980's. Early work in this region was conducted by A.E. Marks and colleagues in the central Negev highlands (Marks, 1975, 1976). Other early research in this region was conducted by Bar-Yosef and Phillips (1977) near Gebel Maghara in the Sinai. The largest archaeological survey to be conducted in this region was the Emergency Survey of the Negev, commencing in 1979, the results of which were published by the director of excavations, Nigel Goring-Morris (1987), as part of his dissertation research. This survey began as the Israeli Defense Forces were redeployed into the Negev, allowing easier access into the region. By the mid-1980's, over 280 Epipalaeolithic sites had been identified in the Negev and Sinai regions of the Southern Levant (Goring-Morris, 1987).

During the '70s and '80s, research was also expanding in Jordan, with the beginning of several regional survey projects. Although these surveys were not exclusively focused towards the identification of Epipalaeolithic sites, they did discover and map numerous Late Pleistocene occupations across Jordan. These survey projects have covered the areas of southern Jordan, Wadi Hasa, the Azraq Basin, Wadi Hammeh, Wadi Hisban, and Wadi Ziqlab.

Directed by Donald Henry, the Southern Jordan survey project covered four study areas, including the Judayid Basin, Jebel Qalkha, Jebel Mueisi/Mishraq/Muheimi, and Jebel Hamra (Henry, 1995). This project began active field research in 1979 and concluded in 1988. The project identified eighteen Epipalaeolithic sites ranging from the beginning to the end of the Epipalaeolithic sequence. Henry defined several new archaeological entities from these Epipalaeolithic assemblages, diverging from the generally used typology originally constructed by Bar-Yosef (1970). These include the Early Epipalaeolithic industries of the Qalkhan and the Early Hamran, the Middle Epipalaeolithic Hamran industry, and the Late Epipalaeolithic Madamaghan industry (Henry, 1995). These designations were not widely adopted by the archaeological community, with most researchers favouring the more commonly used typological groupings mentioned above.

The Wadi Hasa Survey Project also began in 1979 under the direction of Burton MacDonald (MacDonald, et al., 1998). This wadi is located southeast of the Dead Sea, in West-Central Jordan. Although it was originally focused on identifying sites dating to the earlier historic periods, the project mapped all archaeological occupations found within the wadi. The identification of over 200 prehistoric sites during this survey led to the creation of the Wadi Hasa Paleolithic Project, which focused on the Palaeolithic occupations in the wadi. This resulted in the discovery of over 10 Epipalaeolithic sites throughout the wadi ranging from the Early to the Late Epipalaeolithic (Clark, et al., 1998). Test excavations began on these Epipalaeolithic site during 1984 and continued over several seasons (Olszewski, 2011).

Survey and excavation in the Azraq Basin area, eastern Jordan, was conducted by Andrew Garrard and colleagues from the mid-1970's to early-1990's as part of the Azraq Basin Early Prehistory Project (Garrard, et al., 1994, Garrard and Byrd, 1992, Garrard, et al., 1985, Garrard and Stanley Price, 1977). This survey project covered the 12 000 km^2 area of the Azraq Basin, identifying prehistoric sites in an area previously considered environmentally 'marginal'. Fourteen Epipalaeolithic sites ranging from the Early Epipalaeolithic to the Late Epipalaeolithic were discovered in the region around and to the west of the oasis (Garrard, et al., 1994). These sites include the only Epipalaeolithic 'mega-sites': Jilat 6, Uwaynid 18, Uwaynid 14, and Kharaneh IV. These sites are notable for their density of deposits and large size (Kharaneh IV, the largest of these sites, is 21 000 m^2). Jilat 6 and Kharaneh IV both contain stratified Early and Middle Epipalaeolithic deposits, while the Uwaynid sites are primarily composed of Early

Epipalaeolithic material (Garrard, et al., 1994). Additional work was conducted to the east of Azraq in the basalt desert (Betts, 1986). This work has identified several Late Epipalaeolithic occupations and renewed work is just beginning in this area to continue excavations of Natufian deposits at Shubekha.

Moving to the north of Jordan, systematic survey was conducted throughout Wadi Hammeh (Edwards, 2001, Edwards, et al., 1996). This survey identified early, middle and late Epipalaeolithic occupations, totaling six sites (Edwards, et al., 1996). The site Wadi Hammeh 27 is notable for the discovery of a preserved 'sickle' with two rows of microlith inserts (Edwards, 2007). Philip Edwards also directed the Wadi Hisban survey, located just to the north of the Dead Sea in the Jordan Valley. This survey located an additional five Epipalaeolithic sites ranging from the Middle to the Late Epipalaeolithic (Edwards, et al., 1999).

Wadi Ziqlab, located in northern Jordan, has been subject to intensive survey by E.B. Banning since 1981. Extensive survey of the wadi in 2000 and 2001 located six sites containing material from the Early and Middle Epipalaeolithic (Maher, 2005a, Maher, et al., 2001, Maher and Banning, 2001). The site of 'Uyun al-Hammâm was found during this survey and was subsequently excavated (Maher, 2005b, 2007a, Maher and Banning, 2003, Maher, 2011). Other Epipalaeolithic sites found during this survey were ephemeral occupations or disturbed contexts within later occupations. Under the same project, the neighbouring Wadi Taiyiba was surveyed and two additional Early Epipalaeolithic sites were located (Maher and Banning, 2001, Maher, et al., n.d.).

Epipalaeolithic research has been ongoing in the Levant for over 80 years. During these decades, hundreds of sites have been identified or excavated, resulting in a rich archaeological record (Figure 4). The above-mentioned projects represent some of the larger initiatives aimed towards the survey and excavation of multiple Epipalaeolithic sites. However, there has also been ongoing work across the Levant of single excavations, targeting large sites such as el-Wad, Ohalo II, Kebara Cave, Neve David, Hayonim, 'Ain Mallaha, and Nahel Oren. The importance of these excavations and others like them cannot be underestimated in their contribution to our understanding of the Epipalaeolithic.

2.3 Culture and the Environment

Interpretations of the Epipalaeolithic have been intrinsically intertwined with the changing environment and climate (e.g. Bar-Yosef and Belfer-Cohen, 1989, Belfer-Cohen and Bar-Yosef, 2000, Goring-Morris and Belfer-Cohen, 1998, Goring-Morris, et al., 2009). Epipalaeolithic cultures are divided into Mediterranean or steppe/desert groups, creating a dichotomy between those that lived in the core and those that lived on the margins (see Table 1). Furthermore, interpretations of Epipalaeolithic mobility are linked to these environmental zones. It is thought that Early Epipalaeolithic groups concentrated in the Mediterranean zones and sparsely populated the steppe (Bar-Yosef and Belfer-Cohen, 1989). Later, Geometric Kebaran groups spread further into the steppe and into the desert as the vegetation zones fluctuated. During the Early Natufian, larger villages began in the Mediterranean zone and dispersed outwards, spreading Natufian cultural traits across the region (e.g. Goring-Morris, et al., 2009). This ‘core-periphery’ model has recently been challenged, highlighting the problems associated with using climate data to explain culture change (Richter, 2009). A brief description of the geography, environmental regions, and climate is presented to situate the Epipalaeolithic typology in context.

The Levant is situated between the southern Taurus Mountains to the north, and the Sinai Peninsula to the south. Its eastern extent stretches to the Middle Euphrates valley and the western edge borders the Mediterranean Sea (Bar-Yosef and Belfer-Cohen, 1989) (Figure 3, Figure 4). The topography of the southern Levant is divided into several north-south strips (from west to east), the coastal plain, the mountainous region, the Jordan-Araba rift valley, the eastern plateau, and the eastern lowlands (Horowitz, 1979). The coastal plain, which borders the Mediterranean Sea, and the mountainous region are both located in modern Israel/Palestine. The mountainous zone is composed of carbonate rocks, limestone, dolomites, and chalk (Horowitz, 1979), and are filled with caves as a result of karstic or marine processes (Fellner, 1995b). Adjacent to this region is the Jordan-Araba Rift Valley which divides Israel/Palestine and Jordan. The Dead Sea is situated in this valley, providing the lowest land elevations at 423 m below sea level. Finally, the eastern extent of the southern Levant is characterized by the Jordanian Plateau, a landscape gently inclined to the east. The plateau is punctuated by large depressions such as the Azraq Basin, which covers 12,000 km^2 of the plateau (Garrard, et al., 1994).

Figure 3: Map of the Levant with modern geo-political boundaries.

Figure 4: Map of the Levant with sites named in the text. Sites analyzed in this research (Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV) are capitalized.

Modern climate zones are often used as a basis for understanding the distribution of Epipalaeolithic cultures across Levantine geography. The current environment is characterized by three vegetation zones; the Mediterranean zone, the Irano-Turanian steppe, and the Saharo-Arabian desert (Bar-Yosef and Belfer-Cohen, 1989). The Mediterranean zone is characterized by a high average rainfall with over 350mm of precipitation per year. Over 800 plant species can be found in this region including deciduous forest plants and evergreen varieties (Zohary, 1962). Prior to agriculture, these forests would have covered much of the Mediterranean area. In contrast, the Irano-Turanian steppe is drier, with only 200-350mm of average rainfall. There is a decrease in the range of flora species present in the steppe with approximately 300 different species including small shrubs, brushwood, and pistachio trees (Zohary, 1962). Finally, the Saharo-Arabian desert has a mean precipitation of less than 200mm per year, with as little as 50mm of average rain in some regions. This zone is populated by approximately 300 different species of desert plants. Palynological evidence from the Huleh Basin, Israel, indicates that the extent of these vegetation zones has fluctuated over time (van Zeist and Bottema, 1982). During the Epipalaeolithic, the boundaries of these zones would have been in flux, shifting based on the relative precipitation at the time (Bottema and van Zeist, 1981, van Zeist and Bottema, 1982, van Zeist and Bottema, 1991).

The fluctuations in vegetation zones are linked to several notable global climate events that took place during the Epipalaeolithic. Multiple lines of evidence build an image of the palaeoclimatic conditions for the Levant during the Terminal Pleistocene, including lacustrine sediments, palaeosols, fluvial sediments, terrestrial palaeobotanical records, speleothems, mollusks, calcretes, deep-sea cores and coral records (Robinson, et al., 2006).

The beginning of the Epipalaeolithic took place during the Last Glacial Maximum (25 000-18 000 cal BP), which was generally cooler and drier than current conditions. During this time Lake Lisan, the Late Pleistocene lake present in the current location of the Dead Sea basin, would have been high, having reached its maximum height of >164 m below sea level at approximately 25,000 cal BP (Bartov, et al., 2002). Towards the end of the Last Glacial Maximum in the Levant the climate began to ameliorate, with rainfall increasing in the region. This would have resulted in more vegetation during the Middle Epipalaeolithic. The levels of Lake Lisan also dropped significantly, reaching levels of 300 m below sea level at approximately 15,000 cal BP.

Following the Last Glacial Maximum was the Heinrich 1 event, a rapid but short cooling event. The presence of this event in the Levant is evident through cooling phases witnessed in the speleothem records from Soreq Cave, Israel (Bar-Matthews, et al., 1999). This event occurred at 16 800-16 500 cal BP, just prior to the warmer climate of the Bølling-Allerød interstadial (Maher, et al., 2011b). Current evidence suggests that the Middle Epipalaeolithic began 795-1145 years prior to the beginning of the Heinrich 1 event and was therefore not a motivator for the cultural change seen between the Early and Middle Epipalaeolithic (Maher, et al., 2011b). However, the people living during the Middle Epipalaeolithic would have experienced the environmental effects of the Heinrich I event and would have adapted within their own cultural framework to the change in climate.

The Bølling-Allerød interstadial is characterized by an increase in precipitation and rapid warming (Robinson, et al., 2006). This is viewed as a phase of climate amelioration in the region and was accompanied by increased soil development in the Levant (Maher, et al., 2011b). The Bølling-Allerød likely began 60-410 years after the beginning of the Early Natufian (Maher, et al., 2011b). This suggests that the Early Natufian people enjoyed this warmer weather but that climate change did not herald the beginning of the Natufian.

The final major Pleistocene climate event was the Younger Dryas, marked by arid and cold conditions in comparison to the preceding period (Robinson, et al., 2006). The aridity during this period happened very rapidly and was very pronounced. Lake Lisan levels also continued to fall, reaching levels lower than the current levels of the Dead Sea. This event likely happened during the Late Natufian, some 230-680 years after the transition from the Early Natufian (Maher, et al., 2011b).

Traditional models of cultural groups in the Epipalaeolithic cite these climatic events as the prime motivator for cultural change. For example, Bar-Yosef and Belfer-Cohen (1989) suggest that the Geometric Kebaran developed during the climatic amelioration that arose after the Last Glacial Maximum. They go on to state that resource stress brought about by the abrupt climatic change caused Geometric Kebaran populations living in arid regions to move back into the Mediterranean zone (Bar-Yosef and Belfer-Cohen, 1989: 486). These shrinking territories resulted in pressure on available resources and a shift in social organization towards the features seen in the Early Natufian. Other prevailing models associate the onset of the Early Natufian with the Bølling-Allerød and link the climatic stress associated with the Younger Dryas to increased mobility witnessed in the Late Natufian (e.g. Grosman and Belfer-Cohen, 1999).

The model of climate change as a prime mover of cultural change has recently been challenged (Maher, et al., 2011b, Richter, 2009). These researchers suggest that the relationship between humans and climate change is more complex than the current models, and that nuanced, regional views of human environment interactions need to be adopted (Maher, et al., 2011b).

2.4 The Early Epipalaeolithic (23,000-17,500 cal BP)

The Early Epipalaeolithic period in the Southern Levant exhibits continuity with the preceding Upper Palaeolithic through the continued use of microlith technologies (Goring-Morris and Belfer-Cohen, 1998). These Early Epipalaeolithic microliths tend to be continuously backed with abrupt retouch and very little modification from the blank to the finished tool (Belfer-Cohen and Goring-Morris, 2002). This minimal retouch probably reflects the nature of the haft. Unfortunately, no hafts have been recovered from this period, therefore there is little known about the composition or form of hafted Early Epipalaeolithic tools.

2.4.1 Masraqan

The earliest Epipalaeolithic entity is the Masraqan. These sites are found along the western shores of Lake Lisan and the lowlands of the central Negev and north Sinai (Goring-Morris and Belfer-Cohen, 1998). Masraqan lithic assemblages are dominated by bladelets with Ouchtata (very fine) and steep retouch. The microburin technique was not used for the production of bladelets during this period. Settlement patterns suggest that there was periodic aggregation and dispersal of small groups (Goring-Morris and Belfer-Cohen, 1998). This entity is characterized by small hunting and gatherer communities moving across the eastern and southern portion of the Southern Levant.

The best studied Masraqan assemblage is the site of Ohalo II, located on the southern coast of the Sea of Galilee, Israel. This site was submerged until the waters retreated in the late-1980's, exposing several well preserved hut structures (Nadel, 2002, Nadel and Werker, 1999). Stratigraphic levels from the hut floors indicates that they were re-occupied several times, with evidence for maintenance and rebuilding of the structures (Nadel and Werker, 1999). Botanical remains shows that the inhabitants of Ohalo II were using local grasses as bedding around the interior of the hut (Nadel, et al., 2004) and a variety of plants, including willow, tamarisk, and oak, to construct the hut superstructures (Nadel and Werker, 1999). Recent evidence suggests that the inhabitants of the site were grinding starchy cereals such as wheat, barley, and oats, on a large stone in one of the hut features (Nadel, et al., 2012). Other archaeological evidence from the site includes a human burial and an abundance of lithics. A single adult male burial was found to the west of the huts; skeletal evidence suggests he suffered from physical disabilities in his later years (Nadel and Werker, 1999). Detailed recording of artifact distributions located discrete interior and exterior flintknapping areas (Nadel, 2001), where the inhabitants of the site were manufacturing microliths with Ouchtata or abrupt retouch (and at times the both retouch styles along the same piece) (Nadel, 2003). This unique preservation of Ohalo II allows a glimpse into the use of perishable materials at the very beginning of the Epipalaeolithic, highlighting the complexity of material culture used by hunter-gatherers during this period that is often forgotten in less well-preserved contexts.

2.4.2 Nebekian

The Nebekian is contemporaneous with the Masraqan and is found in arid regions on the eastern margins of the Transjordanian plateau. This industry was first defined in the 1950s by Rust at Rockshelter 3, Jabrub, based on the presence of very narrow backed bladelets with truncations (Olszewski, 2006). The microburin technique was habitually used during the Nebekain to produce narrow, arched-backed and curved pointed bladelets (Belfer-Cohen and Goring-Morris, 2002). Tentatively, the Azraq ‘mega-sites’ of Wadi Jilat 6 (lower phase), Uwaynid 14, and Uwaynid 18 have been labeled as Nebekian occupations, but these assignments have not been solidified (see Byrd, 1988, Olszewski, 2006).

2.4.3 Kebaran

The most widespread cultural entity identified in the Early Epipalaeolithic period is the Kebaran, and these sites are primarily found in the Mediterranean zone (Bar-Yosef and Belfer-Cohen, 1989). This culture was originally named by Dorothy Garrod after the assemblage collected from layer ‘C’ at Kebara Cave. The lithic assemblages of the Kebaran are dominated by microliths (>50%), the majority of which are non-geometric microliths (>90%) including obliquely truncated bladelets and micropoints. These are manufactured on single-platform bladelet cores

(Bar-Yosef, 1975). The microburin technique was not used for microlith production. The non-microlithic assemblage includes tools such as burins and scrapers (Bar-Yosef, 1970).

Several regional and chronological variants of the Kebaran have been identified, sub-divided on the basis of frequency of different non-geometric microlith types (Bar-Yosef, 1981, Fellner, 1995b:21-22). These include 'Cluster A' (narrow, curved micropoints), 'Cluster B' (curved, pointed backed bladelets, sometimes with a basal truncation), 'Cluster C' (narrow micropoints and obliquely truncated backed bladelets), and 'Cluster D' (obliquely truncated backed bladelets, also called Kebara points). 'Clusters A' and 'B' are viewed as early, regionally distinct groups, while 'Cluster Cs' and 'D' are viewed as later chronological (Bar-Yosef, 1981). In addition, the presence of Kebara points is usually considered to be characteristic of the late Kebaran (Bar-Yosef and Belfer-Cohen, 1989). More recent publications have opted to remove the distinction between these clusters, favouring a more fluid interpretation of material culture variability. There is some evidence of groundstone technologies during this period, with the presence of basalt bowls, mortars, and pestles recovered from Kebaran sites.

Kebaran sites tend to be relatively small, ranging between 25 and 400 m^2 (Bar-Yosef, 1970, Bar-Yosef and Belfer-Cohen, 1989), although it has also been suggested that the larger sites, >50 m^2, are the result of periphery scatters of material and realistically sites should be considered as 25-50 m^2 in area (Bar-Yosef, 1981). Kebaran occupations are usually interpreted as ephemeral seasonal camps. Site distribution patterns and gazelle cementum analysis suggest that there was a pattern of circulating seasonal mobility, with highlands occupied during the spring/summer and lowlands occupied during the autumn/winter (Bar-Yosef and Belfer-Cohen, 1989, Lieberman, 1993). Stratified assemblages such as Ein Gev I and Nahal Hadera V indicate that groups were repeatedly occupying the same location on the landscape, resulting in thick cultural deposits (Bar-Yosef and Belfer-Cohen, 1989).

2.4.4 Nizzanan

The Nizzanan is a late Early Epipalaeolithic variant with sites primarily to the east and the south of Lake Lisan (Goring-Morris and Belfer-Cohen, 1998). The lithic technology is similar to the Nebekian with the habitual use of the microburin technique. The dominant microliths are scalene and isosceles triangles, with the latter often bring very small at 0.4 mm (Garrard and Byrd, 1992). Non-geometric microliths include microgravettes, curved, pointed, and arched backed pieces (Garrard and Byrd, 1992). Ephemeral Nizzanan sites are found in the Negev and there is evidence for larger occupations in the eastern desert of Jordan (Goring-Morris and Belfer-Cohen, 1998), including the upper deposits of Wadi Jilat 6 (Phase A) (Garrard and Byrd, 1992).

2.5 The Middle Epipalaeolithic (17,500 – 14,600 cal BP)

During the Middle Epipalaeolithic sites spread further into the arid regions of the Southern Levant (Bar-Yosef and Vogel, 1987). Like the Early Epipalaeolithic, the Middle Epipalaeolithic is divided into cultural units based on the variability in lithic assemblages across the region. Primary changes in the lithic technology include a shift from non-geometric microliths to the systematic use of geometric microliths such as trapeze-rectangles.

2.5.1 Geometric Kebaran

The Geometric Kebaran is the most prominent and widespread culture group during the Middle Epipalaeolithic (Bar-Yosef and Vogel, 1987). It is suggested that the Geometric Kebaran was derived from the Kebaran industry, spreading beyond the Mediterranean zone into the Negev, Sinai, and the Sahara-Arabian desert of eastern Jordan (Bar-Yosef and Belfer-Cohen, 1989). Geometric Kebaran lithic assemblages are characterized by a high proportion of trapeze-rectangle geometric microliths in the tool assemblages (>50%) (Bar-Yosef, 1970). The microburin technique was rarely used in the production of these microliths.

Initially, Bar-Yosef (1981) split the Geometric Kebaran into two distinct groups, those with thick geometrics and those with thin geometrics. The Geometric Kebaran A had trapeze-rectangles manufactured on narrow bladelets, approximately 4.5-6.5 mm wide. These sites are concentrated in the Mediterranean zone and Bar-Yosef suggested that they represent a continuum from the preceding Kebaran period. In contrast, the Geometric Kebaran B group is identified on the basis of thick microliths, 7-8mm wide, and sites of this group are found in arid regions such as the Negev and Sinai. Recently, these distinctions have been abandoned as it becomes clearer that microlith width is a continuum and does not cluster into two distinct groups.

Trapeze-rectangle microliths are standardized across a large portion of the Southern Levant (Maher, 2005a), suggesting that there may have been some cultural contact or exchange across the region. It has been suggested that the introduction of geometric microliths in the Levant was the result of a heavy reliance on composite tools (Belfer-Cohen and Goring-Morris, 2002).

Although there are no recovered hafts from the Geometric Kebaran, there is indirect evidence for hafting found at the site of Lagama North VIII. At this location, a concentration of trapeze-rectangles was found with preserved calcareous adhesive along the backed edge, indicating that these were placed longitudinally in a haft (Bar-Yosef and Goring-Morris, 1977). Groundstone tools are found at many Geometric Kebaran sites, including pestles and bowls used for grinding (Bar-Yosef and Belfer-Cohen, 1989).

Geometric Kebaran sites range from very small occupations (15-25 m^2) to larger sites at 300-400 m^2 (Bar-Yosef, 1981, Bar-Yosef and Belfer-Cohen, 1989). Recent excavations have identified very large Geometric Kebaran occupations at the site of 'Uyun al-Hammâm, approximately 1,500 m^2 (Maher, 2007b). In addition, the mega-site of Kharaneh IV in the Eastern Desert contains trapeze-rectangle microliths and could tentatively be assigned to the Geometric Kebaran. These two sites indicate there is a large range in the size of Geometric Kebaran occupations during the Middle Epipalaeolithic, with some exceptionally large sites occupied during this time.

2.5.2 Mushabian

The Mushabian was first identified near Gebel Maghara in Wadi Mushabi, northern Sinai (Bar-Yosef and Phillips, 1977, Phillips and Mintz, 1977). This industry is contemporaneous with the Geometric Kebaran and is located in arid regions of the Negev and Sinai. The Mushabian is characterized by the intensive use of the microburin technique to produce La Mouillah points (backed bladelets with a microburin scar creating an oblique truncation), arched backed bladelets, and scalene triangles (Bar-Yosef and Phillips, 1977, Goring-Morris, 1987, Phillips and Mintz, 1977). Larger tools such as scrapers, perforators, and burins are rare in these assemblages. This industry may have been contemporaneous with the Geometric Kebaran, or it may have begun at the end of Geometric Kebaran occupations of the Negev and Sinai (Fellner, 1995b).

The sites are generally small and range from 25 to 150 m^2. There is some evidence of stratification suggesting the reuse of a single locale (Bar-Yosef, 1981). It has been noted that the Mushabian bears a resemblance to Epipalaeolithic assemblages in North Africa, particularly in the presence of La Mouillah points, which are found in the Iberomaurusian of the Maghreb (Phillips and Mintz, 1977). However, a clear link between these and African assemblages has not been established.

2.5.3 Ramonian

Sites of the Ramonian industry are also located in the Negev and the Sinai (Goring-Morris, 1987). This entity is characterized by the Ramon point, a bladelet with an oblique truncation over a microburin scar, with concave backing. The Ramon point has been described as a variant of a La Mouillah point because of the use of the microburin technique to truncate the bladelet. This industry has been divided into two phases, early and terminal, with the former lacking geometric microliths and the latter having lunates. Based on the presence of lunates, the Terminal Ramonian is associated with the Late Epipalaeolithic. Although there is evidence of stratified Ramonian deposits overlying Mushabian assemblages (Fellner, 1995b), some authors have argued that there are numerous similarities between the Mushabian and the Ramonian, suggesting that they should not be classified as separate cultural entities but lumped together as one group (Henry, 1998, Maher, 2005a).

2.6 The Late Epipalaeolithic (14,600-11,600 cal BP)

As with the other Epipalaeolithic periods, the Late Epipalaeolithic is divided into distinct cultural entities based on variability within the lithic assemblages. The most prominently studied cultural entity is the Natufian, which immediately precedes the advent of farming villages. Some researches divide the Natufian into three different stages, the Early, Late, and Final Natufian. Others create a simple dichotomy between the Early and the Late Natufian; it is this distinction that will be discussed below. The majority of Epipalaeolithic research has focused on the Natufian to better comprehend the shift from hunter-gatherer to agricultural practices.

2.6.1 Early Natufian

The Early Natufian is characterized by stone architecture, large groundstone tools, worked bone, on-site burials, and personal ornamentation. Many of these archaeological features are also found during the preceding Middle Epipalaeolithic and even into the Early Epipalaeolithic, but the systematic adoption of this suite of traits is not witnessed until the Natufian. Early Natufian sites range in size from small occupations to larger ‘base camps’ with stone architecture. These large sites, such as Hayonim, ‘Ain Mallaha, and el-Wad, are concentrated in the Mediterranean Zone, which has been labeled the Natufian ‘homeland’ (Bar-Yosef, 1998).

Stone structures from the Early Natufian are generally semi-subterranean and circular with stone-lined walls (Bar-Yosef, 1998). It has been argued that the Early Natufian occupation pattern has more evidence for semi-sedentary to sedentary behaviours then the Middle Epipalaeolithic, with evidence of permanent stone architecture and on-site burials (Perlès and Phillips, 1991). This interpretation is supported by the high density of fast-moving animals in Early Natufian faunal assemblages, suggesting that the inhabitants of these communities were able to focus on the small game that surrounded their base camps (Munro, 2003). Faunal evidence of year-round hunting at Natufian sites has been linked to the change from circulating mobility to radiating mobility, where foraging groups would continually return to the same base camp (Lieberman, 1993).

The interpretation that the Early Natufian people were sedentary has recently been challenged. Using discard distribution patterns from Wadi Hammeh 27, Hardy-Smith and Edwards (2004) suggest that Natufian structures were filled with refuse. The lack of disposal strategies suggests that Natufian populations were not yet adapted to sedentary living, and the authors advocate more nuanced definitions of mobility and sedentism. Boyd (2006) furthers this debate by suggesting that Early Natufian structures may reflect a shift towards new conceptions of 'place' on the landscape rather than sedentism. This links the architecture to the landscape without presupposing settlement patterns. Regardless of the interpretation, the systematic use of stone architecture is a feature of the Natufian not seen in previous periods.

The lithic assemblage from the Natufian period is characterized by the production of lunates, often using the microburin technique. These miniature half-moon-shaped lithics were hafted together to create larger composite tools. Bone hafts with longitudinal grooves for insets have been recovered in Natufian archaeological assemblages, such as those found at Wadi Hammeh 27 and Kebara Cave (Edwards, 2007, Noy, 1991). Lunates occur in sites all across the Southern Levant, suggesting that there was some cultural contact or interaction between groups throughout the region. In the Early Natufian, lunates were primarily backed using Helwan retouch, a method of bifacial backing that creates a pointed edge (Bar-Yosef, 1998, Valla and Bar-Yosef, 1979). This method of backing was abandoned in the Late Natufian. As well, Early Natufian microlith assemblages tend to have larger lunates than the Late Natufian, with an average length of 21mm or longer (Valla and Bar-Yosef, 1979). Other authors have suggested that these size divisions are also geographically sensitive (Olszewski, 1986).

The Natufian also saw a florescence of groundstone and art objects. Although both of these artifact types occurred in the preceding Geometric Kebaran, there was a dramatic increase in their prevalence during the Natufian. Numerous art objects have been recovered from Natufian sites, including decorated functional objects such as shaft straighteners and non-functional objects like animal figurines (Noy, 1991). As well, beads and pendants that would have served as personal ornaments are found in Natufian contexts (Belfer-Cohen, 1991). Several Early Natufian sites, including Hayonim Cave, el-Wad, and ‘Ain Mallaha, have burials that exhibit evidence for personal ornamentation (Belfer-Cohen, 1988, 1995). Although it has been implied that this represents social stratification, this hypothesis has been challenged, suggesting there is not sufficient evidence for hierarchy in the Early Natufian (Belfer-Cohen, 1995)

2.6.2 Late Natufian

During the Late Natufian, populations became increasing mobile, moving away from the larger villages with stone architecture. Communities spread beyond the Natufian ‘homeland’ centralized in the Mediterranean Zone and moved outwards into new territories. However, in some areas these populations continued to return to the old sites such as Hayonim, ‘Ain Mallaha, and Nahal Oren to bury their dead in secondary contexts (Bar-Yosef, 1998, Valla, et al., 1991).

Although the microlith assemblages of the Late Natufian are also dominated by lunates, they are notably different from the lunates found in the Early Natufian. Late Natufian lunates are usually backed using unifacial retouch, creating a blunted back. They are also smaller than the Early Natufian lunates, with an average length of approximately 13mm (Olszewski, 1986).

2.6.3 Harifian

The Harifian is a Late Epipalaeolithic variant, restricted to the arid regions of the Levant in the Negev and Sinai (Goring-Morris, 1991). Site size ranges from 200 to 750 m^2. Several sites display evidence of architecture in the form of round stone structures. Larger structures are semi-subterranean and circular, lined with stone slabs (Goring-Morris, 1991). Settlement patterns suggest that Harifian groups aggregated in large camps at high elevation from spring to autumn. As colder winter conditions set in these aggregated groups would disperse into smaller camps at lower elevations (Goring-Morris, 1991).

The material culture exhibits many of the same traits as the preceding Natufian, including bladelets produced from single-platform cores, and the use of the microburin technique for bladelet truncation (Henry, 1989: 220). What makes the Harifian unique is the presence of the Shunera and Harif points, the first projectile points to be used in this region. Shunera points are associated with the earliest Harifian, and are small, triangular points with rounded bases often made with Helwan retouch (Goring-Morris, 1991). Harif points are found in later Harifian sites and are small unifacially retouched points with a sharp point at the distal end and a triangular/stemmed shaped base (Marks, 1973). These minimally retouched projectile points replaced geometric microliths as the primary hunting technology in these arid regions (Henry, 1989: 221). The continued use of projectile points and the abandonment of microliths characterize subsequent Pre-Pottery Neolithic A lithic assemblages. Exotic materials are also present in Harifian assemblages including turquoise pendants and shell beads from the Red and Mediterranean Seas (Goring-Morris, 1991). Ground-stone artifacts are common with both non-portable bedrock cup-marks and portable ground-stone tools such as grinding tools and shaft straighteners.

2.7 Recent Debates in Epipalaeolithic Research

Active debates among scholars have tried to identify the reason for the variability seen in Epipalaeolithic microlith assemblages (e.g. Barton and Neeley, 1996, Clark, 1996, Goring-Morris, 1996, Goring-Morris, et al., 1996, Henry, 1996, Neeley and Barton, 1994, Phillips, 1996). Early interpretations suggest that boundaries between microlith types represent boundaries between people, and that different forms of tools are markers of different ethnic or cultural groups (Bar-Yosef, 1970, Fellner, 1995b, Goring-Morris and Belfer-Cohen, 1998, Henry, 1995). These theories suggest that our typological classifications of microlith types represent meaningful distinctions between different groups on the Epipalaeolithic landscape. The interpretation that variability in stone tool form is indicative of ethnic group identity has been questioned by some recent scholars who highlight the inherent bias in typological analysis (Neeley and Barton, 1994, Olszewski, 2001, 2006, Pirie, 2004). In addition, a few studies have attempted to move beyond solely typological analysis of Epipalaeolithic lithics by addressing stone tool function (Richter, 2007, Tomenchuk, 1983, 1985).

A major critique of the 'ethnic' interpretation of typological diversity in microliths is that of Neeley and Barton (1994). These authors compare non-geometric backed bladelets with geometric microliths to assess whether the typological classification scheme currently used for Epipalaeolithic lithic assemblages is useful for distinguishing different groups. From this analysis, they suggest that the types currently identified in the archaeological record are not the result of different groups but represent different stages in a 'reduction sequence'. In their constructed sequence, straight-backed bladelets are the initial stage, which are then retouched into scalene or arched-backed bladelets. They propose a similar scheme for geometric microliths, with various geometric shapes retouched into other geometrics based on the configuration of the haft. For example, they exhibit how a rectangle, triangle, or lunate could be retouched into a trapeze microlith. Through this retouching sequence, they suggest that sites with assemblages composed primarily of microliths in the 'earlier stages' of reduction are initial flint-knapping and tooling sites. Using traditional typologies, these sites would be separated on a chronological or regional basis and interpreted to represent different groups.

These authors also suggest that the differences in the abundance of the microburin technique was part of a 'technological continuum' (Neeley and Barton, 1994: 277) and not the result of different ethnic groups. They propose that low microburin frequencies seen in the Geometric Kebaran were not because this technique was not used for bladelet truncation (as usually inferred). Instead, they hypothesize that the geometric microliths were manufactured on the microburin waste product, thereby removing evidence of this technological technique from the archaeological record of the period. Using metrics, they show that bladelets from Geometric Kebaran assemblages are almost twice as long as the geometrics from the same time period. They link this evidence to raw material availability, suggesting that the Geometric Kebaran may represent a different expression of the contemporary Mushabian (where the microburin technique is prevalent). Thus, they postulate that the lack of microburin technique seen during the Geometric Kebaran is the result of raw material conservation, where every part of the bladelet was retouched into a tool.

These technological interpretations of Epipalaeolithic microlith variability caused a wave of negative reaction in the archaeological community. Several rounds of comments were subsequently published, with a response from the original authors. Many of these comments focus on perceived methodological flaws or misinterpretation of the archaeological material. In the initial critiques, Fellner (1995a) points out that the metrics provided by Neeley and Barton for the Geometric Kebaran fail to account for the double truncation needed to produce the typical trapeze-rectangle microliths, which would result in needing longer blanks to produce two microliths from a single bladelet. He further argues that microlith types are often geographically and chronologically restricted; if different types were the results of resharpening, logically multiple geometric types would be found at each site (Fellner, 1995a). Other critiques highlight the same issue, stating that Neeley and Barton (1994) are inaccurate in their assertion that trapeze-rectangles, triangles, and lunates occur throughout the Levantine Epipalaeolithic (Goring-Morris, 1996).

Kaufman's critique (1995) emphasizes the fact that there are multiple documented ways to segment a bladelet, many of which do not require the use of the microburin technique. This is supported by Henry (1996), who states that trapeze-rectangles were manufactured through snapping and the flexion scars are witnessed on the debitage in these assemblages. Furthermore, the vast amount of debitage present on Epipalaeolithic sites suggests that raw material conservation was not a concern for most Epipalaeolithic knappers. Thus, there would be no need to conserve raw materials by retouching all of the microburins into geometric microliths (Goring-Morris, 1996, Henry, 1996, Kaufman, 1995). As well, there is evidence for Mushabian and Geometric Kebaran populations occupying similar territories, therefore each group would have had access to the same food and raw material resources. This shows that there are differences between the Mushabian and the Geometric Kebaran sites relate to more than economics and raw material conservation.

Finally, many microlith assemblages truncated with the microburin technique have residual evidence of the microburin scar on the retouched microlith. Thus, it would be highly unlikely that the microburin scar would have been retouched away on all trapeze-rectangles (Goring-Morris, 1996). Phillips (1996) argues that a technological approach alone is not enough to understand the variability witnessed in the Levantine Epipalaeolithic; using the *chaîne opératoire*, researchers can gain a deeper understanding for lithic variability. All five commentaries adhere to the hypothesis that microlith variability is the result of cultural groups and social factors, and not technological differences (Fellner, 1995a, Goring-Morris, 1996, Henry, 1996, Kaufman, 1995, Phillips, 1996).

A single voice supported the technological hypothesis proposed by Neeley and Barton, suggesting that the researchers critiquing the technological hypothesis are bound to French typological systems that links patterns in the archaeological record to culture (Clark, 1996). In response to the critiques, Barton and Neeley (1996) adhered to their original position, stressing the economic reasons behind material culture variability. This debate accentuated the divide between archaeologists favouring a cultural hypothesis and those favouring a behavioural hypothesis for lithic variability. No resolution was found between Neeley and Barton and their detractors, however the published debate did highlight a need for further inquest into the nature and meaning of lithic variability in the Epipalaeolithic.

As time has progressed, other researchers have questioned the paradigm that lithic variability is representative of cultural groups. Despite this, most researchers would contend that the technological hypothesis proposed by Neeley and Barton (1994) does not properly reflect the archaeological lithic assemblages from the Epipalaeolithic. If the variability witnessed in the archaeological microlith assemblages of the Epipalaeolithic is not the result of reduction sequences, as posited by Neeley and Barton (1994), then what is the driving force? Is it the result of cultural differences between contemporary groups or functional differences? Furthermore, is there variability within Epipalaeolithic assemblages attributable to the same cultural group? A detailed analysis of the microlith assemblages from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV will contribute to this debate by integrating typological, technological, and functional analyses to understand material cultural variability in the Epipalaeolithic.

Chapter 3
The Sites: Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV

3 Introduction

This chapter will introduce the three sites chosen for analysis: Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV. These three sites are situated in southern Jordan, northern Jordan, and eastern Jordan respectively, offering a range of different ecological resources to the sites’ inhabitants. For each site, the location, stratigraphy, and major archaeological features are presented to provide context for the analysis of the microlith assemblages.

3.1 Wadi Mataha

Wadi Mataha is a multicomponent Epipalaeolithic site, located near the ancient city of Petra in southern Jordan. Geometric Kebaran, Early Natufian, and Late Natufian occupations are present at Wadi Mataha. The site is located in the Mediterranean zone and is close to the desert lowlands and the Irano-Turanian steppe (Baadsgaard, et al., 2010). The Epipalaeolithic occupations are situated on a steep talus slope at the edge of Mughar al-Mataha, a large sandstone monolith. The site is approximately 950 m above sea level and is adjacent to Wadi Mataha, a river valley flowing towards Petra to the south. Chert nodules are readily available in this main drainage (Janetski and Chazan, 2001a), providing the site’s inhabitants with lithic raw materials. The site excavation divided into three areas, the lower, middle, and upper slopes (Figure 5). The lower and middle slope areas contain exclusively Early Natufian deposits. The Geometric Kebaran deposits are located on the upper slope of the site, where Late Natufian deposits overlie them (Janetski and Chazan, 2001b).

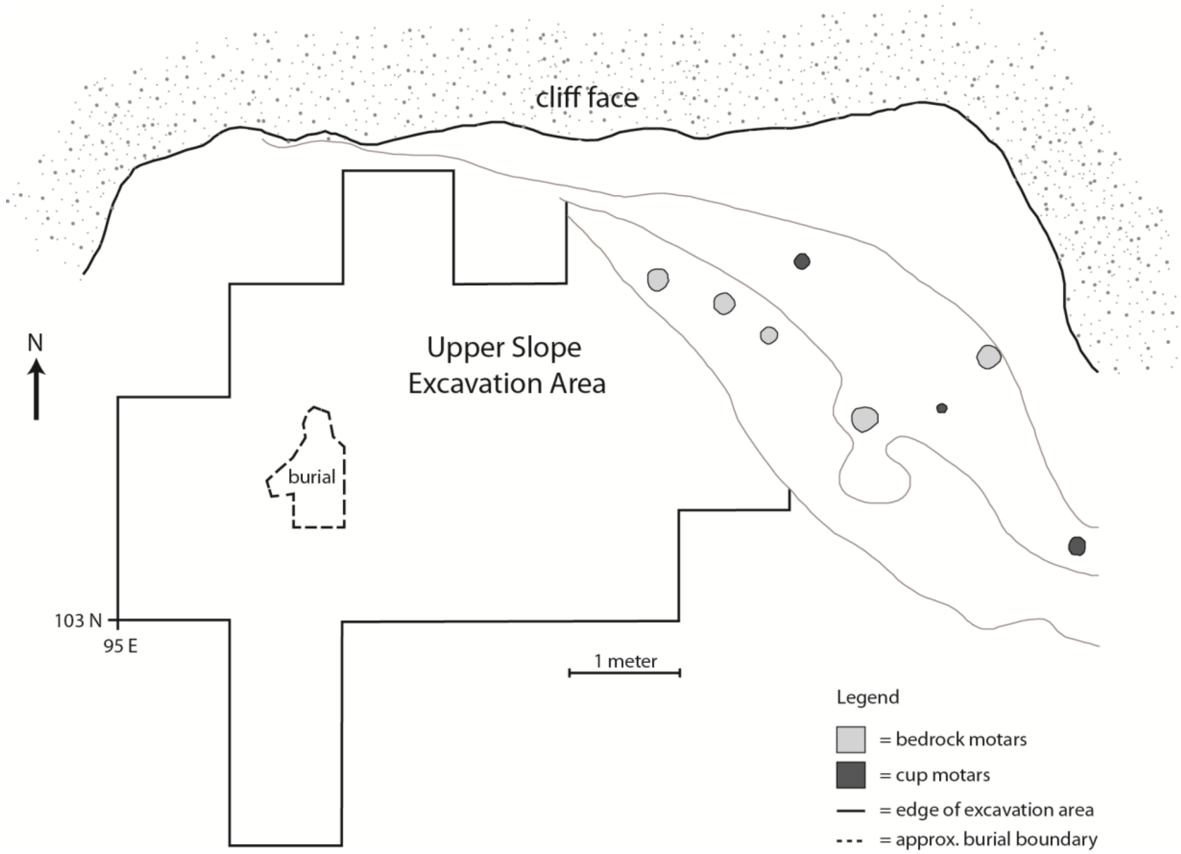


Figure 5: Plan map of Upper Slope excavation areas, Wadi Mataha (adapted from Baadsgaard, et al., 2010).

3.1.1 Wadi Mataha Stratigraphy and Dates

Excavations at Wadi Mataha began at the site in 1997 and were completed in 2005. The Geometric Kebaran component is located on the upper slope of the site and contained a human burial, as well as a wealth of lithic and faunal material (Stock, et al., 2005). The majority of the Geometric Kebaran deposits were contained in a single stratigraphic unit of compact reddish sand (labelled F17) underlying the Late Natufian deposits (Figure 6). Field notes indicate that this sediment was artifact-rich with lithics (including trapeze-rectangles) and faunal remains. Within this sediment, a single human burial was discovered (labelled F81). The burial was surrounded by artifact-rich sediment containing both lithics and bones (labelled F89) and no clear burial pit could be distinguished from the surrounding sediment (Stock, et al., 2005).

One radiocarbon date was taken from the Geometric Kebaran deposits at Wadi Mataha. This date places the Middle Epipalaeolithic occupation at 14,100±130 BP (lab # CAMS-55899) (Baadsgaard, et al., 2010).

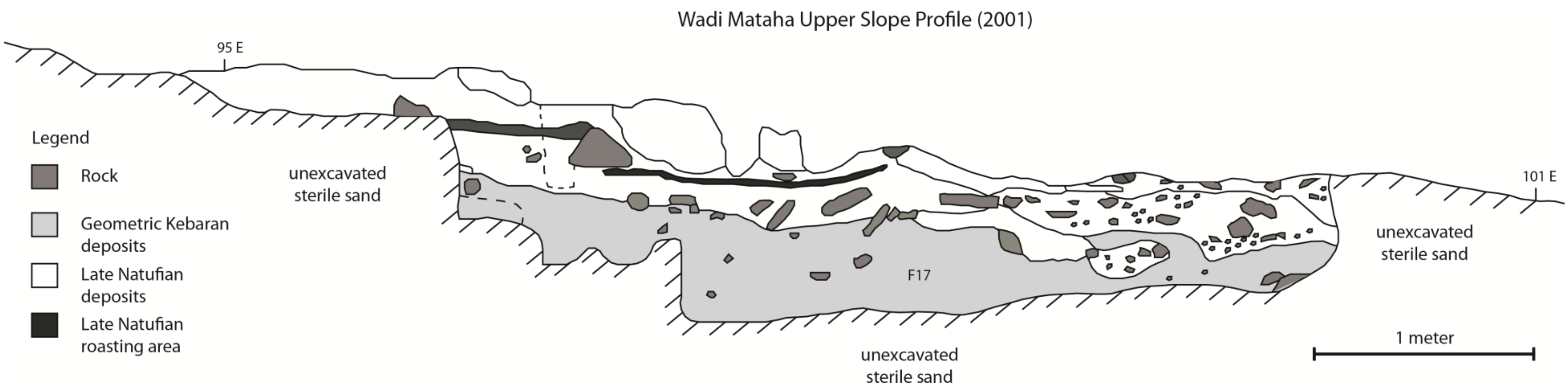


Figure 6: Stratigraphic section of the Upper Slope excavation area, Wadi Mataha (2001 excavations season).

3.1.2 Geometric Kebaran Occupation

The Geometric Kebaran deposits at Wadi Mataha are located in the upper slope area of the site, beneath the Late Natufian occupation. The Geometric Kebaran deposits contain lithics and well preserved faunal material. The faunal remains recovered from the Geometric Kebaran deposits indicate that the inhabitants of the site hunted a wide range of fauna, including medium and small mammals, reptiles, and birds (Baadsgaard, et al., 2002). The assemblage is particularly rich in gazelles and caprines, both of which would have been locally available. The small animal assemblage is dominated by tortoises, followed by birds in lower numbers (Baadsgaard, et al., 2002). Botanical remains show evidence for *Cerealia* sp. pollen, suggesting that cereal crops were present in the local environment (Baadsgaard, et al., 2010). It is unknown if these cereals were exploited for food during the Geometric Kebaran occupation of the site.

The most remarkable find from the Geometric Kebaran deposits is a complete human burial. The adult male skeleton (F81) was found in association with a fragmentary juvenile skeleton. The adult was lying face-down in the burial pit, with the hands and feet positioned behind the back, presumably bound together (Stock, et al., 2005). This unusual placement of the body suggests that there may have been a negative association with this individual during his lifetime. The skeleton itself has bilateral asymmetry in the upper limbs, which were also very strong and robust. There is no evidence of pathology, leading the authors to suggest that the asymmetry is the result of hunting-gathering behaviours. The lower limb robusticity corresponds with high terrestrial mobility, indicating the individual spent time walking the landscape (Stock, et al., 2005). This burial is associated with several grave offerings including a breached ground stone bowl and a large flint blade.

A single chert nodule recovered from the Geometric Kebaran deposits displayed a unique anthropogenic shape (Gregg, et al., 2011). This nodule was analyzed using scanning electron microscopy to identify microscopic manufacturing traces. Microscopic analysis revealed incisions and evidence of intentional smoothing of the surface. These manufacturing traces were in areas where the object was thinned or shaped, suggesting that the nodule was worked to accentuate the 'human' form of a natural formation. In addition, striations along the back of the 'head' were interpreted to represent hair (Gregg, et al., 2011). These types of objects are rare from the Geometric Kebaran, although not completely absent from the archaeological record.

3.1.3 Natufian Occupations

In addition to the Geometric Kebaran deposits, there are extensive Early and Late Natufian occupations at Wadi Mataha. The Early Natufian occupations are located on the lower and middle slope and contain two structures, interpreted to be terrace walls with artifact-dense fill. There is evidence that the wall underwent several phases of maintenance and repair (Janetski and Chazan, 2004). A carved stone bowl and a decorated basalt shaft-straightener were found in the floor deposits adjacent to the walls. Several modified pebbles and an incised chert nodule were recovered from the Natufian deposits at the site. Several of these pieces have incised line patterns and designs across the object, while one is interpreted to be a schematic representation of a figure with up-stretched arms. One of these structures also has evidence for an activity area in front of the wall containing roasting pits.

The Late Natufian occupations contain a roasting area and a rich, dark midden. Additional features include five bedrock mortars and three cup mortars at the northeastern edge of the site, adjacent to the Late Natufian occupation area. Due to the difficultly in dating these features, it is not known when they were manufactured or whether they were used during any single occupation phase at the site. However, grooves on the deepest mortars match grooved pestles recovered from the Late Natufian deposits, making it likely that they were used during this period (Janetski and Chazan, 2004). Botanical data and starch grain analysis recovered starches from several Late Natufian pestles suggesting that inhabitants of the site were exploiting cereals at during the Late Natufian (Baadsgaard, et al., 2010).

3.1.4 Wadi Mataha Summary

In summary, of the Epipalaeolithic occupations at Wadi Mataha, the Geometric Kebaran one was not extensive and likely represents a small habitation site. Despite the small occupation, these deposits contain several features that are rare for Geometric Kebaran occupations, including a bound human burial and an incised chert nodule. The Early Natufian deposits have evidence for terrace walls and stone structures, while the Late Natufian occupations have evidence for middens, roasting areas, and cereal exploitation.

3.2 ‘Uyun al-Hammâm

The site of ‘Uyun al-Hammâm is located in Wadi Ziqlab, northern Jordan, situated between the Transjordanian Highlands to the east and the Jordan Valley to the west (Maher, et al., 2011a). University of Toronto excavations at ‘Uyun al-Hammâm, conducted by the Wadi Ziqlab Project, have been ongoing at this site since 2000 (Maher, 2005b, 2007a, Maher and Banning, 2003). The original site would have extended approximately 1000-1500 m^2 and is 200 m asl (Maher, et al., 2011a). A large portion of the site was destroyed by a modern road cut, exposing the stratigraphic section along the side of the road. Figure 7 shows the excavation units situated on the far side of the road. The site extended along the terrace and up the slope into the olive trees. ‘Uyun al-Hammâm is located near a permanent spring and has abundant chert raw materials in the immediate vicinity (Maher, 2005a). The archaeological strata at ‘Uyun al-Hammâm are primarily composed of Geometric Kebaran deposits; however there is evidence of Byzantine terrace walls in the upper colluvium and some isolated Neolithic artifacts.

Figure 7: 'Uyun al-Hammâm, excavation units can be seen on the far side of the road (taken during 2005 excavations).

3.2.1 ‘Uyun al-Hammâm Stratigraphy and Dates

Excavations at ‘Uyun al-Hammâm commenced in 2000 with a series of test pits along the terrace adjacent to the road cut. Major excavations were conducted in 2002, 2005, and 2008, opening the majority of the excavations units. In 2012, a small crew reopened a few units to remove human remains discovered at the end of the 2008 excavation season. This season concluded excavations at the site for the immediate future. Excavations opened approximately 70 m^2 across the terrace, with units interspersed between olive trees (Figure 8).

Extensive geomorphological work in Wadi Ziqlab has resulted in a detailed understanding of the relationship between archaeological and climatic events in the wadi (Maher, 2011). Terminal Pleistocene conditions in Wadi Ziqlab were wetter and more humid then current environmental conditions in northern Jordan. This is corroborated by the well-developed soils in the Middle Epipalaeolithic deposits at 'Uyun al-Hammâm which would have formed during the warm and wet conditions (Maher, 2011). Therefore, the environment during Geometric Kebaran occupation of ‘Uyun al-Hammâm would have been warmer and with more precipitation than current conditions.

The uppermost stratum at ‘Uyun al-Hammâm is composed of Holocene colluvium. Underlying this colluvium is a Pleistocene palaeosol. These deposits are separated from each other by an unconformity resulting from an erosional event that took place at the end of the Pleistocene and beginning of the Holocene (Maher, 2011). Although no evidence for Late Epipalaeolithic occupation was evident in any deposits at the site, it is possible that any potential Late Epipalaeolithic occupations were destroyed by erosional events during this arid climatic phase. Although the upper stratum is reworked from upslope, the lower deposits of the red palaeosol represent undisturbed contexts of Middle Epipalaeolithic material. The archaeological material in the Holocene-age colluvial deposits includes a Roman or Byzantine field wall that crosses the excavation units and mixed Epipalaeolithic artifacts from upslope. The wall foundations are in the top of the reworked portion of the palaeosol, slightly cutting into the Epipalaeolithic deposits (Maher, 2011).

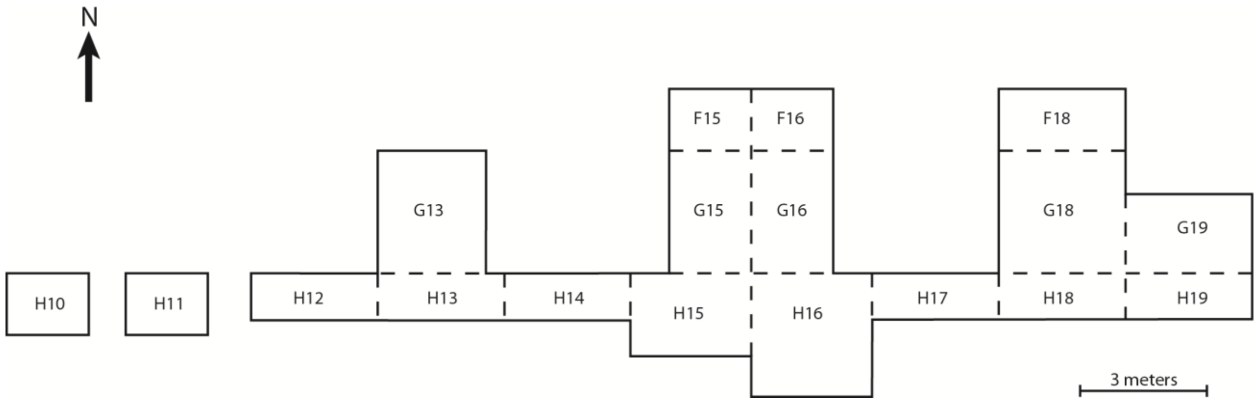


Figure 8: 'Uyun al-Hammâm excavation plan map.

Middle Epipalaeolithic sites in Wadi Ziqlab, including ‘Uyun al-Hammâm, are located in a red palaeosol (Maher, 2011). These deposits are distinctive in their sub-angular, blocky ped structure and high carbonate levels (Maher, et al., 2001, Maher, 2011). The soil is red in colour due to the deterioration of rich iron-bearing minerals in the soil, a process that requires a high moisture level in the environment (Maher, 2005a). Therefore, in the Levant, red soils are created during periods of increased rainfall and warm temperatures. These high temperatures and wet conditions also create deep soil accumulations (Goldberg and Macphail, 2006), such as those seen at ‘Uyun al-Hammâm. Within this red palaeosol are several distinct *in situ* archaeological loci (Figure 9). These are separated by changes in soil texture and compaction, the presence or absence of cobbles, and density of artifacts. All the loci within the red palaeosol contain Geometric Kebaran material.

Six radiocarbon dates have been obtained from the Geometric Kebaran deposits at ‘Uyun al-Hammâm, five from charcoal and one from human bone. These dates places the site between 17,250-16,350 cal BP and 15,000-14,200 cal BP (95% confidence intervals) (Maher, et al., 2011a) and situate the site firmly within the Middle Epipalaeolithic period.

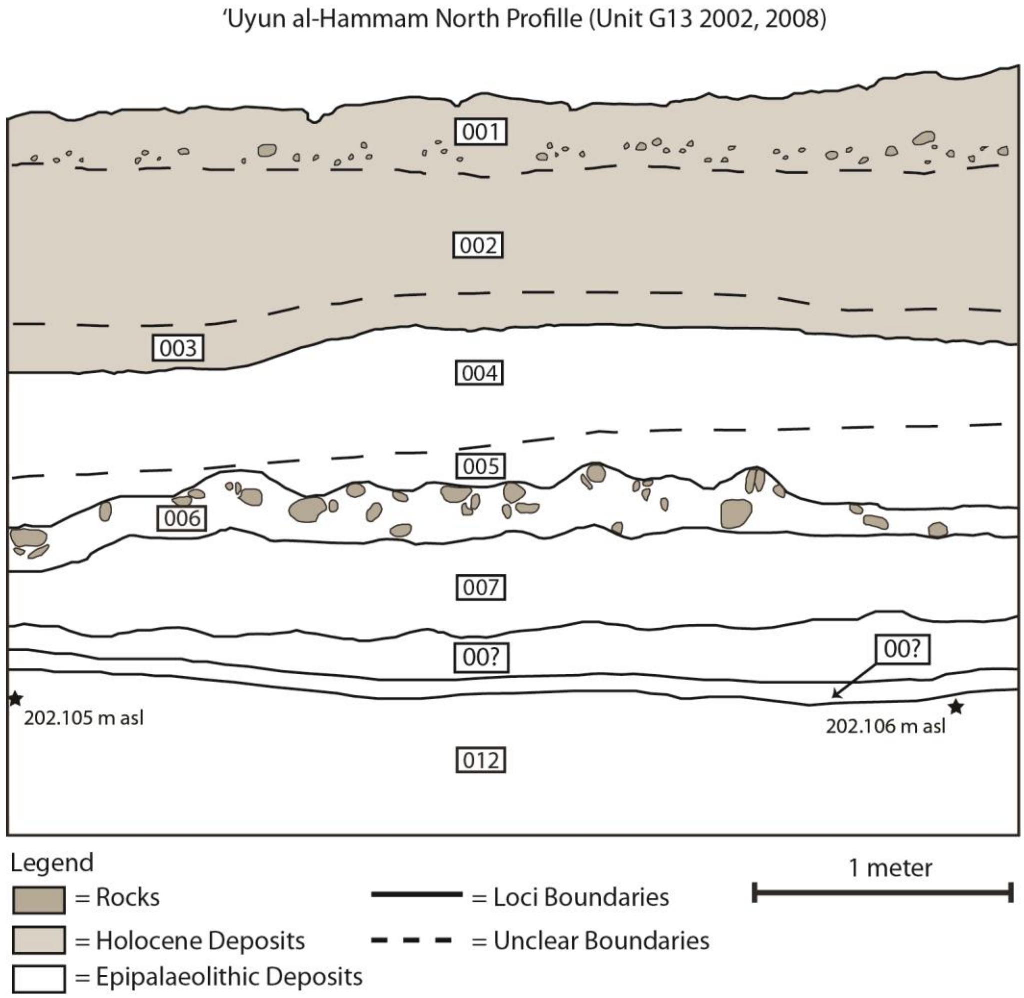


Figure 9: 'Uyun al-Hammâm stratigraphic sequence, north profile (drawn from excavations of unit G13 in 2002 and 2008).

3.2.2 Geometric Kebaran Occupation

In comparison to other Epipalaeolithic sites in northern Jordan, ‘Uyun al-Hammâm has extremely deep cultural deposits. These deposits contain dense concentrations of lithic and faunal material. Excluding the eastern desert ‘mega-sites’, these deposits are significantly denser than contemporary Geometric Kebaran occupations (see Table 5.2 in Maher, 2005a). Site features include middens, concentrations of fire-cracked rock, and at least one stone-lined pit. Preliminary faunal analysis suggests that the inhabitants of ‘Uyun al-Hammâm hunted a wide variety of local fauna including deer (*Cervidae* sp.), gazelle (*Gazella* sp.), hartebeest (*Alcephalus* sp.) and dog (*Canis* sp.) (Humphrey, 2003). All of the identified species found at the site could have been hunted in the surrounding forest-steppe (Maher and Banning, 2003). The faunal remains include items of both high and low utility, suggesting that complete carcasses were brought to the site for butchering (Humphrey, 2003). Detailed faunal analysis currently being conducted for the recent excavation material will provide further insight into the subsistence practices of the people from ‘Uyun al-Hammâm.

The retouched lithic assemblage is composed of classic Middle Epipalaeolithic tools, including trapeze-rectangle microliths and endscrapers on blades (Maher, 2005a). The complete lithic assemblage has been analyzed and the results are summarized in Chapter 3. Attribute analysis of the debitage suggests that the entire flintknapping sequence was undertaken at the site, with evidence for core preparation, maintenance, and discard (Macdonald, 2007).

The site has been interpreted as a cemetery because of the large number of human interments. During the course of excavations, eleven individuals were uncovered (Maher, et al., 2011a). These were buried in a variety of positions, including extended, flexed, multiple burials, and secondary contexts. This number of Middle Epipalaeolithic burials has not been found on any other sites from this period, making the burials at ‘Uyun al-Hammâm unique for the Geometric Kebaran (Maher, 2006). Osteological analysis indicates that none of the human remains show evidence of interpersonal violence (Maher, et al., 2011a), suggesting it is unlikely that the associated burials are the result of a catastrophic violent event, but rather that the site was re-used several times for human burial.

Burial pits are not obvious in the compact sediment, so it is difficult to associate artifacts with individuals. As a result, only items in direct association were considered as grave goods, potentially underestimating the objects offered with the burials (Maher, et al., 2011a). Despite this, there is a wealth of artifacts and faunal remains interred with the individuals at ‘Uyun al-Hammâm. Artifacts include worked bone, chipped and ground stone, unmodified cobbles, and ochre. Animal remains include articulated tortoises, aurochsen, gazelle, deer, and fox elements. The most remarkable find was an articulated post-cranial fox skeleton buried with one individual and a fox skull with a right humerus buried with another, adjacent individual (Maher, et al., 2011a). The proximity of these two fox burials and similar metrics make it likely that these fox elements belong to the same fox individual. This unique treatment of the fox in association with two burials suggests that the fox may have had a significant or special relationship with the people interred in the graves (Maher, et al., 2011a).

Variability in the human isotopic samples taken from ‘Uyun al-Hammâm suggests that Geometric Kebaran groups were seasonally mobile, occupying different regions with different isotope signatures (Diaz, et al., 2012). Despite occupying different regions, isotope work indicates they were not moving into arid zones, rather they were moving within the Mediterranean zone or into steppe environments (Diaz, et al., 2012). These results suggest that the inhabitants of ‘Uyun al-Hammâm had restricted mobility, moving within the local landscape and returning to the same site to bury their dead.

In summary, the depth and density of cultural deposits and human burials on site suggest that Middle Epipalaeolithic groups were repeatedly returning to ‘Uyun al-Hammâm. Lithic and faunal data indicate that a full range of activities was taking place onsite, signifying that this was a habitation locale for Geometric Kebaran groups occupying the Mediterranean zone of the northern Jordan.

3.3 Kharaneh IV

Kharaneh IV is located in the Eastern Desert of Jordan, approximately 70 km east of Jordan’s capital Amman at the western edge of the Azraq Basin. The site is situated approximately 1 km south of Qasr Kharaneh, one of the more notable desert castles. Kharaneh IV is a multi-component Epipalaeolithic site, with Early and Middle Epipalaeolithic occupations. Currently, the site is located in the limestone desert near the border of the Irano-Turanian steppe vegetation region. Although local palaeoenvironmental data is still being compiled, faunal remains from the site include species adapted for wetter climates, such as equids, cattle, and wild boar (Martin, et al., 2010), suggesting that conditions during the Epipalaeolithic were wetter than the current arid climate. Wadi Kharaneh flows into the western side of the Azraq Basin, a depression covering 12,000 km^2 that extends from Jebel Druze in southern Syria to the Saudi Arabian border (Garrard, et al., 1985) and runs adjacent to the site.

Lancaster Hardy (1959) originally discovered Kharaneh IV, which was subsequently resurveyed by Garrard and Stanley Price in the mid-1970’s (Garrard and Stanley Price, 1977). Dr. Mujahed Muheisen from Yarmouk University conducted initial excavations of the site in the 1980s, where he excavated two soundings into the site (Muheisen, 1983, 1988b). Current excavations are being conducted at the site by the Epipalaeolithic Foragers in Azraq Project (EFAP) and have been ongoing since 2008. Kharaneh IV is an exceptionally large Epipalaeolithic site, approximately 21 000 m^2 in size, making it one of the largest Terminal Pleistocene occupations in the Levant. The most abundant artifacts at the site are chipped stone tools, with an estimated two million lithics excavated to date.

Kharaneh IV appears as a low mound on the desert landscape; the accumulation of cultural deposits has created an Epipalaeolithic ‘tell’ rising 2 m above the ground surface (Figure 10). This mound has two peaks, one on the west and one on the east side of the site. During the initial 1980s excavations, test trenches were placed on top of each peak (Muheisen, 1983, 1988b). Early Epipalaeolithic cultural material occurs at the highest point on the site to the east and there are no overlying Middle Epipalaeolithic artifacts in this location (Area B). The western portion of the mound contains Middle Epipalaeolithic material and has stratified Early Epipalaeolithic material below the later deposits (Area A). Beginning excavations in 2008, EFAP reopened Muheisen’s trenches on the east and west peaks of the site and placed new excavation units around them to trace the deposits identified in the initial excavations.

Faunal analysis of the 1980’s assemblages indicates that gazelle (*Gazella subguttorosa*) was the primary hunted animal throughout the Early and Middle Epipalaeolithic occupation of Kharaneh IV (80-90%) (Martin, et al., 2010). Other animals present in the faunal assemblage include equids, aurochsen, wild boar, fox, hare, tortoises, and birds. There is no evidence for off-site butchering or selective transportation of elements, suggesting that hunting was happening within the immediate vicinity of the site (Martin, et al., 2010).

Cementum analysis of gazelle teeth indicates that the site was occupied in both spring/summer and autumn/winter (Jones, 2012). Although the sample size was small for this study, it shows that the site was occupied during multiple seasons during both the Early and the Middle Epipalaeolithic occupations.

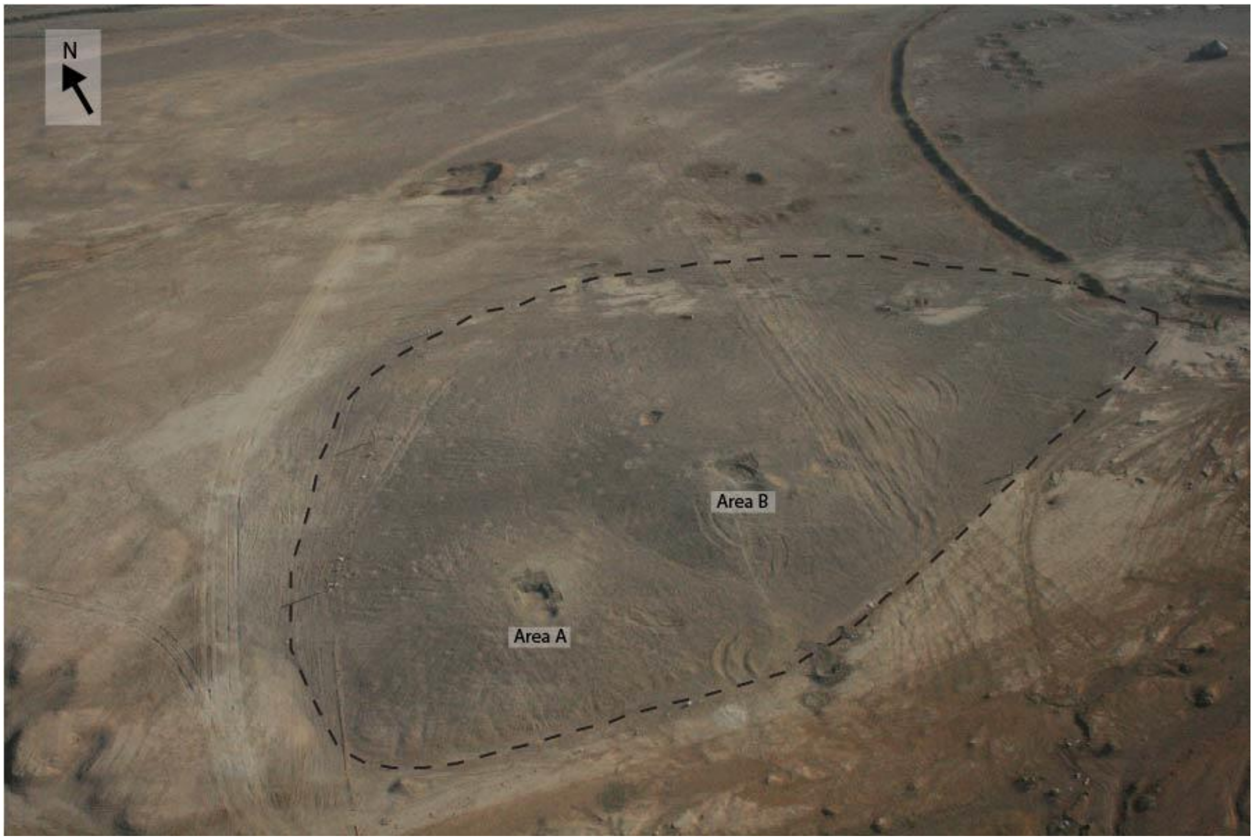


Figure 10: Aerial photograph of Kharaneh IV. The dashed line represents the site boundary. Excavation areas A and B are marked (photo by I. Ruben, 2008).

3.3.1 Kharaneh IV Stratigraphy and Dates

As mentioned above, Kharaneh IV is a multicomponent Epipalaeolithic site with occupations dating from the Early though the Middle Epipalaeolithic. EFAP has renewed excavations at the site and the following discussion of excavations refers to this recent ongoing work. In total, 34 square meter units have been excavated in the Middle Epipalaeolithic area on the western side of the mound (Figure 11).

In addition to opening contiguous excavations units on the east and west peaks of the site, a series of 1 m x1 m test pits were dug around the site to trace the extent of the stratified deposits. As well, a geological trench 9 m in length was dug from the adjacent wadi into the side of the mound to trace the relationship between the wadi deposits and the occupational deposits.

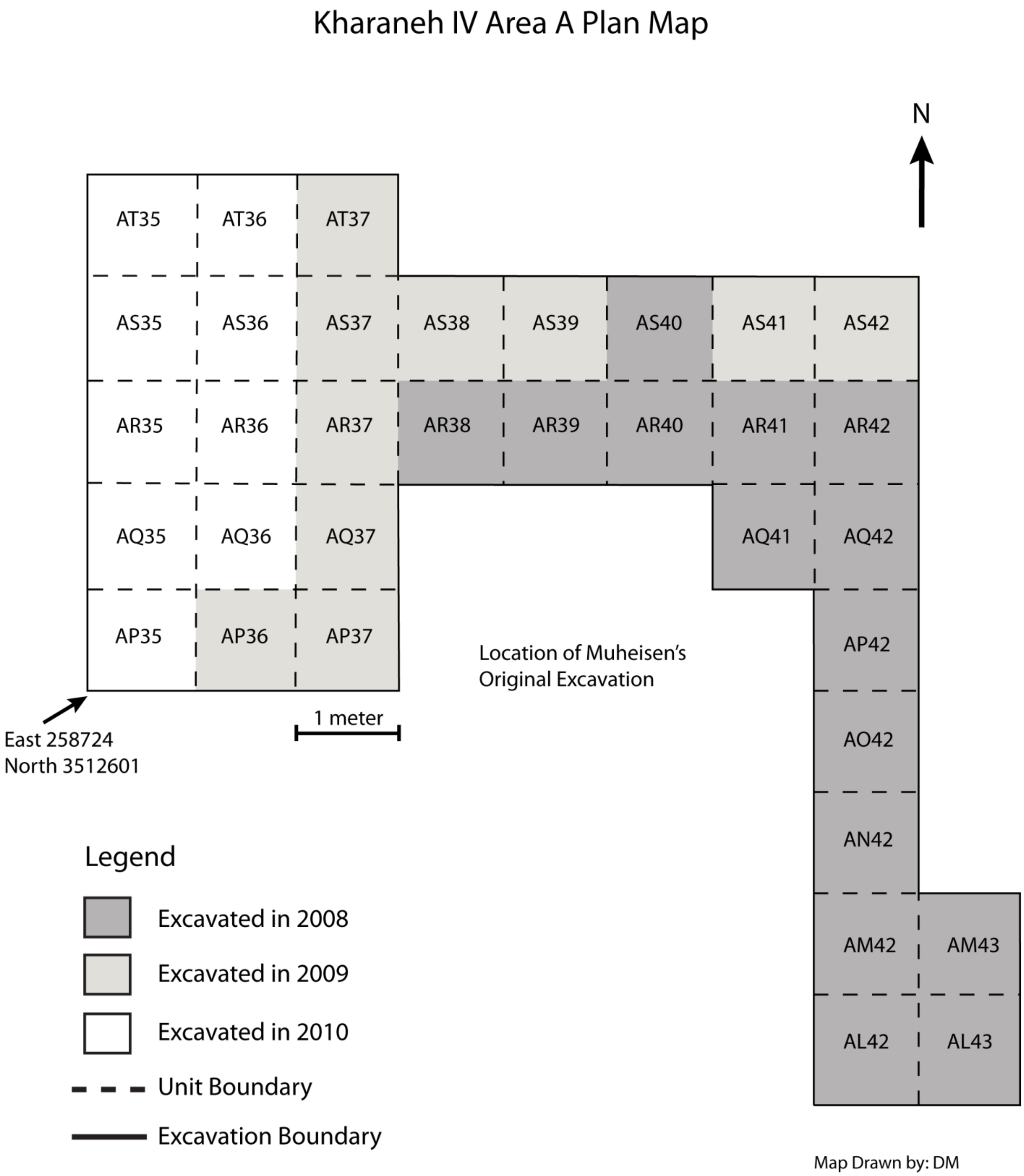


Figure 11: Kharaneh IV excavation plan map of Middle Epipalaeolithic area.

Despite surface deflation, the subsurface stratigraphy is very fine-grained in both excavation areas, with *in situ* deposits to a depth of 1.35 m below the surface. In the Early Epipalaeolithic area, thin, compacted occupation surfaces alternate with thick, dense midden deposits (Maher, et al., 2012b). The Middle Epipalaeolithic deposits are punctuated by a series of compact living surfaces into which postholes and hearths were cut.

A 1 m x 1 m sounding (AS42) was excavated in Area A to test the depth of the deposits (Figure 12). Underlying the Middle Epipalaeolithic material are Early Epipalaeolithic artifacts similar to the ones recovered from Area B. At a depth of 638.96 m ASL (70 cm below ground surface), the sounding encountered deposits that appeared to be lacustrine sediments. These deposits still contained artifacts, although in lower densities than the rest of the site, suggesting that this may be the result of fluctuating levels from a nearby lake periodically inundating the site. However, further excavation and detailed stratigraphic analysis is needed prior to making conclusive interpretations.

Radiocarbon samples date the starting age range for the Early Epipalaeolithic occupations between 19,808-19,367 cal BP and the end range at 18,934-18,865 cal BP (95.4% confidence level) (Richter, et al., n.d.). The beginning of the Middle Epipalaeolithic occupation is dated between 18,934-18,685 cal BP and the end at 18,809-18,560 cal BP (95.4% confidence level) based on five AMS measurements. This gives a very early date for the Middle Epipalaeolithic occupation at Kharaneh IV. Despite these early dates, the geometric microliths present in the assemblage aligns the occupation with other Middle Epipalaeolithic sites.

3.3.2 Early Epipalaeolithic Occupations

In the Early Epipalaeolithic area (Area B), renewed work initially focused on a combination of horizontal and vertical excavations. The excavations of Area B revealed several pit features, compacted surfaces, hearths, middens, and ash dumps (Maher, et al., 2012b). During the 1980’s excavations, two human burials were discovered in these deposits. The burials were primary and extended, with their hands placed along their sides (Rolston, 1982). Two gazelle horn cores were placed on either side of the head of Burial 2. Both burials were male; the first was a young adult and the second between 35 and 45 years old. Burial 2 suffered from several conditions, including a widespread bone infection, when he met his demise (Rolston, 1982).

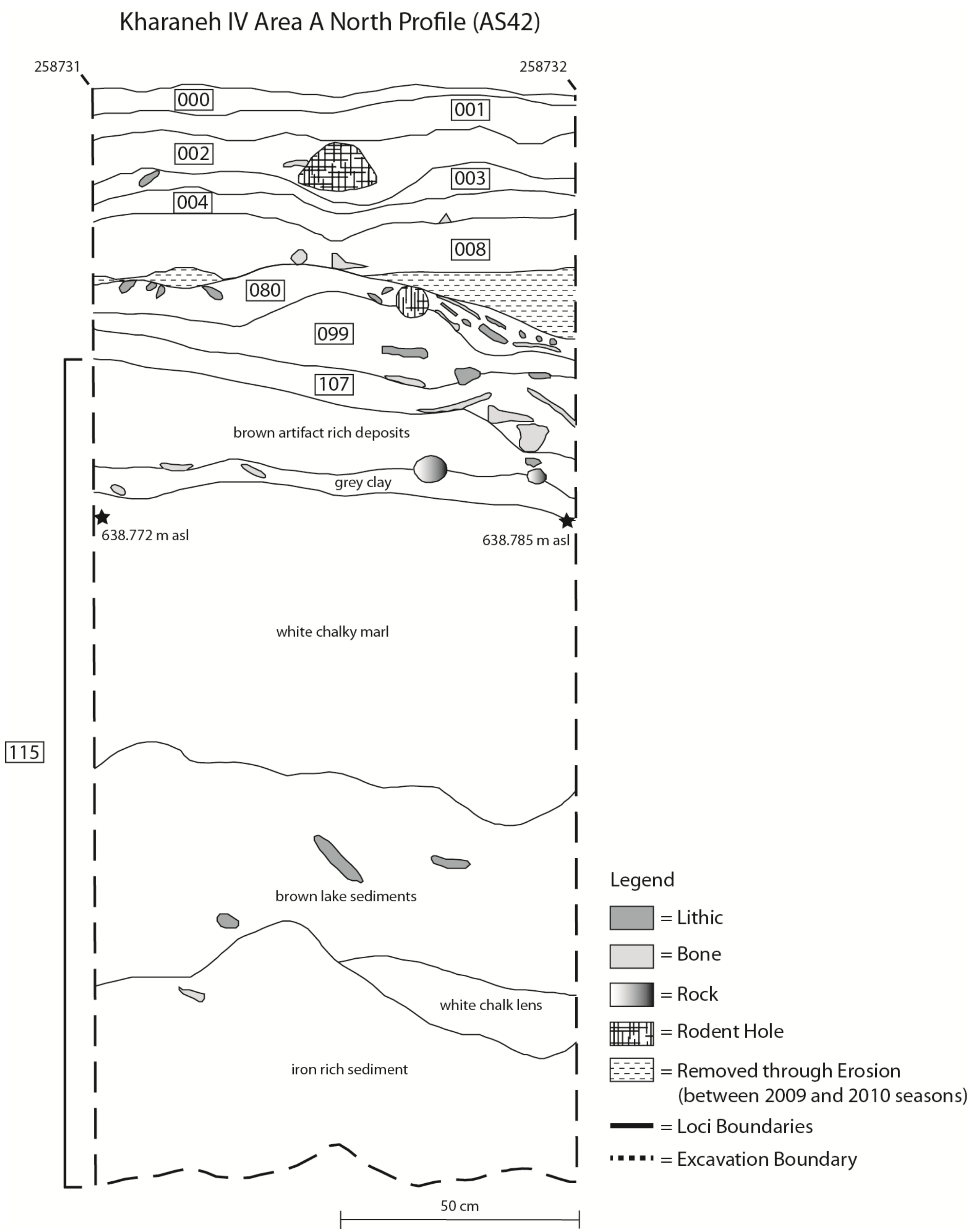


Figure 12: Kharaneh IV Middle Epipalaeolithic stratigraphy.

Preliminary lithic analysis from these deposits shows that 84% of the overall retouched assemblage is composed of microliths, and >50% can be confidently identified as non-geometric microliths (Maher and Macdonald, n.d.). These microliths are primarily gracile oblique-truncated and backed bladelets, and micropoints. The lithic reduction strategy seems to be focused on using narrow chert nodules for the production of gracile blanks to be retouched into microliths. Energy was loaded towards the beginning of the sequence with a lot of investment in core shaping instead of core maintenance. Faunal analysis is still ongoing but field observations suggest that gazelle was the primary prey during the Early Epipalaeolithic.

During the 2010 excavations, evidence for one, possibly two, hut structures was uncovered (Maher, et al., 2012b). Radiocarbon dates from above and below the floor of hut 1 place the date between 19,400 and 18,800 cal BP. The structure is just over 2 m x 3 m in size and is covered by an organic-rich, black layer containing abundant charcoal fragments. This suggests that the huts were burned after abandonment. Situated beneath the burned layer, but on top of the hut floor, are groundstone fragments, red ochre, and articulated aurochs vertebrae. Near the center of the structure are three distinct concentrations of pierced marine shells accompanied by large chunks of red ochre. These concentrations contain over 1,000 shells from both the Mediterranean and Red Seas, imported from up to 270 km away (Maher, et al., 2012b).

3.3.3 Middle Epipalaeolithic Occupations

Muheisen’s original excavations in the Middle Epipalaeolithic component of the site unearthed a variety of archaeological features including what he identified as occupation surfaces, hearths, and post-holes (Muheisen, 1983, 1988a). He identified five hearths on a compact living floor surrounded by a series of small post-holes 10-28 cm in diameter. Muheisen interpreted these as representing a possible hut feature enclosing the hearths. In 2008, a series of excavation units were placed around Muheisen’s previous excavation unit to trace the extent of these features. Muheisen originally labeled this area as ‘Phase D’, but has since been relabeled ‘Area A’ for the new excavations. Initial analysis of the lithic assemblage indicated that, although there are classic trapeze-rectangles, the assemblage also contains asymmetrical trapezoids, lunates, triangles, and a variety of other geometric forms (Muheisen and Wada, 1995). These microlith types will be further explored in Chapter 3.

The three new excavation seasons at Kharaneh IV (2008, 2009, and 2010) identified a number of features similar to those recorded by Muheisen. These features included the three compact surfaces, three hearth deposits, and a series of dark brown sediment deposits interpreted as post-holes. Artifacts chosen for analysis for this dissertation are from the *in situ* compact surfaces. During the 2009 field season, two overlapping hearth deposits were excavated, surrounded by a number of dark brown sediment stains. These deposits were interpreted as post-holes on the basis of their shape and composition. The goal of the 2010 season was to expand the excavation areas to the west and the north of the previous excavations to understand the relationship between the hearths and compact surfaces, to the expose the remainder of the hearth deposits, and to find the compact surfaces' boundaries.

During the 2010 season, an additional 12 m^2 to the north and west of the previous excavations were exposed. The stratigraphy of these areas was similar to that of the previous seasons, with a series of overlying compact surfaces, some covered with loose fill deposits. The remainders of the overlapping hearths left *in situ* from 2009 were exposed and new postholes were identified around the northeast side of the hearths.

The results of the 2010 excavation season further corroborated the results from previous seasons. The Middle Epipalaeolithic deposits contain a series of compact occupation surfaces on which people had discarded lithics and remains of hunted animals. Cut into these surfaces are several hearths. The two overlapping hearths show evidence of an ephemeral structure placed over the fireplace, perhaps as a cooking structure or as a drying or smoking rack. Future excavations at the site will continue to expose the horizontal extent of the Middle Epipalaeolithic deposits at Kharaneh IV to identify potential structural features like the ones found in the Early Epipalaeolithic deposits.

Artifacts recovered during the 2008-2010 excavation seasons include a wealth of lithic and faunal material. In addition, worked bone is abundant, with notched mandibles and long bones, bone points, and awls. A wide range of shell ornaments has been recovered from both the Early and Middle Epipalaeolithic deposits, with increasing frequency during the Middle Epipalaeolithic (Richter, et al., 2011). In total, 15 different species occur in the assemblage. Most common are dentalium shell beads, native to the Mediterranean and Red Seas. Other common species include *Nerita sanguinolenta* from the Red Sea and *Mitrella scripta* from the

Mediterranean Sea. *Euplica turturina* from the Indo-Pacific is present in low frequencies. The presence of shells from the Mediterranean Sea, Red Sea, and possibly as far as the Indian Ocean, suggests that the people of Kharaneh IV had extensive trade networks that stretched at least 290 km (Richter, et al., 2011).

3.4 Summary

The Epipalaeolithic was a diverse period and archaeologists have identified a range of different cultural groups identified by their material culture. The Middle Epipalaeolithic sites of Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV represent three diverse Middle Epipalaeolithic occupations. Wadi Mataha (ca. 14,100 ±130 BP) is a small Geometric Kebaran occupation, but the presence of a bound human burial suggests that some non-subsistence activities took place at the site. ‘Uyun al-Hammâm (17,250-16,350 cal BP and 15,000-14,200 cal BP) has the largest number of human burials for any Geometric Kebaran occupation. The depth and density of cultural deposits suggests that the inhabitants of the site were continuously returning to the same locale, often to bury their dead. Finally, Kharaneh IV (18,800 to 18,600 cal. BP) is the largest recorded Epipalaeolithic site at 21 000 m^2. Excellent preservation at the site allows the recovery of hearths and post-holes from the Middle Epipalaeolithic deposits, features not found at the other two sites. The current marginal location of Kharaneh IV, the reason behind the large size, and the early dates leaves many questions open to pursue in the future.

Although the other site features are diverse, the lithic assemblages from these three Middle Epipalaeolithic sites contain trapeze-rectangle microliths, the hallmark of the Geometric Kebaran period. Comparison of these three assemblages will illuminate how people during the Epipalaeolithic conceptualized, manufactured, and used their tools.

Chapter 4
Typology and Technology of Microliths

4 Introduction

Epipalaeolithic chipped-stone assemblages are characterized by high frequencies of microliths, with different microlith types acting as *fossile directeurs* for each Epipalaeolithic phase (Bar-Yosef, 1970, Goring-Morris, 1987, Henry, 1998, Tixier, 1963). As mentioned in previous chapters, variability in microlith morphology has been used to identify regionally and chronologically distinct groups across the Levant. Chronologically, microliths move from non-geometric forms in the earlier Epipalaeolithic towards geometric forms in the middle and later periods. For this analysis, I employed typologies developed by Bar-Yosef (1970) and Goring-Morris (1987) that are applicable to sites across the Mediterranean and arid zones of the Southern Levant.

This chapter will describe the Middle Epipalaeolithic lithic assemblages from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV, focusing on the microlith components of the assemblages. To place the microliths in context, the lithic assemblage for each site will be discussed, including the cores, debitage, and retouched (macrolithic) tools. Following this, the microliths will be presented, emphasizing typological and technological features, including overall morphology, retouch type, and retouch direction. Finally, I will compare the microliths and overall lithic assemblages of the three sites, highlighting differences and similarities among the assemblages.

4.1 Methods

The lithic assemblages were divided into categories of microliths, debitage[1], retouched pieces (macrolithic), cores, and core-trimming elements (CTEs) for each site. In addition to the analysis of each artifact category, raw material was assessed where possible. Each category was analyzed separately according to criteria developed for those artifacts types, outlined below.

[1] Defined here as the unretouched products of flintknapping including flakes, blades, chips, and shatter

4.1.1 Raw Material Analysis

Raw material analysis was undertaken, where possible, focusing on the microlith category rather than the entire lithic assemblage. For Wadi Mataha and ‘Uyun al-Hammâm, the raw material was also analyzed for the debitage and tool assemblages. Unfortunately, raw material analysis has not been completed for the Kharaneh IV macrolithic tools or debitage. Therefore, only the raw material characteristics for the Kharaneh IV microliths will be presented.

For the raw material analysis, quality and colour were recorded for each artifact. Raw material quality was assessed visually, with ordinal categories of very fine, fine, coarse, very coarse, and indeterminate quality. Colour was similarly evaluated with descriptive classes indicating the overall colour of the artifact. These colour categories were developed for each site independently, therefore, a ‘light-brown’ material from one site is not the same material as a ‘light brown’ material from another site. The colour classifications are used for only intra-site analysis; however, interesting observations about the range of material types can be made through comparing raw material choice among sites. Artifacts that were completely patinated, burned, or otherwise modified, obscuring the raw material, were categorized as ‘indeterminate’. Although general interpretation from the raw material analysis will be discussed, the results are presented in Appendix B since this analysis was not undertaken as a primary focus of this research. A complete list of the raw material quality and colours can be found in Appendix A, Table 55.

4.1.2 Analysis of Reduction Strategy

Detailed debitage attribute analysis was conducted for the Wadi Mataha and ‘Uyun al-Hammâm lithic assemblages. However, due to the large size of the assemblage (> 2 million excavated lithics) only preliminary debitage typological analysis has been completed for Kharaneh IV. The debitage analysis for Kharaneh IV focused on identifying debitage types, modified from the type list developed for the analysis of blade reduction of Levantine Neolithic naviform cores (Wilke and Quintero, 1994) (Appendix A, Table 56). Kharaneh IV cores and core-trimming elements were also classified into typological groups. Future attribute analysis on the Kharaneh IV assemblage is pending.

For Wadi Mataha and ‘Uyun al-Hammâm, debitage was divided into groups of flakes, blades, shatter, and chips (pieces <1cm). For the purposes of this analysis, blades are defined as detached pieces, twice as long as they are wide, with parallel margins. As well, there is no distinction between blades and bladelets in the debitage assemblage, emphasising the continuity in size between smaller and larger blades. The flake and blade categories were further subdivided into complete, proximal, and medial/distal fragments. For each piece, termination type and platform attributes were recorded where possible. Raw material, post-depositional processes, and evidence of burning were also documented for each piece. For the complete list of attributes recorded for each site see Appendix A, Table 57.

Cores were classified on the basis of their morphology and the targeted removals (e.g., blade, bladelet, and flake). Metrics taken on each core included the maximum length and width, the core platform dimensions, maximum facet dimensions, and probable reason for core abandonment. A complete list of core types and attributes is provided in Appendix A, Table 58.

Core-trimming elements (CTEs) were divided into two separate categories: core-preparation and core-maintenance elements. Core-preparation elements are removed during the initial shaping to prepare the core for subsequent removals. These lithics include crested blades and initial platform spalls. In contrast, core-maintenance elements are removed during reduction to maintain the core shape. These elements manipulate the platform or correct issues on the core face so that removals can continue. Platform-maintenance elements include angle-correction elements and core tablets. Elements specifically targeting issues on the core face include core face rejuvenation elements and partially crested blades. In addition to typological classification, metrics were recorded for each CTE, including the maximum length, width, and thickness of each piece (Appendix A, Table 59).

4.1.3 Retouched Tool Analysis

Non-microlithic retouched tools (macrolithic) were classified according to Epipalaeolithic typologies developed by Bar-Yosef (1970) and Goring-Morris (1987) for the Southern Levant that are widely used typologies for this period. The former typology focusses more generally on Epipalaeolithic assemblages from Israel/Palestine, while the latter was developed specifically for sites in the Negev and Sinai. For the retouched tools, metrics were taking on each piece, including the maximum length, width and thickness. Raw material quality and colour was recorded, as well as any post-depositional alternations that affected the identification of the material type (see Appendix A, Table 60 for the complete list of attributes). For Kharaneh IV, a typological list of major tool types will be included because tool attribute analysis is still in the initial stages.

4.1.4 Microlith Analysis

A combination of typological and attribute analysis was employed for the analysis of the microliths. The use of both analytical styles allows comparison of these results with published typologies while also highlighting the subtle variation between and within tool types. As with the macrolithic retouched tools, typologies developed by Bar-Yosef (1970) and Goring-Morris (1987) were used to classify the microlith tools.

To begin the analysis, the microliths were divided into geometric, non-geometric, and fragmentary microliths. Geometric microliths are defined as microlithic artifacts retouched into a geometric shape, often trapezoidal or rectangular forms. Non-geometric microliths are retouched bladelets without a geometric form and tend to be less extensively retouched than geometrics. Often in typological analysis fragmentary microliths such as medial bladelet sections are classified as non-geometrics, which inflate the percentages of non-geometrics in assemblages. For example, in Bar-Yosef's typology (1970), medial sections are classified as 'broken backed bladelets' along with proximal and distal fragments of non-geometrics. As well, medial sections are classified in the non-geometric microlith category of 'retouched/backed-bladelet fragments' in Goring-Morris' Epipalaeolithic typology (1987). For this analysis, the category 'fragmentary microliths' was created to avoid misclassification and remove the bias of classifying these as non-geometrics. Medial backed-bladelet sections were automatically classified as fragmentary microliths. In addition, broken microliths with backing or oblique truncations were often classified as fragmentary microliths if the original tool type was ambiguous. However, if possible, broken microliths were identified to a more specific tool type based on the morphology of the broken piece. From these three overarching categories, the microliths were further subdivided into types based on the typologies developed by Bar-Yosef (1970) and Goring-Morris (1987).

A series of attributes were recorded for each microlith to gain further understanding into the typological and technological details of each piece. These attributes include the shape of the backed edge, the shape of the retouched ends, the preserved component of the tool, raw material type, maximum length, width, and thickness. A complete table of the fields and values used in the data collection appears in Appendix A, Table 61. For the analysis, microliths were oriented with the backed edge down and dorsal side up, with End 1 to the left of the piece and End 2 to the right of the piece (Figure 13). The angle of the retouched end was classified based on the direction of the angle with the backed edge oriented at the bottom. Non-angled ends were described as pointed, concave, convex, or straight (Figure 14). The direction of broken end angles was also recorded using the same system devised for the retouched end angles.

To understand differences in retouching methods among the three sites, details of retouch technique were recorded. The invasiveness of retouch used for backing was recorded for each microlith. A series of categories was employed, with non-invasive, marginal, invasive, or total indicating the overall invasiveness of retouch (Christensen and Valentin, 2004) (Figure 15). If more than one of these retouch techniques were identified on a piece, the retouch was labeled as 'combination'. The direction of retouch, whether unidirectional or bidirectional, was also recorded.

The details of different retouch choice, microlith size, and typological form reflects specific manufacturing choices that the flintknappers made. Placed within the context of the overall lithic assemblages, details about the style, gesture, and knowledge can be illuminated through subtle technological choices.

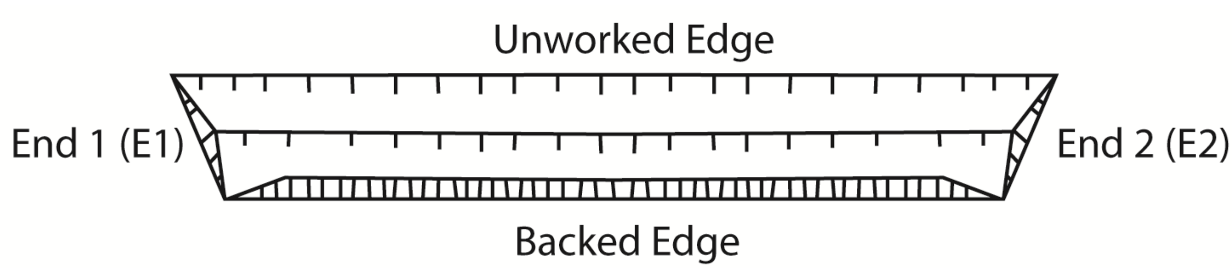


Figure 13: Microlith orientation

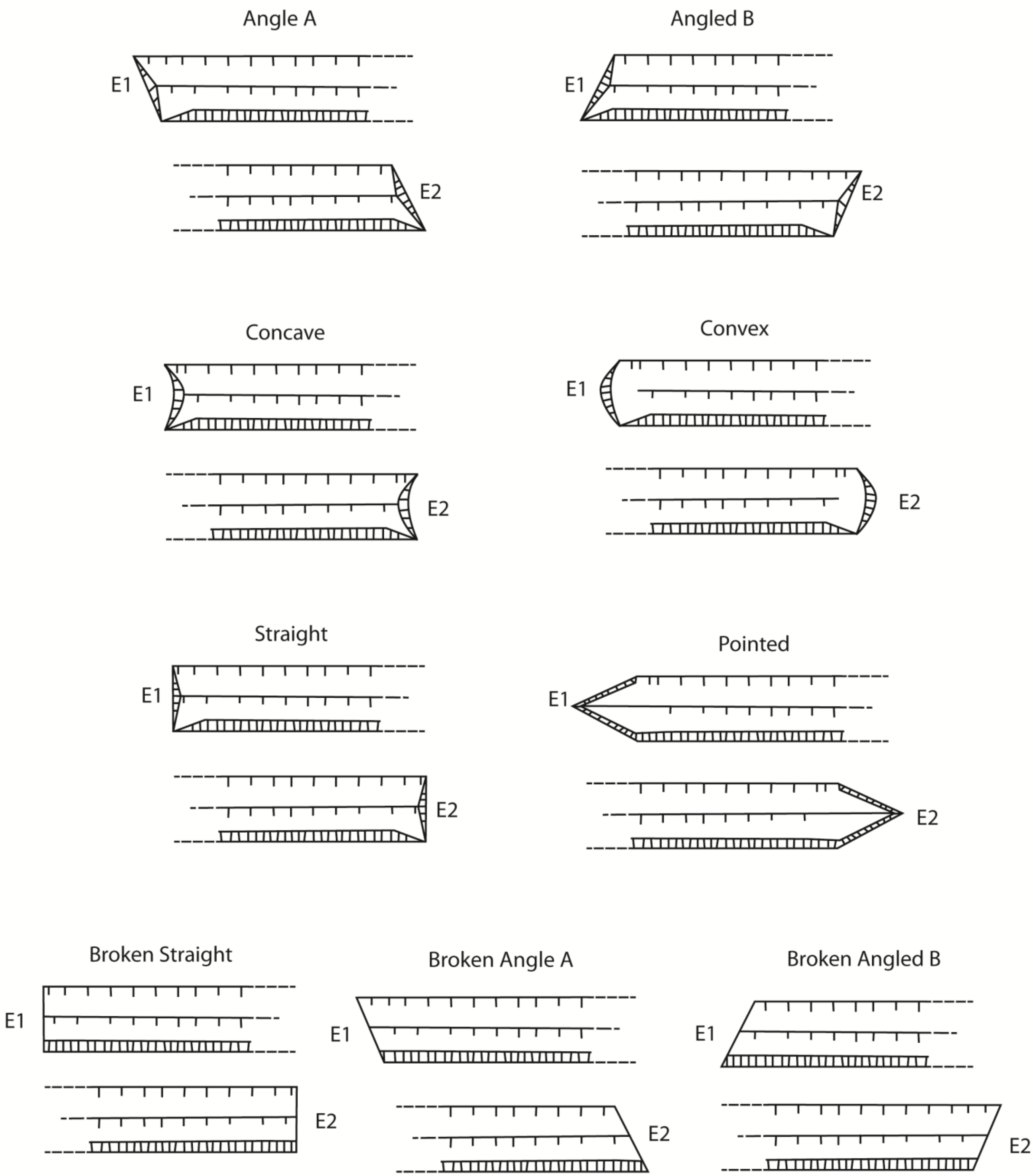


Figure 14: Shape categories used for defining microlith ends. E1 = end 1, E2 = end 2

4.2 Wadi Mataha

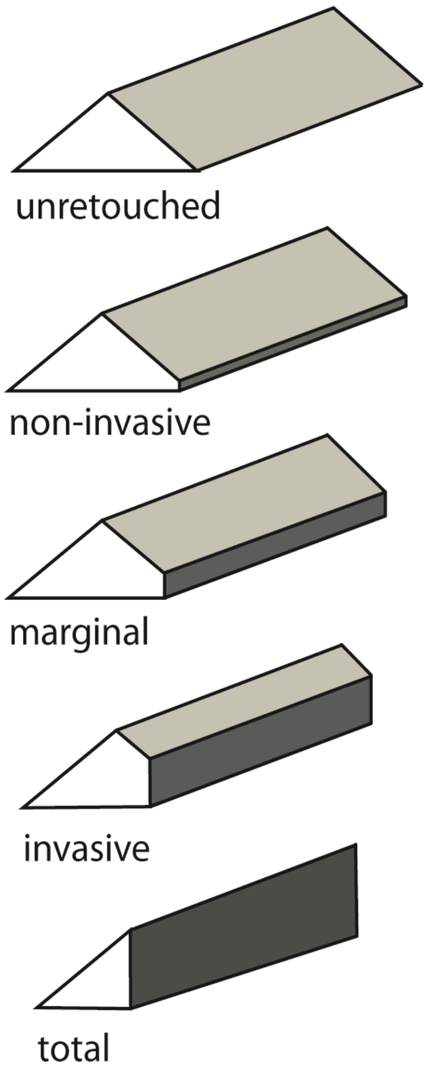


Figure 15: Microlith backing retouch types (adapted from Christensen and Valentin, 2004).

The total excavated lithic assemblage from the Geometric Kebaran levels at Wadi Mataha consists of 2,862 lithics: 412 retouched artifacts, 2,367 pieces of debitage, 12 cores, 26 core-trimming elements, and 45 microburins. Because of the small size of the Geometric Kebaran assemblage at Wadi Mataha, no sampling was necessary and the entire assemblage was analyzed.

4.2.1 Reduction Strategy

In total, 12 cores have been recovered from the Middle Epipalaeolithic deposits at Wadi Mataha. The cores are primarily broad-faced cores (75.0%, n=9) typical of the Middle Epipalaeolithic. Of the broad-faced cores, five have unidirectional removals, two have opposed removals, and one is a change-of-orientation core. In addition to the broad-faced cores, there is one sub-pyramidal bladelet core, one irregularly shaped core, and one broken core. The majority of the cores were discarded because of hinged terminations on the core face (n=4, 33.3%) or because the core was exhausted for further removals (n=4, 33.3%). Another 16.7% were abandoned because the core face was no longer at an optimal angle for removals. One core was broken (8.3%) and one core was discarded for unknown reasons. Disregarding the broken core, 72.7% (n=8) of the cores were still being used to remove bladelets at the point of discard. The other 27.3% (n=3) of the cores had final removals with a length to width ratio of less than two, indicating that the final removals were flakes. Two of these flake cores are wide-faced cores similar in shape to the other wide-faced cores used for microlith production. Therefore these may have also functioned as microlith cores earlier in their life cycle.

Both core-preparation and core-maintenance elements are present in the Wadi Mataha assemblage (Table 2). Core preparation was carried out through the removal of a ridged blade, which initiates the first blade removal from the core face. However, unlike traditional *lame à crêtes*, which are ridged on both sides of the dorsal surface, the Wadi Mataha ridged blades only have removals from one side, with the other side a single facet. The presence of these blades indicates that the initial stages of lithic reduction were taking place at the site.

Cores were maintained at the site with the removal of core tablets, core-face rejuvenation flakes, and partially ridged blades. The core tablets removed the entire core platform, thereby re-preparing the surface for further removals. Removals along the core face were maintained through core-face rejuvenation flakes, which systematically targeted knapping flaws and hinged terminations. Finally, partially crested blades were removed from along the sides of the core-face to narrow the knapping surface, removing portions of the side and bottom of the core. The majority of core maintenance was taking place through the removal of core face rejuvenation flakes, attempting to correct problems rather than preventing them through preparation.

Table 2: Wadi Mataha core-trimming elements (CTEs)

	CTE Type	Count	Percent
core preparation	ridged blade	6	23.1
core maintenance	core tablet	2	7.7
core maintenance	core-face rejuvenation flake	11	42.3
core maintenance	partially ridged blade	7	26.9
	Total	**26**	**100.0**

There are 45 microburins in the assemblage. The presence of microburins shows evidence for snapping bladelets using the microburin technique. It is important to note that 53.3% of the microburins are made from very fine chert and therefore are potentially intrusive from the Natufian deposits. However, 42.2% of the microburins were manufactured on fine quality material commonly used during the Geometric Kebaran and not the Natufian. Within the assemblage there are only a few Krukowski microburins (15.6%, n=7) suggesting that only a small portion of the microburin production was potentially accidental. Thus, there was some systematic use of the microburin technique for snapping bladelets at Wadi Mataha.

The Wadi Mataha debitage assemblage was divided into flakes, blades, chips, and shatter, totaling 2 367 pieces (Table 3). Where possible, the detached pieces were divided into the portion preserved: complete, proximal, medial, distal. Blades represent 21.5% of the overall debitage assemblage, with a ratio of 1.40 flakes to blades. This ratio is in the higher to normal range for Epipalaeolithic assemblages, which tend to have a higher proportion of blades in the debitage (e.g. Henry, 1995). The blades are highly fragmented, with 77.2% (n=393) of the blades broken in comparison to 54.4% of the flakes (n=387). This is likely a reflection of the fragile nature of blades and could be the result of manufacturing errors or post-depositional snapping. Alternatively, some of the broken proximal and distal ends might be the result of snapping for manufacture of geometric microliths.

Table 3: Wadi Mataha debitage

Debitage Type	**Portion**				**Total Count**	**Percent**
	complete	proximal	medial	distal		
blade	116	177	126	90	509	21.5
flake	325	131	125	131	712	30.1
chip					784	33.1
shatter					362	15.3
Total					**2367**	**100.0**

4.2.2 Retouched Tools

The retouched tool assemblage consists primarily of non-geometric and geometric microliths (n=352, 85.2%). The remaining 14.8% of the retouched assemblage (n=61) is composed of larger tool types (Table 4). The most prevalent type of larger tool consists of backed or retouched blades (n=22, 36.1%). Within this tool class are partially retouched blades, alternating retouched blades, inversely retouched blades, and a blade retouched on both edges. An exceptionally long flint blade was found associated with the burial, but it is currently housed in Jordan so that typological and technological details could not be recorded to include in this analysis.

Also common in the larger retouched tool assemblage are retouched flakes (n=19, 31.1%). Most of these flakes were removed after the decortication of the core (87.5%) and are oval or rectangular in shape (72.7%). Retouched flakes are retouched using a varied of methods, including normal (37.5%), abrupt (43.8%), inverse (12.5%), and invasive retouch (6.2%). The site also has a high frequency of notched and denticulated pieces (18.0%), with few scrapers (4.9%).

Table 4: Wadi Mataha retouched tools

Tool Type	Count	Percent (%)
backed blade or retouched blade	22	5.3
burin	2	0.5
multiple tool	2	0.5
notched/denticulated	11	2.7
perforator/borer	1	0.2
retouched flake	19	4.6
scraper	3	0.7
truncation	1	0.2
microliths	352	85.2
Total	**413**	**100.0**

Overall, the macrolithic retouched tool assemblage from Wadi Mataha is characteristic of other Middle Epipalaeolithic sites in the Southern Levant with a large number of retouched blades and the presence of scrapers, notches, and truncations.

4.2.3 Microlith Assemblage

There are 352 microliths in the Geometric Kebaran component of Wadi Mataha, comprising 85.4% of the retouched assemblage (Figure 16, Table 5). Of these, 42.3% are geometric microliths (n=149), 25.6% are non-geometric microliths (n=90), and 32.1% are fragmentary microliths (n=113). The fragmentary pieces are medial backed bladelet fragments, potentially from geometric or non-geometric microliths. The vast majority of the geometric microliths are trapeze-rectangles (n=140, 94.0%), while another three pieces are variations on trapeze-rectangles (2.0%). Lunates are also present, but in low proportions (n=4, 2.7%) and are most likely intrusive from overlying Natufian levels. The non-geometric microliths are more variable, 15 different types in total, with partially backed bladelets the most numerous (n=30, 33.3%).

Table 5: Wadi Mataha microliths

Tool Type	Count	Percent
Geometric Microliths		
lunate	4	1.1
trapeze-rectangle	140	39.8
trapeze-rectangle with one convex end	2	0.6
triangle	1	0.3
unbacked trapeze	1	0.3
straight truncation on a bladelet	1	0.3

Geometric Microlith Subtotal	**149**	**42.3**
Non-Geometric Microliths		
alternating backed bladelet	2	0.6
arch backed bladelet	1	0.3
completely backed	6	1.7
curved	1	0.3
denticulated bladelet fragment	1	0.3
inversely retouched bladelet	6	1.7
microgravette	2	0.6
notched bladelet	7	2.0
obliquely truncated	4	1.1
obliquely truncated and backed	2	0.6
partially backed	30	8.5
pointed	3	0.9
retouched on both sides	5	1.4
scalene bladelet	1	0.3
varia	19	5.4
Non-Geometric Microlith Subtotal	**90**	**25.6**
Fragmentary Microliths		
backed bladelet fragment	113	32.1
Fragmentary Microlith Subtotal	**113**	**32.1**
Total	**352**	**100.0**

In comparison with other southern Jordanian sites, the Wadi Mataha assemblage has a higher percentage of geometric microliths (36.2%) than the Middle Hamran sites identified by Henry (1995:288) (between 6.7% and 19.6%), although both are dominated by trapeze-rectangles.

Within the non-geometric varia category, six microliths have a microburin scar on one end and an inversely retouched concave truncation on the other. These microliths are similar to La Mouillah points but the angle of the microburin scar to the backing is acute on the Wadi Mataha microliths. This is in contrast to La Mouillah points where the angle between the backing and the microburin scar is oblique, a key feature of these artifacts (Olszewski, 2006, Tixier, 1963). The site of Wadi Madamagh has similar microliths with microburin scars acutely angled to the backed edge (Kirkbride, 1958, Olszewski, 2006). Although there are too few to conclusively define a new ‘type’, it is interesting to note the pattern within the assemblage. It should be noted that the Wadi Mataha and the Wadi Madamagh assemblages are typologically distinct, as Wadi Madamagh does not contain geometric microliths.

Figure 16: Microliths from Wadi Mataha. 1-20: trapeze-rectangles; 21: trapeze-rectangle with one convex end; 22-24: varia.

4.2.3.1 Microlith Morphology

Specific microlith attributes were analyzed to understand subtle variations in form and manufacture. The overall morphology is addressed through morphometrics in Chapter 5. In total, there are 110 incomplete geometric microliths and 39 complete geometrics. In contrast, there are 9 complete non-geometrics, 32 distal fragments, 35 medial fragments, and 14 proximal fragments. Only 10% of the non-geometric microlith assemblage is complete in comparison to 35.45% of the geometric microlith assemblage. Fragmentary microliths are excluded as they could belong to either the non-geometric or geometric microlith categories.

General metrics for the complete geometric and non-geometric microliths are presented in Table 6. The geometrics are slightly shorter and narrower in comparison to the non-geometric microliths. The average thickness of the trapeze-rectangles is 2.1mm (standard deviation is 0.55) in comparison to the non-geometric microliths, whose the average thickness if 2.0mm (standard deviation is 0.62). This suggests that the geometric and the non-geometric microliths were likely manufactured from the same pool of bladelets. In addition, there is minimal difference in the size of the hafting insertion slot needed to house these different microlith types, meaning that they could have been hafted in similar tools.

Table 6: Wadi Mataha microlith metrics

microlith	measurement	mean (mm)	number	min (mm)	max (mm)	stand. dev. (mm)
geometric (complete)	length	20.79	39	11.9	29.2	5.0
	width	6.27	39	4.1	9.5	1.2
	thickness	2.25	39	1.6	3.7	0.5
non-geometric (complete)	length	24.38	9	16.1	37.5	8.3
	width	8.52	9	6.7	9.3	1.0
	thickness	2.06	9	1.4	2.8	0.6

The majority of the geometric microliths have a straight profile (n=141, 97%) but one trapeze-rectangle has a twisted profile (0.7%) and three have concave profiles (2%), bending towards the ventral surface. Likewise, most of the non-geometric and fragmentary microliths have straight profiles (n=188, 93%). The remainder of the non-geometric microliths have a concave (n=14, 6.5%) or convex profile (n=1, 0.5%) This suggests that the microliths were well designed to fit laterally into hafts, with even thicknesses and straight profiles.

The ends of the geometric microliths were analyzed, looking for patterns of shaping and breakage (Table 7) (for end shape categories see Figure 14). Microliths with End 1 at angle A and End 2 at angle B are trapezoidal in form, whereas microliths with two straight ends are rectangular. As can be seen from the analysis, the majority of the complete geometric microliths are trapezoidal (n=23, 64%) and not rectangular (n=5, 14%) in form. The vast majority of the breaks are straight (n=74, 69%). Of the oblique snaps, End 1 was more likely to have broken angled A snaps (n=17, 77%), while End 2 had more broken angled B snaps (n=9, 90%) snaps. This pattern is a reflection of the retouch pattern for trapezoidal geometric microliths (End 1= angle A, End 2= angle B), suggesting that these oblique snaps might be intentional, resulting from snapping for manufacture of trapeze-rectangles.

Table 7: Wadi Mataha geometric microlith end shapes (End 1 = rows, End 2 = columns)

End 2 **End 1**	**angled A**	**angled B**	**straight**	**concave**	**convex**	**broken angled A**	**broken angled B**	**broken straight**	**Total**
angled A	1	23	1	1	1	1	8	22	**58**
straight	-	2	5	-	-	-	1	15	**23**
convex	-	-	-	-	1	-	-	-	**1**
pointed	-	1	-	-	-	-	-	-	**1**
broken angled A	1	11	4	1	-	-	-	-	**17**
broken angled B	-	2	3	-	-	-	-	-	**5**
broken straight	-	18	16	1	2	-	-	1	**38**
microburin	-	1	-	1	-	-	-	-	**2**
Total	**2**	**57**	**29**	**4**	**4**	**1**	**9**	**36**	**145**

4.2.3.2 Microlith Retouching

Retouch on the microlith backing was examined for subtle patterns that indicate different choices and techniques. From this analysis, several interesting patterns emerge (Table 8). The most common type of retouch for geometric microliths is invasive retouch (n=86, 58.9%), followed by total retouch (n=38, 26.0%). For the non-geometric microliths, the most common retouch type was also invasive retouch (n=50, 59.5%), but the second-most common retouch type is marginal retouch (n=17, 20.2%). Eleven non-geometric microliths were not included in the analysis since they were unbacked pieces (e.g., notches).

Table 8: Wadi Mataha retouch types

	Geometric Microliths		Non-geometric Microliths		Fragmentary Microliths	
Type of Retouch	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
total	38	26.0	5	6.0	25	22.1
combination	0	0.0	1	1.2	0	0.0
invasive	86	58.9	50	59.5	61	54.0
marginal retouch	20	13.7	17	20.2	25	22.1
non-invasive	2	1.4	11	13.1	2	1.8
Total	**146**	**100.0**	**84**	**100.0**	**113**	**100.0**
Direction of Retouch	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
unidirectional	145	99.3	91	97.8	112	99.1
bidirectional	1	0.7	2	2.2	1	0.9
Total	**146**	**100.0**	**93**	**100.0**	**113**	**100.0**

There is significant difference between retouch types within the geometric and the non-geometric microlith assemblages (χ^2 = 27.623, p <0.001) suggesting that there are meaningful differences in how geometric and non-geometric microliths were manufactured. Total retouch is preferentially performed on geometric microliths while non-invasive retouch is not uncommon on non-geometric microliths, indicating that geometric microliths were more intensively backed than non-geometric microliths. The fragmentary microliths category contains similar frequencies of total retouch and non-invasive retouch to the geometric microlith group. It is more likely that the fragmentary microliths are broken geometrics than non-geometrics based on the type of retouch.

When the retouch types are broken down by geometric microlith types it is possible to see that invasive retouch was preferred for all geometric types, regardless of form (Table 9). Total retouch is used almost exclusively for the trapeze-rectangles, with only one example of a lunate. Trapeze-rectangles were also produced with marginal retouch, suggesting that there was flexibility in how the trapeze-rectangles were manufactured.

Table 9: Wadi Mataha geometric microlith retouch types

	lunate	trapeze-rectangle	trapeze-rectangle with one convex end	triangle

Type of Retouch	Count	Percent	Count	Percent	Count	Percent	Count	Percent
total retouch	1	25.0	38	27.0	-	0.0	-	0.0
invasive retouch	2	50.0	83	58.9	2	100.0	1	100.0
marginal retouch	1	25.0	19	13.5	-	0.0	-	0.0
non-invasive	-	0.0	1	0.7	-	0.0	-	0.0
Total	**4**	**100.0**	**141**	**100.0**	**2**	**100.0**	**1**	**100.0**

4.2.4 Wadi Mataha Summary

In summary, the Geometric Kebaran lithic assemblage from Wadi Mataha exhibits a number of interesting trends. The retouched assemblage is dominated by microliths at 85.4% of the overall tool assemblage. The non-microlithic portion of the tool assemblage contains typical Epipalaeolithic tools such as retouched blades and flakes. Of the microliths, 42.3% are geometric, primarily in the form of invasively retouched trapeze-rectangles. These trapeze-rectangles tend towards trapezoidal, rather than rectangular, forms. Microliths are consistently retouched using unidirectional retouching methods and there is no evidence for the systematic use of bidirectional retouch. Geometric and non-geometric microliths were likely produced from the same blanks, considering their metric characteristics.

4.3 ‘Uyun al-Hammâm

The lithic assemblage from ‘Uyun al-Hammâm is composed of 104 376 lithics, including 9 301 retouched tools, 94 656 pieces of debitage, 270 cores, and 149 core-trimming elements. From this assemblage, a sample of approximately 10% (n=642) of the microliths was selected for more detailed analysis. Previous detailed work has been conducted on the debitage and the reduction sequence (Macdonald, 2007), the results of which will be summarized to place the microlith assemblage in context.

4.3.1 Reduction Strategy

In total, 270 cores were recovered during the excavations at ‘Uyun al-Hammâm. Of these, 40 are fragmentary (14.8%) and cannot be identified to type. The most common cores are pyramidal/sub-pyramidal (n=100, 37.0%), followed by wedge-shaped cores (n=47, 20.4%), and amorphous cores (n=45, 19.6%). The rest of the cores are present in small proportions and include cuboid, disc, and tabular shapes. The majority of these cores were used for the manufacture of bladelets, but some of the amorphous cores were also targeting flake removals.

Despite the proliferation of bladelet cores, some cores were never prepared for blade removal and were used as flake cores only. The intended products for most cores (except amorphous ones) were small bladelets later shaped into trapeze-rectangles. There is no evidence for larger blade cores; large blades were either removed earlier in the reduction sequence or were produced off-site.

Many of the cores were abandoned because the core faces had numerous hinge terminations (n=84, 31.1%) while others had a poor platform angle for removals (n=46, 17.0%). As well, many of the cores were exhausted and could no longer produce the bladelets targeted for removal (n=43, 15.9%). Despite this, numerous cores were still viable for the production of bladelets, with neither hinge terminations, incorrect angles, or exhaustion holding them back from the removal of further microliths (n=51, 18.9%). The abandonment of cores still viable for microlith production might be a reflection of the raw material availability in the local landscape, indicating that conservation was not a concern.

Debitage attribute analysis of a sample from ‘Uyun al-Hammâm was conducted to understand the reduction strategy at the site (Macdonald, 2007) (Table 10). The flake-to-blade ratio is 2.0, indicating that there are twice as many flakes as blades in the debitage assemblage. The blades are more fragmentary than the flake assemblage, and there are a high proportion of proximal bladelet fragments in the debitage assemblage (25.4%). This suggests that bladelet snapping was taking place on-site for the production of geometric microliths.

Table 10: 'Uyun al-Hammâm debitage types

Debitage Type	**Portion**			**Total Count**	**Percent**
	complete	proximal	medial/distal		
blade	2 274	6 281	11 845	20 400	21.6
flake	9 053	4 966	26 959	40 978	43.3
chip				9 762	10.3
shatter				23 516	24.8
Total				**94 656**	**100.0**

There is evidence for both core maintenance and core preparation at ‘Uyun al-Hammâm. The analysis showed that the reduction process began by the removal of cortical flakes, occasionally preparing the core for bladelet removals through the preparation of a crested blade. However there are few crested blades in the assemblage, suggesting that elaborate core preparation was not a major feature of the reduction strategy. Some blades have cortex on one later dorsal scar indicating that the sides of the cores remained cortical as the blades were being removed. Cores were maintained by the removal of core tablets and core-face rejuvenation flakes, the latter to eliminate hinges and bulges from the surface.

4.3.2 Retouched Tools

‘Uyun al-Hammâm’s assemblage of retouched tools is primarily composed of geometric and non-geometric microliths (n=7082, 76.1%). The remainder of the tool assemblage is composed of scrapers (n=932, 10.0%), backed and retouched blades (n=422, 4.5%), and burins (n=304, 3.3%), along with several other tool types in small proportions (Table 11). The scrapers are mainly endscrapers on blades, including some double endscrapers.

Table 11: 'Uyun al-Hammâm retouched tools

Tool Type	Count	Percent
Backed and Retouched Blades	422	4.5
Burins	304	3.3
Heavy-Duty Tools	41	0.4
Multiple Tools	220	2.4
Notches and Denticulates	160	1.7
Perforators	45	0.5
Points	2	0.1
Scrapers	932	10.0
Truncations	93	1.0
Microliths	7 082	76.1
Total	**9 301**	**100.0**

This distribution of tool types is common for Geometric Kebaran lithic assemblages, where >50% of the tool assemblage consists of microliths (Fellner, 1995b). The macrolithic tool frequencies fall within the range described for Geometric Kebaran assemblages, with the frequencies of scrapers ranging between 9 and 12%, retouched/backed blades ranging from 1 to 10%, and extremely rare occurrences of points (Bar-Yosef, 1970:171).

4.3.3 Microlith Assemblage

Of the entire 7082-piece microlith assemblage, a sample of 642 microliths was selected for detailed technological analysis, representing just over 10% of the overall population. The microliths were selected through a stratified, random cluster sample. First, a series of adjacent excavation units were chosen. From these units, bags from *in situ* deposits within the red

Pleistocene sediments were separated from the disturbed loci. From these *in situ* contexts, a 20% random sample was chosen for analysis.

The majority of the microliths are geometrics (n=428, 66.7%), with trapeze-rectangles being the most frequent type (n=403, 94.2%) (Figure 17, Table 12). The remainder of the geometrics are asymmetrical trapeze B (n=12, 2.8%) or other variations on trapeze-rectangles (n=10, 2.3%). As well, a single lunate was recovered from the deposits.

There is more variability in the non-geometric microlith category, but they represent a small proportion of the overall microlith assemblage (n=83, 12.9%). In total, there are 16 different non-geometric microlith types, with the most prevalent being partially backed bladelets (n=11, 13.3%). Completely backed bladelets, inversely retouched bladelets, notched bladelets, obliquely truncated and backed bladelets, and pointed backed bladelets each represent 10.8% of the non-geometric microlith assemblage. The remaining 10 types are represented in frequencies less than 10% of the non-geometric microliths.

The fragmentary microliths are composed entirely of medial backed-bladelet fragments (n=131, 20.4%). These fragments were not identifiable to type, but many could have been medial sections of broken trapeze-rectangles.

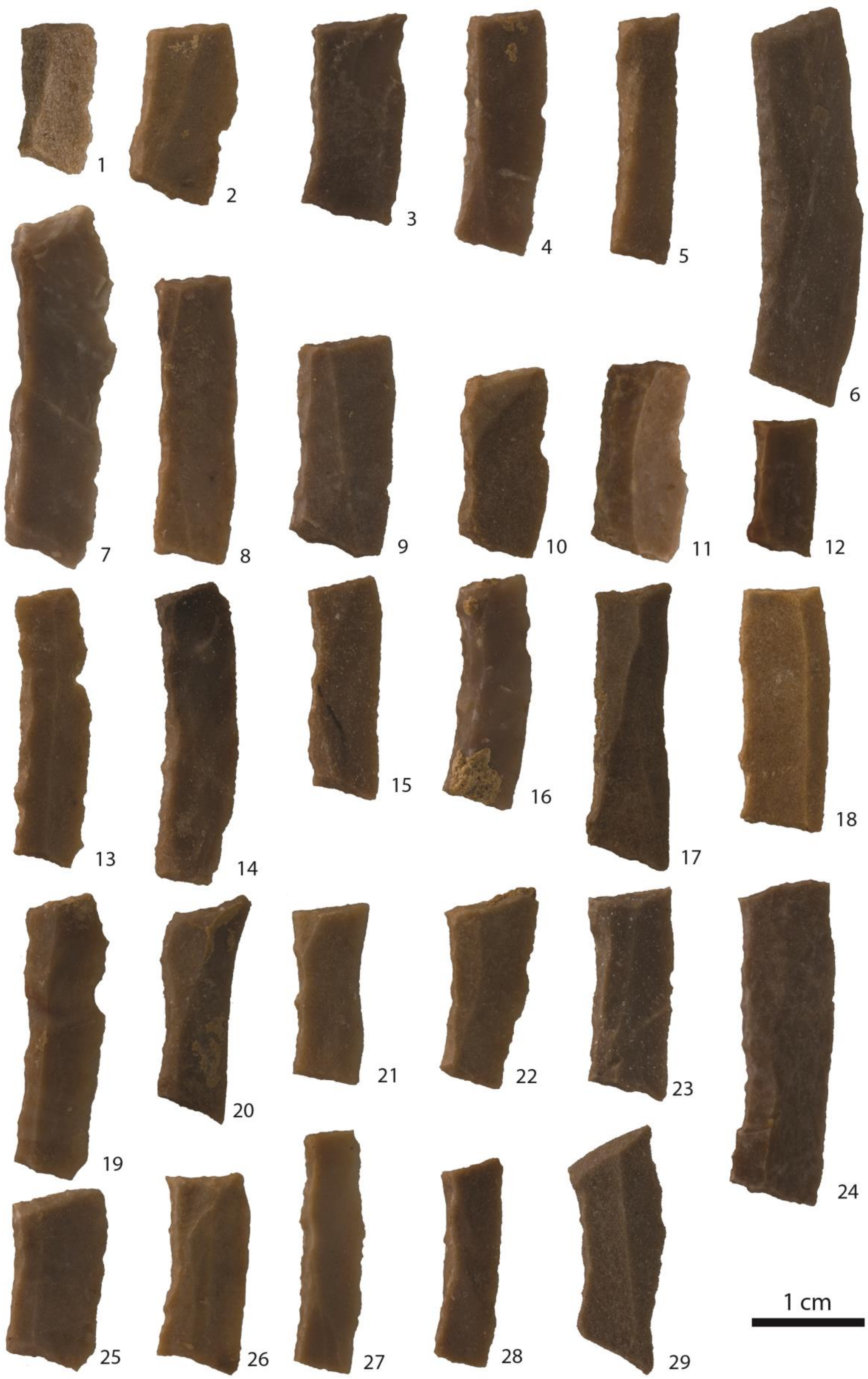


Figure 17: Microliths from 'Uyun al-Hammâm. 1-21, 23-28: trapeze-rectangle; 22: asymmetric trapeze B; 29: trapeze-rectangle (broken)

Table 12: ‘Uyun al-Hammâm microlith types

Tool Type	**Count**	**Percent (%)**
Geometric Microliths		
asymmetrical trapeze A	1	0.2
asymmetrical trapeze B	12	1.9
lunate	1	0.2
trapeze-rectangle	166	25.9
trapeze-rectangle (incomplete)	237	36.9
trapeze-rectangle with notch	1	0.2
trapeze-rectangle with one convex end	7	1.1
unbacked trapeze	1	0.2
varia (geometric)	2	0.3
Geometric Microlith Subtotal	**428**	**66.7**
Non-Geometric Microliths		
alternating retouched bladelet	1	0.2
arched backed bladelet	1	0.2
completely backed	9	1.4
curved and pointed bladelet	5	0.8
denticulated bladelet	2	0.3
inversely retouched bladelet	9	1.4
microgravette	2	0.3
notched bladelet	9	1.4
obliquely truncated	4	0.6
obliquely truncated and backed	9	1.4
partially backed	11	1.7
pointed backed bladelet	9	1.4
retouched burin spall	1	0.2
retouched on both sides	3	0.5
straight truncated and backed bladelet	5	0.8
varia	3	0.5
Non-Geometric Microlith Subtotal	**83**	**12.9**
Fragmentary Microliths		
backed bladelet fragment	131	20.4
Fragmentary Microlith Subtotal	**131**	**20.4**
Total	**642**	**100.0**

4.3.3.1 Microlith Morphology

In the sample from ‘Uyun al-Hammâm there are 180 complete geometric microliths and 248 incomplete geometrics. In contrast, there are 5 complete non-geometrics, 17 proximal, 40 distal, and 21 medial. The geometrics are less fragmentary then the non-geometrics, with 57.9% of the geometrics incomplete, in comparison to 94.0% of the non-geometrics.

The metrics for complete microliths are presented in Table 13. The non-geometric microliths are slightly longer and slightly narrower than the geometric microliths, but the difference in width is not significant (unequal variance t=0.426, p=0.689). The difference in the thickness between the geometric and the non-geometric microliths is not significant (unequal variance t=-0.308, p=0.772). This suggests that the non-geometric and geometric microliths started as the same blanks and the geometrics are slightly shorter and narrower because of their more invasive retouching and snapping.

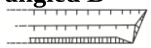
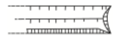
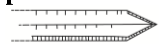
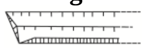
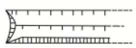
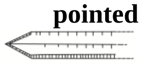
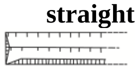
Table 13: 'Uyun al-Hammâm microlith metrics

Microlith	measurement	mean (mm)	number	min (mm)	max (mm)	stand. dev. (mm)
geometric (complete)	length	20.8	180	10.1	41.6	5.5
	width	7.7	180	4.9	16.8	1.7
	thickness	2.6	180	1.3	3.8	0.6
non-geometric (complete)	length	25.9	5	22.7	30.1	2.7
	width	7.5	5	5.9	8.4	1.0
	thickness	2.7	5	2.2	3.6	0.6

The majority of both the geometric and the non-geometric microliths have straight profiles, although the geometric microliths are almost entirely straight (n=420, 98.1%). The remaining 1.9% (n=9) of the geometrics have concave profiles. There are no twisted geometrics in the assemblage, demonstrating that straight profiles were an important feature of geometric hafting. In contrast, there is slightly more flexibility in the non-geometric microliths categories where 10.8% (n=9) of the non-geometrics have twisted or concave profiles.

The most frequent combination of microlith end shape for complete pieces is angled A on End 1, and angled B on End 2 (n=86, 20.1%), indicating that these geometric microliths were trapezoidal in form (Table 14). In addition, only 46 (10.7%) geometric microliths are rectangular with straight truncations on both ends. There is also flexibility between these two forms; 21 (4.9%) of the geometric microliths have End 1 straight and End 2 angled B, while 23 (5.4%) of the microliths have End 1 angled A and End 2 straight. Unfortunately, details of broken end orientation were not collected at the time of analysis for this assemblage. However, a large number of the microliths have one broken end (n=246, 57.5%) which could be the result of manufacturing, use, or post-depositional activities.

Table 14: 'Uyun al-Hammâm microlith end shapes (End 1=rows, End 2=columns).

End 2 / End 1	angled B 	concave 	convex 	pointed 	straight 	broken	Total
angled A 	86	2	1	-	23	61	**173**
concave 	2	-	-	-	-	3	**5**
pointed 	-	-	-	1	-	-	**1**
straight 	21	2	-	-	46	69	**138**
broken	34	3	5	-	67	2	**111**
Total	**143**	**7**	**6**	**1**	**136**	**135**	**428**

4.3.3.2 Microlith Retouch

The most common type of retouch used for backing microliths is invasive (n=385, 51.5%), followed by marginal retouch (n=141, 22.0%) (Table 15). The geometric microliths then diverge from the non-geometric microliths, moving towards more total retouch (n=53, 12.4%), while the non-geometric microliths have more non-invasive retouch (n=17, 20.5%). The fragmentary microliths are split evenly between the total (n=13, 9.9%) and non-invasive retouch (n=13, 9.9%). Since geometric microliths tend to be more heavily modified than non-geometric microliths, this pattern is to be expected.

Table 15: 'Uyun al-Hammâm retouch types and direction of retouch

	Geometric Microliths		**Non-geometric Microliths**		**Fragmentary Microliths**	
Type of Retouch	Count	Percent	Count	Percent	Count	Percent
total	53	12.4	9	10.8	13	9.9
combination	0	0.0	0	0.0	0	0.0
invasive	288	67.3	30	36.1	67	51.1

marginal retouch	76	17.8	27	32.5	38	29.0
non-invasive	11	2.6	17	20.5	13	9.9
Total	**428**	**100.0**	**83**	**100.0**	**131**	**100.0**
Direction of Retouch	Count	Percent	Count	Percent	Count	Percent
unidirectional	389	90.9	79	95.2	126	96.2
bidirectional	39	9.1	4	4.8	5	3.8
Total	**428**	**100.0**	**83**	**100**	**131**	**100**

The direction of retouch indicates that unidirectional retouch was preferred for all microlith types, but bidirectional retouch was also used in microlith production (Table 15). This is most common in the geometric microliths, where 9.1% (n=39) of the geometrics are retouched with bidirectional backing. This type of backing tends to be more extensive, either as total or invasive retouch. In contrast, only 4.8% (n=5) of the non-geometrics are retouched with bidirectional retouch. The inclusion of bidirectional retouch into the knapping repertoire suggests that there was some flexibility in how the microliths were retouched.

The retouch strategy for the different geometric microlith types was essentially the same, with most of the microliths backed using invasive retouch (Table 16). There is roughly an even distribution between the use of total and the use of marginal retouch as a secondary choice.

Table 16: ‘Uyun al-Hammâm geometric microlith retouch types

Type of Retouch	**asymmetrical trapeze B**		**trapeze-rectangle**		**trapeze-rectangle with one convex end**		**other**	
	Count	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
total	2	16.7	49	12.2	1	14.3	1	16.7
invasive	8	66.7	269	66.9	6	85.7	4	66.7
marginal	2	16.7	74	18.4	-	0.0	1	16.7
non-invasive	-	0.0	10	2.5	-	0.0	-	0.0
Total	12	100.0	402	100.0	7	100.0	6	100.0

The majority of the bidirectional retouch was used on trapeze-rectangles (n=36, 92.3%). As well, the single lunate, the trapeze with one end convex, and one of the asymmetrical trapeze B microliths were backed with bidirectional retouch.

4.3.4 ‘Uyun al-Hammâm Summary

The lithic assemblage of ‘Uyun al-Hammâm is dominated by trapeze-rectangle geometric microliths, typical of the Geometric Kebaran. The primary reduction sequence targeted manufacture of blanks for microliths with a separate trajectory for some of the flake and large blade tools. The non-microlithic tool assemblage is composed of a wide suite of tools including scrapers, backed blades, burins, and multiple tools. Most geometrics microliths are trapezoidal in form, followed by rectangular, with some fluidity between the two. There is flexibility in how the microliths were manufactured, with invasive retouch being the most commonly used form of retouch, but marginal, total, and non-invasive retouch were also used for backing microliths. There is no difference in the overall backing strategy among the different types of geometrics. As well, the people at ‘Uyun al-Hammâm used bidirectional retouch as a knapping technique for a small proportion of the geometric microliths. There is little difference in the metrics between the geometric and the non-geometric microliths, suggesting that they were produced from the same blanks.

4.4 Kharaneh IV

The excavated lithic assemblage of Kharaneh IV has been estimated to comprise over 2 million lithics from both the Early and the Middle Epipalaeolithic deposits. To date, 109 368 lithics have been analyzed from the Middle Epipalaeolithic loci including 102 673 pieces of debitage, 26 microburins, 307 cores, 2 564 core-trimming elements, 937 retouched tools (macrolithic), and 2 861 microliths. This represents only a small sample of the excavated material and the analysis of the Middle Epipalaeolithic lithic assemblage is still ongoing. To date, the analysis of Kharaneh IV has focused on typological classification, although attribute analysis is planned for future research.

4.4.1 Reduction Strategy

To date 102 673 pieces of Middle Epipalaeolithic debitage have been analyzed from Kharaneh IV, composed of 30 979 flakes and 26 227 blades. The ratio is 1.2 flakes to every blade, falling within the range of flake/blade ratios for the Middle Epipalaeolithic. There is some evidence for the use of the microburin technique (n=26, <0.1%), but the extremely low frequency of microburins in the assemblage indicates that the inhabitants of Kharaneh IV were not systematically using this technique for microlith snapping.

The cores at Kharaneh IV are heavily focused on the production of blades, with only two cores targeting flake removals. The most common cores are narrow-faced bladelet cores on tabular chert (n=126, 41.0%) that produce narrow, gracile bladelets. Broad-faced bladelet cores are also very common in the assemblage (n=69, 22.5%), producing slightly wider and less standardized bladelets. The broad-faced cores were manufactured on rounded chert nodules.

Table 17: Kharaneh IV core types

Core Type	Count	Percent
Cores (General)	15	4.9
Single Direction Nosed Core	2	0.7
Narrow-Faced Core	126	41.0
Narrow-Faced Two Faces Core	9	2.9
Broad-Faced Core	69	22.5
Subpyramidal Bladelet Core	3	1.0
Flake Cores	2	0.7
Opposed Platform Cores	12	3.9
Change of Orientation Core	24	7.8
Multi-Directional Cores	15	4.9
Core Fragment	30	9.8
Total	**307**	**100.0**

There is evidence of both core preparation and core maintenance at Kharaneh IV and the generalized reduction sequence can be reconstructed through the core-trimming elements present at the site. Reduction is initiated through the removal of an initial spall across the core to prepare a striking platform. This was followed by the preparation and removal of a crested blade from the core face. Lateral core-trimming elements were removed from the sides of the core, thinning and removing some of the cortex.

There was minimal core shaping after the removal of the crested blade and some minor core thinning. The majority of the core-trimming elements are related to maintenance (n=2 035, 79.5%), removed during the knapping sequence to fix problems instead of changing the core shape. The most common maintenance elements are profile correction blades (n=648, 25.3%). These blades remove knapping errors from the face of the core, such as hinge terminations or bulges, while still maintaining the parallel arrises needed for further blade removals. Thus, the Middle Epipalaeolithic reduction strategy is more heavily focused on corrective removals rather than preparation.

Table 18: Kharaneh IV core-trimming element types

	CTE Type	Count	Percent
core preparation	Initial Faceting Platform Spalls	68	2.7

core preparation	Lateral Core-trimming Pieces	378	14.7
core preparation	Crested Blade	83	3.2
core maintenance	Non-Initial Corrective Core Tablets	323	12.6
core maintenance	Initial Core Tablet	43	1.7
core maintenance	Profile Correction Blades	648	25.3
core maintenance	Core Face Rejuvenation	345	13.5
core maintenance	Partial Ridged Blades	343	13.4
core maintenance	Angle Correction Element	326	12.7
core maintenance	Partial Ridges along distal end blade	7	0.3
	Total	**2564**	**100.0**

The lithic assemblage shows that all stages of reduction are present in the assemblage, with the trajectory focused on the production of blades. Effort was placed into maintaining cores for removals, instead of preparing the core in advance.

4.4.2 Retouched Tools

In total, 4 417 retouched artifacts have been analyzed from the Middle Epipalaeolithic deposits. Microliths dominate the assemblage at 83.4% of the analyzed retouched tools (n=3 684). The macrolithic tools represent a range of standard Epipalaeolithic types (Table 19). The most frequent non-microlithic retouched tools are retouched flakes/blades (non-backed) which represent 26.5% of the retouched assemblage (n=194). Non-retouched, utilized debitage comprises 17.2% of the tool assemblage (n=126). This is followed by scrapers at 15.0% (n=110), which are represented by a wide range of types, such as endscrapers on blades, double endscrapers on blades, and flake scrapers. Backed blades make up 14.2% of the tools (n=104) and multiple tools are 11.5% (n=84). Included in the multiple tools are endscrapers on retouched blades, endscrapers with truncations, endscrapers with burins, and burins with truncations. A large portion of the endscrapers and multiple tools were manufactured on blades. Other tool types are represented in small proportions.

Table 19: Kharaneh IV retouched tool types

Tool Class	Count	Percent
Scrapers	110	2.5
Multiple Tools	84	1.9
Burins	43	1.0
Retouched Burin Spalls	11	0.2
Retouched Pieces	194	4.4
Backed Blades	104	2.4

Truncations	14	0.3
Points	1	0.0
Perforators	3	0.1
Notched and Denticulates	40	0.9
Heavy Duty Tools	3	0.1
Utilised Pieces	126	2.8
Microliths	3 684	83.4
Total	**4 417**	**100.0**

The frequencies of tool types fall within the range for other Middle Epipalaeolithic sites in eastern Jordan, with a high frequency of microliths and lower frequencies of macrolithic tools.

4.4.3 Microlith Assemblage

The 3 684 microliths currently analyzed from the Middle Epipalaeolithic component of Kharaneh IV include 948 geometric microliths (25.7%), 716 non-geometric microliths (19.4%), and 2 020 fragmentary microliths (54.8%) (Figure 18). Despite the classification as a Middle Epipalaeolithic site, on the basis of the trapeze-rectangles, these geometric microliths occur in lower frequencies than in classic Middle Epipalaeolithic assemblages. For this analysis, a sample of 823 microliths were chosen for detailed attribute analysis, represented approximately 22.3% of the analyzed microlith assemblage. Microliths were selected from several *in situ* loci. The majority of the artifacts were selected from a deposit containing multiple postholes (locus 047) or an underlying compact, ash-flecked deposit thought to represent a living surface (locus 008=100). The entire microlith assemblage was analyzed from these two contexts. In addition to these, lithics from deposits adjacent to a hearth were analyzed.

The geometric forms tend towards trapeze-rectangles, both backed and unbacked (n=158, 19.2%) (

Table **20**). Although the geometrics are primarily variants of trapeze-rectangles, there many geometric types present in the assemblage. These include lunates, parallelograms, and triangles. The plethora of geometric types is unusual for Middle Epipalaeolithic assemblages, which tend to be dominated by trapeze-rectangles. In addition, there is considerable variability within the trapeze-rectangles themselves. Some are very wide, with rounded corners, while others are narrower with more angular edges. There are also several trapeze-rectangles with large notches (n=12) or denticulations (n=8) on the cutting edge.

As a result of this variability, Muheisen and Wada (1995) identified 14 distinct types of geometric microliths during the initial analysis of the Middle Epipalaeolithic Kharaneh IV assemblage. However, many of these types (quasi-trapezes) are likely broken microliths. Consequently, these types are not adopted for this analysis.

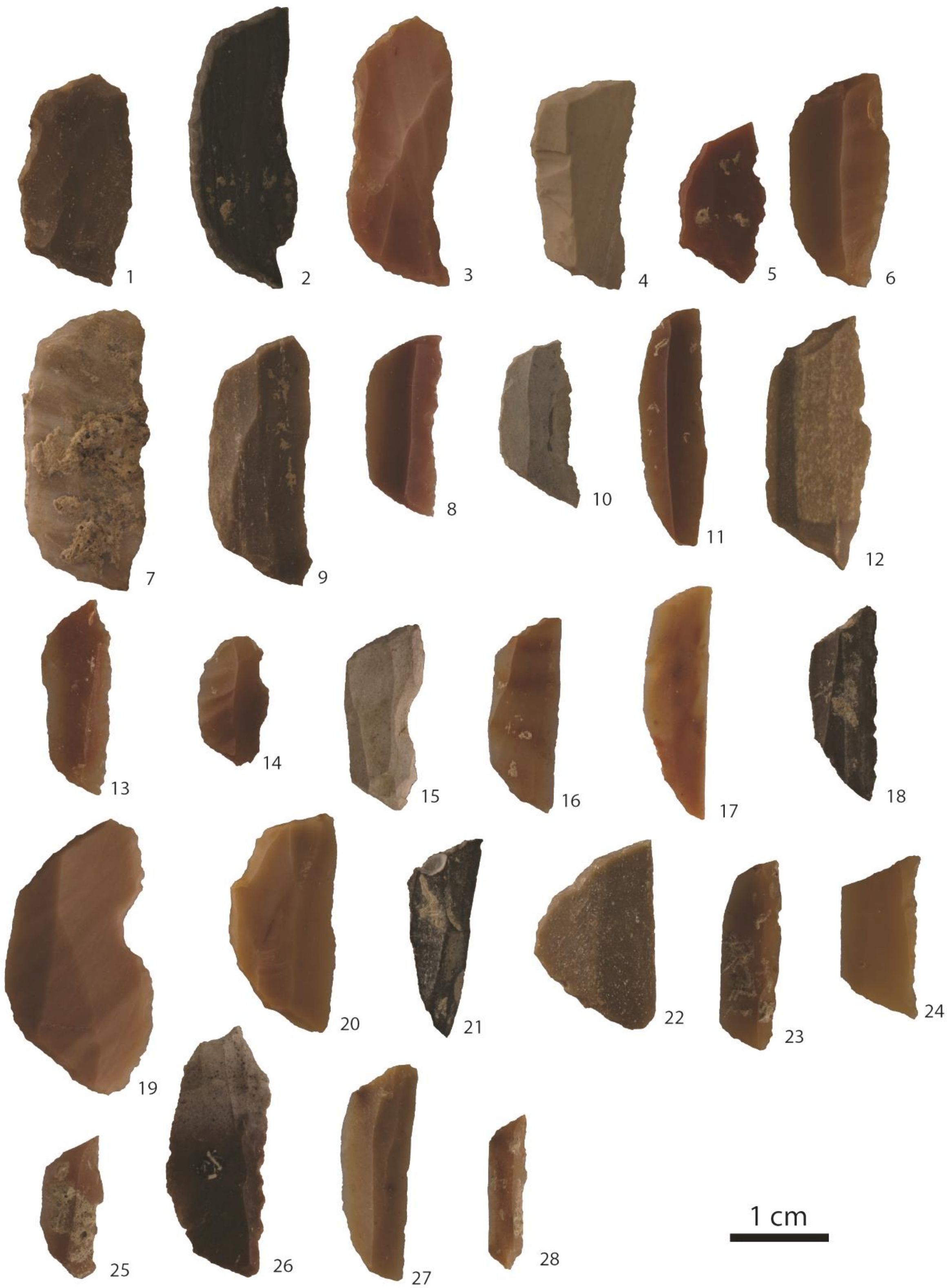


Figure 18: Microliths from Kharaneh IV. 1-10: trapeze-rectangles; 11-16: unbacked trapezes; 17-18: asymmetrical trapeze A; 19-20: lunates (one with notch); 21: scalene bladelet; 22: triangle; 23-25: obliquely truncated bladelets (broken); 26-28: varia.

Table 20: Kharaneh IV microlith types

Tool Type	Count	Percent
Geometric Microliths		
asymmetrical trapeze A	6	0.7
asymmetrical trapeze B	3	0.4
lunate	6	0.7
parallelogram	2	0.2
scalene bladelet	1	0.1
trapeze-rectangle	70	8.5
trapeze-rectangle with one convex end	4	0.5
triangle	2	0.2
unbacked trapeze	88	10.7
unbacked trapeze with one end pointed	3	0.4
Geometric Microlith Subtotal	**185**	**22.5**
Non-Geometric Microliths		
alternating retouch bladelet	1	0.1
arched backed bladelet	3	0.4
completely backed	16	2.0
curved pointed bladelet	13	1.6
inversely retouched bladelet	1	0.1
micropoints	2	0.2
notched bladelet	5	0.6
obliquely truncated	37	4.5
obliquely truncated and backed	2	0.2
partially backed	48	5.8
pointed bladelet	14	1.7
pointed and retouched on both sides	4	0.5
retouched on both sides	4	0.5
varia	12	1.5
Non-Geometric Microlith Subtotal	**162**	**19.7**
Fragmentary Microliths		
backed bladelet fragment	60	7.3
convex truncation	1	0.1
curved pointed bladelet	19	2.3
obliquely truncated	326	39.6
obliquely truncated and backed	70	8.5
Fragmentary Microliths Subtotal	**476**	**57.8**
Total	**823**	**100.0**

4.4.3.1 Microlith Morphology

Of the assemblage analyzed, there are 149 complete and 36 incomplete geometric microliths. In comparison, there are 34 complete, 58 distal, 33 medial, and 37 proximal non-geometric microliths. The incomplete pieces are underrepresented in the geometric microliths because of the problems distinguishing between broken unbacked trapeze-rectangles and obliquely truncated non-geometric microliths. Because of the high percentage of unbacked trapeze-rectangles, it is harder to distinguish broken microliths as geometric or non-geometric. Therefore, there is a higher percentage of microliths classified as 'fragmentary' from Kharaneh IV then in the Wadi Mataha or 'Uyun al-Hammâm assemblages.

The metrics for the complete geometric and non-geometric microliths are presented in Table 21. There are several interesting patterns in comparing the metrics of geometrics and non-geometric microliths not witnessed in the other assemblages. There is no significant difference between the thickness of the geometric and the non-geometric microliths (unequal variance t=1.217, p=0.256). However, the geometric microliths are significantly wider than non-geometric microliths (t=-2.45, p=0.01). This is counter to the idea that if all microliths are being produced on the same blanks, then geometrics should be narrower than the non-geometrics, since the geometrics are often more invasively retouched.

Table 21: Kharaneh IV microlith metrics

Microlith	measurement	mean (mm)	number	min (mm)	max (mm)	stand. dev. (mm)
geometric (complete)	length	22.0	149	11.5	38.3	4.6
	width	7.4	149	3.1	15.1	2.2
	thickness	1.7	149	0.8	3.9	0.6
non-geometric (complete)	length	29.4	34	18.8	47.2	6.1
	width	6.4	34	4.1	10.2	1.5
	thickness	1.6	34	0.8	2.8	0.5

To further explore differences within the microliths categories, the metrics for the two most prominent geometric types, backed trapeze-rectangles and unbacked trapezes, were evaluated (Table 22). The trapeze-rectangles are larger than the unbacked trapezes on every dimension, with significant differences in width (t=-6.197, p=<0.01) and thickness (t=-5.763, p=<0.01). The unbacked trapeze-rectangles are not significantly different in width (t=0.358, p=0.706) and thickness (t=-0.809, p=0.420) from the non-geometric microliths. This evidence suggests that different blanks were being used for the trapeze-rectangles then for unbacked trapeze-rectangles or non-geometric microliths at Kharaneh IV, representing two different reduction sequences for the microliths.

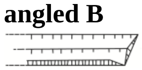
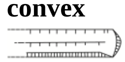
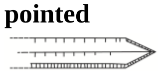
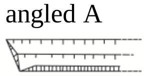
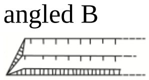
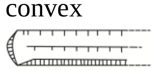
Table 22: Kharaneh IV trapeze-rectangle and unbacked trapeze metrics

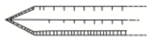
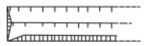
Microlith	measurement	mean (mm)	number	min (mm)	max (mm)	stand. dev. (mm)
unbacked	length	22.1	79	11.5	34.7	4.5
trapeze	width	6.6	79	3.9	15.1	1.7
(complete)	thickness	1.5	79	0.8	2.7	0.4
trapeze-rectangle	length	22.6	46	14.6	38.3	4.9
(backed)	width	8.8	46	4.6	13.2	2.3
(complete)	thickness	2.1	46	1.0	3.9	0.6

The majority of the geometric microliths have a straight profile (n=176, 95.1%). The remaining 4.9% (n=9) have a concave profile. In contrast, the non-geometrics are more variable. Only 68.5% (n=111) of the non-geometrics are straight, with 20.4% (n=33) having a concave profile, and the other 11.1% (n=18) with a twisted profile. Also, as noted above, the mean thicknesses of trapeze-rectangles and non-geometrics are significantly different. This suggests that the haft slots or hafting mechanisms were different for geometric and non-geometric microliths, with less constraint for the non-geometrics.

The end retouch on complete microliths is dominated by patterns that create a trapezoidal form for the completed tool (n=144, 91.1%) (Table 23). Because the trapezoidal form dominates the assemblage the unbacked and backed trapeze-rectangles were not separated out for analysis. There are no rectangular geometric microliths in the assemblage, although there are two microliths that have straight truncations at End 1. In addition, four pieces (2.2%) in the assemblage have pointed ends, a very rare shape in other assemblages.

Table 23: Kharaneh IV microlith end shapes

End 2 End 1	angled B 	convex 	pointed 	broken angled B	broken straight	Total
angled A 	144	3	2	2	7	**158**
angled B 	2	-	-	-	-	**2**
convex 	-	2	-	-	-	**2**

pointed 	2	-	-	-	-	**2**
straight 	2	-	-	-	-	**2**
broken	8	-	-	-	-	**8**
broken angled A	3	1	-	-	-	**4**
broken straight	7	-	-	-	-	**7**
Total	**168**	**6**	**2**	**2**	**7**	**185**

4.4.3.2 Microlith Retouch

Marginal retouch is used most frequently for backing microliths (n=396, 48.1%). Non-invasive retouch is also prevalent in all three general microlith classes (n=269, 32.7%). Invasive retouch is present in lower proportions for all microliths, at 7.0% (n=58). The pattern of retouch type frequency is the same for the geometric, non-geometric, and fragmentary microliths. However, most frequently, geometric microliths are unbacked (n=88, 47.6%).

Table 24: Kharaneh IV retouch types and directions

	Geometric Microliths		**Non-geometric Microliths**		**Fragmentary Microliths**	
Type of Retouch	Count	Percent	Count	Percent	Count	Percent
total	0	0	0	0	1	0.2
combination	9	4.9	1	0.6	1	0.2
invasive	14	7.6	16	9.9	28	5.9
marginal retouch	50	27.0	76	46.9	270	56.7
non-invasive	24	12.9	69	42.6	176	37.0
unbacked	88	47.6	0	0	0	0
Total	**185**	**100%**	**162**	**100%**	**476**	**100%**
Direction of Retouch	Count	Percent	Count	Percent	Count	Percent
unidirectional	185	100	162	100	475	99.8
bidirectional	0	0	0	0	1	0.2
Total	**185**	**100%**	**162**	**100%**	**476**	**100%**

Almost the entire backed assemblage was retouched with unidirectional backing; only one piece had bidirectional retouch. The piece with the bidirectional backing (a backed bladelet fragment) is also the only piece with ‘total retouch’. This suggests the artifact is an outlier in the assemblage. When analyzing the direction of retouch, the retouch ends were included if the piece was unbacked, since the technique of retouching is the same whether on the ends or along the length of the microlith.

The geometrics types are mostly produced with marginal or non-invasive retouch. The rare occurrences of invasive retouch were used to knap a variety of types including trapeze-rectangles, lunates, parallelograms, and triangles. There doesn’t appear to be a pattern associated with retouch types and geometric microlith group, except that marginal and non-invasive retouch are popular for geometrics.

Table 25: Kharaneh IV geometric microlith retouch types

Type of Retouch	asymmetrical trapeze A		asymmetrical trapeze B		lunate		parallelogram		scalene bladelet	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
combination	-	0.0	-	0.0	-	0.0		0.0		0.0
invasive	-	0.0	-	0.0	2	33.3	1	50.0		0.0
marginal	3	50.0	1	33.3	2	33.3	1	50.0		0.0
non-invasive	3	50.0	2	66.7	2	33.3		0.0	1	100.0
Total	6	100.0	3	100.0	6	100.0	2	100.0	1	100.0
	trapeze-rectangle		trapeze-rectangle one convex end		triangle		varia			
	Count	Percent	Count	Percent	Count	Percent	Count	Percent		
combination	8	11.6%	1	25.0%	-	0.0	-	0.0		
invasive	8	11.6%		0.0%	1	50.0	1	33.3		
marginal	38	55.1%	2	50.0%	1	50.0	2	66.7		
non-invasive	15	21.7%	1	25.0%	-	0.0	-	0.0		
Total	69	100.0%	4	100.0%	2	100.0	3	100.0		

4.4.4 Kharaneh IV Summary

The site of Kharaneh IV has an extensive lithic assemblage showing evidence of all reduction stages including core preparation, maintenance, tool manufacture, and discard. The retouched lithic assemblage is predominantly composed of microliths (83.4%), with similar representation of geometric (22.5%) and non-geometric microliths (19.7%). The geometric microliths are highly variable, but trapeze-rectangles still predominate in the form of backed (8.5%) and unbacked trapezes (10.7%). Although there is flexibility in microlith types, there is less variability in the retouch style. All microlith classes are marginally, non-invasively, or invasively retouched with unidirectional backing. Despite the similarities in the raw materials and the retouch patterns between the geometric and the non-geometric microliths, the metrics suggest that trapeze-rectangles were being produced from different blanks then the unbacked trapezes and the non-geometrics.

4.5 Discussion

When evaluated together, the lithic assemblages from Wadi Mataha, ‘Uyun al-Hammâm and Kharaneh IV exhibit some interesting patterns. All these sites have common elements, but they subtly diverge when one considers reduction strategies used and variability in microlith attributes. These differences will be discussed below.

4.5.1 Raw Materials and Reduction Strategy

At Wadi Mataha, the majority of the cores for the production of bladelets are broad-faced. Many of the cores were still able to produce microliths prior to their discard, suggesting that raw material was not scarce on the local landscape or that cores were not transported with the site’s inhabitants. Both core preparation and maintenance were conducted at the site, with an emphasis on maintaining the core face for removals. The microburin technique was used at the site for snapping bladelets, although some of the microburins may be intrusive from later Natufian deposits. Microliths are manufactured on fine or high-quality cherts, with no difference between the raw material selection for geometric and non-geometric microliths.

In contrast, the most common core types at ‘Uyun al-Hammâm are subpyramidal bladelet cores and wedge-shaped cores. As at Wadi Mataha, these cores were targeting the removal of bladelets. Although many cores were abandoned because of hinged terminations, almost 20% had no discernible reason for abandonment. There is a separate reduction sequence for many of the flakes, indicated through the presence of amorphous flake cores and different raw material choices between the flake and blade categories. There is evidence for core preparation and maintenance at the site, although there was very little preparation of the cores. The microburin technique was not used at the site for the production of microliths and bladelets were likely truncated through snapping. Preliminary observation suggests that there is no difference between the cherts chosen for the geometric and the non-geometric microliths (Appendix B).

The cores recovered from Kharaneh IV represent a wide range of types, almost all of which were directed towards the removal of blades and bladelets. These include both narrow-faced and broad-faced cores, among other types. Core-trimming elements are present in the assemblage, representing both core preparation and core maintenance. Most of the effort is focused on maintenance, but there is still more evidence at Kharaneh IV for core preparation than at the other sites. Only 26 microburins have been found in the analyzed lithic assemblage of over 100,000 lithics, indicating un-systematic use of the technique. As with the other sites, there is no difference between the cherts chosen for the geometric and the non-geometric microliths. Ongoing raw material survey at Kharaneh IV will help trace the sources of different cherts used for tool production at the site.

The reduction strategies for the three sites are primarily focused on the production of bladelets to be retouched into various microlith forms. The entire reduction sequence was enacted at each site, with a focus on core maintenance rather than core preparation.

4.5.2 Retouched Tools and Microlith Assemblages

At Wadi Mataha, the retouched assemblage is composed of 85.4% microliths. The rest of the assemblage is primarily comprised of backed blades, retouched flakes, and notches. 42.3% of the microliths are geometric, mostly in the form of invasively retouched trapeze-rectangles. These trapeze-rectangles tend towards trapezoidal, rather than rectangular, forms. Microliths are consistently retouched using unidirectional retouching methods and there is no evidence for the systematic use of bidirectional retouch. Both geometric and non-geometric microliths were probably manufactured from the same blanks, considering their similar metrics and raw material selection.

The microliths at ‘Uyun al-Hammâm comprises 76.1% of the retouched assemblage. The remainder of the assemblage contains scrapers, backed blades, and other types in small proportions. The microliths are primarily geometrics, at 66.7% of the assemblage. Trapeze-rectangles dominate the assemblage at 62.8% of the microliths. There is some flexibility in the form of the trapeze-rectangles; 20.1% of the geometrics are trapezoidal, 10.7% are rectangular, and 4.9% are somewhere in-between. Unidirectional retouch was preferred, but bidirectional retouch was also used for microlith backing. There is little difference in the raw material selection and the metrics between the geometric and the non-geometric microliths, suggesting they were manufactured from the same blanks.

The retouched lithics from Kharaneh IV are also primarily microliths, at 83.4% of the assemblage. Retouched pieces make up the next most frequent tool type, followed by scrapers and backed blades. In contrast to Wadi Mataha and ‘Uyun al-Hammâm, the frequencies of geometric (22.5%) and non-geometric microliths (19.7%) are similar. The geometrics are highly variable, with 10 different types represented in the assemblage. Unbacked trapeze-rectangles (8.5%) and backed trapeze-rectangles are the most prevalent geometric microliths (10.7%). The trapeze-rectangles are highly variable, including narrow angular pieces and wide rounded forms. Despite this variability in trapezoidal form, there are no rectangles in the assemblage. Retouch was most commonly marginal or non-invasive, with a small percentage of invasive retouch. Neither total nor bidirectional retouch were used in the assemblage for the production of microliths. The geometrics are significantly wider and thicker than the non-geometric microliths. In addition, the non-geometric microliths are more variable in their profile shape, including twisted and concave forms. This suggests that these microlith classes are from different reduction trajectories, despite the similarities in raw material choice, and that different hafting configurations were possible. Alternately, these microliths could have been from the same reduction sequence but were actively selected for their width and profile from the pool of available blanks. This is particularly apparent in the differences between the unbacked and the backed trapeze-rectangles. The unbacked trapezes seem to be manufactured on the same blanks as the non-geometric microliths, while the backed trapeze-rectangles are manufactured on very different blanks.

For all three sites, the tools are representative of types typically found in Middle Epipalaeolithic assemblages. They are dominated by microliths, with an emphasis on geometrics. This pattern diverges at Kharaneh IV, where geometric and non-geometric microliths are evenly represented in the assemblage (Figure 19). ‘Uyun al-Hammâm has the highest frequency of geometrics in the microlith assemblage (66.7%).

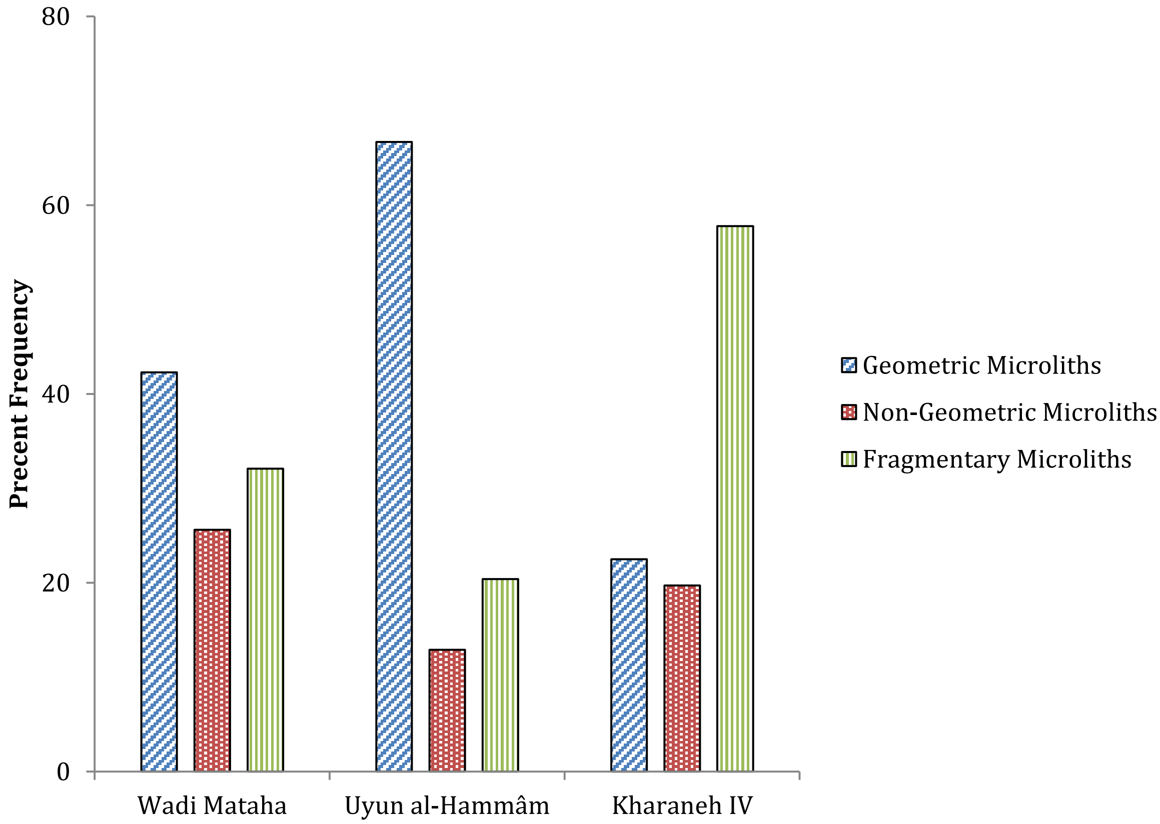


Figure 19: Percent Frequency of microlith classes at Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV.

The geometrics at Wadi Mataha and ‘Uyun al-Hammâm are dominated by trapeze-rectangles (Figure 20). This is in contrast to Kharaneh IV, where the geometrics are represented by both unbacked and backed trapezes. Width evidence suggests that the two different types of microliths at Kharaneh IV might have been part of different reduction sequences.

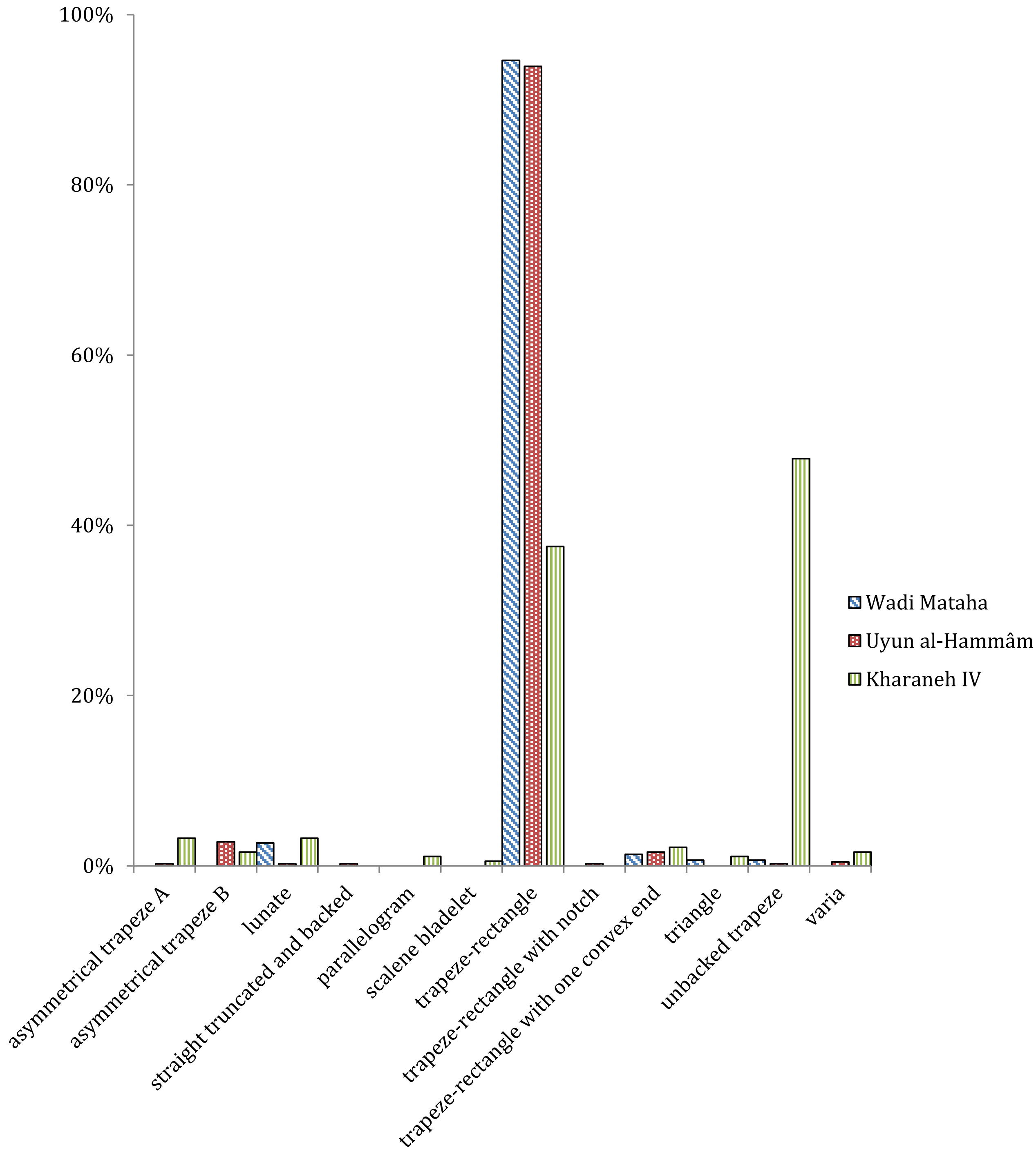


Figure 20: Percent frequencies of geometric microlith types

The type of retouch used for backing the trapeze-rectangle microliths is very similar at Wadi Mataha and ‘Uyun al-Hammâm (Figure 21). At these two sites, there is a low frequency of total retouch, but it is present in the assemblage. There is a high frequency of invasive retouch, some marginal retouch, and little non-invasive retouch. In contrast, the microliths from Kharaneh IV are differently backed. There are no occurrences of total retouch in the assemblage and a low frequency of invasive retouch. However, the use of marginal and non-invasive retouch is more frequent than at Wadi Mataha and ‘Uyun al-Hammâm. This suggests a very different pattern of knapping and backing of microliths at Kharaneh IV.

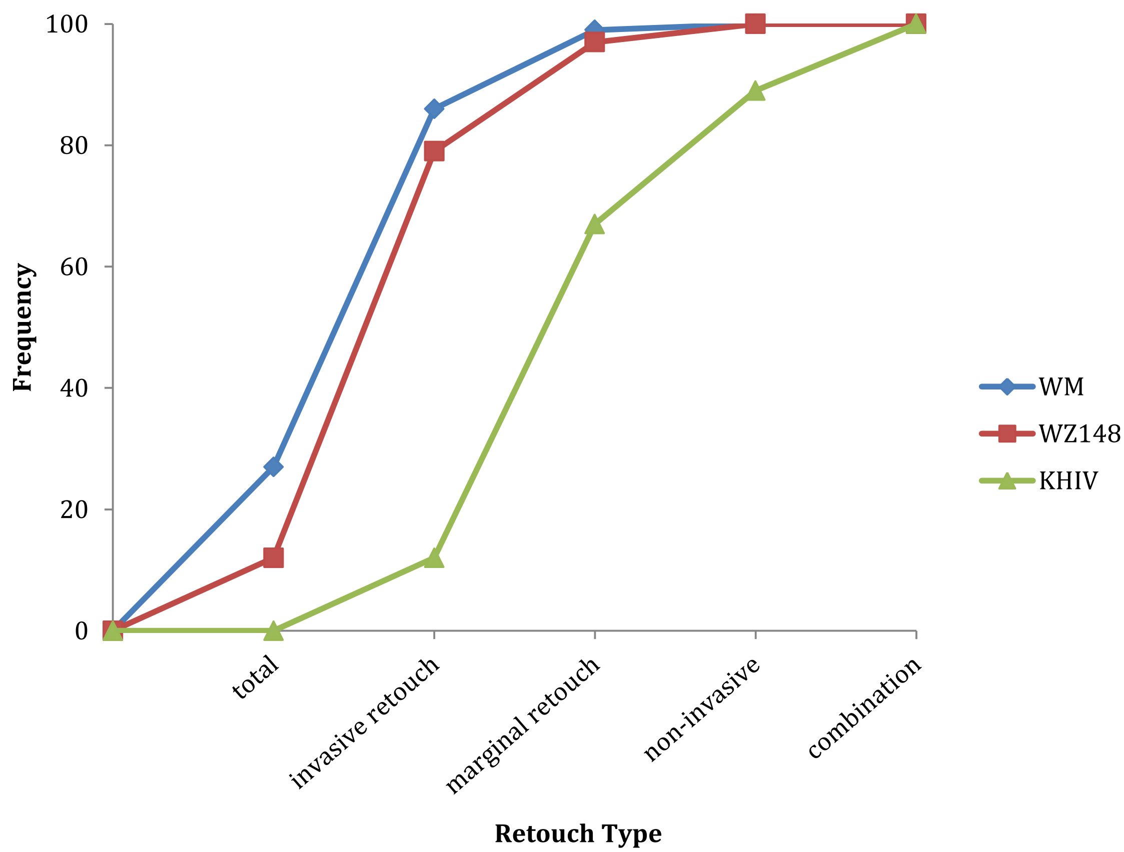


Figure 21: Cumulative frequency graph of trapeze-rectangle microlith retouch type

There are some interesting differences among the sizes of the trapeze-rectangles from the sites (Table 26). On average, Kharaneh IV trapeze-rectangles (both backed and unbacked) are longer than the trapeze-rectangles from Wadi Mataha and ‘Uyun al-Hammâm. The widest microliths are the backed trapeze-rectangles from Kharaneh IV, followed by the trapeze-rectangles from

‘Uyun al-Hammâm. The thickest trapeze-rectangles are found at ‘Uyun al-Hammâm and the thinnest are the unbacked trapezes from Kharaneh IV.

Table 26: Trapeze-rectangle metrics for Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV

Trapeze-rectangle	measurement	mean (mm)	number	min (mm)	max (mm)	stand. dev.
Wadi Mataha	length	20.9	32	11.9	29.2	4.8
trapeze-rectangle	width	6.1	32	4.1	9.5	1.2
	thickness	2.3	32	1.6	3.7	0.5
‘Uyun al-Hammâm	length	20.6	165	10.1	41.6	5.4
trapeze-rectangle	width	7.5	165	4.9	13.5	1.5
	thickness	2.6	165	1.3	3.8	0.6
Kharaneh IV	length	22.1	79	11.5	34.7	4.5
unbacked trapeze	width	6.6	79	3.9	15.1	1.7
	thickness	1.5	79	0.8	2.7	0.4
Kharaneh IV	length	22.6	46	14.6	38.3	4.9
trapeze-rectangle	width	8.8	46	4.6	13.2	2.3
	thickness	2.1	46	1.0	3.9	0.6

The length, width, and thickness data were tested to evaluate the statistical significance of the observed differences in means (Appendix A, Table 62, Table 63, Table 64). Normality was first tested using the Shapiro-Wilk test on the length, width, and thickness data. The results of these tests indicate that the only normal data are the thickness measurements. Therefore, the Kruskal-Wallis test for non-normal distributions was used for the length and width data, and a one-way AVOVA was run for the thickness data.

For the length, there is significant difference between the lengths of the ‘Uyun al-Hammâm trapeze-rectangles in comparison to both the Kharaneh IV trapeze-rectangle groups. There is no significant difference between the Wadi Mataha trapeze-rectangle lengths and the other sites. The differences in widths are significant among all the sites, except for Wadi Mataha and the unbacked trapeze-rectangles from Kharaneh IV. Both these sites have very thin trapezes in comparison to the backed trapeze-rectangles from Kharaneh IV and those from ‘Uyun al-Hammâm. Finally, there are significant differences in thickness between all the trapeze-rectangle microlith assemblages, except for the thickness of the Wadi Mataha and the Kharaneh IV trapeze-rectangles. These two assemblages fall in the middle, between the very thick trapeze-rectangles from ‘Uyun al-Hammâm and the very thin unbacked trapeze-rectangles from Kharaneh IV. These results suggest that there is room for flexibility in all dimensions of the trapeze-rectangles with significant differences between the assemblages of the three sites.

In comparison with other Geometric Kebaran sites, these three sites fall within the normal range of length and width dimensions. Figure 22 compares the published measurements from the Geometric Kebaran sites in the Negev and Sinai (data from Goring-Morris, 1987: 127-128) with the mean length and width measurements from Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV (both the backed and unbacked trapezes).

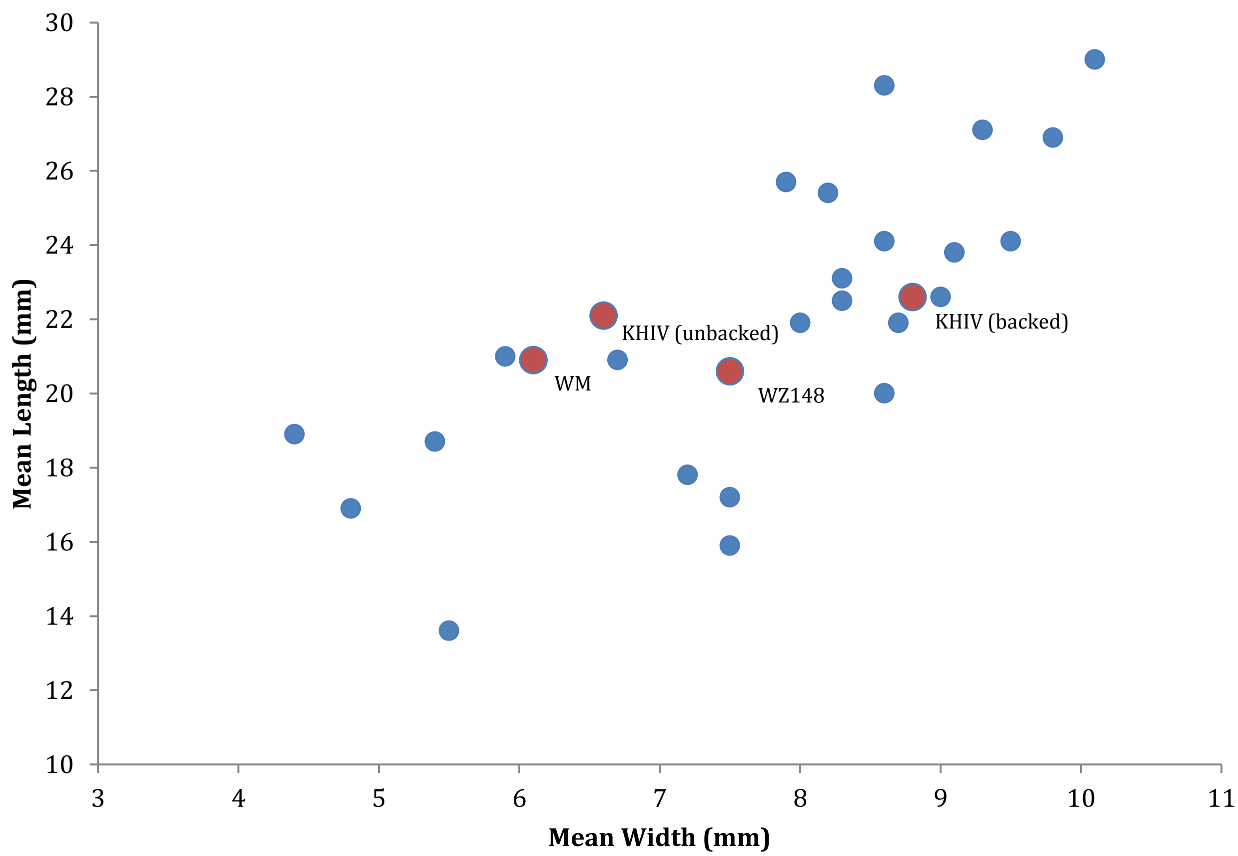


Figure 22: Mean length and widths of trapeze-rectangles from Negev and Sinai Middle Epipalaeolithic sites (data from Goring-Morris 1987) compared to the mean trapeze-rectangle length and widths from Wadi Mataha (WM), 'Uyun al-Hammâm (WZ148), and Kharaneh IV (KHIV unbacked, KHIV backed)

Although Goring-Morris notes there is variability within the measurements, he divides the Negev and Sinai trapeze-rectangles into general groups, those with mean widths >7.5 mm and mean lengths > 20mm, and those with mean widths and lengths smaller (Goring-Morris, 1987: 130). The Wadi Mataha trapeze-rectangles and the unbacked trapezes fall generally into the second group, with mean widths of less than 7.5 mm. However, both sites have mean lengths greater than 20 mm. ‘Uyun al-Hammâm is located at the cusp between the groups defined by Goring-Morris, with a mean width of 7.5 mm and a mean length of 20.6 mm. The backed trapeze-rectangle microliths from Kharaneh IV are aligned with the larger trapeze-rectangle microlith group, although they are not as wide as some of the trapeze-rectangles from Shunera I, Shunera XII, Shunera XIIB, Shunera XXV, Azariq XVIII, and Nahal Lavan 105. The addition of the three study sites to the distribution further strengthens the assessment that there is considerable variability in the range of sizes of trapeze-rectangles. Bar-Yosef (1970) initially hypothesized that sites containing large or small trapeze-rectangles represented two distinct populations. I would suggest that trapeze-rectangle measurements represent a continuum of form and not clear separation between different groups.

4.5.3 Summary

Several interesting patterns are revealed from the results of the technological and typological analysis of Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV. All three sites are located in regions with abundant resources, including high-quality raw materials for flint knapping. The debitage assemblages indicate that the complete reduction sequence is taking place at all three sites, suggesting that flintknapping was an important activity performed at these locations.

Both Wadi Mataha and ‘Uyun al-Hammâm fit conformably within the designation of the Geometric Kebaran. In contrast, Kharaneh IV is a very different assemblage. Although Kharaneh IV has a lot of trapeze-rectangles, it also exhibits a high percentage of non-geometric microliths. There is also a very high frequency of fragmentary microliths at Kharaneh IV. The nature of the microlith assemblage with backed and unbacked trapeze rectangles makes the identification of the fragmentary microliths very difficult. Thus, it is hard to know if many of these pieces were geometric microliths prior to breakage. This site also has the most variable geometric microlith assemblage, suggesting that there are complexities within the notion how microliths could be designed and formed.

The technological and typological analysis of microliths from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV indicates that there were subtle differences in how geometric microliths were being manufactured during the Middle Epipalaeolithic. This variability suggests that there is flexibility within the technology that is expressed differently at different sites. This flexibility may reflect ‘micro-styles’ (Dietler and Herbich, 1998) of trapeze rectangle production at each site, or the technological style that come from producing material culture within a local group. Subtle differences in the backing style between the three sites hint at different techniques for producing microliths that may be taught and shared within each knapping community. The next chapter will further explore the variability in geometric microliths from these sites through a more detailed analysis of microlith shape.

Chapter 5
Geometric Morphometric Analysis

5 Introduction

In the previous chapter, the technological and typological variability of the Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV lithic assemblages was analyzed. However, microlith form and shape can only be described in a limited fashion through typology. Using typological classifications for Epipalaeolithic microliths allows comparability between assemblages, but it homogenizes the variability within these typological classes. Thus, new ways of presenting morphological variability need to be explored if we are to understand fully the subtle variations within microlith classes.

The field of geometric morphometrics studies shape variation in biological specimens (Adams, et al., 2004, Bookstein, 1991), where shape is defined as the “geometric properties of an object invariant to position, orientation, and size differences" (Slice, 2007:262). In this chapter, the results of geometric morphometric analysis of trapeze-rectangle shape will be presented. This analysis was conducted on a sample of complete trapeze rectangles from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV to evaluate variability in microlith form among the sites. Subtle variation in form illuminates the choices made by flintknappers during the Middle Epipalaeolithic and how different communities manipulated technology around a generalized ideal. Geometric morphometric analysis of Epipalaeolithic microliths will contribute to our understanding of how shape changes between different communities, indicating how stylistic behaviour is displayed in everyday technology.

5.1 Background to Morphometrics

Traditional morphometric methods use multivariate statistics to describe shape through the analysis of variables such as length, width, and distances between landmarks (Rohlf and Marcus, 1993). Over time, these traditional methods were replaced with geometric morphometric approaches that allow an object’s shape to be preserved throughout the analysis. Geometric morphometrics allows the non-shape data, including size and orientation, to be removed so that only shape remains for the analysis (Adams, et al., 2004). The inception of geometric morphometric techniques was the result of developing new statistical methods that could be integrated with outline and landmark data (Adams, et al., 2004). When it was first introduced, geometric morphometric analysis was termed a ‘revolution’ for the analysis of biological specimens (Rohlf and Marcus, 1993) because of it its effectiveness at capturing and describing shape variations.

There are several methods used to describe shape in geometric morphometric analysis, including landmark and outline analysis. Landmark methods use definable landmarks on the surface of the specimen to reconstruct shape digitally. These methods operate under the assumption that the specimens have homologous features or landmarks that are consistent across individuals. In contrast, outline methods digitize the perimeter of the specimen to compare the overall shape. This technique does not require the presence of homologous landmark features on the specimens. However, outline methods are limited to the perimeter of the object and are unable to incorporate three-dimensional features. As well, the entire perimeter is treated equally so they do not allow the researcher to incorporate *a priori* knowledge about where meaningful variation may occur.

To address the problems inherent in both landmark and outline methods, the technique of semilandmarks was developed (Bookstein, 1997). Semilandmarks are defined geometrically, rather than morphologically, and can be placed along the outline of the piece. Introduction of semilandmarks into geometric morphometric analysis allows characterization of curves and outlines without the rigidity of landmarks. These can be used in conjunction with homologous landmarks to highlight morphologically significant features. Semilandmarks are best used when landmark placement is not well defined by a specific feature. During analysis, variation in semilandmarks is assessed orthogonally to the outline and not along the curve (Slice, 2007) (Figure 23). Therefore, the position of the semilandmark along the curve does not need to be precise, as long as the semilandmark is situated on the curve itself.

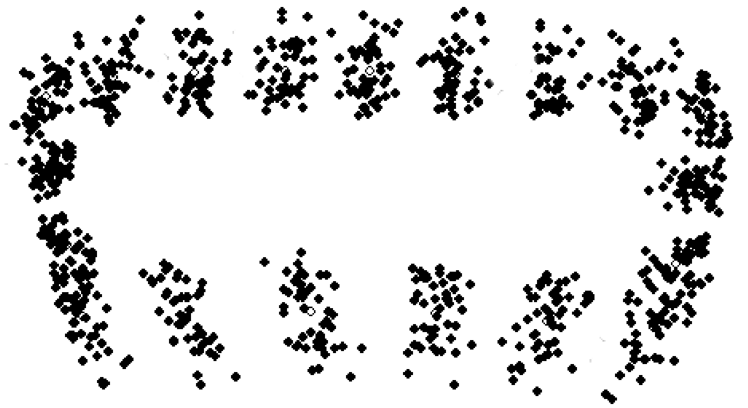


Figure 23: Orthogonal sliding of semilandmarks for 'Uyun al-Hammâm microliths

With all methods, extraneous variables are removed so that shape is assessed without interference from other factors such as size. Size data is often sequestered for later inclusion into the analysis to understand allometric variations between specimens. The removal of variables can be done through various methods, including generalized Procrustes analysis (GPA) which superimposes shapes through matching landmark positions. This generates a consensus shape from which individual specimens deviate. GPA is one of the preferred techniques for landmark and semi-landmark analysis. Once other variables are removed, statistical analysis of shape variation can be performed through multivariate statistical tests, such as principle component analysis, to visually and statistically describe shape.

Morphometric analysis moves beyond the current methods for describing lithic shape, allowing greater objectivity. Currently, lithic shape is described either qualitatively (e.g., Levallois ‘point’ for convergent, triangular Levallois flakes) or in the ratio of two linear dimensions (e.g., maximum length to width). Although the latter is quantitative, it simplifies lithic form into a rectangular shape, removing details and characteristics of the shape itself. Morphometric analysis specifically addresses the shape of objects, without reducing or simplifying form. The techniques described above use two-dimensional images to understand shape variability. However, three-dimensional morphometrics are becoming increasingly popular for shape analysis, moving beyond flat images to assess complete objects and specimens (e.g., Archer and Braun, 2010). The use of three-dimensional images is becoming increasingly common as three-dimensional scanning technologies are becoming more accessible and affordable, moving the ‘revolution’ of geometric morphometrics forward into new territories.

5.2 Geometric Morphometrics and Lithics

Several recent studies have applied the biological technique of geometric morphometrics to lithic assemblages to understand shape variability among artifacts (e.g., Buchanan, 2006, Eren and Lycett, 2012, Iovita, 2011, Lycett, et al., 2010, Thulman, 2012). Geometric morphometric analysis is more powerful for evaluating shape characteristics than metrics currently used by many lithic analysts because it graphically and statistically represents shape without conflating variables such as size into the analysis. Furthermore, it fully defines artifact shape while exploring nuances of form not adequately captured by linear measurements. The tps suite of programs (e.g., Rohlf, 2010a, 2010b, 2011) is popular among researchers since it uses semilandmarks and is available for free online (http://life.bio.sunysb.edu/morph/). These programs are designed by F. James Rohlf and are continuously being adapted and improved.

Some of the earliest research using geometric morphometric analysis to describe lithic variability was conducted using landmark methods. In one early paper, Lycett et al. (2006) collected landmark coordinates using a crossbeam co-ordinate caliper to conduct landmark geometric morphometric analysis on a selection of cores. The primary purpose of this paper was to test the new method of data collection with the crossbeam calipers and its ability to aid in the qualification of lithic shape. Later landmark geometric morphometric analysis by the authors incorporated generalized Procrustes analysis (GPA) using *Morphologika* software to test whether Victoria West cores are actually large Levallois cores (Lycett, et al., 2010). The results of their analysis suggest that the Victoria West cores are more similar to Lower Palaeolithic artifacts such as handaxes and are a continuation of Acheulian traditions.

In other early research using landmark analysis, Buchanan (2006) used geometric morphometrics to quantify resharpening and to evaluate resharpening models of Folsom points. For this research, he used a landmark and semi-landmark approach using the tpsDig software to place the landmarks. Three landmarks were defined (one at the tip and two at the base) and 33 semilandmarks were placed around the outline of the points. The shape of the point was determined through 12 inter-landmark distances, which showed a high degree of asymmetry in the assemblages for blade length. The author suggested that this showed evidence of resharpening Folsom points (Buchanan, 2006). Later work by the same author used morphometrics to distinguish among Clovis, Folsom, and Plainview points through landmark and semi-landmark analysis using the tps suite of programs (Buchanan and Collard, 2010).

In recent work, Costa (2010) used the tps suite of programs to evaluate the shape of both bone and stone handaxes. The tps programs use a Procrustes superimposition to remove size and thin-plate spline deformation to facilitate visualization of shape changes from the mean. The results of the geometric morphometric analysis show that there is no difference between the shapes of the bone and the stone handaxes (Costa, 2010).

Another recent paper used landmark and semi-landmark analysis to look at standardization in Middle and Upper Palaeolithic assemblages (Monnier and McNulty, 2010). For this research, symmetry of the artifacts along the tool axis was used to position the landmarks. Twenty-four semilandmarks were evenly spaced along the tool, with the endpoints of the axis marked as homologous landmarks using tpsDig. The results show that there was more standardization in the Upper than the Middle Palaeolithic, but that the Neolithic (used as a control) was the least standardized (Monnier and McNulty, 2010).

Outline methods such as elliptical Fourier analysis (EFA) have also been used to assess lithic shape. In outline methods no landmarks are assumed and the artifacts are analyzed based on their perimeter outlines. Several studies have used EFA to understand variability in lithic morphology (Iovita, 2009, 2010, 2011, Iovita and McPherron, 2011). These papers have evaluated the interplay between lithic 'development' and shape (Iovita, 2009) and resharpening (Iovita, 2010). In a recent paper Iovita (2011) used elliptical Fourier analysis to evaluate how retooling affects shape variation and the functional implications of resharpening. The results showed that Aterian tools were resharpened in the haft, becoming increasingly more rounded, and that they were resharpened more heavily on one edge than the other. The geometric morphometric analysis on Aterian tools indicates that they are not consistent with projectile points (Iovita, 2011), showing how geometric morphometrics can contribute to our understanding of tool diversity during the Middle Stone Age.

Both landmark and outline methods of analysis have been applied to lithic assemblages, but landmark analysis is most commonly used in the published literature. Robust geometric morphometric analysis for lithic artifacts uses a combination of landmarks and semilandmarks to incorporate data from homologous points with outline data. This is corroborated by recent research that suggests semi-landmark techniques are useful for describing morphological variation in lithic tools (Cardillo, 2010). Ultimately, geometric morphometrics can be used in combination with other analytical methods to lay the foundation for interpretations about lithic variability that are grounded in quantitative data (Lycett, 2009).

5.3 Methods

A sample of 134 complete trapeze-rectangles was selected from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV for geometric morphometric analysis. Fifty trapeze-rectangles were included from both ‘Uyun al-Hammâm and Kharaneh IV. These were chosen using a simple random element sample (without replacement) from the assemblage of complete trapeze-rectangles at these sites. The entire population of complete geometric microliths was chosen for analysis from Wadi Mataha, totaling 34 microliths. For this analysis, a technique using landmarks and sliding semilandmarks was chosen. As mentioned previously, this method is very robust and describes shapes by incorporating data from homologous features and outlines. This will illuminate how different knapping communities altered the general template of the ‘trapeze-rectangle’ to fit within their own template.

To begin, digital images of the trapeze-rectangles were acquired using a Canon EOS40D digital SLR camera in a photography box. In order to minimize parallax differences, one consistent camera set up was used for the photography. The camera was mounted on a tripod facing down towards the artifact. This ensured that the microliths were perpendicular to the camera at all times and that the angle of the camera was consistent. The camera mount and position were stationary throughout the photography, removing any potential distortion. The artifacts were oriented with the cutting edge parallel to the top frame of the camera, dorsal side facing up. The trapeze-rectangles were placed directly onto the photography box stage and there was no need for mounting material because the trapeze-rectangles are very flat.

Following image acquisition, an image database was created to relate the individual photographs to the geometric morphometric data using tpsUtil (Rohlf, 2011). The images from each site were separated, creating a single database per site. In addition, one database was created with all the trapeze-rectangles combined for comparing the shapes between the three sites.

Once the databases of the digitized images were created, landmarks were placed on each of the images using tpsDig2 (Rohlf, 2010a). For each microlith, two fixed landmarks were added at the point of convergence between the cutting edge and the two ends (Figure 24). An additional 17 sliding semilandmarks were equally spaced along the backed and cutting edges. As mentioned previously, these semilandmarks allow the outline of the artifact to be captured without the presence of homologous landmarks. After placing landmarks, the shape variation was isolated using generalized Procrustes analysis in tpsRelw (Rohlf, 2010b), removing size and rotation data.

Shape variables were generated through the use of thin-plate splines with tpsRelw (Rohlf, 2010b). This method maps the deformation of each specimen's shape from the consensus, or mean, form (Adams, et al., 2004). The technique measures the differences in the warping of the landmarks and semilandmarks between each artifact to understand variability in form. Finally, statistical analysis of the shape variation was conducted using principal component analysis (PCA). The relative warp scores were exported from tpsRelw and imported into PAST statistical analysis package to generate the PCA plots.

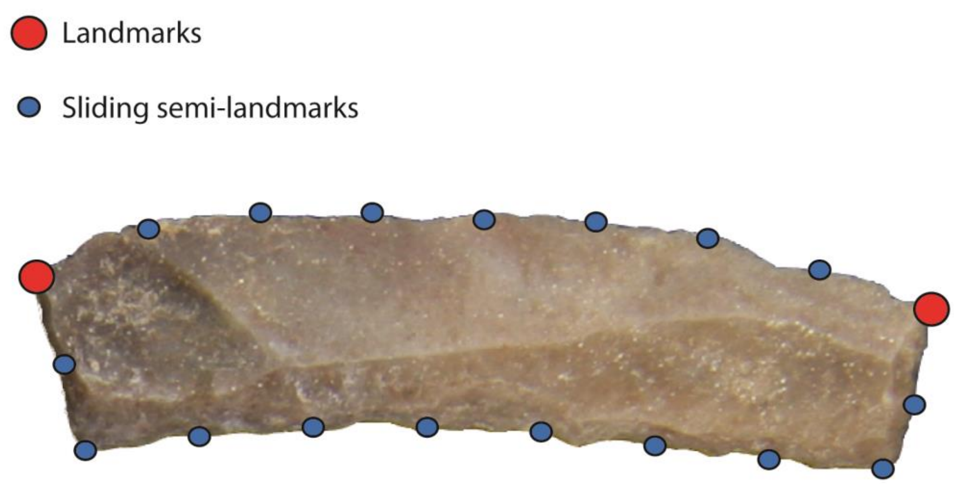


Figure 24: Location of landmarks on a trapeze-rectangle

5.4 Results

All three sites show flexibility in trapeze-rectangle morphology. However, how this variability is expressed is different at each site. For the Wadi Mataha microliths, most of the variance is located in the elongation of the microliths at 66.9%. The second variant is skewness, or asymmetry, which represented 13.2% of the variance (Figure 26). The consensus form at Wadi Mataha has angular corners and an elongated form (Figure 25).

Like Wadi Mataha, at ‘Uyun al-Hammâm the majority of the variance (77.4%) is in elongation of the microlith (Figure 26). The second principle is skewness, which only constitutes 9.5% of the variance. The consensus form at ‘Uyun al-Hammâm is similar to the mean form at Wadi Mataha. However, the form at ‘Uyun al-Hammâm is less elongated.

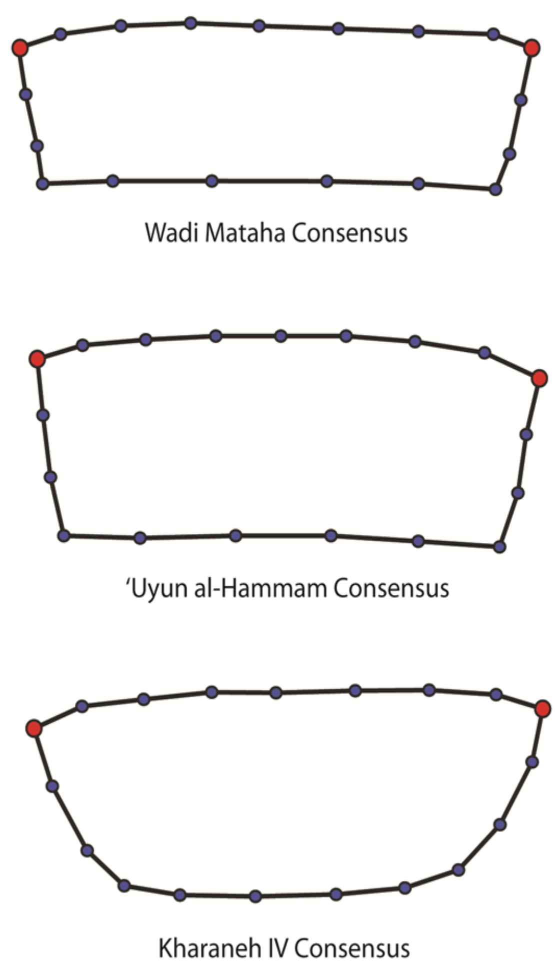


Figure 25: Consensus shape of trapeze-rectangles from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV

For the Kharaneh IV trapeze-rectangles, 58.7% of the variance is in elongation, while 16.8% is in skewness. It should be noted that the average shape at Kharaneh IV has more rounded corners than those at either Wadi Mataha or ‘Uyun al-Hammâm, evidenced in the consensus forms (Figure 25).

The PCA graphs for each site (Figure 26) indicate that there was a lot of flexibility in the elongation of the microliths at Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV. This is particularly apparent at ‘Uyun al-Hammâm, where 77.4% of the variance is in principal component 1 (elongation). This elongation could relate to the haft or hafting slot shape. Alternatively, it could relate to the number of insets placed into a haft with laterally hafted microliths.

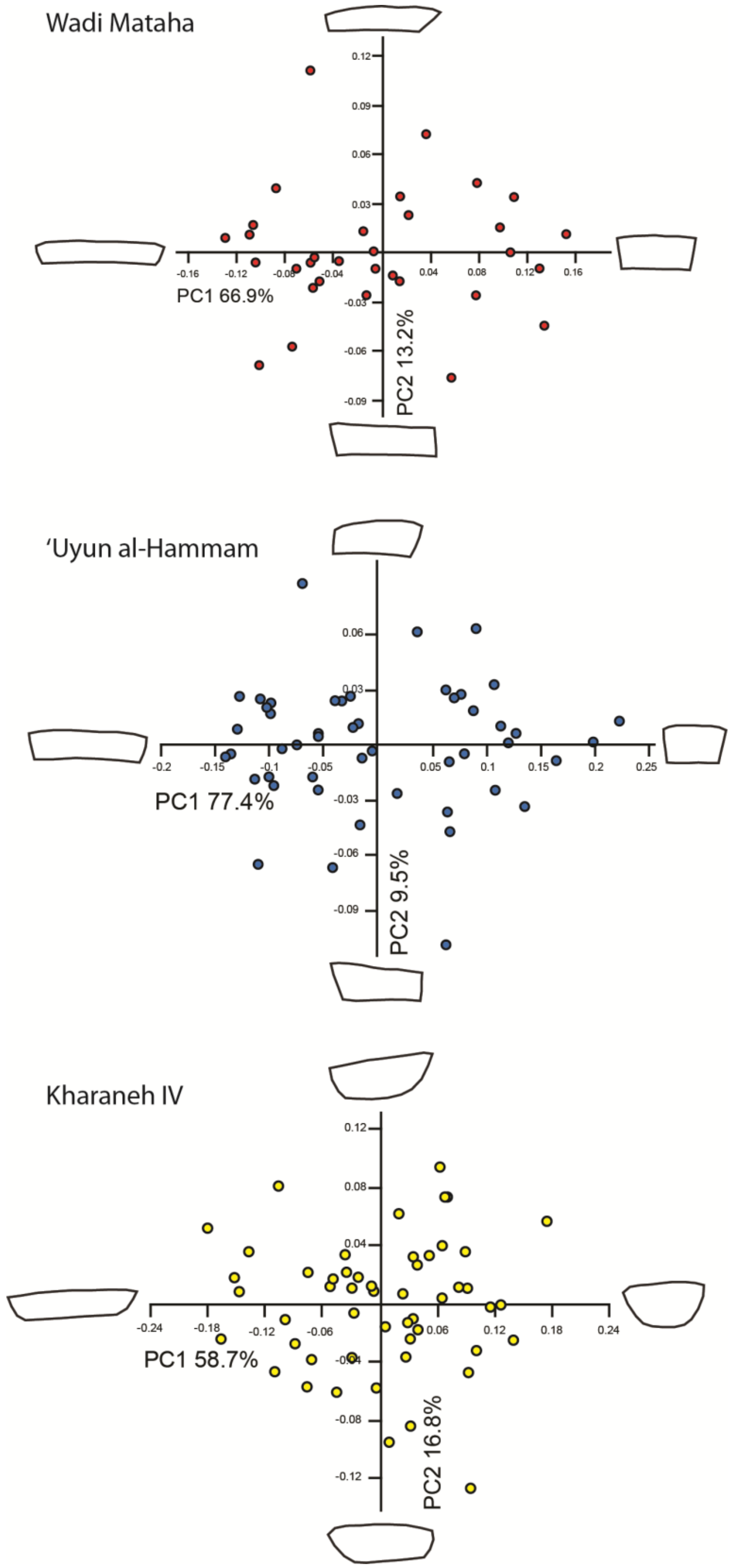


Figure 26: Principal component analysis of Wadi Mataha (top), 'Uyun al-Hammâm (middle), and Kharaneh IV (bottom)

The principal component analysis of all three sites indicates that PC1 is located in the elongation of the microlith (62.4%) and PC2 is located in the convexity of the backing (12.0%). Visually, the three sites separate out very clearly from each other on the PCA graph (Figure 27). The Wadi Mataha trapeze rectangles fall primarily into the elongated and straight-to-concave range in the lower left quadrant. The microliths from ‘Uyun al-Hammâm are situated in the lower half of the graph, suggesting that the variance is located primarily in elongation and not in backing convexity. Finally, Kharaneh IV is located in the upper portion of the graphic showing that there is variance along elongation. The position on the graph also indicates that there are more convex microliths at Kharaneh IV than at the other sites.

Box plots of PC1 and PC2 clearly show the differences among the three sites (Figure 28). ANOVA analysis for PCI (elongation) indicates that there is a significant difference between the elongation of the Wadi Mataha microliths and that of the other two sites, but not among Kharaneh IV and ‘Uyun al-Hammâm (Table 27). The variance of PC1 is not statistically significant among the three sites (Levene’s test for homogeneity of variance, $p=0.156$). This suggests that there is a similar amount of flexibility in elongation at the sites, but that at Wadi Mataha the form is more elongated.

ANOVA analysis of PC2 (convexity) shows there is a significant difference in the convexity variance between Kharaneh IV and the other sites (Table 27) and there is no significant difference in backing shape between Wadi Mataha and ‘Uyun al-Hammâm. These results suggest that the microliths from Kharaneh IV are more convex with more rounded corners than the angular forms at Wadi Mataha and ‘Uyun al-Hammâm. The variance of PC2 between the three sites is not statistically significant (Levene’s test for homogeneity of variance, $p=0.11$). Like elongation, there is a similar amount of flexibility in the shape of backing among the three sites, but that variance is expressed as rounded, convex-backed at Kharaneh IV. In comparison, it is expressed as straight-to-concave backing at Wadi Mataha and ‘Uyun al-Hammâm.

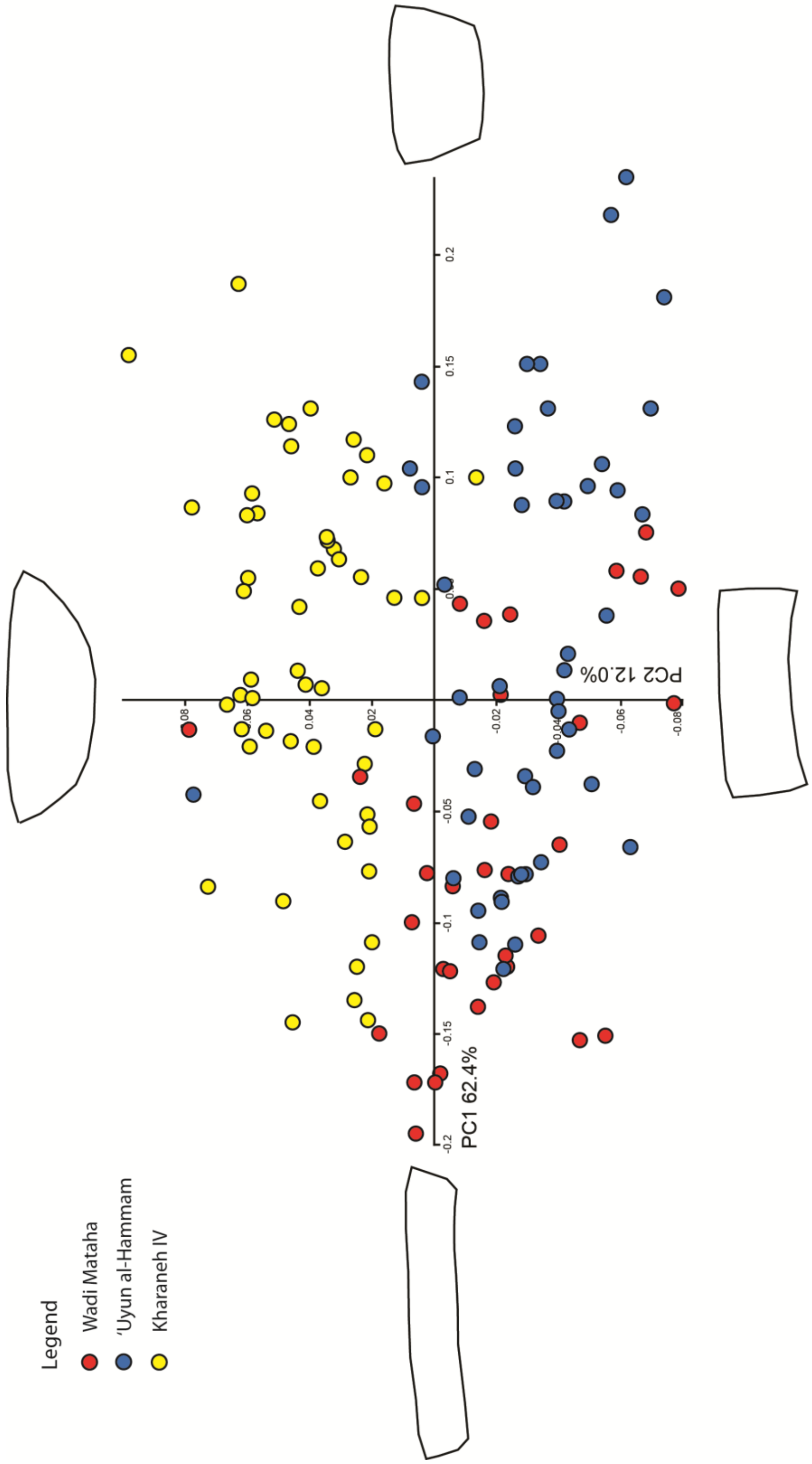


Figure 27: Principal component analysis comparing trapeze-rectangles from Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV

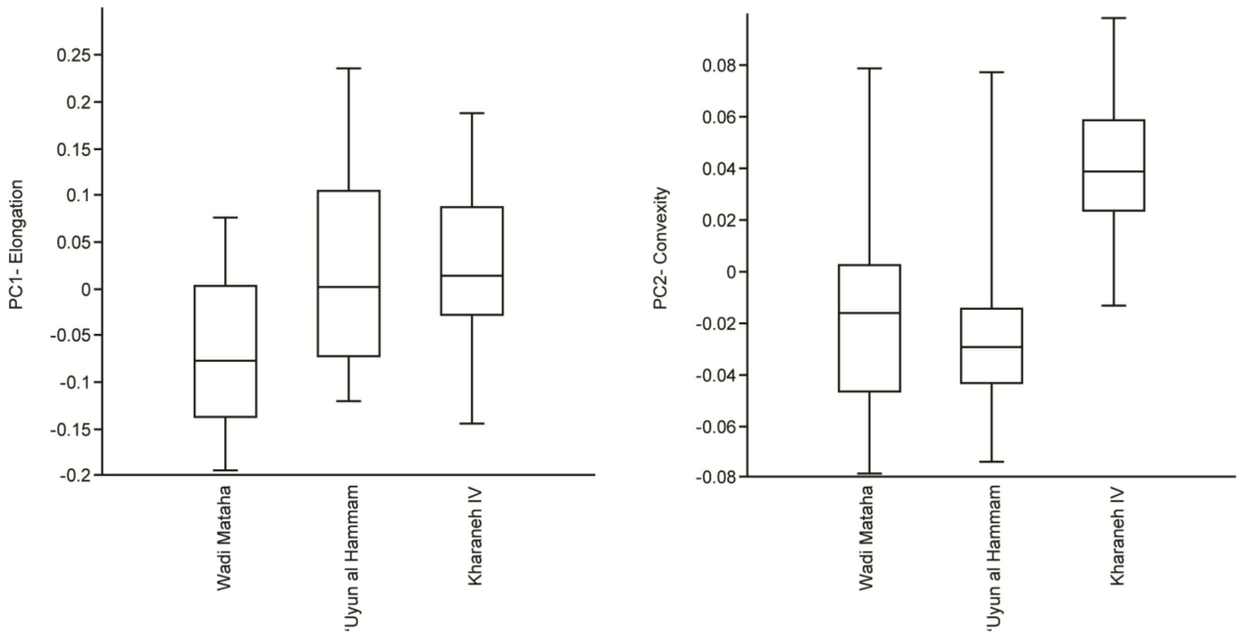


Figure 28: Box plots comparing PC1 and PC2 between Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV

Table 27: ANOVA analysis for box-plots of PC1 and PC2. Significant results are highlighted in red

PC1: Elongation

	WM	**WZ148**	**KHIV**
WM	-	<0.01	<0.01
WZ148		-	0.9999
KHIV			-

PC2: Convexity

	WM	**WZ148**	**KHIV**
WM	-	0.1198	<0.01
WZ148		-	<0.01
KHIV			-

5.5 Discussion

In summary, the geometric morphometric analysis demonstrates that there was flexibility in the idealized template of trapeze-rectangles at Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV. The intersite analysis shows that there was a similar degree of variance between the PC1 (elongation) and PC2 (convexity) at the three sites, but that the variance is expressed differently. At Wadi Mataha trapeze-rectangles are more elongated, with straight to slightly concave backing and an angular form. ‘Uyun al-Hammâm’s trapeze-rectangles are also angular with straight to slightly concave backing, but have the greatest variance in elongation. Kharaneh IV trapeze-rectangles have significantly different backing shape from the other sites, with rounded corners. These results suggest that the flintknappers at the three sites were working around a similar framework of trapeze-rectangle form, but manipulated their technology in slightly different ways to create a unique expression of trapeze-rectangle form at each site. These differences could be the result of different shapes of tool hafting slots, requiring different shaped trapeze-rectangles. Alternately, or in addition, it could be that the overall form of trapeze-rectangles easily permeates regional social boundaries, but that different communities have slightly different ways manufacturing the final form based on local traditions and learning.

The use of morphometrics to describe shape moves beyond traditional typological descriptions, accessing details of form not inherent in typological analysis. This suggests there are elements of technological style inherent in the manufacturing process of trapeze-rectangle microliths, changing the shape of these tools without deviating from the trapeze-rectangle template. Thus, regional interaction may have mitigated the exchange of general technological knowledge; with the trapeze-rectangle acting as a ‘diffuse technology’, one which is easily shared or borrowed (Gosselain, 2000). The adaptation of this microlith form by different communities suggests that it was a technologically malleable form that was easily adopted. This idea will be tested through the analysis of microlith function from Wadi Mataha, ‘Uyun al-Hammâm and Kharaneh IV. How do these differences in technological production and morphology relate to the function of these artifacts? Are the differences witnessed in trapeze-rectangles the result of different communities adopting and using this technology for different tasks? The contribution of functional information into the discussion of the Geometric Kebaran will illuminate how everyday actions were intertwined with material culture variability. The following three chapters tackle the issue of microlith function through experimentation, use-wear analysis, and finally the development of new quantitative use-wear methods.

Chapter 6
Use-wear Experiments

6 Introduction

Experimental programs are a necessity for use-wear analysis; building a reference collection of different motions and tasks allows the researcher to interpret traces of past actions though the analogue of known functions. Observational standards are required to make inferences about function from patterns of wear. These standards are derived from the comparison between archaeological patterns and patterns developed through experimentation on stone tools (Bamforth, 2010). Large experimental programs for lithic functional studies have been ongoing for decades, allowing researchers to develop reference collections for future work or targeted towards specific research questions (e.g., Keeley, 1980, Odell, 1977, Rots, 2002, Tringham, et al., 1974, Vaughan, 1985). For this dissertation, a series of experiments were conducted for two primary purposes: the first was to build a reference collection for future use-wear analysis, including an experimental assemblage on which to conduct quantitative data collection. The second was to test the function of geometric microliths as cutting and harvesting tools, moving beyond microliths as projectiles to include other actions in the realm of microlith use. The experiments included working a variety of contact materials such as hide, antler, meat and wood in a controlled laboratory setting at the University of Toronto. In addition to the experiments conducted in the laboratory, two harvesting experiments were conducted in the field, one in Ontario and one in France, to test the effectiveness of microliths as harvesting implements.

6.1 Experimental Design

As mentioned above, two separate sets of experiments were conducted; one within the laboratory at the University of Toronto and one in the field to test harvesting performance. The former was designed to control variables such as time, motion, and angle so visible characteristics of polish could be observed. The latter was designed to emulate realistic harvesting conditions, mimicking the potential actions performed by Epipalaeolithic peoples to collect cereals from wild stands. The tools used in all experiments were from the same replicated assemblage, described below. Details of the laboratory and field experiments are presented separately to highlight the different research questions and results for each experiment.

The experiments were planned as a version of the pretest-posttest control group design (Campbell and Stanley, 1963). This test begins with a randomized sample observed prior to experimentation. After this initial observation, a subset is removed as a control and experiments are performed on the remainder. Post-experimentation, the samples are reanalyzed for changes. Following this design, a random selection of unworked tools was observed under low- and high-powered magnification, providing information about the tool surfaces prior to use. Experimentation followed the initial observation and a small selection of tools was kept pristine to act as a control sample. After experimentation, the tools were observed again to identify any variability between the pre- and post-experiment surfaces.

6.2 Replicated Tools

The lithic tools were knapped on chert collected in the Negev, Israel, by Dodi Ben Ami. This raw material is similar in quality to the chert used at all three archaeological sites and is therefore a good analogue for the archaeological materials. The chert is of high quality, with an opaque to translucent finish ranging from brown to grey in colour. Mr. Ben Ami manufactured a set of microliths from this chert modeled after examples provided from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV (Figure 29). The tools were knapped using indirect percussion with an antler punch and a hardwood billet. They were then snapped and retouched with a bone spatula, pressing the spatula firmly down along the edge repeatedly to create straight backing. Subsequent retouch with the spatula was conducted to make the backing more invasive. The replicated tools were all trapeze-rectangle geometric microliths, with a mean length of 24.8 mm (std. dev. =2.6, min =19.8 mm, max =30.2 mm), mean width of 9.3 mm (std. dev. =0.8, min =7.8 mm, max =11.2 mm), and a mean thickness of 2.9 mm (std. dev. =0.4, min =2.0 mm, max =3.9 mm). This size is within the range of variability for Geometric Kebaran microliths from the analyzed archaeological assemblages, although falls on the larger end of the spectrum.

Figure 29: Range of replicated microliths used for experiments

The hafts used in the analysis were carved by Dr. Dan Rahimi, Royal Ontario Museum. Three hafts were constructed, modeled on archaeological examples recovered from Natufian archaeological deposits in Israel and Jordan (Figure 30). Unfortunately, no hafts have been recovered from Middle Epipalaeolithic deposits; therefore it was necessary to use Natufian examples for the replicated hafts. The sickle handles were replicated to scale and included all design elements present on the original artifacts.

Figure 30: Experimental hafts. Upper image is the Kebara style haft, lower image is the Wadi Hammeh 27 style haft. Both show hafted microliths, with the lower image missing three microliths closest to the handle.

The first two hafts were modeled after a bone artifact recovered from the Natufian deposits at Kebara Cave, Israel (Noy, 1991).This haft has been interpreted as a sickle, with the lithics inset lengthwise along the handle. In addition, it has a zoomorphic head at the end of the handle representing an ungulate. The piece has a slightly arched profile, curved forwards towards the front of the sickle. Dr. Rahimi carved two examples based on the Kebara sickle and these became the primary hafts used in the harvesting experiments.

The third experimental haft was modeled from a wooden handle recovered from the site of Wadi Hammeh 27, Jordan (Edwards, 2007). This implement is also interpreted as a sickle but unlike the Kebara example, this piece has two parallel grooves for hafting microliths (Figure 31). This haft design also has a curved profile but the curve is in the opposite direction from the Kebara sickle, curving backwards towards the body. This makes the implement difficult to use for cutting grains, as will be described in the harvesting section.

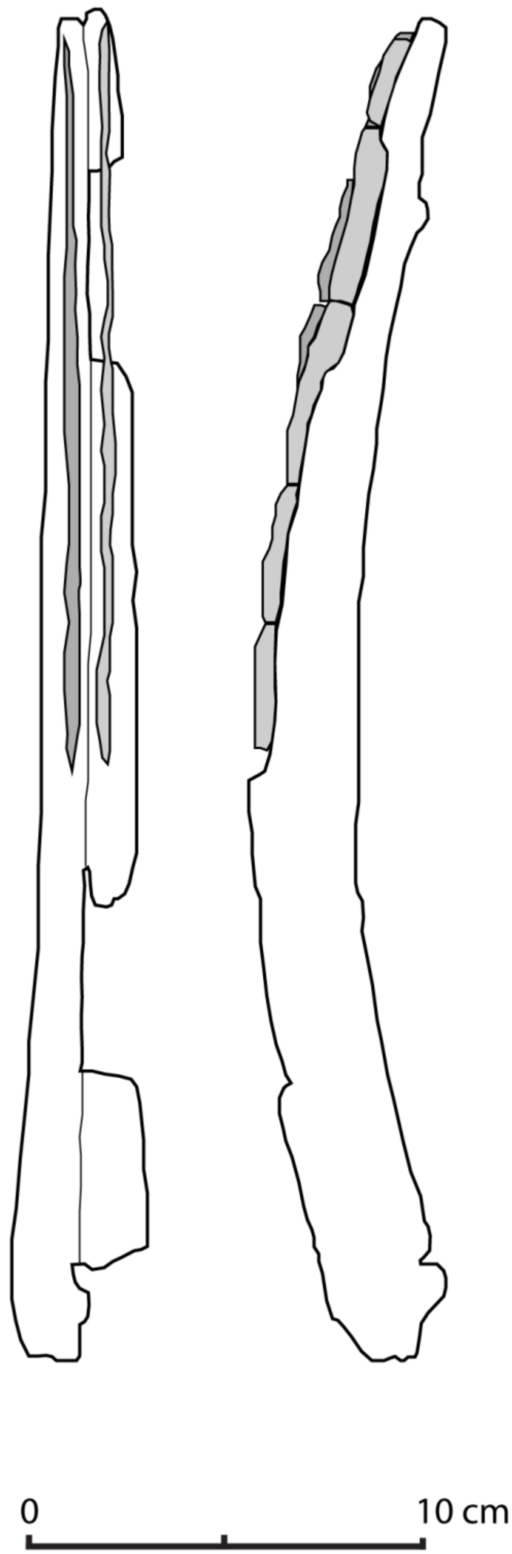


Figure 31: Schematic of Wadi Hammeh 27 sickle (adapted from Edwards 2007)

6.3 Laboratory Experiments

A series of different contact materials were chosen for the laboratory-based experiments. The contact materials chosen were meat, dry hide, hardwood, and antler, representing different possible materials used in prehistory. Also, they range in hardness, thereby producing a large range of different polishes for the reference collection. All of the laboratory-based experiments were performed in a controlled setting by the author in the Department of Anthropology, the University of Toronto.

The majority of the experimental microliths were hand-held, using a piece of dry hide to hold the backed area. However, for the meat cutting experiments the Kebara style 'sickle' handle proved to be a very effective cutting tool, so the microliths were hafted and used in the handle (Figure 32). Using the hafted tools was tried for the other contact materials, but the harder materials pulled the microliths from the handle. This was abandoned in favour of holding the microliths while working the harder materials.

Rather than timing tool use, strokes were counted so that user fatigue did not affect the development of wear on the lithic. Thus, the duration of use was consistent with each tool. For the laboratory experiments, each tool was used for 1000 strokes, allowing the development of polish visible under microscopic view. Details of each experiment are presented in Table 28, while the details of the stroke count are presented in Table 29. In Table 2, pieces that were handheld are listed in 'position #1'.

Figure 32: Meat cutting experiment in the laboratory (University of Toronto)

Table 28: Details of use-wear experiments

Experiment #	Date	Participants	Location	Haft Style	Contact Material	Angle of Tool	Direction
EX-1	20/07/2011	David	Bilton Farm, Omemee ON	single sickle (Kebara)	winter wheat	45-90	one-way
EX-2	20/07/2011	Danielle	Bilton Farm, Omemee ON	single sickle (Kebara)	winter wheat	45-90	one-way
EX-3	20/07/2011	David	Bilton Farm, Omemee ON	double sickle (WH 27)	winter wheat	45-90	one-way
EX-4	17/08/2011	Danielle	University of Toronto Lab	single sickle (Kebara)	meat	45-90	one-way
EX-5	17/08/2011	Danielle	University of Toronto Lab	single sickle (Kebara)	meat	45-90	one-way
EX-6	17/08/2011	Danielle	University of Toronto Lab	hand held	hardwood	90	one-way
EX-7	17/08/2011	Danielle	University of Toronto Lab	hand held	hide	90	one-way
EX-8	17/08/2011	Danielle	University of Toronto Lab	hand held	hide	90	one-way
EX-9	17/08/2011	Danielle	University of Toronto Lab	hand held	antler	45	scraping
EX-10	17/08/2011	Danielle	University of Toronto Lab	hand held	hide	90	one-way
EX-11	17/08/2011	Danielle	University of Toronto Lab	hand held	hide	90	one-way
EX-12	17/08/2011	Danielle	University of Toronto Lab	hand held	antler	45-90	scraping
EX-13	17/08/2011	Danielle	University of Toronto Lab	hand held	antler	45-90	scraping
EX-14	24/08/2011	Danielle	St. Vallier de Thiey, France	single sickle (Kebara)	einkorn wheat	45-90	one-way
EX-15	24/08/2011	Hatem	St. Vallier de Thiey, France	single sickle (Kebara)	einkorn wheat	45-90	one-way

Table 29: Number of strokes per microlith. The '1# Strokes' refers to the position in the haft, with #1 being closest to the handle

Experiment #	1 # Strokes	2 # Strokes	3 # Strokes	4 # Strokes	5 # Strokes	6 # Strokes
EX-1	(lost)	50	(lost)	(lost)	(lost)	(lost)
EX-2	3500	3500	800	3500	3500	3500
EX-3	125	1205	1640	3000	3000	3000
EX-4	500	500	500	1000	1000	1000
EX-5	250	250	250	250	250	250
EX-6	500	500	1000	500	1000	1000
EX-7	500					
EX-8	1000					
EX-9	1000					
EX-10	1000					
EX-11	1000					
EX-12	1000					
EX-13	1000					
EX-14	12,150	12,150	12,150	12,150	12,150	12,150
EX-15	19,234	19,234	19,234	19,234	19,234	19,234

As mentioned previously, I initially attempted to work all contact materials with hafted microliths. However, this quickly proved impossible for the harder contact materials; the microliths caught in the hard surfaces and were pulled from the haft. As a result, microliths were used handheld for working antler, wood, and hide (hide was worked last and it was decided not to haft the microliths, although the soft nature of hide would have been workable with the hafted microliths). Although several of the microliths were used as handheld tools, these tools would not have been used without a haft during the Epipalaeolithic. The small size of the tools makes them challenging to hold for extended periods of time and a user with larger hands would find the task almost impossible.

The only laboratory experiment used with hafted microliths was the meat-cutting experiment. In this experiment, small chunks of meat were severed from the main shoulder. The hafted microliths functioned very well to slice through the meat with minimal physical contact. Using this technique, the meat could be cleanly cut with ease. This suggests that a potential function of the microliths could be longitudinal motions through soft material, such as meat.

6.4 Harvesting Experiments

Harvesting wheat comprised the second stage of the experiments. The goal of these experiments was to test the usability of microliths and Epipalaeolithic hafts for harvesting cereals. Two separate harvesting experiments were conducted, one located in southern Ontario and the other in southern France. The Ontario experiments functioned as a pilot study for the later harvesting experiments in France, where einkorn wheat was harvested as part of a larger experiment. Both experiments are described below, highlighting the experiences of the harvesters using the hafted microliths and the replicated sickles.

6.4.1 Harvesting in Ontario

The initial harvesting experiment took place on a farm owned by the Bilton family outside of Omemee, Ontario on July 20th, 2011. This farm grew winter wheat (*Triticum hybernum*) for sale in local agricultural markets and the farmer had cornered off an area for the experimental harvesting prior to mechanically harvesting the wheat. There were two participants in the study, myself and David Bilton, the son of the farm owner and a fellow archaeologist. The wheat was dry, with a small amount of moisture remaining in the stems. The area harvested was 17.88 m^2

(456 cm x 392 cm) with an average of 690 stalks of wheat per square meter. The mean stem diameter was 3.2 mm, average plant height was 111 cm from the ground (including the ear), and the mean length of the ear was 74.0 mm. The experiment numbers for the sickles used during the harvesting are experiments 1, 2, and 3 (EX-1, EX-2, EX-3). Details about stroke counts, tool angle, and direction of motion can be found in Table 28-2.

We started harvesting by using the two Kebara-style sickles (EX-1, EX-2). Microliths were hafted into the sickle handles using clear silicone. Within the first few minutes the sickle that David was using (EX-1) lost four microliths, possibly due to poor hafting, enthusiastic harvesting, or a combination of both. This sickle was only used for 50 strokes before the microliths were lost. Next, David started using the double sickle (modeled after Wadi Hammeh 27) (EX-3) and used that for the rest of the day. Over the course of harvesting, David lost six microliths from the double sickle, beginning with the two closest to the holding position and then moving up successively. I lost the center microlith about half-way through the day but continued to harvest with the Kebara-style sickle (EX-2) for the remainder of the day, favoring the two microliths closest to the handle to prevent further loss.

Our primary observation at the end of the pilot harvesting study was that the sickles worked extremely well, despite losing some of the microliths. Small spaces between the microliths caught the stalks, which contributed to the microliths being pulled out of the hafts. This problem was remedied for the later experiments conducted in France. Both of the haft designs were very comfortable to hold and did not cause hand fatigue after a full day of harvesting. The zoomorphic head at the base of the Kebara sickle handle kept my hand from slipping off the end of the handle and comfortably fit my grip. Upon reflection, it seems that this zoomorphic head was purposeful as both a decorative and functional design element. Although the Wadi Hammeh 27 sickle does not have a similar animal design, it does have a small ridge at the handle. This ridge also kept David's hand from slipping and was comfortable to hold, functioning the same as the Kebara sickle's handle.

Overall, the Kebara sickle functioned more effectively as a harvesting implement. The sickle's curve towards the front helped to gather multiple stalks towards the microlith's cutting edges. In contact, the Wadi Hammeh 27 sickle curved backwards, making it more challenging to cut multiple stalks. As well, the parallel cutting edges were redundant for harvesting cereals. Based on our experiences using this sickle I would suggest that, although it functions as a harvesting tool, it is not optimally designed as one. Investigations into the use-wear on the archaeological blades inset into the Wadi Hammeh 27 sickle would shed light on the artifact's function either as a harvesting implement or a cutting tool for other materials.

6.4.2 Harvesting in France

In August 2011, I was fortunate to have the opportunity to participate in harvesting experiments in southern France, organized and directed by Dr. Patricia Anderson (Centre National de la Recherche Scientifique). The experiments took place over five days, from August 22^{nd} to August 26^{th}, with three days dedicated to cutting the field, one to threshing the wheat, and one to winnowing the grain. The harvesting field was located outside the town of St. Vallier de Thiey and was planted with einkorn wheat (*Triticum monococcum)* (Figure 33). This is one of the earliest cultivated and domesticated forms of wheat from the Near East (Heun, et al., 1997).

Researchers from Canada, France, and Tunisia participated in the harvesting experiments. Although each researcher had his or her own directed research question, the common goal was to reap, thresh, and winnow the harvest. Our interests ranged from understanding the functional characteristics of Epipalaeolithic and Neolithic tools to observing traditional threshing practices. As mentioned previously, my research question focused on understanding whether microliths could efficiently be used as harvesting implements. In addition, I conducted the experiments to generate a reference collection that could be used as a comparative assemblage for use-wear studies, both qualitative and quantitative. Because my research question focused on the harvesting aspects of the overall experiment, I will only discuss the details of this stage of the work.

Figure 33: Field planted with *Triticum monococcum* (St. Vallier de Thiey, France 2011).

6.4.2.1 Experimental Tools

The two Kebara-style sickles were used in the harvesting experiments (EX-14, EX-15). Initially, the microliths were set into the handles with bitumen. The bitumen was heated in a small pot over a burner, and warmed until the tar became very soft. The microliths were then dipped into the tar and inset into the haft. However, once harvesting commenced, one tool lost three microliths (EX-14) when the bitumen softened due to heat generated by friction between the tool and the plant stems. As a result, the microliths in both tools were rehafted using resin that retained its hard consistency despite hours of use. The resin was collected in local French coniferous forests and prepared by Dr. Bernard Gassin. To prepare the resin as a hafting material, sap was collected by hand from pine trees. The resin was mixed with wax over a hot stove, keeping it liquid. Once the sap and wax melted together, the mixture was poured over the haft with the microliths already inset. The resin hardens within 10 minutes, becoming solid and rigid. Over all, the bitumen did not function as successfully as the resin for hafting the microliths, particularly when used for longer periods of time. There was more flexibility in the bitumen, increasing as the bitumen heated in the sun and with the friction of contact with the cereal. This heating caused the microliths to fall out after continued use. In contrast, the resin was much harder and did not lose strength or soften with continued use.

The only negative aspect of resin hafting was removing the microliths at the end of the experiment. The pieces hafted in bitumen were easy to remove; each microlith was rocked gently back and forth to loosen the hafting material and was then pulled from the haft. The pieces hafted in resin would not wiggle as there was no flexibility in the material. Therefore the resin had to be carefully chipped away from the microlith, removing the surrounding resin until the resin was thin enough to break under lateral pressure, allowing the microliths to be removed. This was done very carefully to protect the surface of the microlith for use-wear traces.

6.4.2.2 Field Characteristics

The field was planted with einkorn wheat (*Triticum monococcum*) in a random pattern mimicking the growth pattern of wild cereals. The overall size of the field was approximately 630 m^2 but it was parceled into smaller sections for each harvester. Einkorn wheat is an early Near Eastern domesticated crop and has a similar breakage pattern to its wild progenitor. The field was planted very densely with wheat, with 792 stems per square meter. This is on the high end of wild cereal strands that usually have 600-800 stalks per square meter (Anderson personal communication). There was an average of 19 spikelets per seed head. The overall grain yield was 15 kg in total at the end of the harvest after threshing and winnowing.

6.4.2.3 Details of the Experiment

The two Kebara-style sickles were used in the experiments; one was used by me (EX-14) and the other by Hatem El Gtari (EX-15), an archaeologist from Tunisia. Stroke counts were approximated by recording the average number of strokes cut per minute, averaged over 10 times at the beginning of each day. The average number of strokes for my harvesting was 30 strokes per minute, while the average for Hatem, who was a more vigorous harvester, was 59 strokes per minute.

Experiment 14 was conducted using a Kebara-style haft with seven hafted microliths. Microliths 1-3 (with 1 being closest to the handle) became dislodged as a result of the bitumen hafting and were re-hafted with resin. To cut the wheat stalks, a handful of approximately 7-10 stems were collected in my left hand. The stems were then twisted half a turn, bundling the stems together into a group. Two to three fast strokes with the sickle were required to cut through the bundle, pulling the sickle towards myself in a smooth motion. Cutting was done close to the ground, approximately 20-30 cm from the soil surface. In total, the sickle was used for approximately 12,150 strokes (405 minutes of cutting) over three days. The total field size harvested during this time was 78 m^2. This use duration exceeds the 10,000 strokes needed to observe macroscopic luster as identified by Unger-Hamilton (1991), but is less than Yamada's 11 hours of harvesting (2000).

Experiment 15 was also conducted using a Kebara-style sickle, but this experiment was performed by Hatem. The microliths in this sickle were originally hafted with bitumen but were reset using resin at the same time as the other sickle was rehafted. In total, this sickle was used for approximately 19,234 strokes, equaling 326 minutes of harvesting time. The total field size harvested with this sickle was 84.25 m^2.

The results of the experiment indicated that the hafted microliths were very efficient harvesting tools. The regular size and shape of the flint implements allowed them to function without breaking, catching stems, or falling out of the handle while harvesting. The Kebara-style hafts were ergonomic, fitting comfortably into the hand without causing fatigue. The gazelle head functioned to keep one's hand from slipping off the end of the tool while vigorously cutting wheat, suggesting that the zoomorphic design had a functional purpose in addition its decorative characteristics. After three days and more than 12,000 strokes, the tools still functioned at cutting grain stems (although the harvester was feeling fatigued).

6.5 Summary

The experimental program was designed for two purposes, 1) to test the functionality of geometric microliths and Epipalaeolithic replicated hafts as harvesting implements and 2) to build a reference collection for use-wear analysis. In addition, a selection of these experimental tools was used to test new methods of use-wear quantification, described in Chapter 7. Wear was visible on many of the experimental tools and polish was most prominent on the wheat-harvesting tools and the harder contact materials, such as antler. These are typical results for polish; both sickle polish and antler polish are described as 'bright', or in the case of cereals, 'extremely bright' (Vaughan, 1985:32,35), and tend to be easy to see. Future experiments will build upon this reference collection to include additional contact materials, motions, and durations of use.

Overall, the microliths function very well as harvesting tools, performing over three days of intensive harvesting without losing cutting ability. Likewise, they also worked as cutting tools for softer contact materials, such as meat, although harvesting felt more natural with the hafted microliths. The straight, thin cutting edge on the microlith performed longitudinal cutting motions effectively and the thin nature of the microliths allowed them to slice quickly through various materials. Through experimentation it became clear that hafting material was an integral element that greatly affected the effectiveness of the tool. Finding a balance between durability and ease of retooling would have been an important consideration in choosing appropriate mastic during the Epipalaeolithic. Both hafts were very comfortable to use, although the Kebara style haft worked better as a harvesting implement than did the Wadi Hammeh 27 style haft. This suggests that the Wadi Hammeh 27 tool may have had an alternative function, or that the design integrated elements beyond functional requirements. The laboratory and harvesting experiments resulted in a better understanding of how microliths functioned as cutting tools and the design features of Epipalaeolithic hafts.

Chapter 7
Use-Wear Analysis of the Microlith Assemblages

7 Introduction

Use-wear analysis reconstructs past actions of tool use through the observation of striations, polish, and microfractures on tool surfaces. The details of action, the duration of use, and the type of materials worked will all impact the development of wear features on the lithic surface. By carefully recording traces and imprints left on the tool we can interpret past behaviours through archaeological materials.

The analytical technique of use-wear analysis has traditionally relied on qualitative observations to identify wear patterns microscopically, either at high or low magnifications. Low-powered microscopy highlights microfractures and damage on a tool's edge (Odell, 1977, Odell and Odell-Vereecken, 1980, Tringham, et al., 1974). This type of analysis is usually conducted with a stereomicroscope at magnifications less than 100x and can be done relatively quickly, allowing for the analysis of large sample sizes. Stereomicroscopy has a good depth of field and allows large image areas to be captured, but it does not image the specimen's surface at high enough resolution to allow the observation of subtle polishes and striations. Overall, the stereomicroscope excels at assessing the pattern of microfractures produced on a flake's edge (Tringham, et al., 1974) and its ease of use makes it excellent for initial analysis of large assemblages.

In contrast, high-powered microscopy at magnifications between 100 and 1 000x allows the observation of polishes and striations (Keeley, 1980, Vaughan, 1985). This analysis is traditionally performed with an incident light microscope. In comparison to stereomicroscopy, incident light microscopy (with bright field illumination) directs light downwards towards the specimen, striking the surface at 90 degrees to the focal plane (Keeley, 1980). This lighting coupled with high numerical apertures allows observation of surface features at high magnifications. Limitations of incident light microscopy are poor depth of field and short working distances. High-powered microscopy is also very time-consuming, meaning only small sample sizes can be analyzed for most studies. The strength of high-powered incident-light microscopy is that it allows identification of microstriations and polish that are not easily detected at lower magnifications.

Due to the strengths and weaknesses of both techniques, the combination of low-powered and high-powered microscopy is integral to interpreting microwear patterns on a tool's surface (e.g., Grace, 1989, Grace, 1996, van Gijn, 2010). Ultimately, high-powered magnification is better at evaluating the types of materials worked through the identification of polish types and the direction of use through striations, while low-powered approaches excel at assessing the direction of use through the analysis of fractures and allows larger samples to be analyzed. Thus, the combination of these approaches provides a more robust analysis of wear features than the use of any single technique.

Although there were a few early ventures into use-wear analysis (e.g., Curwen, 1930, 1935, Evans, 1872, Spurrell, 1892), microscopic approaches to use-wear was first widely applied to lithic assemblages by Russian archaeologist S.A. Semenov (1964). Semenov's early work highlighted the applications of microscopic functional analysis for a variety of archaeological materials and, once translated into English, brought use-wear analysis to a Western audience. Semenov's work combined tool morphology, interpretations of hafting, manufacture, and use-wear (including low- and high-powered magnifications) to inform his interpretation of tool function.

Despite this early integrative approach, during the subsequent decade the study of lithic tribology became dichotomized into two camps, those who advocated low-powered use-wear analysis (<100x magnification) (Odell, 1977, Odell, 1975, Tringham, et al., 1974) and those who advocated high-powered magnifications (>100x magnification) (Keeley, 1974, 1980, Vaughan, 1985) (a debate humorously described in Odell 1990). It should be noted that even the proponents of high-powered analysis used stereomicroscopes at low magnifications to assess edge fractures and locate potential worn surfaces (e.g., Keeley, 1980). Critics of the high-powered approach point out that descriptive terminology for polish such as "melted snow" (see Keeley, 1980:56) and "greasy luster" (see Keeley, 1980:53) are highly subjective and difficult to replicate (Grace, 1996). Other arguments against high-powered analysis cite the extreme time investment in analysis, suggesting that only small samples sizes can be analyzed under high magnifications (Odell and Odell-Vereecken, 1980). In contrast, critics of the low-powered method suggested that post-depositional fractures are difficult to distinguish from use fractures and that multiple variables need to be considered when interpreting fractures (Keeley and Newcomer, 1977).

Over time, this dichotomous relationship between low- and high-powered analyses has disintegrated. Grace states that during the 1989 Uppsala conference “a consensus emerged so that different approaches (high and low power) were not seen as competing techniques, but as alternative strategies dependent on the specific archaeological problem” (1993:385). Recent studies are integrating these two use-wear techniques, providing a more holistic approach to use-wear studies (e.g., Dinnis, et al., 2009, Lemorini, et al., 2006, Lombard, 2005, Richter, 2007, Rots, et al., 2011, Rots and Williamson, 2004). Considering the strengths and weaknesses of both methods, the combination of low-powered and high-powered microscopy is integral to interpreting patterns of polishes, microstrations, and microfractures produced on a tool during use. Therefore, both techniques are used for lithic use-wear analysis in this research.

7.1 Microlith Function

Several lithic use-wear researchers have examined Levantine Epipalaeolithic assemblages. However, most of this work has focused on Natufian sites, attempting to identify tool functions prior to the origins of agriculture (e.g., Anderson, 1991, Büller, 1983, Richter, 2007, Unger-Hamilton, 1991). The cumulative work on Natufian geometric microliths suggests that lunates had multiple functions, including as projectiles, cutting tools, and harvesting elements hafted into composite sickles.

Although most of the use-wear studies have been conducted on Natufian assemblages, there have been a few studies on Geometric Kebaran assemblages. The presence of use-wear fractures has been identified at the Geometric Kebaran site ‘Ain Miri, located in northern Israel. During technological analysis on the lithic assemblage the authors noted several impact fractures on the microliths, reporting 76 fractures from an assemblage of 1734 microliths (Shimelmitz, et al., 2004). As well, tools from the Geometric Kebaran sites of Hefziba and Neve David, both on the Israeli Coastal Plain, were analyzed for projectile fractures (Yaroshevich, 2006). At both sites diagnostic impact fractures were found on the ends and unretouched edges of the geometric microliths, suggesting that trapeze-rectangles could have been used for barbs and projectile tips (Yaroshevich, 2006). Further details about the diagnostic impact fractures from Neve David indicate that most of the fractures are either parallel fractures initiating on the tip (removing the edge) or fractures along the unretouched edge (Yaroshevich, et al., 2010). Where present, striations are oriented parallel to the longitudinal axis. The authors conclude that the trapeze-rectangles at Neve David were hafted as lateral elements or as projectile barbs (Yaroshevich, et al., 2010). It is important to note that the above studies only assessed the assemblages for traces of projectile impact and alternative functions for geometric microliths were not explored. Thus, further exploration is needed into other potential functions for microliths during the Geometric Kebaran.

The multicomponent site of Hayonim Cave and Hayonim Terrace is perhaps the best-studied Epipalaeolithic site for use-wear analysis (Tomenchuk, 1985, Valla, et al., 1991). Hayonim Cave is a large Epipalaeolithic site located in Western Galilee (Bar-Yosef, 1991). This site has both Kebaran and Natufian components and use-wear analysis has been conducted on samples from both occupations. The Natufian component extends onto a terrace in front of the cave where excavations have uncovered several structures and a wealth of material culture (Henry and Leroi-Gourhan, 1976). Several use-wear studies have been conducted on the Natufian lithics from Hayonim Cave and Hayonim Terrace, while only one study has been conducted on the Kebaran assemblage from the cave deposits.

Using a quantitative use-wear method based on fracture mechanics, Tomenchuk (1983, 1985) assessed the microlith assemblages from the Kebaran and Natufian components at Hayonim Cave. He analyzed 78 Kebaran samples from Hayonim Cave, level Ca. Through his analysis he suggested that obliquely-truncated backed bladelets and proto-triangles were used as tips in projectile armatures. Proto-triangles may have been hafted in pairs, creating a point, while the obliquely-truncated backed bladelets were hafted singly. There is also evidence that backed bladelets were used in a longitudinal motion as dagger or spear insets. The analysis indicated that two bladelets occupied the same position in the haft; therefore, Tomenchuk suggests that it was a double-edged tool. Although Tomenchuk suggests that these bladelets were hafted in a bilateral configuration (with bladelets along each side of a dagger) they could have also been hafted in parallel rows like the Natufian ‘sickle’ discovered at Wadi Hammeh 27 (see Edwards, 2007).

Tomenchuk’s analysis of the Natufian levels from Hayonim Cave looked at 52 tools from locus 4. His analysis suggested that, of the seven lunates studied, five lunates functioned as projectile barbs while two functioned as tips. Although Tomenchuk found no evidence of microliths being used as harvesting tools, there was evidence of cereal harvesting in the non-microlithic assemblage (1983, 1985).

Preliminary use-wear analysis of the Natufian deposits of Hayonim Terrace suggested that the geometric microliths were primarily projectile elements (Valla, et al., 1991). In addition to their use as hunting implements, three backed blades and two segments were used as cutting tools; two for cutting meat and three for cutting plant material. The three with plant polish were further explored by Anderson (1991) who suggested that the traces correspond to harvesting of green to semi-green wild cereals. One tool was used for a relatively short time, while the others were used for at least four hours. The cereal was probably harvested low to the ground, as indicated by the presence of striations. Although there is evidence of multiple uses of microliths at Hayonim Terrace, the authors still suggest that microliths primarily functioned as projectile inserts (Valla, et al., 1991).

During subsequent analysis, the entire tool assemblage from Hayonim Terrace was sorted to find pieces with macroscopic evidence of polish and rounding, totaling 344 artifacts (Anderson and Valla, 1996). Of these, 48 tools had clear evidence of cereal polish. These sickle elements were manufactured on both formal and unretouched tools, including geometric and non-geometric microliths. In addition, three tools had evidence for reed cutting, nine tools had traces of hide cutting, and nine tools showed evidence of working mineral materials, such as soft stone.

A recent use-wear study revisited the Hayonim Cave assemblage, as well as the Natufian sites of ‘Ain Rahub (Northern Jordan) and Salibiya I (Jordan Valley). The results of this analysis indicates that microliths were used for a variety of purposes at these sites (Richter, 2007). Microscopic traces suggest that at ‘Ain Rahub, microliths were used on soft material (meat, hide, plants) and semi-soft materials (soaked wood, certain types of hides). Similarly, the Salibiya I microliths had evidence for longitudinal motions on soft and medium materials. Microliths from Hayonim Cave also had some evidence for transverse motions and impact fractures. Looking at the differences between the Early and Late Natufian lunates at Hayonim suggests that the use of lunates as transverse points was common in the earlier period, decreasing in frequency as Helwan retouch decreased (Richter, 2007). The results of the study suggest that lunates were used for a variety of tasks and that there was no correlation between microlith form and function at these three sites during the Natufian (Richter, 2007).

Contrary to the results presented by Richter, use-wear analysis on Natufian assemblages from the sites of el-Wad and ‘Ain Mallaha in Israel suggest that lunates and backed bladelets functioned as parts of composite projectiles and not as multipurpose tools (Büller, 1983). The material at el-Wad had both evidence of meat polish and some spots of bone polish, interpreted as resulting from bone contact during impact. However, the presence of impact fractures is not fully discussed and alternative hypothesis for the presence of meat and bone polishes are not presented in Büllers’ argument. Without impact fractures as corroborating evidence, these polishes could be the result of butchering practices. The ‘Ain Mallaha assemblage also had evidence of hafting material, interpreted as resin, not present on the el-Wad collection (Büller, 1983).

Recent analysis of ‘Ain Mallaha identified several lunates with impact damage from the Early and Late Natufian occupations at the site (Marder, et al., 2006). A potential hafting configuration was reconstructed based on the location pattern of the diagnostic impact fractures, suggesting that the lunates were hafted as transverse or slightly canted tips, or as oblique barbs. The similarity in fracture types between the Early and Late Natufian assemblages at the site suggests that there was little change in hafting configurations over time at the site. This is contrary to the decline seen in transverse arrowhead frequency from the Early to the Late Natufian at Hayonim (Richter, 2007).

Although there is excellent evidence to indicate that Natufian microliths functioned in part as insets for harvesting implements, how these harvesting tools were used and the nature of cultivation has been subject to much debate. Unger-Hamilton (1989, 1991) analyzed a series of Early and Late Natufian sites, including Kebara, el-Wad, Hayonim, Nahal Oren, and Jericho to assess the use of lithics as harvesting tools. Because her research question focused on plant processing, other functions were not addressed during the analysis and only pieces with visible gloss were chosen for microscopic study. This created a bias towards well developed polish, excluding traces of meat and hide working. The results of her study suggested that, of the 360 Natufian lithics analyzed, 138 had definitive cereal polish and 182 had probable cereal polish. The majority of the polishes were created through contact with barley or emmer wheat, but other plants were also harvested, including reeds and bulrushes. Unger-Hamilton also suggested that the presence of striations in the cereal polish on the Natufian tools is indicative of soil tilling, indicating that Natufian people were cultivating cereals. This interpretation is highly debated and Anderson (1991) suggests that heavy striations are the result of harvesting close to the ground and not soil tillage.

More recently, Yamada (2000) researched the development of agricultural practices in the Southern Levant from the Late Natufian through the Pottery Neolithic, examining changes in harvesting practices on the basis of use-wear traces. He analyzed assemblages from three Natufian sites: Saflulim in the Negev and Halizon Tachtit and Iraq ed-Dubb in the Mediterranean zone of the Levant. The results of his analysis suggested that the backed bladelets at Saflumin were used for plant harvesting. In addition, one microlith was found to be used for cutting dry hide. At Hilazon Tachtit, a small sample of eighteen pieces was analyzed. Although he indicates that one sickle element was identified, the lithic type is not given. At Iraq ed-Dubb, four pieces were identified to have sickle sheen. Forty-three lunates were also examined from the site, but they were affected by post-depositional polish, obscuring any use-related polished.

Use-wear studies on the Syrian Natufian assemblages from Mureybet and Abu Hureyra show that geometric microliths functioned primarily as projectile insets (Anderson, 1983). At Mureybet, the large lunates and triangles had evidence for fresh hide and meat polish, as well as abrasion traces oriented perpendicularly and obliquely from the top. From these traces, and based on comparisons with Danish assemblages, the large lunates and triangles were interpreted to be hafted as slightly canted transverse arrowheads (Anderson, 1983). In contrast, the smaller lunates and microliths from Mureybet exhibit different traces with light meat or fresh hide polish, faint striations, and linear abrasion traces. These were interpreted to be hafted as barbs and projectile tips. Finally, at Abu Hureyra there was evidence that one large narrow lunate was hafted as a transverse arrowhead.

In addition to the evidence for projectile function, there was also some evidence from Abu Hureyra that microliths functioned as inserts for sickles (Anderson, 1991). A sample of eight tools from the site had visible gloss, including five microliths. This gloss was similar to the polish produced from einkorn harvesting experiments leading the author to suggest that the gloss on the archaeological tools was from wheat harvesting. The results of the analysis suggested that cereals were harvested in a green-semi green state and were cut close to the ground, similar to the plant harvesting tools found at Hayonim.

Outside of the Levant, only a few use-wear studies have been conducted on Epipalaeolithic North African assemblages and the majority of these studies have been done on Egyptian microliths. These studies suggest that microliths were used for multiple activities and these activities do not correlate with typological classes (Close, 2002). An early study of Epipalaeolithic Qadan material from Egypt evaluated five lunates with macroscopic gloss (Juel Jensen, 1991). The authors were seeking to check the validity of the early claims that these were used for cereal harvesting. This was done using high-powered microscopy. Analysis showed that the orientation of the striations suggests that the tools were used in a perpendicular motion rather than a longitudinal one. The authors were unable to ascertain the contact material, but they suggested that contact could have been with dry hide and not cereals.

Another study of the tools from an Epipalaeolithic Qadan site in Southern Egypt showed that both arch-backed bladelets and lunates have traces of use. The analysis showed that function does not correlate with form at the site, as both arch-backed bladelets and lunates were used for scraping hard materials (bone/wood) and cutting soft materials (meat/hide) (Becker and Wendorf, 1993). In contrast, research on Upper and Epipalaeolithic sites in the Sinai resulted in the recovery of only a few projectile fractures on microliths and no other wear traces (Becker, 1999).

The overall pattern of use-wear traces from previously analyzed Epipalaeolithic assemblages suggests that microliths were used as multifunctional tools. This is not to suggest that a single microlith would be used for a variety of tasks, but that microlith type does not indicate the function of the tool. The analysis of the Kebaran component of Hayonim Cave suggests that non-geometric microliths were used as bilateral cutting implements or spear tips. Current research into Geometric Kebaran assemblages indicates that trapeze-rectangles were used as projectiles, hafted as lateral elements or barbs. However, these studies have been biased towards the identification of projectile fractures, and multiple functions have not been explored. Finally, Natufian lunates were used for a wide variety of functions, including as projectiles, cutting implements, and inserts for sickles. The overall pattern suggests that there is no direct correlation between microlith type and function during the Early and Late Epipalaeolithic. The Middle

Epipalaeolithic needs to be further explored for alternative microlith functions to understand the relationship between form and function during the Geometric Kebaran. The study of Geometric Kebaran assemblages presented in this research is the first to explore alternative microlith functions beyond their use as projectile inserts.

7.2 Identifying Motion

The presence, type, and location of fractures are excellent for the identification of tool motion. The microfracture terminology used in this chapter is defined in the Ho Ho committee report (1979), where fracture initiations and terminations were first defined for archaeological tools. Fractures can either be observed with the aid of a hand lens or low-powered magnification. The nature and types of fractures produced on a tool's edge through use is directly related to how the tool was moved in relation to the contact material. Decades of rigorous experimentation has resulted in a large corpus of features that can be used to understand the motion of working.

7.2.1 Longitudinal Motion

Longitudinal motions are actions in which the movement is parallel with the tool's edge. These motions include cutting (unidirectional) and sawing (bidirectional). As defined by Tringham et al. (1974), cutting is a unidirectional motion with the angle of use approximately vertical or slightly oblique, while sawing is a bidirectional motion with the tool held at the 90 degree angle to the contact material. It has also been suggested that cutting is enacted on soft materials, while sawing is done on harder materials (Tringham, et al., 1974), however not all researchers use this definition.

Longitudinal motions produce fractures that alternate between the dorsal and ventral faces (Odell and Odell-Vereecken, 1980). Although fractures will occur on both sides of the edge, working angle may result in more fractures accumulating on one face as pressure is not equally distributed to both sides (Tringham, et al., 1974). Several types of flake removals can be produced through longitudinal motions (Tringham, et al., 1974). Snap fractures can be indicative of longitudinal motion as they often occur when cutting or sawing with an unretouched edge due to the bending stress on the tool's edge (Grace, 1989). Experiments have shown that sawing harder materials such as wood produce snap fractures on thinner edges (Keeley, 1980) and can result in a highly fractured margin (Vaughan, 1985:31). In contrast, the presence of feather terminating bending initiations along the edge can suggest cutting of a softer material (Lawrence, 1979).

7.2.2 Transverse Motion

Transverse motions are actions that run perpendicular to the tool's edge such as scraping, shaving, or whittling. These tend to have lower angles of contact between the contact material and the tool than longitudinal motions. Transverse motions are identifiable by the presence of unifacial conchoidal flake fractures that often cover a wide area along the tool's edge (Odell and Odell-Vereecken, 1980). Other authors have suggested that the fractures are continuous and localized when contact is concentrated along a small part of the edge (Tringham, et al., 1974). If striations are present they are oriented perpendicularly to the edge of the tool (Odell and Odell-Vereecken, 1980).

7.2.3 Drilling/Boring Motion

Drilling and boring are a combination of downwards pressure and rotational motions to create a hole or depression in the contact material. The wear is localized on a protrusion of the tool, rather than along an edge. Fractures are located on all sides of the used area, usually in a circular arrangement indicating the direction of motion. The downward pressure often results in crushing and fractures initiating from the tool's tip (Odell and Odell-Vereecken, 1980).

7.2.4 Impact

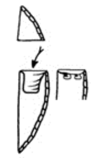
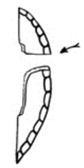
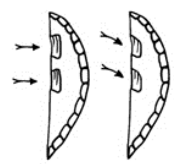
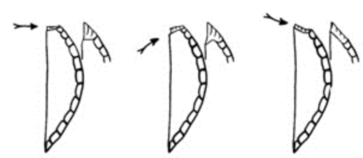
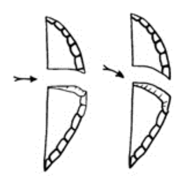
Although impact fractures are often associated with weapons and hunting implements, there are several different motions that can cause diagnostic impact fractures. In addition to projectile and hunting impact, these fractures can also be caused by any percussive motion such as adzing, chopping, or wedging (Grace, 1989, Keeley, 1980). Several studies have conducted large experimental programs identifying and defining diagnostic impact fractures on microlithic tools (e.g. Chesnaux, 2009, Crombé, et al., 2001, Fischer, et al., 1984, Lombard and Pargeter, 2008, Philibert, 2002, Yaroshevich, et al., 2010). Initially identified by Fischer (1984), diagnostic impact fractures include step terminating bending fractures and spin-off fractures. The former fracture type lacks a negative bulb of percussion and terminates in the step facture (for details about fracture definitions, see the Ho-Ho committee report 1979). Spin-off fractures are secondary cone removals that initiate from bending fractures. Based on experimentation, Fischer

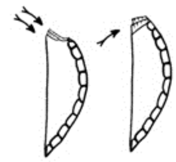
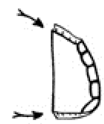
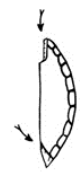
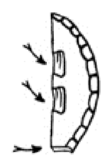
(1984) suggested that spin-offs should be at least 1mm long if present on only one side of the bending fracture. Spin-offs on both sides of the fracture are diagnostic of impact. At times, spin-off fractures can resemble burin blows, removing the edge of a piece. For the purposes of this analysis these are referred to as impact burinations.

The location of diagnostic impact fractures can lead to an understanding of how the microlith was hafted. Experimentation has shown that diagnostic fractures initiating on the un-hafted edge of microliths occur on transversally hafted, obliquely hafted tips, barbs, and laterally hafted microliths (Crombé, et al., 2001, Fischer, et al., 1984, Lombard and Pargeter, 2008, Nuzhnyj, 1989, 1990, Yaroshevich, et al., 2010). In addition, transverse fractures tend to be perpendicular to the long axis of the microlith, while laterally hafted pieces often have obliquely angled fractures. In contrast, microliths hafted as tips have diagnostic impact fractures or burin-like breaks oriented parallel to the longitudinal axis (Barton and Bergman, 1982, Bergman and Newcomer, 1983, Crombé, et al., 2001, Nuzhnyj, 1990). It is important to note that barbs and laterally hafted pieces have lower frequencies of impact damage (5%) than tips, which have higher frequencies (32%) (Crombé, et al., 2001).

Recent research has been conducted on a series of experimentally produced Epipalaeolithic microliths, including trapeze-rectangles, to reconstruct potential hafting configurations (Yaroshevich, et al., 2010). This work resulted in a detailed classification scheme for fracture locations identified on Epipalaeolithic microliths used as projectiles. In this classification scheme fractures are broken into two general groups, a) fractures oriented parallel to the longitudinal axis of the microlith and b) fractures oriented obliquely or perpendicularly to the longitudinal axis of the microlith. These groups each have three subgroups, 1) fractures initiating on the unretouched edge, 2) fractures initiating on the retouched edge that remove only the tip, and 3) fractures initiating on the retouched edge that split the microlith across the body. These are combined into a series of fracture locations and directions that represent the types identified on the experimental set (Table 30). It should be noted that the fractures are diagnostic impact fractures as defined by Fischer et al. (1984); they are step-terminating bending fractures, spin-off fractures, or impact burinations.

Table 30: Classification of impact fracture locations from experimental microlith projectiles (adapted from Yaroshevich, et al., 2010)

Parallel Fractures	**Description**	**Fracture Image**
a1	Fractures oriented parallel to the longitudinal axis initiating on the dorsal surface.	
a2	Parallel fractures initiating on the retouched edge and removing part of the top.	
a3	Parallel fractures initiating on retouched edges across the microlith body.	
Perpendicular Fractures		
b1	Fractures initiating from the unretouched edge. Oriented perpendicular or obliquely to the longitudinal axis.	
b2	Fractures removing the tip. Oriented perpendicular or obliquely to the longitudinal axis.	
b3	Fractures that split the body that initiate from the unretouched edge.	
Multiple Fractures		
a1m	Fractures oriented parallel to the longitudinal axis appearing on both the dorsal and ventral surfaces at one end.	
a2m	Fractures oriented parallel to the longitudinal axis appearing on opposite ends.	

b1m	Multiple fractures on the same end removing the tip. Oriented perpendicular or obliquely to the longitudinal axis.	
b2m	Multiple fractures on both ends removing the tips. Oriented perpendicular or obliquely to the longitudinal axis.	
cm	Fractures removing the tips, one parallel and one perpendicular.	
d1m	Fractures initiating from the unretouched edge. Oriented perpendicular or obliquely to the longitudinal axis. Also fracture oriented parallel to the longitudinal axis initiating on the dorsal surface.	
d2m	Fractures initiating from the unretouched edge and fracture removing the tip. Oriented perpendicular or obliquely to the longitudinal axis.	

Although there is a general trend, as noted above, for parallel fractures to occur on tips and perpendicular fractures to occur on transversally hafted, obliquely hafted tips, barbs, and laterally hafted microliths, equifinality of fracture types must be considered. Yaroshevich (2012) notes that single diagnostic impact fractures have been known to occur in multiple hafting configurations. Therefore, multiple parallel impact fractures are a more reliable indicator of projectile tips, while multiple perpendicular fractures are reliable indicators of other hafting positions.

In addition to macroscopic evidence, there are also microscopic traces diagnostic of impact. These include linear polish and striations oriented parallel or roughly parallel to the longitudinal axis of the impact (Fischer, et al., 1984). Linear polishes appear as a long, shiny line of polish oriented along the direction of impact. Unlike polishes and striations created through longitudinal or transverse motions, these traces can be located away from edge on the ventral surface. Although projectiles come into contact with meat, it is not common for them to develop continuous meat/hide polish along the edge. This is likely because they are not in the same continuous contact with the animals as cutting tools (Fischer, et al., 1984).

7.3 Identifying Contact Material

Although it has been argued that contact material can be identified through the use of low-powered magnification, more success has been found in the use of high-powered magnifications for the identification of contact materials based on polish characteristics. Several general polish descriptions are used in the descriptions of specific contact material polish. The first is generic weak polish, which is distinguishable from the surrounding surface based on a slightly brighter finish (Vaughan, 1985). This weak polish often forms at the beginning of contact, prior to the development of identifiable polishes, but it is also very similar to polishes produced from meat contact. Smooth-pitted polish is characterized by small polish components formed on higher points of microtopography of generic weak polish (Vaughan, 1985:30). These terms are used to describe polish types for various contact materials. A selection of contact materials commonly used in prehistory is described below. This list is not exhaustive and several materials such as fish, ochre, and soft stone use-wear traces are not presented here.

7.3.1 Meat Polish

Meat polish has a dull sheen and low contrast with the surrounding unmodified surface (Keeley, 1980:53, Vaughan, 1985:38). Some researchers have noted a ‘greasy luster’ in association with this polish (Keeley, 1980:53). It tends to be distributed in uneven patches close to the edge of the tool (Vaughan, 1985:38). Meat polish is often classified as a generic weak polish, distinguishable as slightly brighter than the natural reflective properties of the raw material (Vaughan, 1985:30). This polish tends to be associated with hide polishes from butchering practices without bone contact.

7.3.2 Hide Polish

Dry hide polish initially starts as a generic weak polish. It then becomes extremely dull and highly pitted, spreading across the edge of the tool (Vaughan, 1985:37). Dampened hides result in a brighter, smooth-pitted polish along the edge of the tool. In contrast, fresh hide working results in a bright, greasy polish (Keeley, 1980). The greasy polish from fresh hide is highly bumpy and textured, but lacks the micropitting seen in polish from bone contact. Dry-hide or leather is occasionally associated with the presence of circular pits. Striations are rarely associated with hide working (Keeley 1980).

7.3.3 Wood Polish

Wood polish is very bright and appears smooth under high-powered magnifications. It initially forms on microtopographic peaks and gradually spreads, connecting these polished areas. Striations are not common on woodworking tools but, when they do occur, they appear as broad and shallow and are oriented in the direction of movement (Keeley, 1980). Softwoods leave more polish on the tool surface than hardwoods after the same use duration (Keeley, 1980, Vaughan, 1985).

7.3.4 Bone Polish

Bone working produces a bright polish with a pitted appearance. Due to the hard nature of bone, the polish tends to be discontinuous and begins to form on the higher points of the microtopography. ‘Comet tail’ striations in the polish are aligned with the direction of action, indicating motion (Vaughan, 1985). Striations tend to be deep and narrow (Keeley, 1980). Bone polish is also distinguishable by the presence of numerous small pits on the surface (Keeley, 1980).

7.3.5 Antler Polish

Noted differences are seen in antler polish resulting from sawing motions versus antler polish resulting from scraping motions. ‘Smooth’ antler polish is produced by transverse motions across the contact material, resulting in very bright smooth polish. When not well developed, this polish is often difficult to distinguish from wood polish (Keeley, 1980). When the polish is well developed it displays small defuse depressions with vague troughs indicating the direction of motion. In contrast, ‘rough’ antler polish is produced from sawing actions and is characterized by bright smooth pitted polish (Keeley, 1980).

7.3.6 Cereal Polish

Cutting plants results in bright to extremely bright polish, completely linked over the surface with a raised appearance (Vaughan, 1985:36). The polish is ‘pock-marked’ with filled-in striations and ‘comet-shaped pits’ indicating the direction of movement. It has been argued that the frequency of striations is related to the distance of the cut from the ground surface, suggesting that increased striations are the result of sediment particles abrading the polish (Anderson, 1991).

7.3.7 Reed Polish

Cutting reeds results in a very bright, smooth-pitted polish, highly reflective with a 'domed' appearance (Vaughan, 1985:35). Reed polish has also been described as having a 'wet' appearance, with no striations, distinguishing it from cereal polish (van Gijn, 1999).

7.4 Methods

A combination of low- and high-powered analysis was chosen for the functional study of the microlith assemblages. As mentioned previously, this combination allows the most holistic approach to the analysis of wear features through the assessment of features observable at multiple scales including fractures, polish, and striations. Interpretation of microlith function was made through the use of several analogues. The first was the experimental set of tools described in Chapter 6. In addition, there has been a long history of rigorous experimentation in the field of use-wear analysis. Thus, published literature and photomicrographs were used to identify wear traces and link them to potential functions (examples include Anderson, 1991, Keeley, 1980, Tringham, et al., 1974, Vaughan, 1985). A recording sheet was devised so that the results from both the low-powered and high-powered analysis could be mapped onto the same sheet (Figure 34).

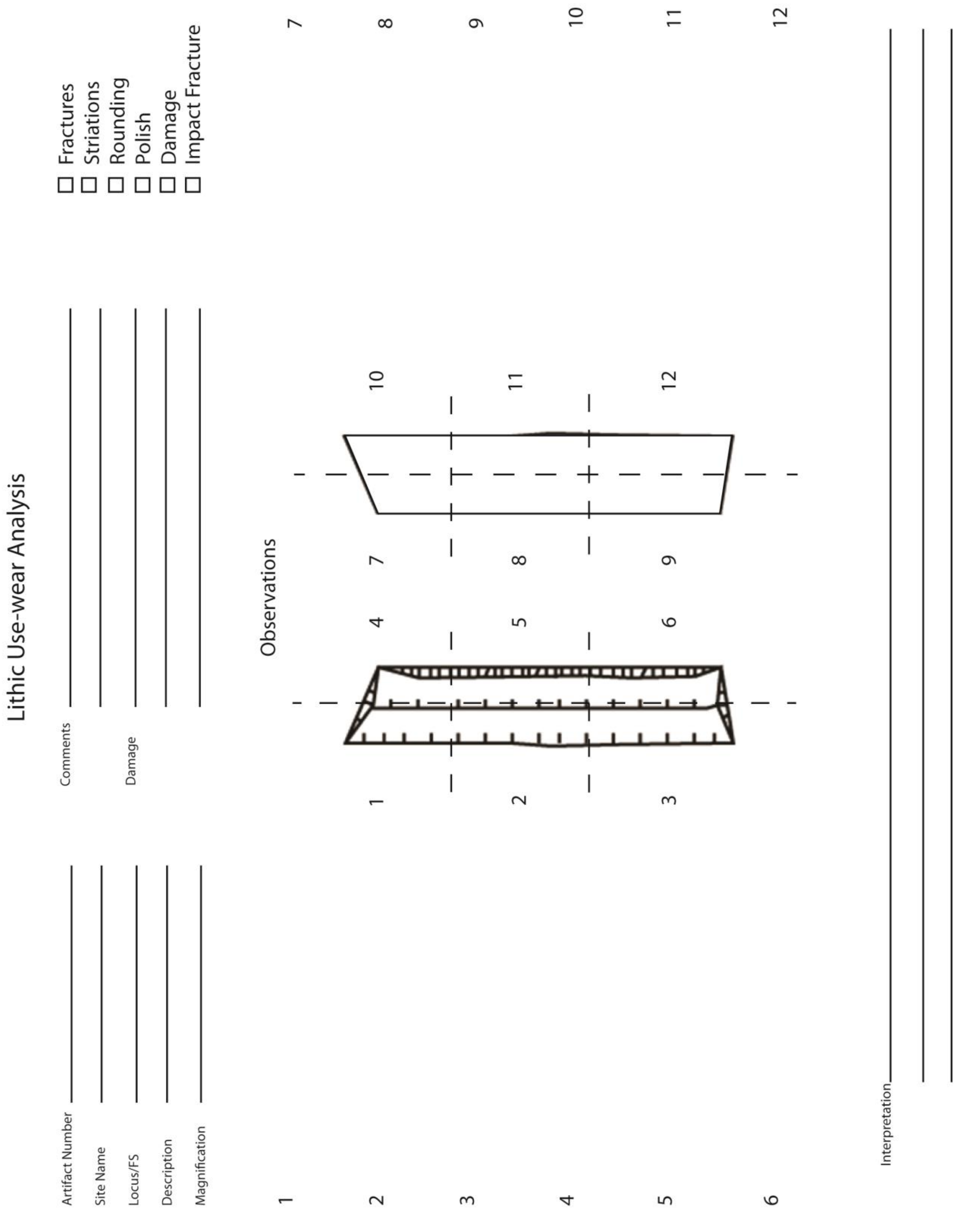


Figure 34: Use-wear recording form

7.4.1 Cleaning

Initially, each tool was cleaned in the field using a soft brush and clean water to remove any adhering soil particles. This cleaning method was sufficient for the low-powered analysis. When necessary the pieces were re-cleaned with technical wipes dipped in pure alcohol to remove finger grease and material that had collected on the pieces prior to microscopic analysis.

The tools chosen for high-powered analysis were further cleaned using chemical methods adapted from Keeley (1980). To begin, each piece was immersed in water and placed in an ultrasonic bath for 10 minutes. The water was changed after each artifact was cleaned. Each artifact was soaked in a bath of 10% sodium hydroxide (NaOH) for 10 minutes and then 10% hydrochloric acid (HCl) for an additional 10 minutes. Finally, the tools were bathed in an ultrasonic water bath for 10 minutes to remove any remaining chemical traces. This method ensures that any adhering mineral or organic traces are removed prior to analysis so they do not interfere with identification of use-wear traces. Additional spot cleaning using alcohol was done as necessary at the time of analysis to remove finger grease, dust, and other materials that adhered to the artifact after chemical cleaning.

7.4.2 Low-Powered Analysis

Low-powered functional analysis was conducted on a sample of 200 microliths from each site. Several contexts were randomly selected from the materials analyzed for the typological analysis to obtain the sample.

Low-powered analysis was conducted prior to high-powered analysis, focusing on identifying macroscopic fractures and visible polishes. An Olympus SZX9 stereomicroscope was used for low-powered analysis of the collections. Magnification ranged from 5 to100x, with the majority of the samples analyzed between 20 and 50x. Samples were illuminated with an adjustable light source, allowing the samples to be illuminated from multiple angles to highlight use features.

The number, type, location, and frequency of fractures were recorded using low-powered magnification. The number of fractures was recorded as greater than or less than five fractures per 10 mm. This division has previously been used by Grace who suggests that isolated and small clusters of fractures may be the result of post-depositional processes and should not recorded as use-features (Grace, 1989). Fracture type was recorded as snap, bending, or conchoidal and the terminating type was noted (feathered, step, hinged). These fracture types were identified on the basis of the typology outlined in the Ho Ho committee report (1979). Diagnostic impact fractures were identified according to the criteria of Fischer et al. (1984). The location of diagnostic impact fractures were classified using Yaroshevich's (2010) system. This classification system provided a reference for the position of impact fractures on the microliths and a guild for interpreting possible hafting configurations (Table 30).

7.4.3 High-Powered Analysis

After the analysis of each piece using a stereomicroscope, 50 pieces identified with evidence of use were selected for high-powered analysis. Any pieces with labeling, patination, burning, or other modifications obscuring the edge were not subjected to further analysis.

Preliminary analysis was conducted with a Nikon Eclipse 50i microscope using the incident-light illumination, with magnifications ranging from 100 to 1000x. Subsequent images were taken using the white light illumination setting on an Olympus LEXT laser-scanning confocal microscope, available at the time of analysis. This microscope was chosen to present the images because it is able to stitch together images at different focal planes, thereby creating an image in focus at all depths of field. Identification of polish and striations was based on comparisons between artifacts and the experimental collections and published photomicrographs of experimentally produced polish (Anderson, 1991, Keeley, 1980, Vaughan, 1985). The criteria used for identification are described above in Section 1.2.

7.4.4 Post-Depositional Alterations

Post-depositional alterations can greatly affect the identification of use-wear features on an artifact's surface. Therefore, it is important to identify the degree of post-depositional modification to an artifact's surface prior to interpreting use-wear analysis. There are several common alterations that happen to lithic surfaces in a depositional environment including fractures, striations, plastic deformation, roundness of edges and ridges, polished surfaces, pits, and patination (Burroni, et al., 2002). The presence of these features can confuse or mask use-wear patterns leading to problems in interpretation.

A number of researchers have used trampling experiments to identify the difference between use and post-depositional fractures (e.g., McBrearty, et al., 1998, Pargeter, 2011, Shea and Klenck, 1993, Tringham, et al., 1974). When resulting from trampling, fractures tend to be unevenly distributed along the tool's edge and can occur in clusters or as isolated fractures. These fractures often occur on both faces of the tool and tend to be broad, oriented perpendicularly to the edge (McBrearty, et al., 1998). Trampling damage can obscure and mimic use-traces causing confusion when interpreting function (Shea and Klenck, 1993). Furthermore, diagnostic impact fractures can be produced from trampling, although these occur in very low frequencies (Pargeter, 2011). This can result in incorrect interpretations of hunting if not corroborated with other evidence such as the presence of other diagnostic impact fractures or linear polish traces.

In addition to the trampling experiments, Grace (1989) has identified several criteria that analysts need to consider when distinguishing wear-related fractures from post-depositional ones. He notes that unpatterned and randomly oriented fractures are easily produced through damage. Damage fractures tend to be isolated or appear in low frequencies, and he uses frequencies of less than five fractures per 10mm as a cut-off value. Also, damage can occur on any edge, therefore the random distribution of fractures along an edge suggests post-depositional fracturing. In contrast, the placement of fractures along a potentially used edge, but not along all edges, suggests that the fractures are the result of use. He also suggests that corroborative evidence of use is needed, and the presence of polish, striations, or rounding should be investigated. Finally, it is notoriously difficult to identify fractures on retouched edges and these should not be considered during low-powered analysis.

The fracture pattern for each microlith was individually assessed during analysis. Using the cut-off that Grace (1989) proposes, fractures occurring with less than five fractures per 10mm were considered to have resulted from trampling or other post-depositional processes and were not included in the functional interpretation. However, diagnostic impact fractures were recorded individually as these can often occur as isolated fractures.

Measurements of lithic edge and ridge roundness are common methods to understand the impact of post-depositional processes on a sample. Roundness can easily be observed through microscopy and can be measured using a variety of image analysis programs from photomicrographs. Rigorous experimentation undertaken by Shackley (1974) showed that lithics travel through several stages of natural wear that impact the rounding of dorsal scar ridges. Initially, a chert flake can sustain a certain amount of movement in sediment without showing any sign of rounding or change to the overall piece. Over time, ridges and other prominent surfaces gradually become smoother and micro-cracks form along the edges of the ridges. After this smoothing, large particles are formed and detach from the surface, removing some of the surface material and creating angular areas. These are further smoothed by movement in sediment. The rate at which these modifications occur is based on the local sediment conditions, including the size of the sediment particles and the amount of water in the sediment (Shackley, 1974). Recent work by Burroni et al. (2002) expanded upon this research to incorporate descriptions of other post-depositional wear features, such as cracks and polishes. In addition, they confirmed many of Shackley's findings in regards to the development of ridge rounding and offered revised measurements for the relationship between ridge width and the degree of post-depositional alternation (Table 31).

Table 31: Relationship between ridge width and degree of post-depositional modification (adapted from Burroni, et al., 2002)

Surface Features	Degree of Post-Depositional Modification			
	Very Low	**Low**	**Moderate**	**High**
Ridge width (µm)	<25	25–70	71–100	>100

To assess the post-depositional alterations affecting the microliths from Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV, a sample of ten microliths were randomly selected from each site to measure post-depositional wear and rounding. These were selected from the microliths that had evidence of use-wear at low-powered magnification, assuring that microliths included in use-wear interpretations were assessed for post-depositional wear. Using the methods outlined in Burroni et al. (2002), a photomicrograph of the center dorsal ridge was taken of each microlith. Ten measurements of ridge width were taken on each photomicrograph and averaged, minimizing fluctuations in ridge width and generating a mean width to assess post-depositional modification.

To obtain the measurements, the dorsal surfaces were scanned using the Olympus LEXT laser-scanning confocal microscope (further details on this microscope are presented in Chapter 7). Each piece was oriented so that the dorsal ridge was the highest point in the image, running in a straight vertical line. A three-dimensional scan of the artifact was taken, allowing cross-sectional slices of the microlith to be obtained. The ridge width was identified using the extracted profiles and the two-dimensional visual image of the dorsal ridge. The profiles indicated where the ridge was beginning to become flatten or rounded and, in the two-dimensional image, the ridge appears reflective when rounded, resulting in a bright line. Using the LEXT software, the ridge width was measured in ten evenly spaced locations along the ridge (Figure 35). The results of these measurements are presented in sections 7.5.1, 7.6.1 and 7.7.1 below.

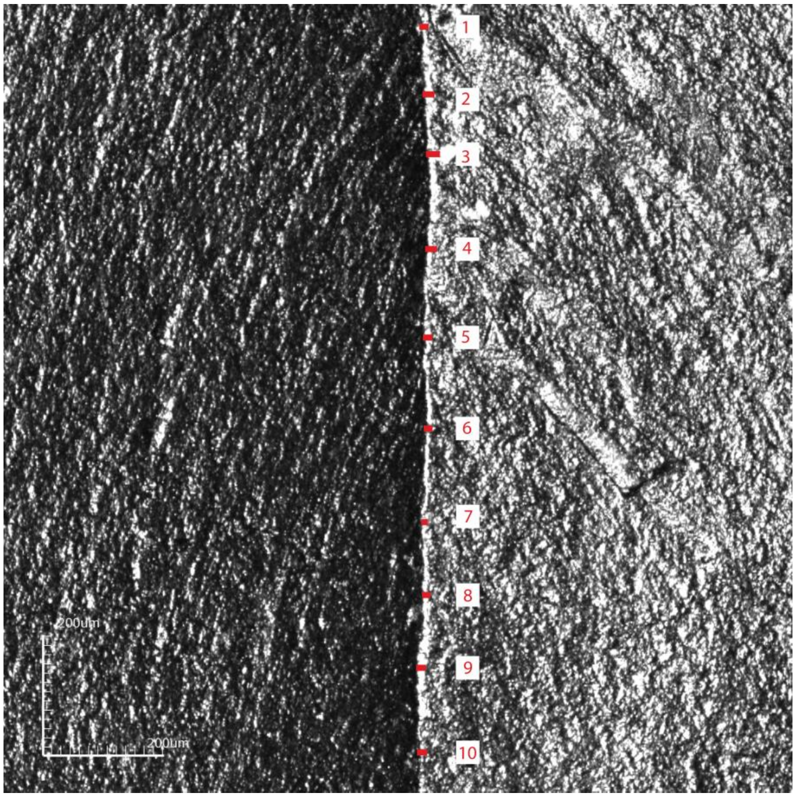


Figure 35: Measurement of ridge width to assess post-depositional alterations

In addition to edge rounding, there are also several polish types that result from post-depositional processes. The first of these is a glossy patina, also called surface or soil sheen, which covers the surface and can range from faint to very glossy. This sheen tends to occur uniformly over the lithic surface but can be more concentrated on the edges and prominent protrusions (Levi-Sala, 1986). Glossy patina is interpreted to be the result of chemical processes from soil contact or from mechanical processes relating to soil movement. In addition to soil sheen, smooth reflective bright spots can occur on the surface. These spots can be distinguished from use-wear because they are not systematically found on the edges of tools, and will occur in the absence of other wear features (Levi-Sala, 1986). These post-depositional polishes are usually only observable under high-powered magnification; therefore, each microlith subjected to high-powered analysis was individually assessed for post-depositional polishes that might obscure or confuse functional interpretations.

7.5 Wadi Mataha Use-Wear Results

As mentioned previously, a sample of 200 microliths were chosen for low powered use-wear analysis, from which 50 were chosen for analysis under high powered magnification. Of the analyzed pieces, 30.5% (n=61) showed evidence of use. The remainder of the microliths either had no microscopic evidence of use or had post-depositional alterations obscuring the identification of functional traces.

7.5.1 Post-Depositional Alterations

Of the assemblage selected for use-wear analysis, 12 microliths (6.0%) were too damaged for analysis due to post-depositional alternations or burning. During low-powered analysis an additional 51 microliths (25.5%) were identified as having fractures associated with trampling or other post-depositional processes. These fractures were non-diagnostic and often isolated or appeared in small groups. One piece was identified with soil sheen (0.5%).

Overall, the microliths from Wadi Mataha exhibit very low to low post-depositional modifications based on ridge width measurements (Table 32). This suggests that the assemblage is well suited for use-wear analysis.

Table 32: Wadi Mataha post-depositional modification

Artifact Number	# measurements	mean ridge width (um)	stand. dev.	post-dep. modification
WM-2702	10	12.5	4.2	very low
WM-2611	10	23.6	5.0	very low
WM-2435	10	33.7	11.4	low
WM-2575	10	20.2	8.5	very low
WM-2547	10	20.0	5.3	very low
WM-2551	10	24.6	9.7	very low
WM-2542	10	25.7	5.4	low
WM-2427	10	12.4	4.3	very low
WM-2433	10	26.7	8.6	low
WM-2549	10	16.4	5.3	very low

7.5.2 Form and Function

The microliths analyzed from Wadi Mataha show a wide range of functions (Table 33). Most commonly, microliths had diagnostic impact fractures and are interpreted as projectile inserts (n=28, 14.0%). The second-most common microlith function is as cutting tools, used in a longitudinal motion (n=24, 12.0%). The difference between the frequencies of these two functions is very small, suggesting that microliths were not designated for a single function.

Table 33: Wadi Mataha summary of microlith function

Function	Count	Percent
projectile	28	14.0%
longitudinal motion	24	12.0%
transverse motion	3	1.5%
unknown function	6	3.0%
damage/post-depositional	12	6.0%
no use	127	63.5%
Total	**200**	**100.0%**

When broken down by microlith type, it is clear that a single microlith form can be used for multiple functions (Table 34). For example, 11.7% of trapeze-rectangles have evidence indicative of projectiles, while 16.9% of the trapeze-rectangles were used in a longitudinal motion. Removing the fragmentary microliths (backed bladelet fragments), 38.9% (n=7) of the projectiles were on non-geometric microliths and 61.1% (n=11) were geometric microliths. Conversely, 21.7% (n=5) of the other functions (longitudinal motions, transverse motions, unknown) were attributed to the non-geometric microliths and 78.3% (n=18) were attributed to the geometric microliths. Although it is important to note that differing sample sizes could play a role in the difference seen between these frequencies, both non-geometric and geometric microliths were being used for different actions, such as impact, cutting, and transverse motions. The difference between the functional uses of non-geometric and geometric microliths is not significant (χ^2= 1.43, p= 0.23102), thus no strong pattern emerges that could link microlith form to function at Wadi Mataha.

Table 34: Wadi Mataha microlith function by type

Tool Types	projectile		longitudinal motion		transverse motion		unknown function		damage/post-depositional		no use		Total
Geometrics	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**
lunate	1	33.3	1	33.3	-		-		-		1	33.3	**3**
trapeze-rectangle	9	11.7	13	16.9	-		4	5.2	3	3.9	48	62.3	**77**
triangle	1	50.0	-		-		-		-		1	50.0	**2**
Non-geometrics													
completely backed	1	50.0	-		-		-		-		1	50.0	**2**
notched bladelet	1	16.7	-		-		-		-		5	83.3	**6**
partially backed	-		1	6.3	1	6.3	-		-		14	87.5	**16**
pointed	1	50.0	-		-		-		-		1	50.0	**2**
retouched on both sides	-		-		1	33.3	-		-		2	66.7	**3**
varia	4	33.3	1	8.3	-		1	8.3	-		6	50.0	**12**
Fragmentary													
backed bladelet fragment	10	14.9	8	11.9	1	1.5	1	1.5	7	10.4	40	59.7	**67**
Total	**28**		**24**		**3**		**6**		**12**		**127**		**200**

7.5.3 Projectiles

As mentioned above, 14.0% (n=28) of the microlith assemblage has macroscopic evidence of diagnostic impact fractures (see Appendix C for images of diagnostic impact fractures). Using the typology for impact fractures on Epipalaeolithic microliths that Yaroshevich et al. (2010) developed, the results suggest that microliths were being hafted as both tips and barbs on projectiles (Table 35). In total, 39.3% of the microliths have parallel fractures, while 60.7% have fractures that are obliquely or perpendicularly oriented to the longitudinal axis. Of the non-geometric microliths 75.0% (n=6) have fractures that are parallel to the long axis, while only 25.0% (n=2) have fractures that are obliquely oriented or perpendicular to the axis of percussion. The higher frequency of parallel fractures suggests that the majority of the non-geometric microliths were hafted as projectile tips. In contrast, 72.7% (n=8) of the geometric microliths have evidence of oblique or perpendicular impact fractures. The differences between the orientation of diagnostic impact fractures on non-geometric and geometric microliths is statistically significant (χ^2= 5.445, p= 0.0196). From this data, a pattern emerges where the non-geometric microliths are likely functioning as straight projectile tips and the geometric microliths acted as barbs, laterally hafted inserts, obliquely hafted, or transverse tips.

Table 35: Wadi Mataha projectile types

Tool Types	Parallel					Oblique/Perpendicular			Multiple		Total	%
	a1	a1m	a2	a2m	a3	b1	b2	b3	d1m	dm2		
Geometrics												
lunate	-	-	1	-	-	-	-	-	-	-	**1**	**3.6**
trapeze-rectangle	-	-	1	-	1	3	1	1	2	-	**9**	**32.1**
triangle	-	-	-	-	-	-	-	1	-	-	**1**	**3.6**
Non-geometrics												
completely backed	-	-	-	1	-	-	-	-	-	-	**1**	**3.6**
notched bladelet	-	1	-	-	-	-	-	-	-	-	**1**	**3.6**
pointed	1	-	-	-	-	-	-	-	-	-	**1**	**3.6**
varia	-	2	-	1	-	-	-	-	-	1	**4**	**14.3**
Fragmentary												
backed bladelet fragment	-	1	1	-	-	3	2	1	2	-	**10**	**35.7**
Total	**1**	**4**	**3**	**2**	**1**	**6**	**3**	**3**	**4**	**1**	**28**	**100.0**
Percent	**3.6**	**14.3**	**10.7**	**7.1**	**3.6**	**21.4**	**10.7**	**10.7**	**14.3**	**3.6**	**100.0**	

High-powered use-wear analysis revealed evidence of striations and linear polish resulting from impact. One backed bladelet fragment had one large shallow angled striation running across the ventral face. Two other backed bladelets had evidence of angled linear polish. In addition, five microliths had localized areas of weak generic polish, possibly resulting from contact with animal flesh and hide during the hunting process.

7.5.4 Other Functions

In addition to functioning as projectile inserts, functional traces indicate that microliths also acted in longitudinal and transverse motions (Table 36). At Wadi Mataha 12% (n=24) of the analyzed assemblage has evidence of longitudinal motions, identified through low-powered analysis of fractures. A small number of microliths showed evidence of transverse motion through the presence of continuous but localized conchoidal fractures initiating from the ventral face (n=3). Although the regular use of microliths as scraping tools seems unlikely, the evidence suggests that occasionally these tools were used in a transverse motion.

Table 36: Wadi Mataha other functions of microliths

Tool Type	longitudinal motion	transverse motion	unknown function	Total
Geometrics				
lunate	1	-	-	**1**
trapeze-rectangle	13	-	4	**17**
Non-Geometrics				
partially backed	1	1	-	**2**
retouched on both sides	-	1	-	**1**
varia	1	-	1	**2**
Fragmentary				
backed bladelet fragment	8	1	1	**10**
Total	**24**	**3**	**6**	**33**

In addition to the evidence of longitudinal motions witnessed through low-powered analysis, several tools have evidence of polish under high-powered magnifications, further corroborating the interpretation that microliths functioned as cutting tools (Table 37, Appendix C). As mentioned previously, 50 microliths identified with use-wear traces at low-powered magnifications were selected for high-powered analysis to look for polishes and striations. On the Wadi Mataha microliths, weak polish consistent with soft material contact was identified on eight tools: three trapeze-rectangles, four backed bladelets, and one varia. The other 42 tools did not exhibit clear traces of polish under high-powered magnification. These tools also have evidence of longitudinal motions observed at low-powered magnifications, suggesting they were used for cutting meat or hide. These traces could be the result of butchery activities or food preparation after the meat was removed from the animal carcass.

Table 37: Wadi Mataha contact materials

Motion (low-power)	Material (high-power)	Count
longitudinal motion	cutting meat/hide	8
Total		**8**

The overall pattern of evidence from Wadi Mataha suggests that microliths had multiple functions, including as projectile and cutting implement insets. Function is not linked to microlith type or form, indicating that style does not dictate function (nor does function dictate style). However, when evaluating the diagnostic impact fractures, non-geometric microliths have a higher frequency of parallel fractures while geometric microliths have a higher frequency of oblique fractures. Although there is not a direct correlation between fracture orientation and hafting configurations, general patterns suggest that parallel fractures result from impact when the microlith was hafted as a projectile tip, while oblique fractures result from hafting microliths as barbs, lateral elements, transverse or oblique points. This suggests that there were different hafting considerations between geometric and non-geometric microliths when they were used as projectile insets.

The high frequency of microliths without use-wear traces is within the normal range for frequencies of wear traces on Epipalaeolithic assemblages. In the comprehensive analysis of four Natufian assemblages, Richter (2007) showed that on average 58.9% of the analyzed lithic assemblage showed no evidence of use-wear traces. In addition, experimental work has shown that projectile barbs can have low frequencies of damage (Crombé, et al., 2001). The high frequency of un-used microliths (or microliths without use-wear traces) from Wadi Mataha may be the result of their use as project barb insets. Furthermore, using a tool for a very short time may not result in visible use-wear traces. Excluding these considerations, it is also highly likely that many of these pieces were never used. The regularized nature of microliths allows for them to be produced on-mass. Thus, many of these pieces may have been lost or discarded prior to use.

7.6 Uyun al-Hammâm Use-Wear Results

Two-hundred microliths were chosen from ‘Uyun al-Hammâm for low-powered use-wear analysis. From the microliths identified with use-wear, 50 were randomly chosen for analysis under high-powered magnification. Of the analyzed pieces, 42.5% (n=85) had evidence of use-wear. The remainder of the microliths either had no evidence of use or had post-depositional alterations obliterating any remnants of functional traces.

7.6.1 Post-Depositional Alterations

During the initial stages of use-wear analysis, 18 (9.0%) tools were deemed too damaged from post-depositional processes or burning for subsequent analysis. An additional 29 (14.5%) microliths were identified with post-depositional fractures. Only one microlith had evidence for soil sheen (0.5%).

The same sampling and analytical procedures used to assess post-depositional modifications for the Wadi Mataha lithics were followed for the microliths from ‘Uyun al-Hammâm. Ten tools were selected and ten measurements were taken per tool. The resulting measurements suggest that the microliths from ‘Uyun al-Hammâm have undergone very-low to low post-depositional modifications (Table 38). As with the assemblage from Wadi Mataha, this indicates that ‘Uyun al-Hammâm is a suitable assemblage for use-wear analysis.

Table 38: 'Uyun al-Hammâm post-depositional modifications

Artifact Number	# measurements	mean ridge width (μm)	stand. dev.	post-dep modification
WZ148.G13.39.236	10	21.1	8.1	very low
WZ148.G13.29.216	10	57	12.9	low
WZ148.G13.29.217	10	16.6	5.5	very low
WZ148.G13.30.254	10	15.2	4.5	very low
WZ148.G13.30.260	10	14.2	2.6	very low
WZ148.G13.30.263	10	28.3	11.2	low
WZ148.G13.30.269	10	16.4	2.7	very low
WZ148.H11.20.201	10	12.7	3.8	very low
WZ148.G16.49.224	10	11.6	2.7	very low
WZ148.H11.9.200	10	23.4	8	very low

7.6.2 Form and Function

The low-powered use-wear analysis of microliths from ‘Uyun al-Hammâm shows a similar pattern to the use-wear results from Wadi Mataha. Of the analyzed sample, 42.5% showed some functional traces. The microliths were most frequently used as projectiles (18.0%, n=36), followed closely by longitudinal motions (16.0%, n=32). There is also some evidence of transverse motions (3.5%, n=7), although in low frequencies. These traces suggest that overall, microliths were used for a variety of different functions.

Table 39: 'Uyun al-Hammâm summary of microlith function

Function	Count	Percent
projectile	36	18.0%
longitudinal motion	32	16.0%
transverse motion	7	3.5%
unknown function	10	5.0%
damage/post-depositional	18	9.0%
no use	97	48.5%
Total	**200**	**100.0%**

When assessing function by microlith type it is clear that each type was used for several different actions. Trapeze-rectangle microliths were used for a wide range of functions including as projectiles (n=22, 16.4%), in longitudinal motions (n=24, 18.0%), and in transverse motions (n=6, 4.5%). This suggests that for this dominant tool class the form of the piece did not dictate the function. When assessing the differences between the geometric and non-geometric microliths at ‘Uyun al-Hammâm it becomes clear that both classes were used in multiple ways. Removing the backed bladelets from analysis, projectile fractures are found on both geometrics (n=24, 82.8%) and non-geometric microliths (n=5, 17.2%). In addition, traces of longitudinal motions appear on geometrics (n=27, 87.1%) and non-geometrics (n=4, 12.9%). There is no significant difference in the proportions of use when comparing projectile and cutting functions of non-geometric and geometric microliths (χ^2= 0.805, p= 0.36946). However, it is important to note that the microlith assemblage is dominated by trapeze-rectangles, so the sample size of non-geometric microliths is very small.

Table 40: 'Uyun al-Hammâm microlith function by type

Tool Types	**projectile**		**longitudinal motion**		**transverse motion**		**unknown function**		**damage/post-depositional**		**no use**		**Total**
	n	%	n	%	n	%	n	%	n	%	n	%	n
Geometrics													
asymmetrical trapeze A	-		1	100.0	-		-		-		-		**1**
asymmetrical trapeze B	2	28.6	2	28.6	-		-		-		3	42.9	**7**
trapeze-rectangle	22	16.4	24	18.0	6	4.5	8	6.0	10	7.5	63	47.4	**133**
Non-geometrics													

notched bladelet	-		1	33.3	-		-		-		2		**3**
obliquely truncated	1	33.3	-		-		-		1	33.3	1	33.3	**3**
obliquely truncated and backed	2	100.0	-		-		-		-		-		**2**
partially backed			-		-		1	20.0	-		4	80.0	**5**
pointed and backed bladelet	1	100.0	-		-		-		-		-		**1**
retouched on both sides	-		2	100.0	-		-		-		-		**2**
straight truncated and backed	-		1	50.0	-		-		-		1	50.0	**2**
varia	1	33.3	-		-		-		-		2		**3**
Fragmentary													
backed bladelet fragment	7	20.6	1	2.9	1	2.9	1	2.9	7	20.6	17	50.0	**34**
Total	**36**		**32**		**7**		**10**		**18**		**97**		**200**

7.6.3 Projectiles

In total, 36 microliths (18% of the analyzed assemblage) have evidence of projectile fractures. When evaluating the microliths with diagnostic impact fractures from ‘Uyun al-Hammâm, it is apparent that both non-geometric and geometric microliths were used to arm projectiles. The majority of the geometric microliths have oblique and perpendicular fractures (n=20, 90.9%) while non-geometrics are evenly distributed between parallel (n=2) and perpendicular fractures (n=2). It seems unlikely that geometric microliths were hafted as projectile tips, with only two trapeze-rectangles having evidence of parallel fractures. In contrast, 18 trapeze-rectangles have oblique, perpendicular, or multiple fractures indicative of hafting as barbs, lateral elements or oblique tips. No clear pattern emerges for the use of non-geometric microliths as a group, due in part to the small sample size. However, the two oblique/perpendicular fractures occur on obliquely truncated and backed microliths, while the parallel fractures occur on other types. Further work is needed to test whether this pattern is reflected in a larger sample.

Table 41: Uyun al-Hammâm projectile types

Tool Type	Parallel			Oblique/Perpendicular			Multiple		Total	Percent
	a1	a1m	a2	b1	b2	b3	d1m	d2m		
Geometrics										
asymmetrical trapeze B	-	-	-	1	-	-	-	1	**2**	**5.9**
trapeze-rectangle	1	-	1	12	2	1	2	1	**20**	**58.8**
Non-geometrics										
obliquely truncated	1	-	-	-	-	-	-	-	**1**	**2.9**
obliquely truncated and backed	-	-	-	2	-	-	-	-	**2**	**5.9**
pointed and backed bladelet	1	-	-	-	-	-	-	-	**1**	**2.9**
varia	-	-	-	-	-	-	1	-	**1**	**2.9**
Fragmentary										
backed bladelet fragment	1	1	-	4	-	-	1	-	**7**	**20.6**
Total	**4**	**1**	**1**	**19**	**2**	**1**	**4**	**2**	**34**	**100.0**
Percent	**11.8**	**2.9**	**2.9**	**55.9**	**5.9**	**2.9**	**11.8**	**5.9**	**100.0**	

Some of the microliths with impact fractures have traces of polish, further corroborating their function as projectile inserts. Two microliths, one backed bladelet fragment and one asymmetrical trapeze B, have angled linear striations on the ventral face. As well, one trapeze-rectangle with impact fractures also has a localized spot of bright polish, possibly the result of bone contact during impact. Finally, one trapeze-rectangle has weak generic polish surrounding the edges of the impact fracture.

7.6.4 Other Functions

Other microlith functions include ones involving longitudinal (82.1%, n=32) and transverse motions (17.9%, n=7). These actions were identified through low-powered fracture analysis. There is also one trapeze-rectangle with use fractures whose corresponding function could not be inferred with confidence. The majority of the microliths identified with non-impact traces are trapeze-rectangles and these were primarily used for cutting motions (n=9).

Table 42: Uyun al-Hammâm other functions

Tool Type	longitudinal motion	transverse motion	unknown function	Total
Geometrics				
asymmetrical trapeze A	1	-	-	1
asymmetrical trapeze B	2	-	-	2
trapeze-rectangle	24	6	8	38
Non-Geometrics				
notched bladelet	1			1
partially backed	-	-	1	1
retouched on both sides	2	-	-	2
straight truncated and backed	1	-	-	1
Fragmentary				
backed bladelet fragment	1	1	1	3
Total	**32**	**7**	**10**	**49**

Of these pieces, 15 had evidence of polish or striations visible under incident light microscopy. The contact materials ranged from cutting meat/hide (n=10, 66.7%), to scraping soft materials (n=2, 13.3%), cutting hard materials (n=2, 13.3%), and unknown motion against a medium hard material (n=1, 6.7%). Unfortunately, the hard contact material could not be identified to specific material. Images of these polishes are included in Appendix C. These traces suggest that microliths may have been used in butchering tasks and potentially working harder materials such as wood or bone.

Table 43: Uyun al-Hammâm materials and motions

Motion (low-power)	Material (high-powered)	Count
longitudinal motion	cutting meat/hide	10
transverse motion	soft contact material	2
longitudinal motion	hard material contact	2
unknown motion	medium hard material	1
Total		**15**

The results of the use-wear analysis suggest that the microliths at ‘Uyun al-Hammâm had multiple functions, being used primarily as projectiles or as cutting tools. Although there is not a clear difference between the hafting configurations of non-geometric and geometric microliths, it appears that trapeze-rectangles were not used as projectile tips. When used in a longitudinal motion, microliths were likely used for butchering tasks. At times microliths were also used to cut or scrape hard contact materials or scrape soft materials, but these activities occurred very infrequently. Overall, there appears to be little connection between form and function at ‘Uyun al-Hammâm, with all types of microliths being used for multiple tasks.

7.7 Kharaneh IV Use-Wear Results

As with the other sites, a sample of 200 microliths from Kharaneh IV was selected for use-wear analysis. Fifty microliths were chosen for high-powered microscopy from the pieces identified with use fractures during low-powered analysis. In total 97 (48.5%) microliths showed evidence of use-wear. The remaining microliths were either lacking use-wear traces or had post-depositional processes obscuring traces of use.

7.7.1 Post-Depositional Alterations

Of the microlith assemblage analyzed for use-wear, 31 (15.5%) had damage obscuring the potential for surviving use-wear traces. Thirteen (6.5%) additional microliths had evidence of fractures attributed to post-depositional damage. There were also several pieces with soil sheen (n=7, 3.5%) identified in the assemblage, a much higher frequency then identified at Wadi Mataha and ‘Uyun al-Hammâm. This may be the result of the arid environment at the site and the fine silty sediment in which the artifacts are buried.

The results of the edge-rounding measurements suggest that, although there is soil sheen present on some of the lithics, they have not been subjected to intense post-depositional rounding. The measurements indicate that most of the microliths have very-low post-depositional modification in relation to edge width (Table 44). Therefore, lithics from Kharaneh IV are good candidates for use-wear analysis.

Table 44: Kharaneh IV post-depositional modifications

Artifact Number	# measurements	mean ridge width (um)	stand. dev.	post-dep modification
KHIV.AQ40.13.2	10	24.2	7.3	very low
KHIV.AQ40.13.10	10	23.9	8.3	very low
KHIV.AS42.10.11	10	22.5	5.9	very low
KHIV.AQ35.12.4	10	56.9	29.8	low
KHIV.AS38.12.2	10	16.3	6.8	very low

KHIV.AS35.9.4	10	15.1	2.6	very low
KHIV.AR38.11.10	10	12.8	3.3	very low
KHIV.AS42.10.1	10	13.7	4.8	very low
KHIV.AS42.10.2	10	23.4	7	very low
KHIV.AQ36.24.2	10	17	7.3	very low

7.7.2 Form and Function

Of the sample chosen for analysis, 48.5% (n=97) showed evidence of use. The use-wear analysis of the microliths from Kharaneh IV also shows that microliths were used for a variety of functions. However, at Kharaneh IV microliths were used more frequently as projectiles then at Wadi Mataha or 'Uyun al-Hammâm. Of the tools with use-wear, 56.7% functioned as projectile inserts, while 21.6% were used as cutting tools (Table 45). This contrasts to the other sites where the distribution of projectile to cutting functions was similar. Other functions such as transverse motions and twisting appear in low frequencies at Kharaneh IV.

Table 45: Kharaneh IV summary of microlith function

Function	Count	Percent
projectile	55	27.5%
longitudinal motion	21	10.5%
transverse motion	7	3.5%
twisting motion	1	0.5%
unknown function	13	6.5%
damage/post-depositional	31	15.5%
no use	72	36.0%
Total	**200**	**100.0%**

Analysis of microlith function by typological group does not show a clear relationship between form and function (Table 46). Each microlith type was used for a variety of purposes, including as projectiles or cutting implements. The geometric microliths were used as projectiles (n=25, 36.2%), for longitudinal motions (n=9, 13.0%), and transverse motions (n=3, 4.3%). The distribution of functions between the backed and the unbacked trapeze rectangles shows almost equal distributions of projectile, longitudinal, and transverse motions, with unbacked trapezes being used slightly more frequently as cutting tools (Figure 36). However, the difference between the functions of unbacked trapezes and trapeze rectangles is not significant (χ^2=2.4943, p=0.28733).

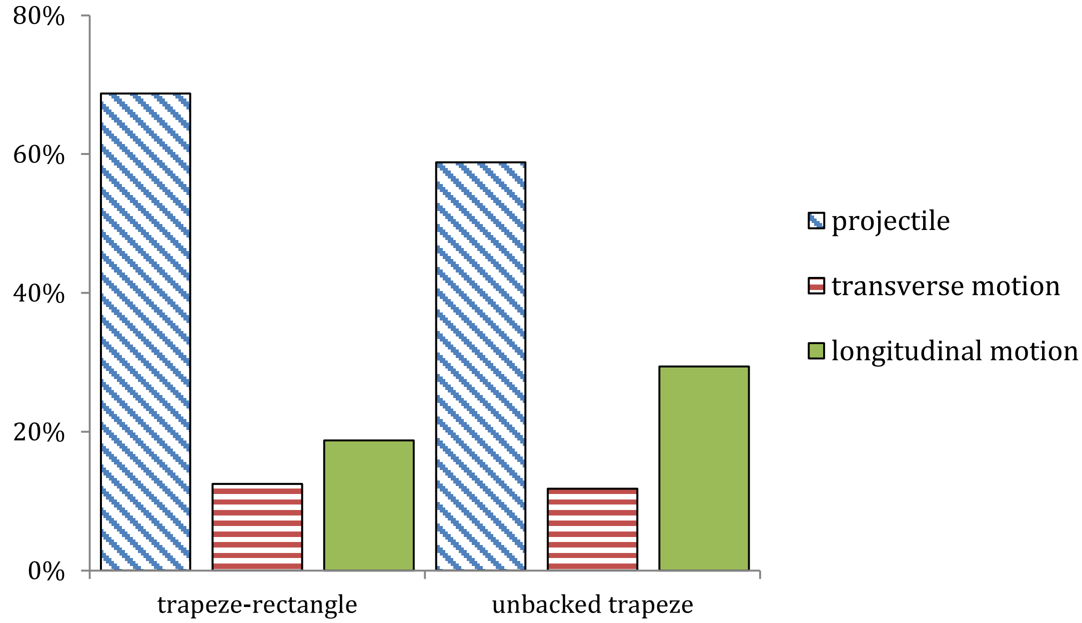


Figure 36: Frequency of functions for trapeze-rectangles and unbacked trapezes at Kharaneh IV

For the Kharaneh IV assemblage, it is difficult to distinguish the fragmentary microliths from the non-geometric microliths due to the similarity of obliquely truncated microliths to broken, unbacked trapezes, and obliquely truncated and backed microliths to broken trapeze-rectangles. However, after removing the ambiguous pieces, six non-geometric microliths have diagnostic impact fractures, four have fractures indicative of longitudinal motions, and one has traces of transverse actions.

Table 46: Kharaneh IV microlith function by type

Tool Types	projectile		longitudinal motion		transverse motion		twisting motion		unknown function		damage/post -depositional		no use		Total
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
Geometrics															
asymmetrical trapeze B	1	100.0	-		-		-		-		-		-		**1**
lunate	1	25.0	1	25.0	-		-		-		2	50.0	-		**4**
trapeze-rectangle	11	32.6	3	8.8	1	2.9	-		2	5.9	7	20.6	10	29.4	**34**
trapeze-rectangle with one convex end	2	100.0	-		-		-		-		-		-		**2**
unbacked trapeze	10	33.3	5	16.7	2	6.7	-		2	6.7	4	13.3	7	23.3	**30**

Non-geometrics/ Fragmentary															
backed bladelet fragment	2	20.0	-		-		-		1	10.0	4	40.0	3	30.0	**10**
completely backed	-		-		-		-		2	66.7	-		1	33.3	**3**
inversely retouched bladelet	-		1	100.0	-		-		-		-		-		**1**
notched bladelet	-		1	25.0	-		-		-		-		3	75.0	**4**
obliquely truncated	18	28.1	7	10.9	3	4.7	1	1.7	3	4.7	6	9.4	27	42.2	**64**
obliquely truncated and backed	4	26.7	1	6.7	-		-		2	13.3	1	6.7	7	46.7	**15**
partially backed	3	37.5	1	12.5	-		-		-		-		4	50.0	**8**
pointed backed bladelet	-		-		-		-		1	100.0	-		-		**1**
pointed bladelet	1	50.0	-		-		-		-		-		1	50.0	**2**
utilized bladelet	1	25.0	1	25.0	-		-		-		1	25.0	1	25.0	**4**
varia	1	20.0	-		1	20.0	-		-		1	25.0	1	25.0	**4**
Total	**55**		**21**		**7**		**1**		**13**		**31**		**71**		**200**

7.7.3 Projectiles

As with Wadi Mataha and ‘Uyun al-Hammâm, both geometric and non-geometric microliths have evidence of diagnostic impact fractures (Table 47). Overall, 14.3% of the impact fractures are parallel to the longitudinal axis, while 85.7% are oriented obliquely or perpendicular to the long axis. Thus, the frequency of microlith use as straight tips is lower than the frequency for barbs, lateral elements, transverse tips, and oblique tips. For the geometrics, 90.9% (n=20) have fractures obliquely or perpendicularly oriented to the axis of percussion. There is little variability in the type of oblique/perpendicular fracture types; only fractures initiating on the unretouched edge are present in the assemblage. Of the geometrics, only 9.1% (n=2) have evidence for impact fractures parallel to the long axis, indicative of use as a tip.

As mentioned above, because of the difficulty distinguishing the fragmentary microliths from the non-geometric microliths, the typological classes of obliquely truncated and obliquely truncated and backed microliths are not included in the analysis of the non-geometrics. For the other non-geometric microliths, two have parallel fractures and three have oblique/perpendicular fractures. Like the non-geometric microliths from ‘Uyun al-Hammâm, there is little pattern in the assemblage, potentially due to the same sample size.

Table 47: Kharaneh IV projectile types

Tool Type	Parallel			Oblique/Perpendicular	Multiple		Total	Percent
	a1	**a2**	**a2m**	**b1**	**d1m**	**d2m**		
Geometrics								
asymmetrical trapeze B	-	-	-	1	-	-	**1**	**2.0**
trapeze-rectangle	-	1	1	7	-	1	**10**	**20.4**
trapeze-rectangle with one convex end	-	-	-	2	-	-	**2**	**4.1**
unbacked trapeze	-	-	-	5	1	3	**9**	**18.4**
Non-geometrics/ Fragmentary								
backed bladelet fragment	-	1	-	1	-	-	**2**	**4.1**
obliquely truncated	2	-	-	9	1	4	**16**	**32.7**
obliquely truncated and backed	-	-	-	4	-	-	**4**	**8.2**
partially backed	1	-	-	1	-	-	**2**	**4.1**
pointed bladelet	-	-	-	-	1	-	**1**	**2.0**
utilized bladelet	-	-	-	-	1	-	**1**	**2.0**
varia	1	-	-	-	-	-	**1**	**2.0**
Total	**4**	**2**	**1**	**30**	**4**	**8**	**49**	**100.0**
Percent	**8.2**	**4.1**	**2.0**	**61.2**	**8.2**	**16.3**	**100.0**	

High-powered analysis of microliths with impact fractures shows that several microliths also have traces of polish left from impact. Two trapeze-rectangles have linear polish oriented at an angle to the edge. One unbacked trapeze has angled linear polish associated with two striations on the ventral surface. Other evidence includes one obliquely truncated bladelet, one trapeze-rectangle and one trapeze-rectangle with a convex end that have very bright polish localized near the edge. This is likely the result of impact with bone during hunting. Finally, two trapeze-rectangles, one partially backed bladelet and one lunate have isolated spots of generic weak polish along the edge. The presence of impact fractures on these pieces suggests that this polish was the result of hunting activities and not butchering traces.

7.7.4 Other Functions

Microliths at Kharaneh IV functioned for other tasks beyond projectile inserts. They also functioned as cutting (n=21), scraping (n=7), and boring (n=1) implements (Table 48). The low frequency of scraping and boring actions suggests that these were not common functions for microliths at the site. The majority of the microliths that exhibit non-projectile use-wear were used as cutting tools (n=21, 70%). All types of microliths show traces of wear indicating longitudinal motion, suggesting that any microlith form could be hafted as a cutting tool. However, most of the non-geometric types have single occurrences of cutting tools while obliquely truncated microliths, trapeze-rectangles, and unbacked trapezes have multiple occurrences. This suggests that geometric microliths were more likely to be used as cutting implements than non-geometric microliths.

Table 48: Kharaneh IV other functions

Row Labels	longitudinal motion	transverse motion	twisting motion	unknown function	Total
Geometrics					
lunate	1	-	-	-	**1**
trapeze-rectangle	3	1	-	-	**4**
unbacked trapeze	5	2	-	-	**7**
Non-geometrics/ Fragmentary					
inversely retouched bladelet	1	-	-	-	**1**
notched bladelet	1	-	-	-	**1**
obliquely truncated	7	3	1	1	**12**
obliquely truncated and backed	1	-	-	-	**1**

partially backed	1	-	-	-	**1**
utilized bladelet	1	-	-	-	**1**
varia	-	1	-	-	**1**
Grand Total	**21**	**7**	**1**	**1**	**30**

Only a few microliths identified as non-projectile tools show evidence of polish under high powered magnification. Evidence of generic weak polish was found on one lunate, one obliquely truncated microlith and one unbacked trapeze. These three tools also have fractures consistent with longitudinal motions, suggesting that they were used as cutting tools for meat and hide. Another unbacked trapeze has meat polish and bright, localized polish along the cutting edge, indicative of contact with a hard material. The presence of meat polish and hard material contact suggests that the tool might have been used in heavy butchering activities. One microlith from the 'varia' class was used on a hard contact material in a transverse motion. A pointed backed bladelet, identified as having an unknown function during low-powered analysis, had bright polish at the tip, indicating contact with a hard material. The point of this bladelet may have been used for boring or carving hard materials such as bone. Finally, one trapeze-rectangle has potential hafting polish at one retouched end. The fractures on this piece were irregular and could not be attributed to a particular motion.

Table 49: Kharaneh IV materials and motions

Motion (low-power)	**Material (high-power)**	**Count**
longitudinal motion	cutting meat/hide	3
longitudinal motion	butchering with bone contact	1
transverse motion	hard material	1
unknown	hard material	1
unknown	hafting with hard material	1
Total		**7**

Overall, the microliths from Kharaneh IV were used for a variety of purposes. However, the use of microliths as projectiles was more common than the use of microliths for other functions. Microliths used as projectiles were most often used as barbs, lateral elements, transverse tips, or oblique tips and not as straight points. This is especially true for the geometric microliths, where 90.9% of the projectile assemblage has oblique/perpendicular fractures. Other functions include cutting meat or hide, butchering, and working hard materials. The functional traces found on the microlith assemblage at Kharaneh IV suggest that microlith morphology did not constrain the function of the tool.

7.8 Comparison between Sites and Discussion

The overall pattern at Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV suggests that there is not a direct correlation between microlith form and how the microlith functioned. Use-wear traces indicate that microliths were used for a wide range of functions, from projectile components to cutting implements to scraping tools.

In summary, 30.5% of the Wadi Mataha assemblage had evidence of use-wear. Similar frequencies of microliths used as projectile inserts (14.0%) and microliths used as cutting tools (12.0%). The most dominant geometric microlith type, trapeze-rectangles, had 11.7% used as projectiles and 16.9% used as cutting tools. High-powered analysis suggests that the cutting tools were used to cut meat or hide, perhaps for butchering activities. A pattern emerges from the projectile data where non-geometric microliths functioned as projectile tips, while geometric microliths were hafted as barbs, laterally hafted inserts, obliquely hafted, or transverse tips. Unfortunately, it is not possible to tease out the specifics of the geometric microlith hafting configurations with the current data as currently published experiments do not exhibit strong patterns in fracture types among these modes of hafting. Hopefully future experiments with larger sample sizes will be able to illuminate differences. Overall, no clear pattern emerges between microlith type and function, with non-geometric and geometric microliths being used for all functions.

‘Uyun al-Hammâm had a higher frequency of use-wear than Wadi Mataha; 42.5% of the assemblage has evidence of use. The analysis indicates that microliths were primarily used as projectiles (18.0%) or as cutting tools (16.0%). Like the assemblage from Wadi Mataha, these actions occurred with similar frequency. Trapeze-rectangles were used for a variety of tasks, but projectiles and cutting were the most prevalent activities. There is no clear pattern between the hafting configurations of geometric and non-geometric microliths, yet geometrics were rarely used as projectile tips. High-powered analysis suggests that microliths were used on a wider variety of materials than the microliths from Wadi Mataha. There is evidence that microliths were used to cut meat and hide, scrape soft material, and cut hard materials.

Kharaneh IV had the highest frequency of used microliths at 48.5%. The majority of these were projectiles (27.5%), followed by cutting tools (10.5%). This is distinctly different from the Wadi Mataha and ‘Uyun al-Hammâm assemblages where the microliths were almost evenly distributed in function between projectiles and cutting. There is no correlation between microlith form and function at Kharaneh IV, with microlith types being used for several different functions. Trapeze-rectangles and unbacked trapezes were not used for different tasks and functioned as projectile inserts, cutting tools, and scraping tools. Diagnostic impact fractures occur as parallel fractures (14.3%) and oblique/perpendicular fractures (85.7%). The majority of the geometric microliths have the latter type of fractures, indicating that they were not used as tips for arming projectiles. Non-projectile functions include cutting meat and hide, butchering activities with bone contact, and working hard materials.

Comparing the functions between the three sites, it is clear that Kharaneh IV had the highest frequency of projectile use (Figure 37). Although the archaeological deposits at Kharaneh IV have clear evidence of activities outside of hunting, the microlith functional analysis suggests that these tools were a large part of the hunting tool kit. If Kharaneh IV is an aggregation site, this suggests that groups coming to the site had less flexibility in their use of microliths than did the occupants of ‘Uyun al-Hammâm or Wadi Mataha. In addition, the high frequency of projectile use at Kharaneh IV could be a reflection of increasing focus on gazelle hunting at the site, at witnessed in high frequency of gazelle remains in the faunal assemblage (Martin, et al., 2010).

The distribution of diagnostic impact fracture location on the projectile inserts for each site shows some interesting patterns (Figure 38). At Wadi Mataha, there is a clear divide between the use of non-geometrics as projectile tips and geometrics in other hafting configurations. This functional segregation of non-geometric and geometric microliths has also been recorded for microliths from the Belgian Mesolithic site of Verrebroek, where non-geometric microliths were used as tips and geometric microliths were used as barbs (Crombé, et al., 2001). The same pattern is not present at ‘Uyun al-Hammâm or Kharaneh IV. In contrast, the geometric microliths from ‘Uyun al-Hammâm and Kharaneh IV are almost exclusively used as barbs, lateral elements, oblique tips, or transverse tips, where non-geometrics are used in all hafting arrangements. This suggests that non-geometric microliths had a different role in the projectile technology at Wadi Mataha than it did at the other sites.

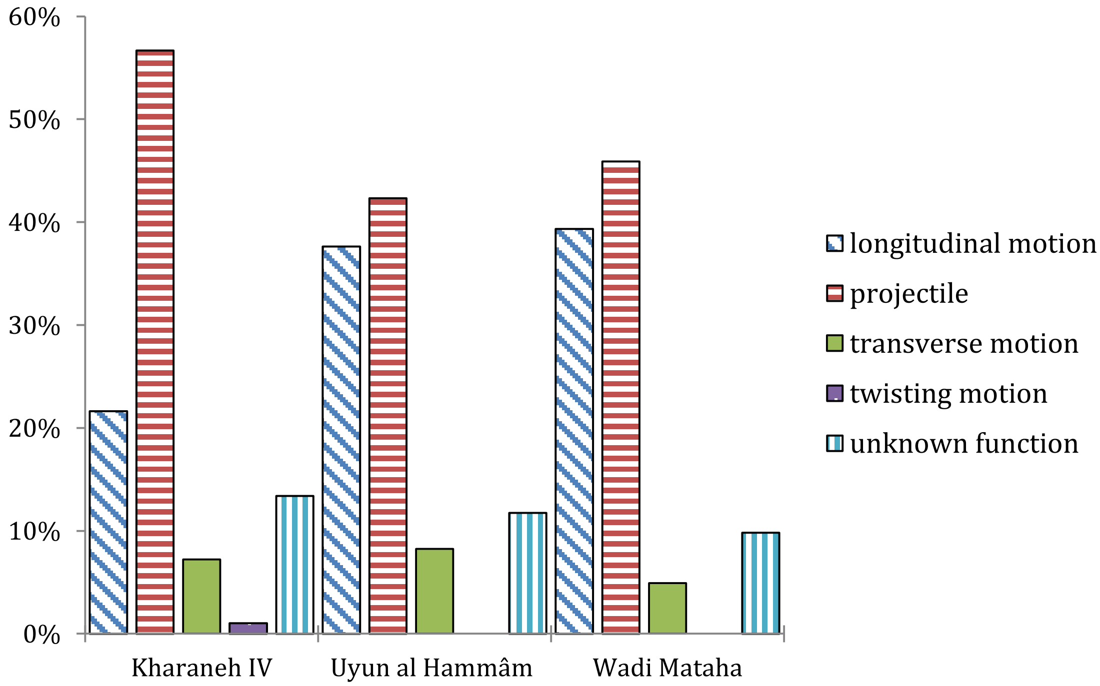


Figure 37: Frequency of functional actions at Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV

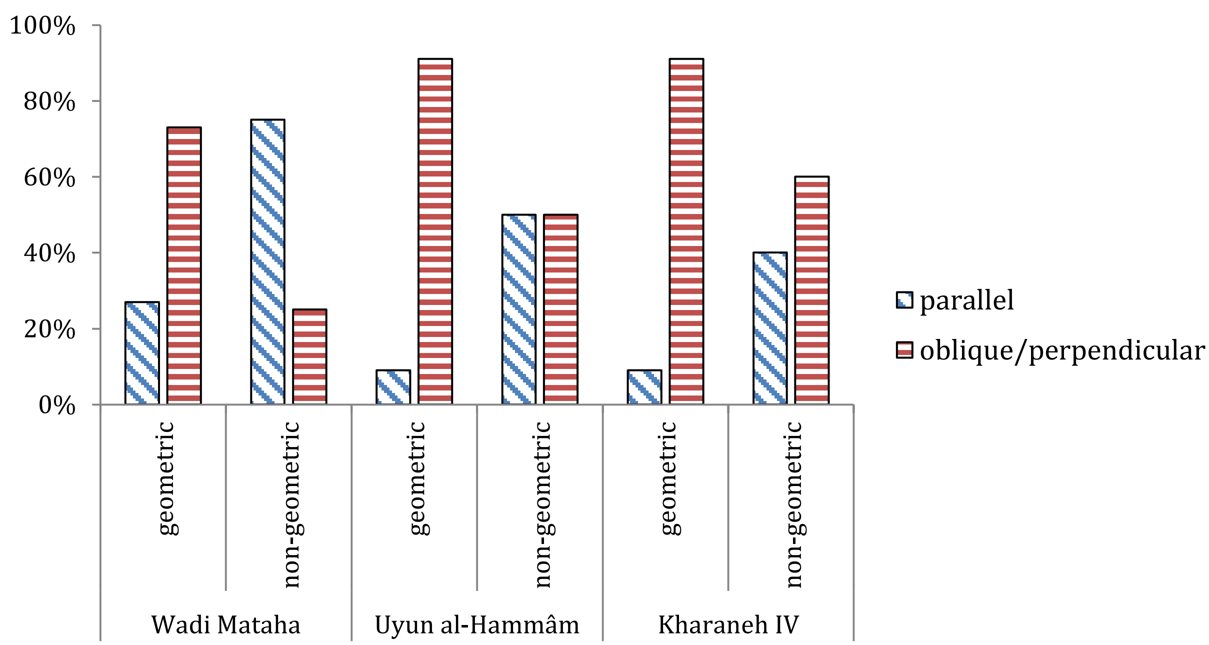


Figure 38: Frequency of diagnostic impact fracture location on geometric and non-geometric microliths from Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV

The use-wear analysis of Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV fits with patterns seen in previous research. The frequency of microlith use for Wadi Mataha and ‘Uyun al-Hammâm fall generally within the pattern seen in Natufian assemblages (Richter, 2007). However, the frequency of use for Kharaneh IV is higher. This suggests that microliths were being more heavily used at this site in comparison to the other locations. This does not relate to raw material availability, as high quality raw material is available in the immediate vicinity of Kharaneh IV. Therefore, this suggests different patterns of behaviour between Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV, with the inhabitants of the latter site using their tools more intensively.

Studies of Natufian microliths have presented diverse interpretations about the functional uses of microliths; research has shown that use has ranged from projectiles, to cutting tools, to segments for harvesting equipment (e.g., Anderson and Valla, 1996, Richter, 2007). Currently published research of Geometric Kebaran microlith assemblages has focused on the use of microliths as projectiles, to the detriment of other functions (e.g., Shimelmitz, et al., 2004, Yaroshevich, et al., 2010). The analysis from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV suggests that the microliths from these Geometric Kebaran assemblages were used for multiple functions. Although extensive experimental work was conducted to create a reference sample for harvesting traces, none were found in the microlith assemblage. This suggests that if the Geometric Kebaran groups were collecting, they were not using microliths for the task. Furthermore, there is no correlation between the function of a microlith and its typological class. This fits within the general pattern seen in later Natufian assemblages, where microliths were functioning in multiple ways and were used to perform multiple tasks. Previous use-wear analysis shows evidence of microliths being used both in harvesting implements and in projectiles during the Natufian. This suggests that they adapted a known technology, microliths, to perform new tasks such as harvesting.

The results of low- and high-powered use-wear analysis reveal interesting patterns of how microliths functioned during the Middle Epipalaeolithic. However, several of the polish types, particularly the hard material polishes, were not identifiable to a specific contact material. Further information into the specifics of these contact materials is important for our understanding of potential ‘craft’ activities undertaken by Geometric Kebaran groups, such as manufacture of bone tools and ornaments, shell beads, and wooden objects. The following chapter explores a new method of use-wear analysis which has the potential to tease out differences in polish types through the quantification of surface roughness. Although this method is still in development, preliminary results conducted on the experimental assemblage (presented in Chapter 5) are very promising.

Chapter 8
Use-wear Quantification

8 Introduction

As the field of use-wear analysis has developed, so has the number of techniques that address tool function. Several new methods have been published in recent years, incorporating both qualitative and quantitative approaches. In this chapter, I will present a recent development in quantitative microscopy, specifically the Alicona InfiniteFocus microscope, and its applications to lithic micro-wear analysis. The Alicona InfiniteFocus microscope characterizes surface texture and has the ability to generate measurements of surface roughness, particularly useful for lithic use-wear studies. The application of this microscope to the quantification of use-wear is explored through the analysis of an experimental collection of lithic tools used on known materials. The results suggest that the microscope is a promising new technology that can contribute to the further development of lithic use-wear quantification.

To begin, this chapter introduces key issues within the current practice of archaeological use-wear analysis and how quantification can contribute to the field. Next, the history of quantitative use-wear analysis is presented, followed by a description of the Alicona InfiniteFocus microscope. A description of the methods used for this work is detailed and the surface parameters chosen for analysis are outlined. The results from study of the experimental tools are discussed in context of the applications of the microscope. Finally, future directions of research with use-wear quantification are discussed, highlighting areas where the Alicona InfiniteFocus microscope can contribute to the growing discipline of use-wear analysis.

8.1 Quantitative and Qualitative Use-Wear Analysis

As seen in previous chapters, the technique of use-wear has traditionally relied on the qualitative observations of specialists who identify wear patterns microscopically. The ability to recognize visual differences between types of wear is a highly specialized field, requiring the use of experimental reference collections to interpret archaeological assemblages. Within the current literature, most authors suggest that the combination of low- and high-powered approaches provides a more holistic picture of tool function than the use of a single method alone (e.g., Lemorini, et al., 2006, Richter, 2007, Rots, 2008, van Gijn, 2010).

However, qualitative use-wear analysis is vulnerable to observer error and conflicting interpretations among analysts. Numerous researchers have conducted blind tests with variable degrees of reliability and reproducibility (e.g., Moss, 1987, Newcomer, et al., 1986, 1988, Odell and Odell-Vereecken, 1980, Rots, et al., 2006). Some of these tests have produced very positive results, while others have shown that there is a high degree of variability among use-wear analysts' interpretations of wear features. As a result, interpretations made by different researchers greatly influence and impact research outcomes and this causes difficulties when attempting to compare results from assemblages analyzed by different researchers. Table 50 shows results from published blind-test studies, where analysts were asked to identify the contact material and motion of working on sets of experimentally produced tools (reproduced from Evans and Macdonald, 2011). As the table indicates, there is little consistency in the identification of materials (48% correctly identified), while motion is identified correctly 73% of the time. Thus, the current qualitative method for identifying contact material needs refinement to increase its success rate. It is in this aspect that quantification can contribute to the field of use-wear analysis.

Table 50: Percent of correctly identified materials and motions based on published blind-test studies (reproduced from Evans and Macdonald 2011)

	Correct Score	
Test	**Material (%)**	**Motion (%)**
Newcomer and Keeley (1979)	43	75
Odell and Odell-Vereeken (1980)	40	68
Gendel and Pirnay (1982)	65	91
Tübingen (1986)	42	55
Newcomer et al. (1986)	16	43
Bamforth et al. (1990)	58	83
van den Dries (1998)	40	76
Rots et al. (2006)	79	91
Average correct score	**48**	**73**

In addition to qualitative methods, recent studies have been taking a quantitative approach to lithic microwear analysis, using new technologies that generate measurements of surface topography, polish brightness, and profile paths across surface features (e.g., Anderson, et al., 2006, Evans and Donahue, 2008, González-Urquijo and Ibáñez-Estévez, 2003, Kimball, et al., 1995, Stemp and Stemp, 2001, Stevens, et al., 2010). These papers use a variety of instrumentation methods to understand the characteristics of surface roughness, including laser-scanning confocal microscopy (Evans and Donahue, 2008, Stemp and Chung, 2011), laser profilometry (Stemp and Stemp, 2001, 2003), optical interferometry (Anderson, et al., 2006), and atomic force microscopy (Faulks, et al., 2011, Kimball, et al., 1995). In these studies, the authors focus specifically on the analysis of polished surfaces, operating under the principle that different contact materials (e.g., hide, wood, and antler) have surface characteristics that are distinguishable from each other on a microscopic scale. When these contact materials interact with lithics they react with and cause modification to the surface of the lithic. Surface wear will have different textures based on the contact material, because each material has a different surface texture and material hardness. For example, harder contact materials will produce a smoother surface on the used portion of the lithic, as they influence the lithic surface to a greater degree than would a softer material.

The future development of quantitative analysis has the potential to allow greater comparability among tools, assemblages, and the results of different researchers. In combination with qualitative research, quantitative analysis can provide a robust understanding of lithic tool function.

8.2 History of Use-Wear Quantification

Some of the earliest attempts at quantifying use-wear on lithics used grayscale analysis on images of surface polish (Grace, et al., 1985). In Grace's early studies, images of experimental lithics were captured by photography and histograms were generated to represent wear statistically on the basis of brightness of polish (as grey scales). To characterize each polish type, Grace compared each pixel to the neighboring pixels, developing grey levels for the images. He aimed to quantify the texture of the used surface, with rougher surfaces having greater differences in the neighboring grey levels and smoother surfaces having less difference. The results of the study showed that the grey-scale images of the different polish types had significant overlap and Grace et al. concluded that, although the technique seems promising, further work was needed.

Later studies by Knutsson (Knutsson, 1988, Knutsson, et al., 1988) built on the work by Grace and colleagues by trying to correlate the manual identification of polish with digitized pictures of wear. As with Grace's method, images were converted to grey scales and each pixel's grey levels were compared to the neighbouring pixel to analyze the texture of the image. The results show a separation between groups of unused, vegetable, wood, hide and antler working tools. However, although there was separation, there was also overlap between the wood, antler, and plant tools, and the unused and the hide tools. The final results show that there are three different texture groups: bone, wood/antler/plant, and unused/hide.

Vila and Gallart (1993) also used image analysis by examining the bright areas (polished surfaces) on photomicrographs, excluding darker areas thought to be unworn. They analyzed tools used on five different contact materials (wood, bone, antler, hide, and grasses) and unworked tools, and were able to show differences between pairs of contact materials using t-tests.

More recent work by Gonzalez-Urquijo and Ibanez-Estevez (2003) used an approach similar to that of Vila and Gallart (1993). In their study, the authors evaluated the grey scale of pixels on digitized images, looking at the texture, pattern of distribution, and the degree of development of the polished areas. Specifically they were interested in the degree of polish linkage (how connected the polished areas are), the size, and the morphology of the polished areas. Through this research, they were able to show that polish pattern was a good indicator of contact material.

Image analysis has been used in other ways, including investigating the fractal properties of microwear polishes. For example, Rees et al. (1991) conducted experiments to determine whether flint microwear polishes have fractal properties and to ascertain whether there are quantifiable differences in calculated fractal dimensions for microwear polishes produced by different worked materials. The authors used grey-scale image analysis based upon previous image analysis publications. Their results suggested that both polished and unpolished flint surfaces have fractal properties and that most polished flint surfaces have a lower fractal dimension than unpolished flints. However, different contact materials did not produce differences in the fractal dimension. Therefore, this method was successful at determining the differences among polished and unpolished surfaces, but not for determining differences among polishes.

Recent image analysis includes the measurement of surface features on scanning electron microscope (SEM) images. Although these measurements are not attempting to describe surface texture, surface features can still be quantified in two dimensions. For example, research by Goodale et al. (2010) measured the thickness of blade edges to determine the intensity of use and the curation of harvesting tools, showing that thick edges result from sickle elements being used for more than 16 hours.

Image analysis has also been used to characterize surface textures of different raw material types (Lerner, 2009, Lerner, et al., 2007). For this research, Lerner uses SEM images imported into ClemexVision Professional Edition image analysis software to quantify the texture of different non-flint raw material surfaces after use. In the software, images are converted into binary format and features of the tool's surface, such as the degree of rounding and the invasiveness of polish, are measured. Perhaps the most influential aspect of this work is its contribution to understanding how raw material affects the development of polish and the degree of wear visible on different tools. Lerner's work highlights the importance of assessing and reporting raw material type when conducting use-wear studies.

Other recent research into image analysis includes the use of rotated image with maximum average power spectrum (RIMPS). This system characterizes surfaces by using digitized images to detect the directions of surface topography patterns that can then be quantified using statistical packages (Alvarez, et al., 2011). Using the RIMPS method, Alvarez et al. (2011) show differences between contact materials as they conclude that wear produced by harder materials is concentrated at topographic peaks while that from softer materials also affects valley bottoms.

Finally, red laser He-Ne has been used to collect data from gloss on sickle elements that can then be analyzed using methods similar to image analysis (Vardi, et al., 2010). In this study, the authors analyzed the reflection of polish from archaeological tools interpreted as harvesting tools. These reflections were then transformed into grey-scale images and flattened into two-dimensional histograms. The results show that very glossy blades reflect a narrower scatter beam and have taller curves in comparison to less glossy blades.

In addition to image analysis, several early studies attempted to quantify use-wear by directly measuring the surface of the tool. One of the earliest studies incorporating the direct measurement of surface characteristics was the work by Beyries et al. (1988). Here the authors used a roughometer to characterize use-wear observations and to understand the differences among wear types. Their study showed that different types of polish produce different average roughness measurements and that the differentiation among polish types is possible with quantitative methods.

Other early research into direct surface characterization by Anderson et al. (1998) used an optical rugosimeter to measure worn areas in three-dimensions. In this study, measurements of lithic surfaces were made on four randomly selected areas, two from unused areas and two from used areas on the tool's surface. The computational software Toposurf was used to calculate several surface characteristics, including average peak, average valley, developed surface, and bearing area. Their results showed that the nature of the raw material has an influence in optical microscopy and in quantified texture analysis on the microtopography. Furthermore, the bearing area parameter is always greater on the used portions of the tool in comparison to the unused portions, suggesting that this would be a useful parameter for distinguishing worn surfaces.

Profilometry techniques characterize surface texture along a two-dimensional profile, or cross-sectional path, along the used surface of the tool. These methods have been used by a several researchers to quantify surface characteristics, but especially by James Stemp (2009, 2001, 2003). Stemp uses laser profilometry, a non-contact form of profilmetry that calculates profile paths across a surface based on a laser path rather than a contact stylus, to quantify polished areas on tool surfaces. His experimental work has addressed several archaeological questions, including how wear accrues over increasing stroke counts using pottery and wood as contact materials (Stemp and Stemp, 2003) and whether different contact materials can be distinguished by their fractal properties (Stemp, et al., 2009). Using scale-sensitive fractal analysis and length-scale plots, Stemp was also able to show that roughness from use happens frequently below 0.1 mm (and always below 1 mm). This indicates that roughness needs to be measured at very small scales to differentiate among materials (Stemp, et al., 2009).

Astruc et al. (2011) conducted recent work using profile measurements to understand the manufacturing techniques employed to create a rare obsidian bracelet found at the Aceramic Neolithic site of Aşikli Höyük. In this study, the authors extracted profiles of the bracelet at 1mm intervals to reconstruct its overall symmetry. They also evaluated the mean roughness for various areas on the bracelet to see if they corresponded to different manufacturing stages. The results indicate that three different techniques were used to shape and finish the bracelet, suggesting that the crafts-person who produced the bracelet was highly skilled. Furthermore, they suggest that the skill level required training and, although this find is unique so far, likely there would have been more of these artifacts in prehistory. This work moves beyond the identification of contact material, integrating elements of technique and skill to employ quantitative data for interpretation of social processes.

In another case of research on surface profiles, Anderson et al. (2006) used a vertical-scanning interferometer to access the development of wear produced by wheat on flint blades from a tribulum. First, they scanned a blade with the interferometer and extracted a profile. Then they used the blade in controlled cereal-cutting experiments and rescanned it across the same profile to identify the processes by which wear develops on the tool. The results showed that the profile had been smoothed after use and that the valleys in the surface had been filled, indicating that part of the contract material was deposited on the tool's surface.

Dumont published earlier work using an optical interferometer (1982) to measure striations on the surface of lithics. This goal of this work was to differentiate between polish types based on the assumption that different polishes have distinguishable microtopographies. In this study, Dumont surmised that hard contact materials exhibit more 'point pressures' because they do not deform over the surface of the flint. Other studies using more updated interferometry techniques include the use of white-light interferometry. This has recently been used with great success to evaluate techniques of stone vase manufacture in Bronze Age Crete (Vargiolu, et al., 2007).

Research into use-wear quantification has shifted to the exploration of surface texture in three dimensions, evaluating areal characteristics rather than profile paths. Early work by Kimball (Kimball, et al., 1998, Kimball, et al., 1995) focused on the use of atomic force microscopy (AFM) to characterize surface texture. They looked at experimental tools used for one hour each on meat, dry hide, wood, and antler contact materials. Ten 1x1 µm areas were selected for roughness analysis, five from peaks and five from valleys within a 255 μm^2 area. The results of the analysis show that hard contact materials smooth the tool surface more than softer materials, providing a small average roughness value.

More recent work by Faulks et al. (2011) further explores the utility of AFM for lithic use-wear analysis. These researchers address the question of whether AFM can determine polish formation. However, they operate under the assumption that visual qualitative methods are adequate for determining contact material. Combining high-powered microscopy methods with AFM, the authors analyzed six different polishes produced from different contact materials (bone, dry hide, fresh hide, wood, meat and hafting polish) on Mousterian tools from the site of

Weasel Cave, Russia. The AFM images were 50 µm x 50 µm (512x512 pixels) in size and the researchers use the microscope's proprietary software to calculate the average roughness of the peaks, valleys, and slopes using approximately ten different 2 µm x 2 µm areas. The results of the study show that all of the polishes, except for those resulting from dry hide, have lower average roughness values than the unused flint polish. Meat and dry hide were the least developed polishes while bone and wood were better developed.

Several studies have shown the potential of the laser-scanning confocal microscope for use-wear quantification (Evans and Donahue, 2008, Evans and Macdonald, 2011, Stemp and Chung, 2011, Stemp, et al., 2012). These studies have highlighted the utility of this technique for determining the roughness characteristics of polishes caused by different contact materials. Research by Evans (2008) using the Olympus LEXT 3100 laser-scanning confocal microscope showed that different contact materials produce clearly different average roughness values. Unworked artifacts had the most variable, roughest surfaces. Greasy hide and dry hide produced the next roughest signatures, and could not be distinguished statistically at the smaller scale, but could at the larger scale. Fresh hide was next and could be distinguished at the smaller scale, but not at the larger scale. Antler and wood produced the smoothest surfaces and separate very well from the hide.

Stemp and Chung (2011) build upon Stemp's (2009) previous fractal work by evaluating the fractal properties of areal surfaces, rather than profile paths. Using the Olympus LEXT OLS4000 laser-scanning confocal microscope (LSCM) the authors showed that the LSCM was useful for documenting surface textures of obsidian tools at lower magnifications of 20x. Furthermore, fractal analysis was able to discriminate between the contact materials of hide and wood, but shell posed some difficulties.

Another study using a LSCM, in this case a NEAT ORU Spectral Imaging FluoView FV1000, worked under the assumption that different contact materials produce distinct quantitative signatures (Stevens, et al., 2010). In this work, the authors present use-wear data in the form of probability statements that report on the use of the tool and the certainty of the attribution. Their aim was to combine quantitative data on use-wear polishes with qualitative data on edge damage to arrive at a multivariate approach to classification. Results showed good probability of correctly identifying contact materials, but they are not comparable with other quantitative studies as Stevens et al. do not measure the same surface parameters.

White-light scanning confocal microscopy has been used to identify wear on teeth with great success, but has not been used on lithic samples. For example, Scott el al. (2006, 2005) used the surface parameters of complexity, anisotropy, heterogeneity, and textural volume fill to differentiate surface textures of teeth among different primate species. These measurements on modern species were then used as an analogy to conclude that *Australopithecus africanus* microwear is more anisotropic, meaning that they ate more tough foods than *Paranthropus robustus*, whose teeth exhibited a more complex microwear pattern produced by a diet of hard and brittle foods.

Although there are currently no published studies using the Alicona InfiniteFocus microscope for lithic analysis, there have been a few studies using the microscope for the analysis of faunal remains and human teeth. Research into the morphology of cut marks on faunal remains has shown very promising results (Bello, et al., 2009, Bello and Soligo, 2008). This work has focused on evaluating various parameters associated with cut marks, including the slope angle, the opening angle, bisector angle, shoulder angle, and floor radius of a cut to determine characteristics of the cutting tool and hand position. Results have shown that force and tool edge angles differed between the researchers' experimental work and the cut marks produced by *H. erectus* at the Boxgrove site, England. In addition, the Alicona InfiniteFocus microscope has also been used to measure profile paths of perikymata ridges to quantify the growth and development of human teeth (Bocaege, et al., 2010). My research explores the application of this microscope for lithic use-wear studies, building upon previous research conducted in the quantification of lithic use-wear analysis.

8.3 Surface Metrology and the Alicona InfiniteFocus

Many of the new microscopy technologies employed by archaeologists for use-wear quantification, including the Alicona InfiniteFocus microscope, were designed for surface metrology applications in the field of engineering. Surface metrology is the measurement of deviations on a surface (Whitehouse, 2011) characterizing surface texture. Traditionally, surface metrology has been used to study machined and engineered surfaces, evaluating deviations produced through manufacturing processes and wear. However, it has recently been applied to more interdisciplinary fields such as anthropology and archaeology, evidenced in the studies mentioned in the previous section.

The field of surface metrology is currently undergoing exciting changes in areal definitions (three-dimensional parameters), including the development of a new ISO standard (25178). This standard defines the parameters of three-dimensional surfaces, including parameters useful for characterization of lithic use-wear (Table 51). Microscopes currently being used for archaeological applications, such as laser-scanning confocal microscopy and the Alicona system, adhere to these standards of surface characterization. In addition, new developments in the field of micro- and nano-metrology are greatly contributing to the traceability and calibration of these instrumentation types (Leach 2010). The integration of knowledge from both surface metrology and nano-metrology, in conjunction with the practice of qualitative use-wear analysis, will help propel the study of quantitative use-wear analysis forward.

Table 51: Areal surface parameters (ISO 25178)

Parameter	Description
Sa	Arithmetical mean height
Sq	Root mean square of mean height
Sv	Maximum pit depth
Sz	Maximum height of the scale limited surface
Sdq	Root mean square gradient of the scale limited surface
Sdr	Developed interfacial area ratio of the scale limited surface
Smr(c)	Area material ratio of the scale limited surface
Sdc (mr)	Inverse areal material ratio of the scale limited surface
Sxp	Peak extreme height
Vv (mr)	Void volume
Vvc	Core void volume of the scale limited surface
Vmc	Core material volume of the scale limited surface

8.3.1 Surface Roughness Parameters

As mentioned previously, the Alicona microscope has the ability to take measurements useful for a variety of surface metrology applications. Included in these measurements is average roughness, or *Sa*, defined as the mean height of a selected area, and *Sq*, the root mean square of the mean height (ISO 25178). Unlike *Ra*, which is the average roughness on a two-dimensional plane and is used in profilometry measurements (Figure 39), *Sa* calculates average roughness in three-dimensions. This areal measurement is useful for the quantification of wear features, as it is less sensitive to small variation in surface texture.

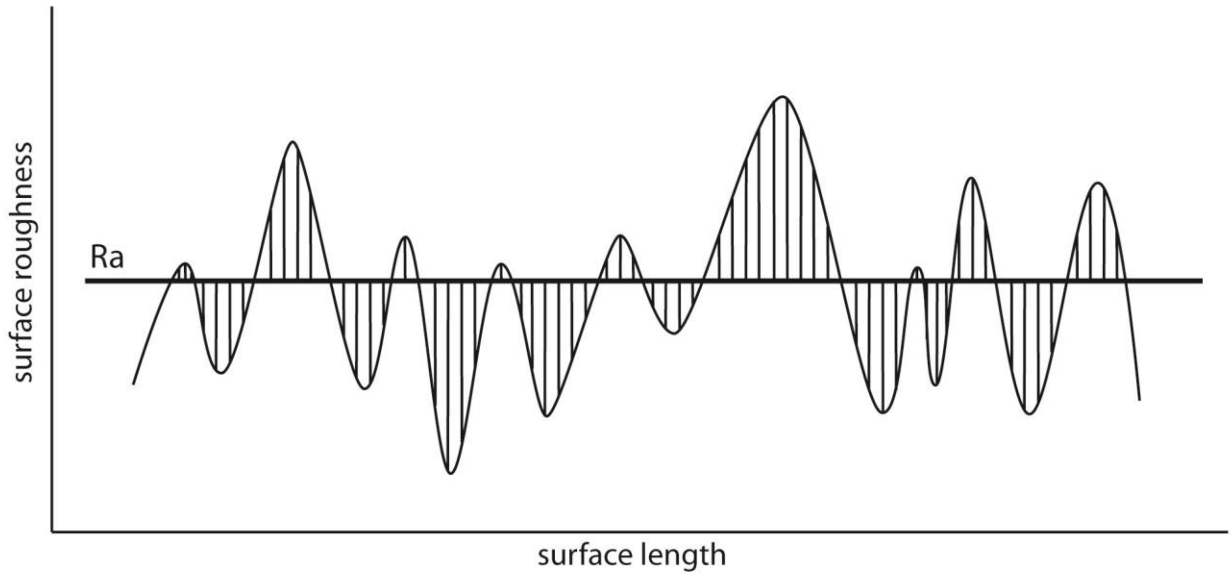


Figure 39: Schematic of *Ra* (mean roughness) calculation across a surface profile path (surface length). Average roughness is calculated by finding the average deviation of the peaks and valleys, indicated in the shaded area. The horizontal mid-line represents the average roughness, *Ra*, of this surface.

The use of *Sa* and *Sq* to identify contact materials has been successful in previous studies (Evans and Donahue, 2008, Evans and Macdonald, 2011, Giusca, et al., 2012) and it is hypothesized that different contact materials will produce different *Sa* and *Sq* values on the surface of stone tools. For this study, I have chosen to evaluate the differences in *Sq* between contact materials because of its previous success in lithic use-wear quantification studies, making my research comparable with the published literature. However, future investigation is required into other areal parameters to assess whether there are different measurements that are more suitable for distinguishing wear.

8.3.2 Alicona Infinite Focus Microscope

The Alicona InfiniteFocus Microscope is a new technology that has the potential to contribute to the field of lithic use-wear quantification (Figure 40). The high resolution of images and the numerical data generated by this microscope allows cross-comparison of surface features among different tools. As mentioned previously, this microscope has been used for archaeological applications relating to dental studies (Bocaege, et al. 2010) and faunal analysis (Bello, et al. 2009; Bello and Soligo 2008), but its applications for lithic use-wear studies show great potential that, until now, remains untested.

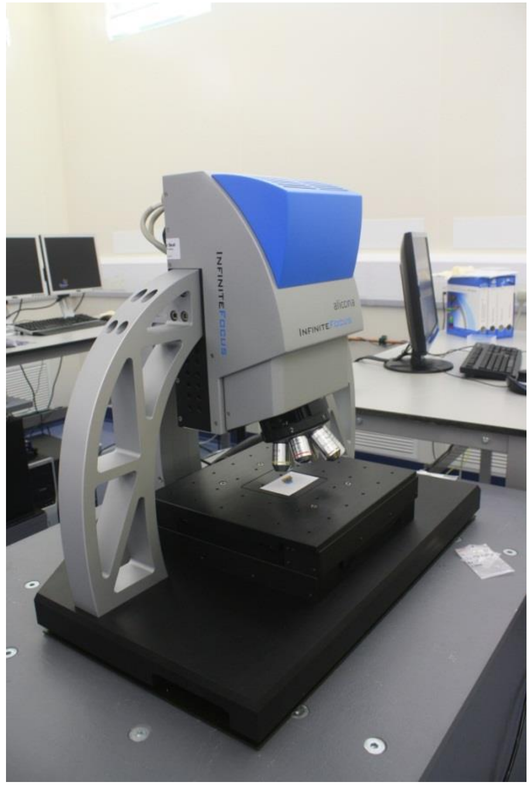


Figure 40: The Alicona InfiniteFocus microscope with lithic sample on the stage

The Alicona InfiniteFocus microscope is based on the principle of Focus Variation (Danzl, et al., 2009) where the microscope lens is moved away from the specimen, allowing images to be captured at difference focal planes. The depth of each in-focus slice is calculated from the light refraction back to sensors in the microscope. Thus, the surface topography is calculated through the in-focus depth of each plane and a composite image is generated from the in-focus slices (Helmli, 2011). Currently, the Alicona is one of the few commercial microscopes on the market that use Focus Variation for the acquisition of surface-texture data.

The principle of Focus Variation has been described in a recent volume edited by Helmli (2011), the head of Research and Development at Alicona. The following section summarizes these principles as outlined by Helmli in reference to the Alicona InfiniteFocus microscope. To create a three-dimensional image, the microscope searches for the best focus related to a known distance from the sample. This system of image capture is performed for numerous lateral positions, generating a topographic map of the tool's surface. With the Alicona microscope, the lateral resolution can be set to as fine as 3 nm at the higher magnifications, creating a highly detailed topographic model. The image is acquired by moving the microscope vertically in relation to the object, bringing the object in and out of focus. The sensor within the microscope identifies and measures where the object was best in focus. This is then repeated at sequential lateral positions to build an image. The sensor then evaluates the region around each pixel to calculate the standard deviation of the grey levels of the local region, thereby measuring the focus. If the focus is very low or very high, the grey values are almost identical with a low standard deviation. Focus variation for different types of light sources can be used to collect information, not just coaxial illumination used by techniques such as image confocal microscopy. Light types available for this system include ring light, dark field illumination, diffuse illumination, point light source, and coaxial illumination. This allows different sample types to be imaged.

The Alicona microscope has a motorized stage that moves in the *xy* directions, while the microscope objectives move in the *z* direction. The microscope has a vertical range of 100 mm, making it excellent for highly variable surfaces. The available objectives range from 2.5x-100x magnification and have a vertical resolution of up to 10 nm, but increasing the vertical resolution also increases the scan time. The Alicona microscope generates three-dimensional images of surface topography, useful for optical surface metrology applications such as surface roughness measurements, profile path measurements, and visual details of topographic features. In addition to its applications for surface metrology, the microscope produces high-resolution images with a good depth of field. This eliminates the challenges of many other microscopy techniques where the depth of field limits the ability to assess topographic features. The microscope is non-contact and any surface can be analyzed with no sample preparation. This is particularity useful for archaeological materials, as the technique is non-destructive.

Although the Alicona InfiniteFocus microscope has a lot of strengths, the technology also has limitations in comparison to other techniques. Translucent materials cause significant problems when acquiring a focus variation measurement. Although replicas or coatings can be used to counteract this problem, it is not always possible to replicate or modify the object. Also, because the microscope measures a range of focuses, there needs to be sufficient contrast on the sample's surface to obtain a measurement. Thus, the microscope has difficulties obtaining measurements from highly polished or smooth surfaces. The surface must have a level of roughness and a surface texture >15 nm is required to obtain a measurement (Helmli, 2011).

8.4 Methodology

8.4.1 Experimental Methodology

For quantitative analysis, experimental tools used on five different contact materials were analyzed. These tools were chosen from the experimental assemblage described in Chapter 6. The chosen contact materials were antler, wood, hide, meat, and wheat. Unworked surfaces were also included in the analysis to create a control sample. Two different experimental tools for antler, hide, and meat were included in the analysis. Unfortunately, due to limitations in accessing the microscope, only one experimental tool was included for both wood and wheat. Details about the experimental tools included in this analysis are summarized in Table 52.

Prior to analysis with the Alicona, each tool was thoroughly cleaned using methods adapted from Keeley (1980). First, each piece was cleaned with warm water and a mild detergent while being lightly brushed with a soft-bristled tooth brush. Next each piece was soaked in a bath of 10% sodium hydroxide (NaOH) for 10 minutes to remove organic deposits. Following this cleaning, the artifacts were soaked in 10% hydrochloric acid (HCl) for 10 minutes to remove any mineral deposits. The NaOH and the HCl were changed after the cleaning of each piece. Finally, the experimental tools were bathed in water for 10 minutes to remove any remaining chemical traces. Although chemical cleaning is not accepted by all use-wear analysts, it was chosen for this study to remove the possibility that the roughness measurements of the tools' surfaces were measuring adhering materials and not measuring actual surface texture. I am currently involved in a study with Dr. Adrian Evans to investigate the impact of widely used cleaning methods on surface roughness measurements, including the described chemical cleaning, cleaning with only soap and water, and cleaning with soap, water and alcohol. This study will shed light on the impact of cleaning methods for use-wear quantification and help standardize sample preparation.

Table 52: Details of experiments included in the use-wear quantification study

Experiment #	Date	Location	Haft	Contact Material	Angle	Direction of Motion	# of Strokes	Additional Comments
EX-4a	17-Aug-11	U of T Lab	hand held	meat	45-90	longitudinal	1000	pig or pork
EX-4b	17-Aug-11	U of T Lab	hand held	meat	45-90	longitudinal	1000	pig or pork
EX-6	17-Aug-11	U of T Lab	hand held	hardwood	90	longitudinal	1000	dry hardwood
EX-9	17-Aug-11	U of T Lab	hand held	antler	45-90	transverse	1000	ventral surface towards the antler
EX-13	17-Aug-11	U of T Lab	hand held	antler	45-90	transverse	1000	ventral surface towards the antler
EX-10	17-Aug-11	U of T Lab	hand held	hide	90	longitudinal	1000	dry hide cutting
EX-11	17-Aug-11	U of T Lab	hand held	hide	90	longitudinal	1000	dry hide cutting
EX-14	24-Aug-11	St. Valleir de Theiy	sickle (Kebara)	einkorn wheat	45-90	longitudinal	12 150	part of larger harvesting experiments

8.4.2 Microscopy Methodology

The samples do not require any further sample preparation after cleaning to obtain microscopic measurements or images and can be mounted directly onto the stage with a piece of plasticine modeling clay. Unlike other modeling clays, plasticine has low elastic properties and does not oscillate once the object has been mounted. Each piece was scanned under the Alicona using the 20x objective to identify areas heavily affected by wear. Once an area was selected, the magnification was increased to 50x. Scans of 286 µm x218 µm were acquired at this magnification (Figure 41). For each tool, a total of five areas were selected along the worn edge at 50x magnification, targeting areas that had the most visible modification from use when assessed microscopically.

Once the scans were acquired, the files were imported into Mountains Map 6.2 for analysis (www.digitalsurf.fr). This software was designed for surface metrology applications and measures areal parameters based on ISO 25178. For this study, I employed the sampling methodology of Evans and Donahue (2008) for the quantification of lithic use-wear using a laser-scanning confocal microscope. On each 286 µm x 218 µm image, ten areas of 10 µm x 10 µm were selected for roughness analysis (*Sq*) (Figure 42). These areas were selected from the areas visibly worn on the larger surface. For each tool, fifty 10 µm x 10 µm scans were collected from the worn areas. Additionally, ten areas of the same size were measured from the unused chert surface just below the areas that had evidence of wear. These were also selected randomly from the unworn surface and were used as a control for the contact material roughness, providing a base roughness for the original raw material.

A series of areal surface parameters, including *Sa* and *Sq*, were collected from each 10 µm x 10 µm scan. Additional parameters were also measured for future research but are not included in this analysis. For this study, *Sq* (root-mean-square of height) was chosen as the parameter for comparison among the contact materials because it is the standard in the field of surface metrology and is especially useful for sinusoidal data. This parameter has also shown potential in recent publications for the quantification of wear (Evans and Macdonald, 2011, Giusca, et al., 2012).

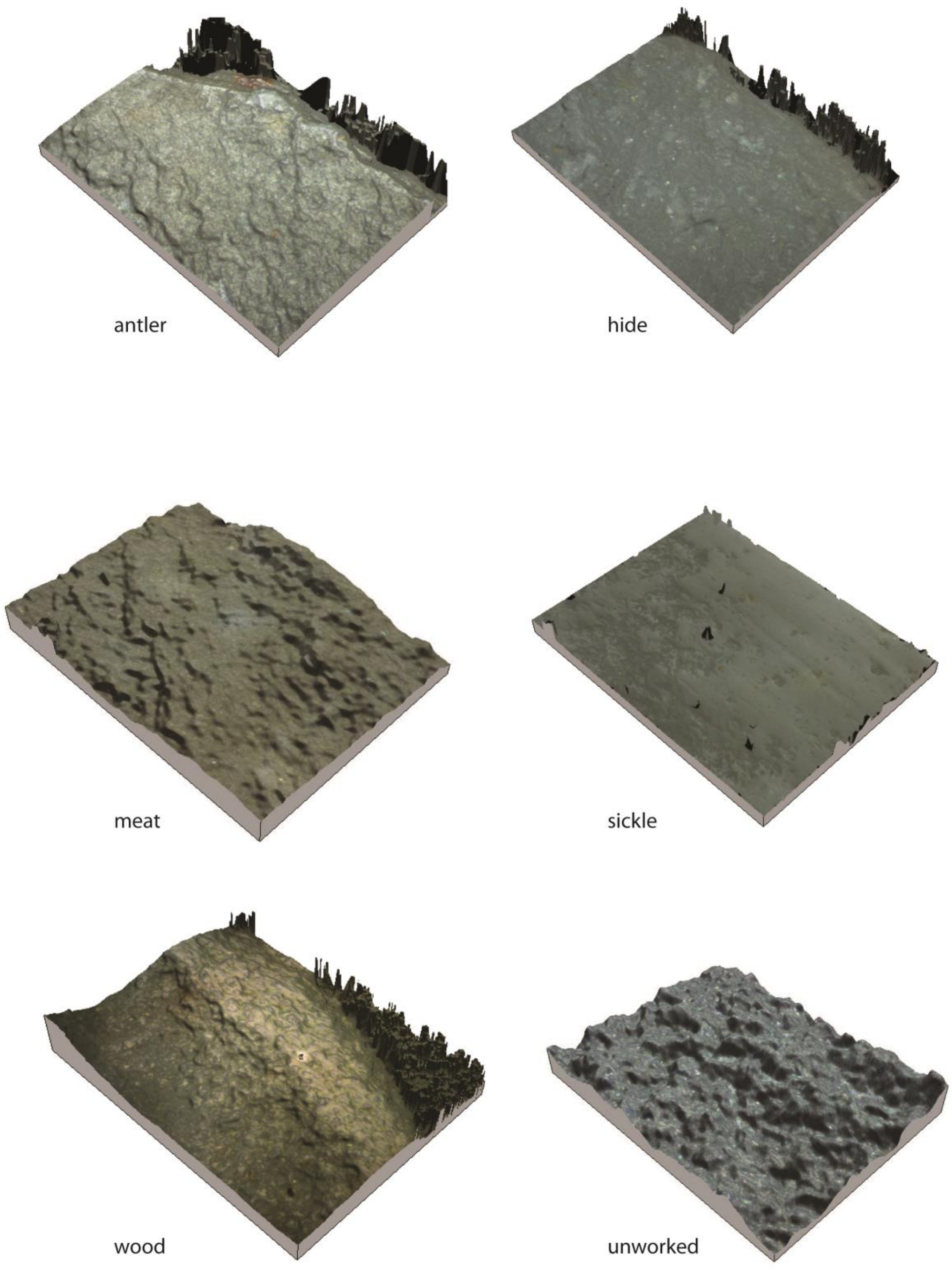


Figure 41: Examples of the images produced by the Alicona microscope for each contact material. The edge of the tool is to the upper right side of the image (black spikes are scans off of the tool's edge).

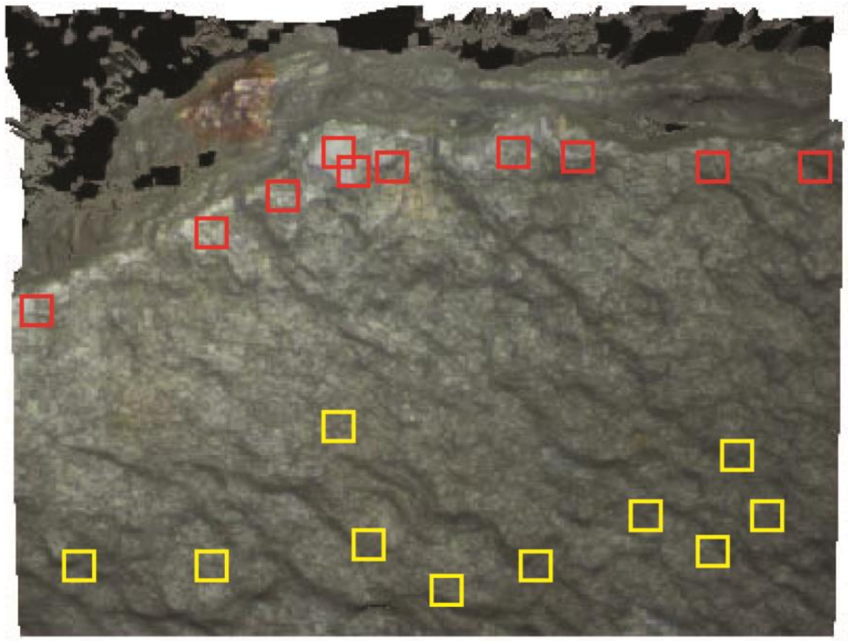


Figure 42: Example of sampling method of 10 µm x10 µm squares from the lithic surface (antler working tool). Red squares are sampled from the polished area and yellow squares are sampled from the unpolished area.

8.5 Results

Prior to analysis of the full assemblage, t-tests were run on the tools in each contact material group to test whether the mean roughness between the tools used on the same contact material were significantly different. This is important to test prior to analyzing the full assemblage to make sure that each contact material is producing comparable roughness measurements. For the antler working tools, a t-test for unequal variance was run between the two tools. The results of the test indicate that the means of the two tools are not significantly different (unequal variance t-test = 0.671, p=0.507). The mean cutting tools also show that the means are not significantly different between the two tools (unequal variance t-test = -1.4025, p=0.166). This is encouraging as it indicates that the same contact materials on different tools produce average roughness measurements that are not significantly different. However, the results between the hide working tools are not as positive. The t-test shows that the means of the two hide-working tools are significantly different (t=4.037, p=<0.001). This suggests that there is more variability in the measurements for hide-working tools. The polish from the hide tools is less developed than that on the harder materials and the variability in measurements may be the results of the less developed polish. It may also be the result of sampling errors where the unworked surface was also sampled due to difficulties in distinguishing polished from un-polished areas.

The results of this analysis indicate that there are significant differences in average roughness among the contact materials (Table 53, Figure 43). The contact material that produced the smoothest surface was wheat, with a mean *Sq* of 0.415 µm. The antler-working tools' surface roughness was 0.472 µm (mean), with the meat producing a slightly rougher signature at 0.545 µm (mean). The two roughest contact materials were wood at 0.982 µm (mean) and the hide at 0.982 µm (mean). In addition, the unworked material roughness produced a significantly rougher signature, with a mean *Sq* of 1.230 µm.

Table 53: Statistics, including mean *Sq*, for each contact material

Contact Material	No. Scans	Min (µm)	Max (µm)	Std. Dev.	Mean *Sq*
Antler	100	0.082	1.610	0.268	0.472 µm
Wood	50	0.278	2.870	0.555	0.982 µm
Hide	100	0.186	2.860	0.498	0.929 µm
Meat	100	0.140	1.840	0.310	0.545 µm
Wheat	50	0.088	1.040	0.239	0.415 µm
Unworked	400	0.088	7.950	1.011	1.230 µm

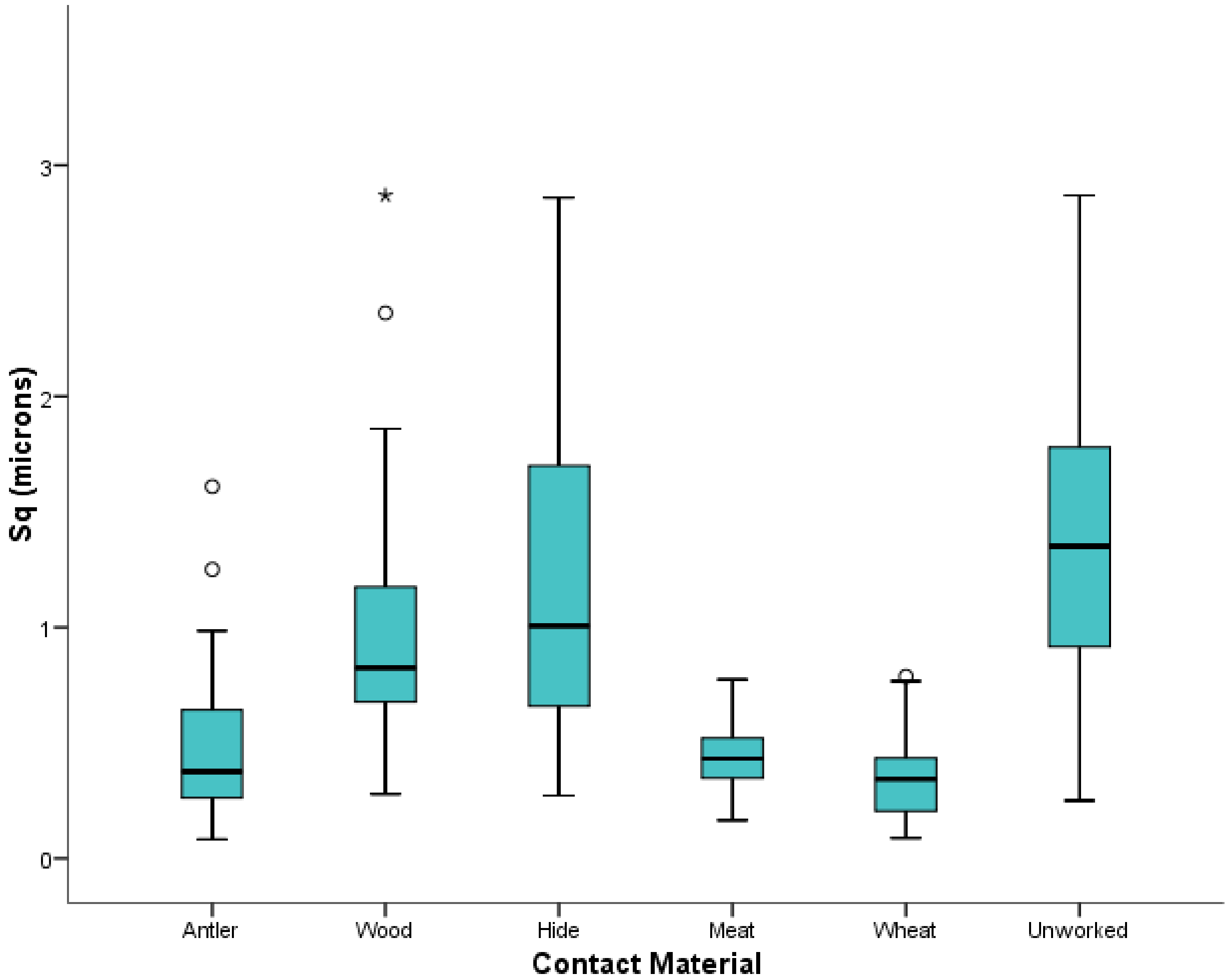


Figure 43: Box-plot showing the *Sq* values for each contact material

The Shapiro-Wilk normality test was run on each distribution. The results of the tests indicated that the distributions were significantly different from normal ($p<0.05$). Therefore the Kruskal-Wallis test was chosen to evaluate whether the means of the six different groups are significantly different. This test is equivalent to the one-way ANOVA for non-parametric data and allows comparison of more than two means.

The results of the Kruskal-Wallis test are presented in the table below (Table 54). Using a 95% confidence interval, the p-values that are significantly different are highlighted in red.

Table 54: The p-values for the experimental collection of tools (significantly different values highlight in red)

	Antler	Wood	Hide	Meat	Wheat	Unworked
Antler	x	<0.001	<0.001	0.052	0.131	<0.001
Wood		x	0.551	<0.001	<0.001	0.657
Hide			x	<0.001	<0.001	0.159
Meat				x	0.002	<0.001
Wheat					x	<0.001
Unworked						x

The results of the analysis show that many of the contact material means are significantly different. Through this method it is possible to distinguish between antler and wood polish, antler and hide polish, antler polish and an unworked surface, wood and meat polish, wood and wheat polish, hide and meat polish, hide and wheat polish, meat and wheat polished, meat polish and an unworked surface, and wheat polish and an unworked surface. However, the differences between antler and meat or wheat polishes are ambiguous, as are the differences between wood and hide polish or an unworked surface. The difference between antler and meat polish is very close to significant, suggesting that the relationship between these two contact materials might be better understood with an increase in sample size. Overall, the results of the analysis indicate that the Alicona InfiniteFocus microscope is able to distinguish some polish textures produced by different contact materials, adding to the growing types of methods useful for lithic use-wear quantification.

8.6 Future Research

The quantification of use-wear is an important step in moving towards new comparative approaches. The Alicona InfiniteFocus microscope is a new tool for archaeological research that can contribute to use-wear quantification through the identification and separation of different polish types. Significant differences are present in the roughness measurements between antler and wood, antler and hide, antler and unworked, wood and meat, wood and wheat, hide and meat, hide and wheat, meat and wheat, meat and unworked, and wheat and unworked. Despite the potential, there are also some important considerations and limitations to quantitative methods. One of the most important issues that analysts need to address is how to determine the scan area. For this study, each 10 µm x10 µm zone was randomly selected at an area where the wear was most developed. This area was determined through observations of the tool’s surface. However, further work is needed to determine the best areas of analysis. Are the results more meaningful on the areas completely modified by wear? Or are they more meaningful on areas where the original tool's surface can be contrasted with the texture produced through use?

The assessment that the surface roughness of the worn areas is a useful parameter for determining contact material is based on previous studies, but this does not mean that it is the only useful surface parameter. The ISO standard includes measurements of volume analysis, maximum peaks, maximum valleys, along with numerous other measurements. A recent study conducted with the National Physical Laboratories, UK, evaluated the evolution of wear as lithic tools were used over increasing periods of time (Giusca, et al., 2012). Included in this study was a secondary aim of finding suitable areal surface texture parameters (ISO/FDIS 25178-2: 2010) that can differentiate between use duration. The results of this experiment showed that in addition to *Sa* and *Sq*, the parameters *Sz, Smr, Smc, Sdq, Sdr* and *Vvc* also were useful in accessing use duration (Table 51). More research is required to understand the nature of these parameters in relation to the identification of contact material.

As shown in the review of previous studies, there are multiple microscopes on the market that have the ability to generate surface roughness values. However, it is not known if the values from these microscopes are comparable with one another. A recently published study to test the comparability of the Alicona and the LEXT laser-scanning confocal microscope (Evans and Macdonald, 2011) showed that average roughness was comparable between the two microscopes when measuring an antler working tool, but there were some unexplained differences in the *Sq* value. This study is currently being expanded to include an experimental collection of hide-scraping tools to increase the sample size. These tools will be evaluated under a LEXT laser-scanning confocal microscope, an atomic force microscope, and the Alicona InfiniteFocus microscope to understand the results of areal analysis among these three systems. Understanding how the results from different types of instrumentation relate to each other is imperative to moving quantitative use-wear analysis forward.

As part of this project, a blind test study is currently being conducted on the LEXT laser-scanning confocal microscope. This study targets the identification of two hard contact materials, wood and antler, which are notoriously difficult to distinguish by use-wear analysis. The results from the LEXT measurements will be compared to the results from an experienced use-wear analyst to determine the potential of surface metrology microscopes for the classification of ambiguous contact material traces.

Finally, further expansion into the field of tribology is needed to understand the characteristics of wear. Understanding the type of wear, whether adhesive, abrasive or other, will help develop the methods needed to understand how and why lithic surfaces are changed during use. This will further our understanding of the parameters needed to test these changes.

8.7 Summary

In conclusion, quantitative methods have the potential to contribute to the growing field of lithic use-wear analysis. While this appears to be a very useful endeavor, it is important to move towards developing best-practice methods for quantitative analysis, including how to choose the area of analysis and the best parameters for characterizing surface features. Finally, the use of qualitative methods of use-wear analysis cannot be divorced from quantitative methods. Choice of the location for analysis and the interpretations made from the results are built upon the traditional use-wear methods. Quantitative methods are not replacements for low- and high-powered microscopy; they are new methodologies to be used in tandem with qualitative research to gain a robust view of lithic tool function. The continued development of this methodology will allow researchers to interpret difficult use-wear traces, thereby gaining further insight into Palaeolithic stone tool use.

Chapter 9
Conclusion: Microliths in the Middle Epipalaeolithic

9 Summary

Interpretations of microlith variability have shaped our conceptions of the Epipalaeolithic. Regional and chronological variability in microlith form has been interpreted to represent distinct culture groups (e.g. Bar-Yosef, 1970, Goring-Morris, 1987, Henry, 1995). This interpretation was challenged by Neeley and Barton (1994) who suggested that microlith form was the result of different reduction stages. Their highly controversial interpretation sparked a storm of debate as people defended the cultural hypothesis (Fellner, 1995a, Goring-Morris, 1996, Henry, 1996, Kaufman, 1995, Phillips, 1996). Despite this debate, functional interpretations of microlith form were not explored as an explanation for variability. This dissertation set out to evaluate microlith variability in the Middle Epipalaeolithic by integrating functional analysis into the debate.

The three sites of Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV contain a range of features and vary in size, suggesting that there were differences in the way these communities inhabited the landscape at the end of the Pleistocene. These differences could relate, in part, to site function, with Kharaneh IV acting as an aggregation locale for several different groups. Despite these differences, all three communities were using the same microlith technology, the trapeze-rectangle, which was widespread in the southern Levant during the Middle Epipalaeolithic. Using multiple methods including typology, technological analysis, morphometrics, and use-wear, differences in visible and non-visible aspects of technology were explored to assess the variability witnessed in material culture at the three study sites.

Initially, I set out to test several hypotheses in regards to the microliths found at Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV. I hypothesized that microliths would have overlapping functions, indicating that function does not drive form. Second, I hypothesized that microliths would show differences in technological style as witnessed through subtle variations in manufacture. Finally, I hypothesized that microliths functioned as sickle elements, suggesting a deep time depth for harvesting behaviours that are found later in the Natufian. These hypothesizes relate back to current debates in Epipalaeolithic research about the nature of microlith variability. Is variation in microlith morphology the product of different technological sequences of production? Or the result of varying function? Or is it the result of different cultural group’s stylistic preferences?

Through the exploration of microlith form, function, and technology, I suggest that the subtle variability witnessed among the Middle Epipalaeolithic microliths results from different learning communities. Using Gosselain’s (2000) interpretations of social identity and the *chaîne opératoire*, I propose that the *concept* of trapeze-rectangles was easily transmitted between groups because of its high visibility, but the details of manufacture vary among communities as these were enacted within a localized and inter-personal context. Thus, the trapeze-rectangle was a wide-spread technology without the need for identical sequences of production or exact duplication in form. People were performing culturally and community-situated gestures that transformed materials into trapeze-rectangles specific to their group.

The third hypothesis, whether microliths were used as harvesting tools, was addressed through use-wear analysis. The analysis shows that microliths were employed for several different tasks at the three sites, suggesting that they could be easily adapted to fit a variety of applications. However, from the sample selected, harvesting was not one of these functions. Further sampling of other tool types, such as retouched blades, is needed to determine if harvesting behaviours were enacted using different tools. The absence of cereal traces on the microliths does, however, indicate that the function of microliths changed over time, with the adoption of a previously used form (geometric microliths) for new uses such as harvesting during the Natufian. This highlights the flexibility of microlith technology as it can be adapted to new applications.

9.1 Integrating Multiple Methods

The methods employed for this research varied from traditional typological analysis to the development of new quantitative microscopy techniques. The integration of quantitative techniques, such as morphometrics and Focus Variation microscopy, allow an increased level of comparability among the assemblages. Furthermore, these methods allow us to access aspects of material culture that were previously unobtainable. For example, morphometric analysis complements traditional metrics to describe shape more precisely. It allows subtle details in form, such as the curvature of the backed edge, and the angles between the retouched ends and use-edge, to be described and compared. Although still in early stages of development, quantitative microscopy can be useful to tease out differences in contact materials that are difficult to identity visually. Details of surface texture at the nanoscale moves beyond what traditional microscopy is able to assess and gives new information on the nature of use-wear polishes. These techniques are useful in combination with traditional qualitative analyses and the integration of multiple methods presents a robust understanding of microlith variation. Using methods that explore technology, typology and function allows us to extend the *chaîne opératoire* beyond manufacture and into later stages of the tool's 'life-history', incorporating the use of the tool.

Lithic use-wear analysis contributes to our understanding of human behaviour in the past through addressing tool function within the *chaîne opératoire*. Classic analyses of the *chaîne opératoire* used refitting and technological studies to understand the manufacturing processes of lithic tools. These studies reconstruct the *chaîne opératoire* by using macroscale data, using the artifact's qualities and properties to understand process within the larger lithic sub-system. However, microwear analysis builds from the microscopic scale outwards to understand tools in their social context. Use-wear analysis brings us further into the non-visible realm, operating on scales of nanometers and microns. This leaves us with the question of how microscale traces can contribute to our understanding of macro-scale phenomena. Can non-visible traces be related to social processes? I suggest that use-wear provides an integral element of the *chaîne opératoire* and that microscopic information can illuminate details of gestures not captured in typological and technological analysis. Traces of use remaining on a tool's surface, such as fractures, polishes, and striations, hint at dynamic movement in the past. Without this information, the later stages of a tool's life-history are lost. It can be argued that when a tool is used it is most visible and active in its social realm, therefore understanding its function brings us closest to the social realm. Lithic microwear analysis has an important place in our conceptualization of the *chaîne opératoire* and, by moving into realms of non-visible data, we can reveal subtle features of human behaviour not captured at the macroscopic scale.

9.2 Microliths in the Geometric Kebaran

Through the analysis of Wadi Mataha, 'Uyun al-Hammâm, and Kharaneh IV microlith assemblages, we can reconstruct a general *chaîne opératoire* of these tools. From a *prescriptive* perspective (Knappett, 2011), the *chaîne opératoire* of Geometric Kebaran trapeze-rectangle microliths can be viewed as follows:

- Acquire raw materials
- Knap blanks for microlith production
- Retouch blanks into trapeze-rectangles
- Haft trapeze-rectangles longitudinally or as barbs or as transverse tips
- Use hafted tools as cutting tools or projectiles
- Discard

This creates a generalized scheme for how microliths functioned across the region. However, we can also take a *descriptive* perspective (Knappett, 2011), focusing on the variability within and among the sites. Through this descriptive lens, details of the fluctuations and changes in material culture are highlighted.

To begin, the reduction strategies for the three sites were primarily focused on the production of bladelets to be retouched into various microlith forms. All three sites used raw materials that were available within the surrounding region, although some material from Wadi Mataha and small amounts of material from Kharaneh IV may have traveled from greater distances. Raw material is plentiful at all three sites, suggesting that there was no need for conservation. The entire reduction sequence was enacted at the sites, evidenced through the presence of cores, core-trimming elements, and debitage, as well as finished tools. The knapping sequence focused on core maintenance rather than core preparation, indicating that the size and shape of the microlith blank did not need to be standardized.

For all three sites, the tools are representative of types typically found in Middle Epipalaeolithic assemblages, including scrapers, burins, and notches. Tool assemblages are dominated by microliths, with an emphasis on geometrics. This pattern diverges at Kharaneh IV, where geometric and non-geometric microliths are evenly represented in the assemblage. However, this may be the result of fragmentation patterns as Kharaneh IV has the highest proportion of fragmentary microliths. ‘Uyun al-Hammâm has the highest frequency of geometrics in the microlith assemblage, primarily composed of trapeze-rectangles. The geometrics at Wadi Mataha are also dominated by trapeze-rectangle microliths. This is in contrast to Kharaneh IV, where the geometrics are represented by both unbacked and backed trapezes. Width evidence suggests that the two different types of microliths at Kharaneh IV might have been part of different reduction sequences. The microliths from Wadi Mataha and ‘Uyun al-Hammâm were backed using invasive retouch. In contrast, the microliths from Kharaneh IV were backed with non-invasive retouch, indicating a very different pattern in retouching traditions in comparison to the other two sites.

Morphometric analysis reveals variability in trapeze-rectangle shape among the three sites. The geometric microliths from Wadi Mataha are elongated with straight to concave backing, the ones from ‘Uyun al-Hammâm are angular with straight to concave backing and have a high degree of variance in elongation, and the trapeze-rectangles from Kharaneh IV have rounded corners, a feature not seen at the other two sites. The variability witnessed in one typological group from three sites suggests that different communities adapted and envisioned these geometric microliths in their own ways. I would suggest that this is because trapeze-rectangles can be considered as a diffuse technology that is easily transmitted between groups with minimal interaction.

Previous experimental and functional studies of Geometric Kebaran sites focused on the application of microliths as projectile insets (e.g., Yaroshevich, et al., 2010). For this dissertation, I focused experimental work on alternative uses of geometric microliths, including their potential function as harvesting or cutting implements. Experimentation using replicated Epipalaeolithic hafts showed that, when hafted longitudinally, trapeze-rectangle microliths functioned very well as cutting tools for cereals and soft materials such as meat.

Use-wear analysis of the three assemblages displays no direct correlation between microlith function and form. At all three sites, microliths preformed numerous tasks, including as projectile insets and as cutting implements. The trapeze-rectangles from Wadi Mataha and ‘Uyun al-Hammâm had almost equal incidences of use as cutting and projectile tools, while Kharaneh IV had a much higher frequency of projectile use. Microliths used as cutting tools were likely hafted longitudinally in the haft, although there is no evidence as to whether there would have been a single blade (similar to the haft from Kebara) or parallel blades (similar to the Wadi Hammeh 27 haft). The pattern of poly-functionality for a single form fits with previous use-wear analyses of Natufian assemblages that suggest lunates were used for multiple purposes. However, unlike Natufian assemblages, there is no evidence for the use of trapeze-rectangles for harvesting in the Geometric Kebaran.

The clearest pattern of projectile use is found at the site of Wadi Mataha, where geometric microliths were primarily hafted as oblique barbs or transverse tips while non-geometrics were hafted as straight tips. This suggests that at Wadi Mataha there was as clear notion of how geometric and non-geometric microliths were hafted when used as projectiles. In contrast, at both ‘Uyun al-Hammâm and Kharaneh IV, geometric microliths were used also exclusively as barbs or transverse tips, while non-geometric microliths were more variable in their hafting configuration as projectiles. Thus, projectiles at Wadi Mataha may have had trapeze-rectangles hafted as oblique barbs, with a non-geometric microlith at the tip. Both ‘Uyun-al Hammâm and Kharaneh IV would have had geometrics hafted as barbs or transverse tips, and non-geometrics either hafted at the tip or also hafted in a similar manner to the geometrics. This suggests a range of different hafting configurations for microliths as projectile insets.

Overall, there is a lot of flexibility in how microliths were used and manufactured during the Middle Epipalaeolithic. Although the form of the trapeze-rectangle was widespread, it was expressed differently within different communities.

9.3 Conclusion

In conclusion, the results from the analysis suggest that there is not a direct causal relationship between form and function in Epipalaeolithic microliths. Although the two are intrinsically intertwined, different communities had flexibility within the constraints of their technology. Skilled people made decisions within the norm of their community about how a microlith was made and used. Future work will explore the remainder of the lithic assemblages, situating the *chaîne opératoire* of microliths into the wider sphere of technology.

In a recent paper, Ingold (2010) discusses the interrelations between people and objects. The paper seeks to break down the common model that agents impose form onto materials. Instead, Ingold advocates the view that we should *follow the materials*. Instead of imposing form, people bring together diverse materials, combining and redirecting their flow, thus changing the course of materials. This paper alludes to some of the biggest problems in the *chaîne opératoire*: what is the beginning and end of a material? Where do you begin and end the *chaîne opératoire*? Although this question is not easily answered, I advocate the integration of function into our conceptions of *the chaîne opératoire*, incorporating additional aspects of the tool’s life-history that can illuminate gestures in prehistory.

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Appendix A Lithic Technology

This appendix contains tables outlining the attributes and types used for defining raw material, debitage, cores, core-trimming elements, retouched tools, and microliths in Chapter 4.

Table 55: List of Raw Material Quality and Colour

Raw Material Quality	Raw Material Colour
very fine	light brown
fine	medium brown
coarse	dark brown
very-coarse	mottled brown
	black
	red/brown
	red
	pink
	purple
	white
	grey
	translucent
	other

Table 56: Debitage types for Kharaneh IV

Debitage Type	Description
Microburins	
Microburins	microburin
Burin Spalls (Inizan, et al., 1992)	
First Burin Spall	burin spall with triangular profile
Sharpening Burin Spall	burin spall with evidence of previous burin removal
Plunging Burin Spall	burin spall with plunging profile
Hinging Burin Spall	burin spall with hinged profile
Twisted Burin Spall	burin spall with twisted profile
Unretouched Debitage (Wilke and Quintero, 1994)	
Blades/Bladelets	twice as long as they are wide
Secondary Blades	blade with <100% dorsal cortex
Flakes	non-blade detached piece
Secondary Flakes	flake with <100% dorsal cortex
Primary Pieces (100%)	piece with 100% dorsal cortex
Platform Isolation Elements	small curved bladelets that isolate the platform

Edge-Preparation Elements	small, broad flakes removed to strengthen platform
Chips (under 1 cm)	pieces under 1 cm
Shatter (chunks)	pieces with no discernible dorsal or ventral surface
Burnt Shatter	burnt pieces with no discernible dorsal or ventral surface

Table 57: Debitage Attributes for Wadi Mataha and Uyun al-Hammâm.

Field Name	Values	Description
Artifact Number		unique identification number
Locus or FS Number		stratigraphic information
Fragment	complete	preserved proximal and distal ends
	proximal	preserved proximal end
	medial	preserved medial section
	distal	preserved distal end
	chip	<1cm in size
	shatter	no preserved ventral or dorsal surface
Maximum Length		millimeters
Maximum Width		perpendicular to length, millimeters
Maximum Thickness		millimeters
Platform Type	single	no facets
	multiple	2 or more platform facets
	cortical	cortex covering the platform
	abraded	evidence of platform abrasion
	broken	unidentifiable due to breakage
Platform Shape	punctiform	very small to non-existent platform
(recorded for Wadi Mataha	narrow linear	narrow and linear platform
only) (Soriano, et al., 2007)	oval/triangular	oval shaped platform
	curved	curved shaped platform
	wide trapezoidal	large, wide trapezoidal platform
	other	
Platform Preparation	none	no preparation
(recorded for Wadi Mataha	long removals on scar ridges	reducing overhang through long removals
only) (Soriano, et al., 2007)	edge trimming with short removals	trimming platform edge with short removals
	impact point is set in relief by lateral removals	lateral notching to make impact point prominent
Termination	feathered	terminating in to a feathered edge
	step	terminating with a 90 degree step
	hinge	terminating with a hinged edge
	plunging	terminating with a plunging edge, towards to ventral surface
Section at Midpoint	expanded and pointed	wide, flat profile with middle peak (arris)
(recorded for Wadi Mataha	concave	two dorsal scars on each side of the piece

only)	pointed to the left	one dorsal scar to the left side
	pointed to the right	one dorsal scar to the right side
	triangular	one prominent central dorsal ride
Plan	expanding	expanding flake with wide distal end
(recorded for Wadi Mataha	oval/rectangle	oval or rectangular flake
only)	convergent	flake with margins converging into a point
	offset	distal termination offset to either the right or left side
	irregular	irregularly shaped flake
	laminar	blade/bladelet with parallel margins
Number of Dorsal Scars		Count of dorsal scars, excluding scars related to platform preparation
Direction of Dorsal Scars	unidirectional	scars initiating from one direction (proximal to distal)
	opposed direction	scars initiating from both the proximal and the distal ends
	multidirectional	scars initiating from multiple directions
	change of orientation	scars initiating from one direction, then initiating from a second direction with a turn of approximately 90 degrees
	indeterminate	unable to identify direction of removals
Raw Material Quality	see Table 55	
Raw Material Colour	see Table 55	
Post-depositional Processes	none	no alteration
	carbonate	calcium carbonate
	soil sheen	gloss produced from soils
	patina	white or grey patination
	rounding	worn edges and dorsal ridges
	edge fractures	post-depositional edge fractures
Burnt	yes/no	present or absence of burning
Potential for Use-wear	yes/no	evidence of marcoscopic use-wear
Comments		additional comments

Table 58: Core attributes for Wadi Mataha and Uyun al-Hammâm

Field	**Value**	**Description**
Artifact Number		unique identification number
Locus or FS Number		stratigraphic information
Core Shape	pyramidal	single platform with removals around 360 degrees of the face, equal removals on all faces
	sub-pyramidal	single platform with removals around 360 degrees of the face, unequal removals on all faces
	wide-faced	removals on >20% of the core face
	narrow-faced	removals on <20% of the core face
	irregular	irregularly shaped core

	broken	broken with indeterminate shape
Core Platform Orientation	unidirectional	removals initiating from one direction
	multidirectional	removals initiating from multiple directions
	opposed	removals initiating from two opposed directions (180 degrees)
	change of orientation	removals initiating from one direction, then initiating from a second direction with a turn of approximately 90 degrees
Number of Platforms		count
Core Maximum Facet Length		millimeters
Core Maximum Facet Width		measured perpendicular to the length, millimeters
Core Platform Length		millimeters
Core Platform Width		measured perpendicular to the length, millimeters
Core Maximum Length		millimeters
Core Maximum Width		measured perpendicular to the length, millimeters
Core Maximum Thickness		millimeters
Core Abandonment	exhausted	core too small for further removals
	hinged	multiple hinge terminations impeding further removals
	wrong angle	platform angle too acute or obtuse for further removals
	broken	core broken
	unknown	core still functional
Raw Material Quality	see Table 55	
Raw Material Colour	see Table 55	
Percent of Cortex	0%	no cortex
	1-25%	percent of cortex on the dorsal surface
	26-50%	percent of cortex on the dorsal surface
	51-75%	percent of cortex on the dorsal surface
	75-100%	percent of cortex on the dorsal surface
Post-depositional Processes	none	no alteration
	carbonate	calcium carbonate
	soil sheen	gloss produced from soils
	patina	white or grey patination
	rounding	worn edges and dorsal ridges
	edge fractures	post-depositional edge fractures
Burnt	yes/no	present or absence of burning
Potential for Use-wear	yes/no	evidence of marcoscopic use-wear
Comments		additional comments

Table 59: Core-Trimming Element (CTE) attributes

Field	Value	Description
Artifact Number		unique identification number
Locus or FS Number		stratigraphic information
CTE Type	ridged blade	initial blade removal, prepared with flaking towards a central ridge
	partially ridged blade	blades with a half crest towards the distal end used to shape the core face for further blade removals
	core tablet	removes the entire platform
	angle correction elements	detached along the edge of the core to change the removal angle
	core face rejuvenation elements	removal of knapping flaws
Flake/Blade Component	complete	preserved proximal and distal ends
	proximal	preserved proximal end
	medial	preserved medial section
	distal	preserved distal end
Termination	feathered	terminating in to a feathered edge
	step	terminating with a 90 degree step
	hinge	terminating with a hinged edge
	plunging	terminating with a plunging edge, towards to ventral surface
Platform Type	single	no facets
	multiple	2 or more platform facets
	cortical	cortex covering the platform
	abraded	evidence of platform abrasion
	broken	unidentifiable due to breakage
Platform Shape (Wadi Mataha only)	punctiform	very small to non-existent platform
	narrow linear	narrow and linear platform
	oval/triangular	oval shaped platform
	curved	curved shaped platform
	wide trapezoidal	large, wide trapezoidal platform
	other	
Platform Preparation (Wadi Mataha only)	none	no preparation
	long removals on scar ridges	reducing overhang through long removals
	edge trimming with short removals	trimming platform edge with short removals
	impact point is set in relief by lateral removals	lateral notching to make impact point prominent
Maximum Length		millimeters
Maximum Width		perpendicular to length, millimeters
Maximum Thickness		millimeters
Raw Material Quality	see Table 55	
Raw Material Colour	see Table 55	
Percent of Cortex	0%	no cortex
	1-25%	percent of cortex on the dorsal surface

	26-50%	percent of cortex on the dorsal surface
	51-75%	percent of cortex on the dorsal surface
	75-100%	percent of cortex on the dorsal surface
Post-depositional Processes	none	no alteration
	carbonate	calcium carbonate
	soil sheen	gloss produced from soils
	patina	white or grey patination
	rounding	worn edges and dorsal ridges
	edge fractures	post-depositional edge fractures
Burnt	yes/no	present or absence of burning
Potential for Use-wear	yes/no	evidence of marcoscopic use-wear
Comments		additional comments

Table 60: Retouched tool attributes

Field	**Value**	**Description**
Artifact Number		unique identification number
Locus or FS Number		stratigraphic information
Tool Class	scraper	from Bar-Yosef (1970) and Goring-Morris (1987)
	burin	from Bar-Yosef (1970) and Goring-Morris (1987)
	retouched flake	from Bar-Yosef (1970) and Goring-Morris (1987)
	retouched blade	from Bar-Yosef (1970) and Goring-Morris (1987)
	backed blade	from Bar-Yosef (1970) and Goring-Morris (1987)
	notched/denticulated	from Bar-Yosef (1970) and Goring-Morris (1987)
	multiple tool	from Bar-Yosef (1970) and Goring-Morris (1987)
	truncation	from Bar-Yosef (1970) and Goring-Morris (1987)
	perforator/borer	from Bar-Yosef (1970) and Goring-Morris (1987)
	other	from Bar-Yosef (1970) and Goring-Morris (1987)
Tool Type		types from Bar-Yosef (1970) and Goring Morris (1987)
Tool Component	complete	preserved proximal and distal ends
	proximal	preserved proximal end
	medial	preserved medial section
	distal	preserved distal end
	incomplete	indeterminate or split portion
Maximum Length		millimeters
Maximum Width		perpendicular to length, millimeters
Maximum Thickness		millimeters
Platform Type	single	no facets
	multiple	2 or more platform facets
	cortical	cortex covering the platform
	abraded	evidence of platform abrasion

	broken	unidentifiable due to breakage
Platform Shape (Wadi Mataha only)	punctiform	very small to non-existent platform
	narrow linear	narrow and linear platform
	oval/triangular	oval platform
	curved	curved platform
	wide trapezoidal	large, wide trapezoidal platform
	other	
Platform Preparation (Wadi Mataha only)	none	no preparation
	long removals on scar ridges	reducing overhang through long removals
	edge trimming with short removals	trimming platform edge with short removals
	impact point is set in relief by lateral removals	lateral notching to make impact point prominent
Curvature	straight	straight in profile view
	concave	bending towards the ventral surface in profile
	convex	bending towards the dorsal surface in profile
	twisted	twisted profile
Section at Midpoint (Wadi Mataha only)	expanded and pointed	wide, flat profile with middle peak (arris)
	concave	two dorsal scars on each side of the piece
	pointed to the left	one dorsal scar to the left side
	pointed to the right	one dorsal scar to the right side
	triangular	one prominent central dorsal ride
Plan (Wadi Mataha only)	expanding	expanding flake with wide distal end
	oval/rectangle	oval or rectangular flake
	convergent	flake with margins converging into a point
	offset	distal termination offset to either the right or left side
	irregular	irregularly shaped flake
	laminar	blade/bladelet with parallel margins
Type of Retouch	abrupt	unidirectional abrupt retouch
	bipolar	bidirectional abrupt retouch
	normal	marginal angled retouch, slightly invasive
	fine	fine, marginal retouch
	combination	combination of multiple types of retouch
Raw Material Quality	see Table 55	
Raw Material Colour	see Table 55	
Percent of Cortex	0%	no cortex
	1-25%	percent of cortex on the dorsal surface
	26-50%	percent of cortex on the dorsal surface
	51-75%	percent of cortex on the dorsal surface
	75-100%	percent of cortex on the dorsal surface
Number of Dorsal Scars		Count of dorsal scars, excluding scars related to platform preparation
Direction of Dorsal Scars	unidirectional	scars initiating from one direction (proximal to distal)

	opposed direction	scars initiating from both the proximal and the distal ends
	multidirectional	scars initiating from multiple directions
	change of orientation	scars initiating from one direction, then initiating from a second direction with a turn of approximately 90 degrees
	indeterminate	unable to identify direction of removals
Post-depositional Processes	none	no alteration
	carbonate	calcium carbonate
	soil sheen	gloss produced from soils
	patina	white or grey patination
	rounding	worn edges and dorsal ridges
	edge fractures	post-depositional edge fractures
Burnt	yes/no	present or absence of burning
Potential for Use-wear	yes/no	evidence of marcoscopic use-wear
Comments		additional comments

Table 61: Microlith Attributes

Field	**Value**	**Description**
Artifact Number		unique identification number
Locus or FS number		stratigraphic information
Site Name	Wadi Mataha	
	Uyun al-Hammâm	
	Kharaneh IV	
Geometric Microlith Type	trapeze-rectangle	from Bar-Yosef (1970) and Goring-Morris (1987)
	unbacked trapeze	from Bar-Yosef (1970) and Goring-Morris (1987)
	asymmetrical trapeze A	from Bar-Yosef (1970) and Goring-Morris (1987)
	asymmetrical trapeze B	from Bar-Yosef (1970) and Goring-Morris (1987)
	trapeze-rectangle with one convex end	from Bar-Yosef (1970) and Goring-Morris (1987)
	triangle	from Bar-Yosef (1970) and Goring-Morris (1987)
	lunate	from Bar-Yosef (1970) and Goring-Morris (1987)
	parallelogram	from Bar-Yosef (1970) and Goring-Morris (1987)
	non-geometric	from Bar-Yosef (1970) and Goring-Morris (1987)
	other	from Bar-Yosef (1970) and Goring-Morris (1987)
Non-geometric Type	backed bladelet fragment	from Bar-Yosef (1970) and Goring-Morris (1987)
	partially backed	from Bar-Yosef (1970) and Goring-Morris (1987)
	completely backed	from Bar-Yosef (1970) and Goring-Morris (1987)
	retouched on both sides	from Bar-Yosef (1970) and Goring-Morris (1987)
	obliquely truncated and backed	from Bar-Yosef (1970) and Goring-Morris (1987)
	obliquely truncated	from Bar-Yosef (1970) and Goring-Morris (1987)
	micropoint	from Bar-Yosef (1970) and Goring-Morris (1987)

	curved	from Bar-Yosef (1970) and Goring-Morris (1987)
	pointed	from Bar-Yosef (1970) and Goring-Morris (1987)
	pointed and retouched on both sides	from Bar-Yosef (1970) and Goring-Morris (1987)
	microgravette	from Bar-Yosef (1970) and Goring-Morris (1987)
Tool Component	complete	preserved proximal and distal ends
	proximal	preserved proximal end
	medial	preserved medial section
	distal	preserved distal end
	incomplete	indeterminate or split portion
Maximum Length		millimeters
Maximum Width		perpendicular to length, millimeters
Maximum Thickness		millimeters
Backed Edge Shape	straight	straight backed edge, in plan
	concave	concaved backed edge, in plan
	convex	convex backed edge, in plan
	notched	backed edge with one or more notches, in plan
	broken	broken, indeterminate shape
Cutting Edge Shape	straight	straight unworked edge, in plan
	concave	concaved unworked edge, in plan
	convex	convex unworked edge, in plan
	notched	unworked edge with one or more notches, in plan
	broken	broken, indeterminate shape
End 1 Shape (Figure 14)	straight	straight end
	angled A 45	end angled at 45 degree
	angled B 45	end angled at 45 degree, opposite direction
	angled A 20	end angled at 20 degree
	angled B 20	end angled at 20 degree, opposite direction
	concave	concave end
	convex	convex end
	pointed	pointed end
	broken straight	broken end, with straight break
	broken angled A	broken end, with angled break
	broken angled B	broken end, with opposite direction angled break
End 2 Shape (Figure 14)	straight	straight end
	angled A 45	end angled at 45 degree
	angled B 45	end angled at 45 degree, opposite direction
	angled A 20	end angled at 20 degree
	angled B 20	end angled at 20 degree, opposite direction
	concave	concave end
	convex	convex end
	pointed	pointed end
	broken straight	broken end, with straight break
	broken angled A	broken end, with angled break

	broken angled B	broken end, with opposite direction angled break
Curvature	straight	straight in profile view
	concave	bending towards the ventral surface in profile
	convex	bending towards the dorsal surface in profile
	twisted	twisted profile
Invasiveness of Retouch	non-invasive	backing removing ≈6% or less of edge
	marginal retouch	backing removing ≈12% of edge
	invasive retouch	backing removing ≈25% of edge
	total retouch	backing removing ≈50% of edge
Type of Retouch	abrupt	unidirectional abrupt retouch
	bipolar	bidirectional abrupt retouch
	normal	marginal angled retouch, slightly invasive
	fine	fine, marginal retouch
	combination	combination of multiple types of retouch
Raw Material Quality	see Table 55	
Raw Material Colour	see Table 55	
Percent of Cortex	0%	no cortex
	1-25%	percent of cortex on the dorsal surface
	26-50%	percent of cortex on the dorsal surface
	51-75%	percent of cortex on the dorsal surface
	76-100%	percent of cortex on the dorsal surface
Number of Dorsal Scars		Count of dorsal scars, excluding scars related to platform preparation
Direction of Dorsal Scars	unidirectional	scars initiating from one direction (proximal to distal)
	opposed direction	scars initiating from both the proximal and the distal ends
	multidirectional	scars initiating from multiple directions
	change of orientation	scars initiating from one direction, then initiating from a second direction with a turn of approximately 90 degrees
	indeterminate	unable to identify direction of removals
Post-depositional Processes	none	no alteration
	carbonate	calcium carbonate
	soil sheen	gloss produced from soils
	patina	white or grey patination
	rounding	worn edges and dorsal ridges
	edge fractures	post-depositional edge fractures
Burnt	yes/no	present or absence of burning
Potential for Use-wear	yes/no	evidence of marcoscopic use-wear
Bulb of Percussion	yes/no	is there a remnant bulb present?
Comments		additional comments

Below are the results from the statistical tests run on the metrics for complete trapeze-rectangles from Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV (Tables 8-10). The p-values with significant differences are highlighted in red. Abbreviations used in the tables are: WM=Wadi Mataha; WZ148=’Uyun al-Hammâm; KHIV=Kharaneh IV; UB=unbacked trapeze-rectangle.

Table 62: The p-values for complete trapeze-rectangle length (Kruskal-Wallis test)

	WM length	WZ148 length	KHIV length	KHIV UB length
WM length	0	0.6089	0.1883	0.2586
WZ148 length		0	0.01836	0.009546
KHIV length			0	0.8678
KHIV UB length				0

Table 63: The p-values for complete trapeze-rectangle width (Kruskal-Wallis test)

	WM width	WZ148 width	KHIV width	KHIV UB width
WM width	0	2.96E-07	2.50E-07	0.1713
WZ148 width		0	0.0004319	2.23E-07
KHIV width			0	6.86E-08
KHIV UB width				0

Table 64: The p-values for complete trapeze-rectangle thickness (one-way ANOVA)

	WM thickness	WZ148 thickness	KHIV thickness	KHIV UB thickness
WM thickness	0	0.02824	0.1062	7.72E-06
WZ148 thickness		0	1.02E-05	7.72E-06
KHIV thickness			0	8.40E-06
KHIV UB thickness				0

Appendix B Raw Material Analysis

This appendix outlines the qualitative raw material analysis undertaken for the Wadi Mataha, ‘Uyun al-Hammâm, and Kharaneh IV assemblages. This analysis is meant for general comparison and description only. Regional survey and sourcing is still needed to understand the raw material variability and source location for these three sites.

9.4 Wadi Mataha Raw Material

The chipped lithic assemblage was manufactured on raw materials of varying qualities and colours, with the majority made from fine or very fine cherts (68.2%) (Table 65). There has been no formal raw material survey conducted in the vicinity of Wadi Mataha so the exact locations of the raw material sources are unknown. However, the very fine lustrous material appears in small cobbles at the site and in beds in the surrounding hills (Chazan *pers. comm*.). In addition, chert nodules are available in the main wadi within 500 m of the site (Gregg, et al., 2011). The other materials are not present in the immediate area but may be present in the local landscape. Survey is needed to understand fully the distances traveled for the movement of raw material to Wadi Mataha.

Burning is present on 19.2% of the assemblage (n=548), the majority of which consists of debitage and shatter (n=512). The rest of the indeterminate pieces are heavily patinated (3.5%). One of the more frequently used raw materials is a very fine chert with a high luster (32.9%). This very fine-textured, lustrous raw material was also commonly used in the Natufian assemblages at the site and some of this material might be intrusive from later deposits. However, there are a number of trapeze-rectangles manufactured on this material (n=56), so this data was kept in the analysis.

Table 65: Wadi Mataha raw material texture by lithic class (MB=microburins)

Quality	core (%)	CTE (%)	debitage(%)	tools (%)	MB (%)	microlith (%)	Total (%)
very fine	41.7	19.2	34.4	38.3	53.3	20.2	**32.9**
fine	33.3	61.5	32.8	20.0	42.2	52.3	**35.3**
coarse	8.3	19.2	8.2	26.7	2.2	11.1	**9.0**
indeterminate	16.7	0.0	24.5	15.0	2.2	16.5	**22.7**

Total	100.0	100.0	100.0	100.0	100.0	100.0	**100.0**

There are interesting differences in the raw material selection for lithic classes at Wadi Mataha (Figure 44). Both microliths and core-trimming elements (CTEs) were manufactured more frequently on the fine raw material, in contrast to tools, microburins, and cores, which were primarily made from very fine cherts. As well, a large proportion of tools, in particular retouched blades (16.7%), were made on coarse raw materials (26.6%). This suggests that there were different choices in raw material selection for the manufacturing of larger tools, with retouched flakes most often manufactured on very fine materials and retouched blades manufactured on coarser textured materials. This is counterintuitive to the idea that retouched flakes are expedient opportunistic tools in contrast to blades, as the retouched flakes are produced on what could be conceived as more desirable, high-quality raw materials. It might also suggest that the coarse textured materials occur in larger nodules suitable for large tools.

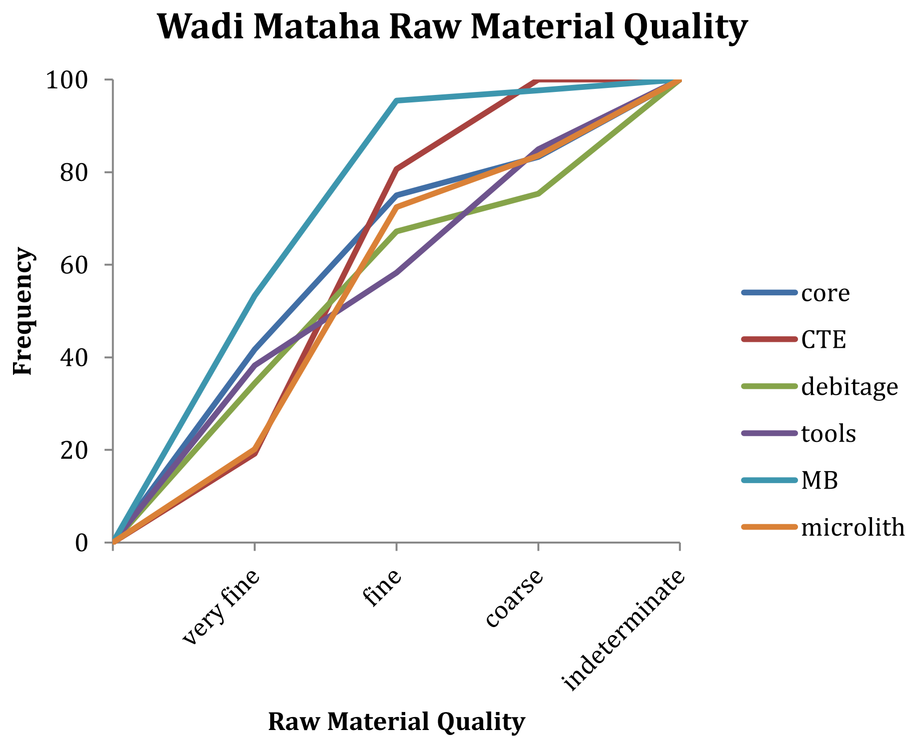

Figure 44: Cumulative frequency graph of Wadi Mataha raw material quality

The microliths are primarily manufactured on fine (52.3%) or very fine (20.2%) chert materials. There is little difference between the raw material selection for non-geometric and geometric microliths in both the quality ($\chi^2 = 11.90$, $p = 0.2696$) and the colour ($\chi^2 = 30.50$, $p = 0.9062$) suggesting that these microliths were likely part of the same reduction sequence and diverged during retouching. The most common colour selected for microlith production was light brown chert (48.4%), followed by grey (20.2%), then medium brown (16.6%), and finally white (6.8%). The remaining six raw material colours are represented in proportions under 4% of the overall microlith assemblage (Table 66).

Table 66: Wadi Mataha raw material colour by microlith group

Colour	geometric (%)	non-geometric (%)	fragmentary (%)	Total (%)
black	0.8	0	0	**0.4**
dark brown	2.4	1.5	2.3	**2.2**
grey	21.6	15.2	22.1	**20.2**
light brown	48	51.5	46.5	**48.4**
medium brown	17.6	13.6	17.4	**16.6**
orange	2.4	4.6	3.5	**3.2**
other	0.8	0	0	**0.4**
red/brown	0	1.5	1.2	**0.7**
translucent	0.8	3	0	**1.1**
white	5.6	9.1	7	**6.8**
Total	**100.0**	**100.0**	**100.0**	**100.0**

9.5 ‘Uyun al-Hammâm Raw Material

The majority of the lithics were manufactured on fine-textured, brown and grey cherts available as cobbles in the local landscape (72.8%). In addition to these locally sourced materials, very fine cherts from neighbouring valleys were used for lithic production (12.0%). This suggests that some materials of higher quality were actively sought from sources beyond the site’s local region. Although the very fine materials are not collected from Wadi Ziqlab, they show the highest percent of cortex, indicating that the raw materials were being transported as complete nodules to be retouched into tools on site.

Despite the prominent use of fine-textured, brown and grey cherts for flake production (65.8%), coarse (5.3%) and very fine materials are also represented in the flake category (11.3%) (Table 67). This suggests that flake production was not constrained by raw material choice. In contrast, blades show a slightly more regimented raw material selection. Although fine cherts are again the most prominent materials (76.9%), there is very minimal coarse chert in the blade assemblage (1.7%). Among blades very fine raw materials appear in the same frequency as among flakes (11.4%). This suggests that coarse materials were avoided for the production of blades and microlith blanks at ‘Uyun al-Hammâm (Figure 45).

Table 67: ‘Uyun al-Hammâm raw material texture by category

Quality	core (%)	CTE (%)	debitage(%)	tools (%)	microlith (%)	Total (%)
very fine	15.5	11.7	11.4	12.7	8.8	**12.0**
fine	75.9	79.9	69.5	60.0	78.9	**72.8**
coarse	5.2	5.1	4.1	27.3	3.1	**9.0**
indeterminate	3.4	3.3	15.1	0.0	9.1	**6.2**
Total	100.0	100.0	100.0	100.0	100.0	**100.0**

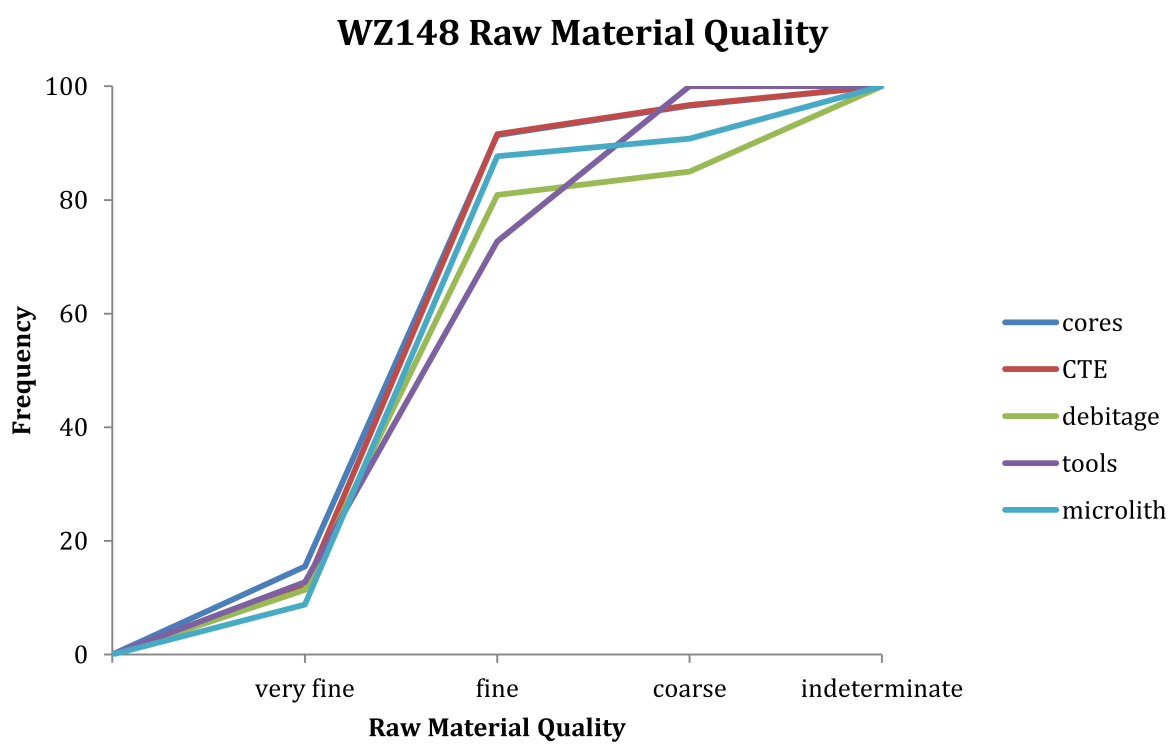

Figure 45: Cumulative frequency graph of 'Uyun al-Hammâm raw material quality

The majority of the microliths from ‘Uyun al-Hammâm were manufactured on a light brown chert (n=328, 51.1%), followed by a medium brown chert (n=174, 27.1%) (Table 68). It should be noted that several of the cores from this site show evidence of both medium and light brown cherts in the same nodule, suggesting that many of these microliths could have been manufactured from the same core. There is no significant difference between the raw material colour chosen for geometric and non-geometric microliths ($\chi^2 = 11.007$, $p = 0.138$). This indicates that these microliths might have been part of the same reduction sequence.

Table 68: ‘Uyun al-Hammâm raw material colour by microlith group

Colour	geometric (%)	non-geometric (%)	fragmentary (%)	Total
grey	6.5	3.6	8.4	**6.5**
light brown	51.9	55.4	45.8	**51.1**
medium brown	28.7	22.9	24.4	**27.1**
dark brown	1.4	6.0	0.8	**1.9**
pink	0.2	0.0	0.8	**0.3**
red/brown	2.8	3.6	5.3	**3.4**
white	0.2	1.2	3.1	**0.9**
indeterminate	8.2	7.2	11.5	**8.7**
Total	**100.0**	**100.0**	**100.0**	**100.0**

Overall, the raw material selection at ‘Uyun al-Hammâm was constrained, focusing primarily on fine-quality, light and medium brown cherts found within the vicinity of the site.

9.6 Kharaneh IV Raw Material

Raw material survey conducted in the vicinity of Kharaneh IV indicates that the majority of the materials are from the local landscape, within 10 km of the site. The raw material selection is less constrained than the raw materials from the Early Epipalaeolithic. There is a lot of diversity in the choice of chert, in both the colour and the shape of the nodules used for lithic production. Both rounded and long, narrow chert nodules were used in the assemblage.

The majority of the geometric microliths were manufactured on cherts of very fine quality (n=101, 54.9%), followed by fine cherts (n=57, 31.0%). The quality of the remainder of the raw material for the geometrics is indeterminable based on post-depositional alterations or burning. The raw material pattern is similar in the non-geometric microliths, where the majority of the microliths were manufactured on very fine raw materials (n=93, 57.4%). For both these microlith classes, the most prevalent colour choice is a red/brown chert (48.7%).

Table 69: Kharaneh IV microlith raw material colour

Colour	**geometrics (%)**	**non-geometrics (%)**	**fragmentary (%)**	**total (%)**
dark brown	0.0	1.4	3.2	**1.2**
grey	3.8	1.6	4.8	**2.3**
light brown	11.4	10.3	11.1	**10.6**
medium brown	19.6	14.7	17.5	**16.0**
orange	2.7	4.0	4.8	**3.7**
pink	2.2	1.2	0.0	**1.3**
purple	0.5	0.2	0.0	**0.2**
red/brown	43.5	51.7	36.5	**48.7**
translucent	0.0	0.9	1.6	**0.7**
white	3.3	0.5	0.0	**1.1**
indeterminate	13.0	13.6	20.6	**14.0**
Total	100.0	100.0	100.0	**100.0**

Appendix C Use-Wear Tables

This appendix contains the details of the use-wear traces identified through both low-powered and high-powered microscopic analysis. Impact data is presented first, followed by data on other functions such as longitudinal cutting, transverse, and unknown functions.

Table 70: Wadi Mataha details of use-wear resulting from impact

Artifact Number	Microlith Type	Magnification	Interpretation	Projectile Type	Evidence (low)	Evidence (high)
WM-1002b	varia	stereo	projectile		Step terminating bending fracture 0.8mm. Unifacial spin-off on the dorsal side 0.6mm (area 1)	
WM-2366	varia	stereo, high-powered	projectile	a1m	Feathered bending fracture 0.9mm. Unifacial spinoff fracture on dorsal surface (area 2)	
WM-2367	lunate	stereo, high-powered	projectile	a2	Step terminating burination but off the dorsal surface. Also a step terminating burination off the edge (area 3)	
WM-2410	trapeze-rectangle	stereo, high-powered	projectile	a2	Burination 0.8mm (area 1)	
WM-2415	trapeze-rectangle	stereo, high-powered	projectile	b3	Step terminating bending fractures (area 3)	
WM-2416	notched bladelet	stereo, high-powered	projectile	a1m	Step terminating bending fracture. Spin off fractures on the dorsal surface (area 3)	
WM-2425	backed bladelet fragment	stereo, high-powered	projectile	b1	Large step terminating bending fracture and multiple smaller ones (area 11)	
WM-2426	trapeze-rectangle	stereo, high-powered	projectile	b1	Step terminating bending fractures with some crushing (area 10)	
WM-2437	backed bladelet fragment	stereo, high-powered	projectile	d1m	Two step terminating bending fractures on cutting edge (area 2). Spin-off fracture (area 11)	One large shallow striation running along the piece, angled (area 11)
WM-2442	backed bladelet fragment	stereo, high-powered	projectile tip	a2		

WM-2444	varia	stereo, high-powered	projectile	dm2	Twisted bending fractures with a step termination (area 3). On the edge, step terminating bending fractures >5per 10 mm	
WM-2454	backed bladelet fragment	stereo, high-powered	projectile	b2	Step terminating bending fracture (area 3)	
WM-2460	pointed	stereo, high-powered	projectile tip	a1	Step terminating bending fracture 1.6mm (area 1)	
WM-2462	trapeze-rectangle	stereo, high-powered	projectile	a3	Very long twisted snap fracture (area 2)	
WM-2471	trapeze-rectangle	stereo, high-powered	projectile	d1m	Step terminating bending fractures on the cutting edge (area 2). Spin-off fracture 1.2mm (area 11)	Small patch of weak generic polish (area 11)
WM-2473	backed bladelet fragment	stereo, high-powered	projectile (transverse)	b1	Step terminating bending fracture 2.1mm (area 11)	Weak generic polish on either side of the impact fracture (area 11)
WM-2476	trapeze-rectangle	stereo	projectile	b1	Step terminating impact fracture coming from 2 directions, angled (area 2)	
WM-2477	backed bladelet fragment	stereo, high-powered	projectile	b3	Impact fracture across microlith body. Twisted snap fracture (area 1). Edge has a series of conchoidal fractures with some step terminating bending fractures (area 2). Bending fracture, feathered 3.0mm (area 3)	
WM-2484	triangle	stereo, high-powered	projectile	b3	Fracture across microlith. Hinged termination (area 3)	
WM-2493	trapeze-rectangle	stereo, high-powered	projectile or chopping	b1	Step terminating bending fracture 2.2mm (area 3). Step terminating bending fracture 3.1mm (areas 10-11)	

WM-2501	completely backed	stereo, high-powered	projectile	a2m	Impact burination 2.4mm (area 1). Step terminating bending fracture on a snap, 0.6mm (area 12)	
WM-2503	backed bladelet fragment	stereo, high-powered	projectile barb	d1m	Step terminating bending fractures overlapping >5 per 10mm, angled and perpendicular (areas 1-3, 10-12)	
WM-2510	varia	stereo, high-powered	projectile tip with hafting damage	a2m	Impact burination scar on the ventral face 5.3mm (area 1). Step terminating bending fractures <5 per 10mm (area 3). Very fine feather terminating scars (area 12)	
WM-2570	backed bladelet fragment	stereo, high-powered	projectile tip		Twisted impact burination (area 3)	Weak generic polish at the tip (area 7). Weak generic polish along the backed edge (hafting?) And linear polish (area 8)
WM-2571	backed bladelet fragment	stereo, high-powered	projectile tip	a1m	End- spin off (area 1). Step terminating bending fracture, parallel (area 10)	Linear polish, angled, very light (area 11)
WM-2611	trapeze-rectangle	stereo, high-powered	projectile	b2	Step terminating conchoidal fracture (area 11). Small step terminating conchoidal fracture. Burination at the end (area 12)	Weak generic polish, localized near the burination (area 12)
WM-2619	trapeze-rectangle	stereo, high-powered	projectile	d1m	Step terminating bending fracture x4 (area 1-2). Large step terminating bending fracture at the corner (2.5 mm), 4 smaller step term bending fractures (area 12)	

WM-2702	trapeze-rectangle	stereo, high-powered	projectile or chopping	b1	Step terminating bending fractures (area 1-3)	Evidence of a long crack where the burination should have been removed (area 10). Weak generic polish and some rounding (area 11)
WM-3a	backed bladelet fragment	stereo, high-powered	projectile tip		Step terminating bending fracture, parallel, 1.3mm (area 1)	

Table 71: 'Uyun al-Hammâm details of use-wear resulting from impact

Artifact Number	**Microlith Type**	**Magnification**	**Interpretation**	**Projectile Type**	**Evidence (low)**	**Evidence (high)**
WZ148.G13.20.205	trapeze-rectangle	stereo, high-powered	projectile		Impact burination (area 2)	
WZ148.G13.29.206	backed bladelet fragment	stereo, high-powered	projectile barb	b1	Step terminating bending fracture 3.1 mm, angled up (area 10). Step terminating bending fracture at the tip 0.4mm (area 12)	
WZ148.G13.29.207	trapeze-rectangle	stereo, high-powered	projectile barb	b1	Step terminating conchoidal fractures (area 1). Step terminating bending fracture 2.2 mm (area 3). Step terminating bending fractures (area 11)	
WZ148.G13.29.217	trapeze-rectangle	stereo, high-powered	projectile barbs	b1	Very large step terminating behind fracture at an angle (area 12)	
WZ148.G13.29.218	trapeze-rectangle	stereo, high-powered	projectile barb or laterally hafted	b1	Step terminating bending fractures >5 per 10mm, continuous (area 2). Step terminating bending fractures 4.7 mm (area 3)	

WZ148.G13.30.265	trapeze-rectangle	stereo, high-powered	projectile barb or lateral	d2m	Step terminating bending fracture 1.2mm (area 1). Step terminating bending fracture 1.5mm (area 2). Step terminating bending fracture 1.1mm (all angled) (area 3). Step terminating bending fracture 1.5mm (area 10)	
WZ148.G13.30.268	trapeze-rectangle	stereo, high-powered	projectile	a2	Impact burination (area 10). Very small fractures and rounding along the edge (areas 10-12)	Weak generic polish between the fractures (area 11)
WZ148.G13.39.222	asymmetrical trapeze B	stereo, high-powered	projectile barb or laterally hafted	b1	Step terminating bending fracture, two large (area 2). Step terminating bending fracture (area 9). Step terminating bending fracture (area 10)	
WZ148.G13.39.232	varia	stereo, high-powered	projectile	d1m	Impact burination (area 1). Step terminating bending fractures (areas 2-3, 10-11)	
WZ148.G13.39.236	trapeze-rectangle	stereo, high-powered	projectile tip or barb	a1	Step terminating bending fractures initiating from the tip (area 10)	
WZ148.G13.39.237	trapeze-rectangle	stereo	very heavy chopping or projectile	b1	Step terminating bending fractures >5 per 10mm, perpendicular (areas 1-2). One large step terminating bending fracture angled (area 10). Several step terminating bending fracture angled (area 11). One large step terminating bending fracture angled (area 12)	
WZ148.G15.32.203	backed bladelet fragment	stereo	projectile tip	d1m	Step terminating bending fracture 2.6mm, parallel (area 1). Conchoidal fractures with step	

					terminations and rounding (area 3, 12)
WZ148.G15.32.204	trapeze-rectangle	stereo	projectile	b1	Overlapping snap fractures. Hinge terminating bending fracture (area 3)
WZ148.G15.32.221	obliquely truncated	stereo	projectile tip	a1	Step terminating bending fracture 2.6mm (area 3)
WZ148.G16.49.215	backed bladelet fragment	stereo	projectile tip	a1m	Impact burination (area 3). Step terminating bending fracture (area 12)
WZ148.G16.49.222	obliquely truncated and backed	stereo, high-powered	projectile barb	b1	Irregularly spaced step terminating bending fractures >5 per 10mm (area 2). Step terminating bending fracture (area 12)
WZ148.G16.49.224	trapeze-rectangle	stereo, high-powered	projectile tip or barb	d1m	Step terminating bending fracture 1.6mm, parallel (area 1). Overlapping irregularly sized conchoidal fractures with step terminations >5 per 10mm (area 3). Step terminating bending fractures (area 11)
WZ148.G16.58.206	trapeze-rectangle	stereo	projectile barb	b1	Feather terminating bending break 0.9mm (area 1). Step terminating bending fractures x5 (areas 2-3)
WZ148.G16.62.205	backed bladelet fragment	stereo	projectile barb	b1	Series of overlapping step terminating bending fractures (area 2)
WZ148.G16.62.206	backed bladelet fragment	stereo	projectile barb	b1	Step terminating bending fractures >5 per 10mm (area 2)

WZ148.H11.11.201	trapeze-rectangle	stereo, high-powered	projectile	b1	Step terminating bending fracture 1.9mm (area 2). Step terminating bending fracture (area 12)	
WZ148.H11.11.202	trapeze-rectangle	stereo, high-powered	projectile	b2	Overlapping, small snap fractures >5 per 10mm (area 2). Rounding (areas 10-11). Step terminating bending fractures 1.6mm (area 12)	
WZ148.H11.11.203	trapeze-rectangle	stereo, high-powered	projectile	b1	Very small conchoidal fractures >5 per 10mm (area 1). Step terminating bending fracture 4.3mm, angled (area 2). Irregularly sized and spaced conchoidal fractures >5 per 10mm (area 3, 12)	
WZ148.H11.11.204	trapeze-rectangle	stereo	projectile	b1	Step terminating fractures in a large 'notch', some bending, some conchoidal (area 3, 12)	
WZ148.H11.8.206	trapeze-rectangle	stereo, high-powered	projectile	b1	Step terminating bending fractures, 0.4mm, 2.5mm (areas 2-3). Step terminating bending fracture at the corner (area 12)	
WZ148.H15.110.210	obliquely truncated and backed	stereo, high-powered	projectile barb	b1	Two large step terminating bending fractures on a slight angle (area 12)	
WZ148.H15.110.214	trapeze-rectangle	stereo, high-powered	projectile barb	b1	Step terminating bending fractures x3, angled (area 3). Step terminating bending fractures x2, angled (area 12)	
WZ148.H15.110.219	backed bladelet fragment	stereo, high-powered	projectile tip	a1	Step terminating bending fracture across piece 2.8mm, downwards on a slight angle (area 1)	Some weak generic polish at the edge of the impact fracture and some linear polish (area 11)

WZ148.H15.95.206	trapeze-rectangle	stereo	projectile barb	d1m	Step terminating bending fracture and one feather terminating fracture, parallel (area 2). Spin off fracture from the break (area 12)	
WZ148.H16.105.200	pointed and backed bladelet	stereo, high-powered	projectile tip	a1	Step terminating bending fracture 3.6mm slightly twisted at the end (area 3)	
WZ148.H16.105.201	trapeze-rectangle	stereo	projectile	b3	Burination across piece (angled from 5 to 3)	
WZ148.H16.105.206	asymmetrical trapeze B	stereo, high-powered	projectile barb or lateral haft	d2m	Step terminating bending fractures (area 2). Hinged bending fracture 2.2mm at the corner, angled (area 3). Step terminating bending fractures x3, 2.6mm, angled (area 12)	Some weak generic polish at the edge of the impact fracture and some linear polish, angled (area 11)
WZ148.H16.105.207	trapeze-rectangle	stereo, high-powered	projectile barb	b1	Step terminating bending fracture, angled (area 11)	
WZ148.H16.111.209	trapeze-rectangle	stereo, high-powered	projectile	b2	Burination angled downwards from areas 3-6	
WZ148.H16.111.212	backed bladelet fragment	stereo	projectile?		Step terminating bending fracture 4.3mm (area 3)	
WZ148.H16.114.204	trapeze-rectangle	stereo, high-powered	projectile barb	b1	Step terminating bending fracture x3, angled (area 3). Overlapping step terminating bending fractures, angled (area 10)	Very bright polish, hard contact material (bone) (area 10). Generic weak polish, very localized (area 12)
WZ148.H16.115.201	backed bladelet fragment	stereo, high-powered	projectile barb	b1	Series of overlapping step terminating bending fractures, angled (area 1). Two step terminating bending fractures (area 3)	

Table 72: Kharaneh IV details of use-wear resulting from impact

Artifact Number	Microlith Type	Magnification	Interpretation	Projectile Type	Evidence (low)	Evidence (high)
KHIV.AP35.26.1	obliquely truncated	stereo	projectile	b1	Step terminating bending fracture, angled, 2.9mm (area 12)	
KHIV.AP35.26.2	obliquely truncated	stereo	projectile barb	b1	Step terminating bending fracture, angled, 3.5mm (area 10). Several smaller step terminating bending fractures along the edge, angled, (area 11)	
KHIV.AP36.17.4	partially backed	stereo	transverse projectile		Step terminating bending fractures 1.1mm, perpendicular (area 11). Feather terminating bending fracture 6.6mm, perpendicular (area 12)	
KHIV.AP36.45.5	obliquely truncated	stereo	projectile	d1m	Small step terminating bending fractures <1.0mm, perpendicular, (areas 1-2). Step terminating bending fracture 1.1mm, parallel, (area 11)	
KHIV.AQ35.12.2	obliquely truncated	stereo	projectile barb	d2m	Discontinuous step terminating bending fractures along the edge (areas 1-3, 10-12)	
KHIV.AQ35.12.4	unbacked trapeze	stereo, high-powered	projectile	b1	1 large step terminating bending fracture 3.4mm, angled, (area 3). Feathered and step terminating bending fractures (areas 1, 10-12)	
KHIV.AQ35.4.1	trapeze-rectangle	stereo	projectile	a2	Impact burination, parallel, (area 1)	
KHIV.AQ36.24.2	trapeze-rectangle	stereo, high-powered	projectile	b1	2 large step terminating bending fractures 1.2mm deep, angled (area 2)	

KHIV.AQ36.24.4	asymmetrical trapeze B	stereo	projectile barb	b1	Step terminating bending fracture x2. 4.3mm, 1.8mm, angled (area 10-12)	
KHIV.AQ36.24.5	obliquely truncated and backed	stereo	projectile	b1	Step terminating bending fracture 0.7mm (area 1). Step terminating bending fracture 1.3mm, perpendicular (area 2)	
KHIV.AQ36.3.6	obliquely truncated	stereo	projectile barb	b1	Overlapping small step terminating bending fractures (areas 1, 10). Step terminating bending fracture, angled, 2.5mm (area 11)	
KHIV.AQ36.3.7	unbacked trapeze	stereo, high-powered	projectile-transverse	d2m	Step terminating bending fractures, perpendicular (areas 2-4). Burination, perpendicular (areas 10, 12). Series of irregular step terminating bending fractures (area 11)	
KHIV.AQ36.36.1	trapeze-rectangle	stereo, high-powered	projectile		Feather terminating bending fracture 1x large (area 2). Step terminating bending fractures overlapping, perpendicular, >5 per 10mm (area 3)	Linear polish, angled (area 11)
KHIV.AQ36.7.1	obliquely truncated	stereo	projectile	b1	Small step terminating bending fractures, perpendicular (area 10). Step terminating bending fracture, perpendicular, 2.5mm (area 11)	
KHIV.AQ36.7.4	obliquely truncated and backed	stereo	projectile	b1	Step terminating bending fractures, small and overlapping (areas 1-2, 10-11)	

KHIV.AQ40.13.10	obliquely truncated	stereo, high-powered	projectile	d2m	Step terminating bending fracture 1.0mm, perpendicular (area 1). Large snaps overlapping large step terminating bending fracture 2.3mm, angled (area 2). Step terminating bending fracture, angled, at tip 1.7mm (area 10)	Very bright localized polish close to the edge (area 10)
KHIV.AQ40.13.3	trapeze-rectangle	stereo, high-powered	projectile	dm2	Step terminating bending fractures x3, perpendicular (area 1). Small bending fractures with feather terminations. Burination, perpendicular (area 3). Overlapping step terminating bending fractures (area 12)	
KHIV.AQ40.13.4	partially backed	stereo, high-powered	projectile barb	b1	Series of overlapping step terminating bending fractures 1.0mm, perpendicular (area 2). Feather terminating bending fractures 3.4mm, angled (area 11). Several overlapping fractures feather terminating bending. >5 per 10mm. Different sizes, angled (area 12)	Generic weak polish (area 9)
KHIV.AQ40.13.5	unbacked trapeze	stereo, high-powered	projectile		Step terminating bending fracture x3 (areas 10-12)	Linear polish, angled two striations (area 10)
KHIV.AQ40.13.69	trapeze-rectangle with one convex end	stereo, high-powered	projectile	b1	Step terminating bending fracture, perpendicular (area 3). Conchoidal fracture with step terminations. Step terminating bending fractures at the end, angled (area 12)	Concentrated bright polish (area 11)
KHIV.AQ40.13.76	backed bladelet fragment	stereo, high-powered	projectile tip	a2	Impact burination 4.8mm (area 1). Impact burination 1.7mm (area 10)	

KHIV.AQ40.13.8	trapeze-rectangle	stereo, high-powered	projectile	b1	Step terminating bending fracture at tip 2.0mm. 4x conchoidal fractures with step terminations (area 1). Two overlapping step terminating bending fractures 1.5mm (area 10)
KHIV.AR36.9.2	partially backed	stereo	projectile tip	a1	Step terminating bending fracture 2.9mm
KHIV.AR36.9.4	varia	stereo	projectile tip	a1	Crushing with spin-off, parallel (area 1)
KHIV.AR36.9.6	utilized bladelet	stereo	projectile	d1m	Step terminating bending fracture, parallel (area 10). Two step terminating bending fractures (largest 2.2mm), perpendicular (area 11). Step terminating bending fracture, angled (area 12)
KHIV.AR38.11.1	unbacked trapeze	stereo, high-powered	projectile-transverse	d2m	Series of overlapping step terminating bending fractures with crushing (areas 1-3, 11-12). Impact burination (area 10)
KHIV.AR38.11.13	unbacked trapeze	stereo, high-powered	projectile	b1	Overlapping step terminating bending fractures >5 per 10mm (areas 1-2, 10)
KHIV.AR38.11.17	obliquely truncated	stereo	projectile tip	a1	Step terminating bending fracture 3.1mm (parallel)
KHIV.AS35.9.4	trapeze-rectangle	stereo, high-powered	projectile	b1	Overlapping feather terminating bending fractures, angled (areas 1, 12). Step terminating bending fractures 1.7mmm angled (area 2)

KHIV.AS36.7.2	trapeze-rectangle	stereo	projectile	a2m	Small feather termination bending fractures with rounding (area 2). Bending fracture on edge (area 9). Step terminating bending fracture 4.0mm, parallel (area 10). Small feather terminating bending fractures (area 11)
KHIV.AS36.7.3	obliquely truncated	stereo	projectile	d2m	Numerous irregular bending fractures (areas 1-2). Feather terminating bending fracture 4.5mm, perpendicular (area 10). Spin off fracture, parallel (area 12)
KHIV.AS37.14.7	unbacked trapeze	stereo, high-powered	projectile	b1	Step terminating bending fractures 0.4mm (area 1). Step terminating bending fracture 2.9mm, angled (area 10)
KHIV.AS38.12.15	pointed bladelet	stereo	projectile	d1m	Overlapping step terminating bending fractures and crushing 1.6mm, perpendicular (area 2). Step terminating bending fracture 2.1mm (area 10)
KHIV.AS38.12.2	trapeze-rectangle with one convex end	stereo, high-powered	projectile-transverse	b1	Large step terminating bending fracture overlapped by lots of little step terminating bending fractures (area 2). Large step terminating bending fracture, perpendicular, 4.7mm (area 12)
KHIV.AS38.12.4	obliquely truncated	stereo	projectile	b1	Step terminating bending fracture 1.6mm, perpendicular (area 11). Step terminating bending fracture 2.3mm, angled (area 12)
KHIV.AS38.12.7	obliquely truncated	stereo	projectile tip		Crushing on the tip and a un-removed step terminating bending fracture (area 10)

KHIV.AS38.12.9	obliquely truncated	stereo	projectile tip	a1	Step terminating bending fracture 2.3mm, parallel (area 3). Step terminating bending fracture 1.1mm (area 12)	
KHIV.AS42.10.2	trapeze-rectangle	stereo, high-powered	projectile barb	b1	Several overlying step terminating bending fractures, perpendicular and parallel (areas 1, 11). Large notch with numerous step terminating bending fracture >5 per 10mm, perpendicular (area 2)	Weak generic polish (area 10)
KHIV.AS42.10.24	obliquely truncated	stereo	projectile barb	b1	Large step terminating bending fracture, perpendicular (areas 11-12)	
KHIV.AS42.10.27	obliquely truncated	stereo	projectile		Step terminating bending fracture 1.7mm, angled (area 11). Step terminating bending fractures x3. 2.7mm (area 12)	
KHIV.AS42.10.28	backed bladelet fragment	stereo	projectile	b1	Several step terminating bending fractures, 1.1mm (area 1), 2.7mm (area 2), 1.7mm (area 10), 1.5mm (area 11), crushing (area 12)	
KHIV.AS42.10.29	unbacked trapeze	stereo, high-powered	projectile	d2m	Step terminating bending fracture, angled (area 2). Burination, parallel (area 3). Spin-off fractures (area 12)	
KHIV.AS42.10.30	obliquely truncated	stereo	projectile	b1	Step terminating bending fracture and crushing, largest is 2.0mm (areas 1-3)	
KHIV.AS42.10.35	obliquely truncated and backed	stereo	projectile	b1	Step terminating bending fractures, overlapping 0.7mm (area 3). Step terminating bending fractures, overlapping 3.0mm, perpendicular (area 12)	

KHIV.AS42.10.37	obliquely truncated	stereo	projectile	b1	Overlapping snap and step terminating fractures, crushing >5 per 10mm (areas 1-3). Step terminating bending fractures, largest is 4.4mm (area 12)	
KHIV.AS42.10.4	unbacked trapeze	stereo, high-powered	projectile barb	b1	Very fine overlapping conchoidal and bending fractures with step terminations (area 1). Step terminating bending fracture 2.5 mm, angled (area 2). Step terminating bending fracture, perpendicular (area 10)	
KHIV.AS42.10.6	trapeze-rectangle	stereo, high-powered	projectile barb	b1	Crushing (area 3). Step terminating bending fracture 2.4mm, angled (area 12)	Generic weak polish, localized in one small area (area 11)
KHIV.AT35.5.2	unbacked trapeze	stereo	projectile	d1m	Impact burination, parallel, (area 1). Overlapping step terminating bending fractures, perpendicular (area 2)	
KHIV.AT35.5.5	obliquely truncated	stereo	projectile barb	d2m	Impact burination, angled, Step terminating bending fracture, angled (area 10). Step terminating bending fracture 1.7mm, angled (area 11)	
KHIV.AT36.6.1	obliquely truncated and backed	stereo	projectile barb	b1	Series of small step terminating bending fractures <1.6mm each (area 2). Large feather terminating bending fracture (area 11)	
KHIV.AT41.9.2	lunate	stereo, high-powered	projectile		Impact burination, angled. Conchoidal fractures >5 per 10mm (area 1). Step terminating bending fractures >5 per 10mm (area 3)	Very small amount of generic weak polish (area 10)

KHIV.AT41.9.3	trapeze-rectangle	stereo, high-powered	projectile	b1	Step terminating bending fracture (area 3). Feather terminating bending fractures x2, perpendicular (area 10)	Line of polish, from impact? Small isolated patch of highly concentrated polish, very bright. From bone contact? (area 10)
KHIV.AT41.9.5	obliquely truncated	stereo	projectile barb	b1	Overlapping step terminating bending fractures >5 per 10mm (areas 1-2). Step terminating bending fracture 2.0mm (area 3). Step terminating bending fractures x2 (area 11)	
KHIV.AT41.9.6	trapeze-rectangle	stereo, high-powered	projectile barb	b1	Step terminating bending fractures, angled (areas 1-2). Feather terminating bending fracture (area 10). Step terminating bending fracture, perpendicular (area 11)	Very bright polish concentrated at the edge, contact with a hard material (bone) (area 11)

Table 73: Wadi Mataha details of use-wear traces resulting from longitudinal, transverse, and unknown functions

Artifact Number	Microlith Type	Magnification	Motion	Material	Evidence (low)	Evidence (high)
WM-1535	partially backed	stereo	transverse motion		Conchoidal fractures not overlapping but continuous >5 per 10mm (area 1, at end). Rounding (area 6)	
WM-1a	trapeze-rectangle	stereo	unknown function		Polish and crushing (area 6)	
WM-2376	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat	Continuous overlapping fractures, very small, feather terminations. Rounding (areas 1-3, 10-12)	Weak generic polish and rounding (areas 10-12)
WM-2382	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat	Across the entire edge, both sides have snap fractures >5 per 10mm with rounding (areas 1-3, 10-12)	Weak generic polish and rounding (areas 10-12)
WM-2395	backed bladelet fragment	stereo, high-powered	unknown function		Step terminating bending fractures >5 per 10mm, overlapping and in different sizes (perpendicular) (area 2). Small overlapping conchoidal fractures with rounding >5 per 10mm (area 10)	
WM-2407	backed bladelet fragment	stereo, high-powered	longitudinal motion	cutting meat	Continuous fine fractures across the edge (area 2)	Weak generic polish and rounding (areas 10-12)
WM-2417	trapeze-rectangle	stereo, high-powered	longitudinal motion		Feather terminating conchoidal fractures >5 per 10mm. Small burination on the tip (area 3)	
WM-2427	partially backed	stereo, high-powered	longitudinal motion		Polish and very fine edge damage (area 2)	
WM-2433	trapeze-rectangle	stereo, high-powered	longitudinal motion		Step terminating overlying fractures, expanding flakes (areas 10-11)	

WM-2434	trapeze-rectangle	stereo, high-powered	longitudinal motion		Snap fractures along the edge >5 per 10mm (area 2). Three large step terminating bending fractures (area 11)	
WM-2435	backed bladelet fragment	stereo, high-powered	unknown function		Crushing at the end/tip (area 1)	
WM-2445	trapeze-rectangle	stereo, high-powered	longitudinal motion		Some rounding and polish along the edge (areas 10-11)	
WM-2456	retouched on both sides	stereo, high-powered	transverse motion		Conchoidal overlapping scars >5 per 10mm (area 2)	
WM-2457	trapeze-rectangle	stereo	unknown function		Three step terminating bending fractures on the edge (area 2)	
WM-2466	varia	stereo, high-powered	unknown function	projectile		Weak generic polish (area 10). Striations (angled), and weak generic polish (area 11)
WM-2469	backed bladelet fragment	stereo, high-powered	transverse motion		Step terminating conchoidal fractures along the cutting edge >5 per 10mm (area 2)	
WM-2519	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat	Overlapping continuous very small conchoidal fractures >5 per 10mm. Rounding (areas 1-3)	Weak generic polish and rounding (areas 10-12)
WM-2521	backed bladelet fragment	stereo, high-powered	longitudinal motion	cutting meat	Snap fractures along the edge >5 per 10mm (area 2)	Weak generic polish with two slightly brighter spots (area 11)
WM-2530	backed bladelet fragment	stereo, high-powered	longitudinal motion		Very fine overlapping continuous fractures with rounding >5 per 10mm (area 2). Very fine overlapping continuous fractures with rounding >5 per 10mm (area 11)	
WM-2532	backed bladelet fragment	stereo, high-powered	longitudinal motion	cutting meat	Rounding (area 2)	Weak generic polish (area 11)

WM-2541	lunate	stereo, high-powered	longitudinal motion		Irregularly spaced feather/step terminating fractures, very small on both sides some seem to be conchoidal, other snaps or bending (areas 1-3, 10-12)	Bright, localized polish on the corner. From hafting?
WM-2543	backed bladelet fragment	stereo	longitudinal motion		Step terminating bending fractures >5 per 10mm. Large and overlapping (area 2). Step terminating bending fractures >5 per 10mm. Almost alternating with dorsal side (areas 10-12)	
WM-2546	varia	stereo, high-powered	longitudinal motion	cutting meat	Some snap fractures and a little rounding between denticulations (areas 2-3)	Weak generic polish adjacent and around the denticulates (areas 10-12
WM-2548	backed bladelet fragment	stereo, high-powered	longitudinal motion	cutting meat	Snap fractures along the edge >5 per 10mm (area 2)	Weak generic polish (areas 11-12)
WM-2549	trapeze-rectangle	stereo, high-powered	longitudinal motion		Irregular and shallow snap fractures along the edges >5 per 10mm (area 1-2)	
WM-2550	backed bladelet fragment	stereo	longitudinal motion		Rounding and very small conchoidal/snap fractures along the edge >5 per 10mm (areas 1-3, 10-12)	
WM-2551	trapeze-rectangle	stereo	longitudinal motion		Very small fractures >5 per 10mm with a few larger fractures interspersed. Overlapping with rounding both feather and step terminating (areas 1-2). A few small fractures and rounding (area 110	
WM-2575	trapeze-rectangle	stereo, high-powered	longitudinal motion		Snap fractures >5 per 10mm (areas 1-3, 10-12)	

WM-2647	trapeze-rectangle	stereo, high-powered	longitudinal motion		Small step terminating bending fractures on the other side of the large conchoidal fractures (area 3)	
WM-2668	trapeze-rectangle	stereo, high-powered	longitudinal motion	projectile	Snap fractures >5 per 10mm (area 1). Large conchoidal fracture (area 3)	Very large striations (angled), moving off of the conchoidal fracture. Some localized weak generic polish and rounding next to the snaps
WM-2711	trapeze-rectangle	sterol	longitudinal motion		Fine fractures across the whole edge >10 per 5mm (area 1).	Rounded and polished snaps (area 10)
WM-2719	trapeze-rectangle	stereo, high-powered	unknown function		Burination initiating from the cutting edge (area 3). Feather terminating conchoidal fractures. >10 per 5mm (area 10)	

Table 74: 'Uyun al-Hammâm details of use-wear traces resulting from longitudinal, transverse, and unknown functions

Artifact Number	Microlith Type	Magnification	Motion	Material	Evidence (low)	Evidence (high)
WZ148.G13.29.208	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Crushing along the edge and snap fractures >5 per 10mm (areas 2-3, 10-12)	Rounding and weak generic polish (area 12)
WZ148.G13.29.216	trapeze-rectangle	stereo, high-powered	transverse motion	meat/hide	Three small patches of small feather terminating scars with rounding (areas 11-12)	Weak generic polish (areas 11-12)
WZ148.G13.29.220	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Continuous irregular sized and spaced snap fractures >5 per 10 mm (areas 3, 10)	Weak generic polish (area 11)
WZ148.G13.30.254	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Rounding (areas 3-5, 10-12)	Weak generic polish (areas 10-12)

WZ148.G13.30.255	trapeze-rectangle	stereo, high-powered	longitudinal motion	hard material contact	Snap fractures all along the edge, >5 per 10mm. Continuous but not overlapping (areas 3-5)	Isolated polish on a peak, very bright and close to the edge
WZ148.G13.30.256	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Irregularly spaced and sized snap fractures >5 per 10mm (areas 1-3). Rounding and polish (areas 10-13)	Weak generic polish (area 10, 12)
WZ148.G13.30.257	trapeze-rectangle	stereo	unknown function		Feather terminating conchoidal fractures (areas 1, 11-12)	
WZ148.G13.30.260	trapeze-rectangle	stereo, high-powered	longitudinal motion		Non-continuous snap fracture >5 per 10mm (areas 1-3, 10-12)	
WZ148.G13.30.263	trapeze-rectangle	stereo, high-powered	transverse motion	soft material contact	Continuous conchoidal fractures with feather terminations >5 per 10mm (area 10)	Small concentrated areas of weak generic polish (area 10)
WZ148.G13.30.266	trapeze-rectangle	stereo	unknown function		Step terminating bending fracture 1.2mm, step terminating bending fracture 0.6mm (area 2-3)	
WZ148.G13.30.269	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Very fine continuous fractures along the edge (areas 10-12)	Weak generic polish (areas 10-12)
WZ148.G13.39.234	asymmetrical trapeze A	stereo, high-powered	longitudinal motion	cutting meat/hide	Rounding and very small fractures along the cutting edge >5 per 10mm (areas 1-3)	Weak generic polish (areas 10-12)
WZ148.G15.31.201	trapeze-rectangle	stereo	unknown function		Rounding (areas 1-2, 12)	
WZ148.G15.32.205	trapeze-rectangle	stereo	longitudinal motion		Snap fractures, small, > 5 per 10mm (area 3)	
WZ148.G15.32.208	retouched on both sides	stereo	longitudinal motion		Snap fracture, rounding (area 2)	

WZ148.G15.32.209	trapeze-rectangle	stereo	transverse motion	Feather terminating conchoidal fractures (area 3).
WZ148.G15.32.214	trapeze-rectangle	stereo	longitudinal motion	Snap fracture with rounding, >5 per 10mm (areas 1-3)
WZ148.G15.38.200	partially backed	stereo	unknown function	Rounding over the retouched (area 3)
WZ148.G15.38.204	trapeze-rectangle	stereo	unknown function	Conchoidal fractures n=4, (area 3). Feather terminating bending fracture with rounding (area 12)
WZ148.G16.49.205	asymmetrical trapeze B	stereo	longitudinal motion	Rounding (areas 2-3, 11-12)
WZ148.G16.58.205	asymmetrical trapeze B	stereo	longitudinal motion	Snap fractures with rounding, >5 per 10mm (areas 1, 10-11)
WZ148.G16.58.207	trapeze-rectangle	stereo	longitudinal motion	Very large overlapping snaps with rounding >5 per 10mm (area 10). Bending fractures with step terminations > 5 per 10mm, (area 11)
WZ148.G16.62.202	trapeze-rectangle	stereo	longitudinal motion	Continuous snap fractures >5 per 10mm with rounding (areas 2, 11)
WZ148.G16.62.208	trapeze-rectangle	stereo	longitudinal motion	Feather terminations >5 per 10mm (area 2). Small conchoidal fracture <5 per 10 (area 11)
WZ148.G16.62.209	backed bladelet fragment	stereo	transverse motion	Continuous and overlapping step terminating bending fractures (area 2)
WZ148.G16.62.210	trapeze-rectangle	stereo	transverse motion	Crushing with larger removals with step terminations >5 per 10mm (area 3)

WZ148.G16.62.211	trapeze-rectangle	stereo	unknown function		Feather terminations very small and continuous >5per 10mm	
WZ148.G16.74.210	notched bladelet	stereo	longitudinal motion		Rounding and snap fractures along the edge, >5 per 10mm (area 2, 12)	
WZ148.H11.20.201	retouched on both sides	stereo, high-powered	longitudinal motion	cutting hard material	Very small conchoidal fractures with polish >5 per 10mm, overlapping and continuous (area 2). Crushing with step terminating fractures (area 3)	Polish very close to the edge, cutting a hard material
WZ148.H11.20.205	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Polish and rounding (areas 1-3, 10-12)	Weak generic polish (areas 10-12)
WZ148.H11.6.200	trapeze-rectangle	stereo, high-powered	transverse motion		Step terminating conchoidal fractures >5 per 10mm, overlapping very large (areas 2-3)	Small, localized polish on the highest point on the artifact (area 10)
WZ148.H11.6.201	trapeze-rectangle	stereo, high-powered	longitudinal motion		Continuous fine snap fractures (area 11)	
WZ148.H11.8.200	trapeze-rectangle	stereo, high-powered	longitudinal motion		Snap fractures overlapping and very small > 5 per 10mm (area 10). Rounding (area 11)	
WZ148.H11.8.201	trapeze-rectangle	stereo, high-powered	transverse motion		Step terminating conchoidal fractures irregularly sized, mostly large overlapping patches (areas 1-3).	
WZ148.H11.8.202	straight truncated and backed	stereo, high-powered	longitudinal motion	cutting meat/hide	Rounding (area 2). Small step of conchoidal fractures, overlapping all same size > 5 per 10mm (areas 2-3). Conchoidal fractures >5 per 10mm, overlapping different sizes (area 12)	Weak generic polish (area 11)

WZ148.H11.9.200	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Rounding (area 10). Overlapping snap fractures, two large patches of snaps with little in between (area 11).	Weak generic polish, away from the edge (areas 10-11)
WZ148.H11.9.201	trapeze-rectangle	stereo	longitudinal motion		Snap fractures with rounding (areas 2-3). Large isolated snaps (areas 10-12)	
WZ148.H15.110.209	trapeze-rectangle	stereo, high-powered	longitudinal motion		Snap fractures >5 per 10mm (area 2, 11)	
WZ148.H15.95.207	trapeze-rectangle	stereo	longitudinal motion		Snap fractures >5 per 10mm (areas 2-3)	
WZ148.H15.95.208	trapeze-rectangle	stereo	unknown function		Rounding (area 12)	
WZ148.H15.95.210	trapeze-rectangle	stereo	longitudinal motion		Snap fractures >5 per 10mm (areas 1-3). Bending fractures (area 10)	
WZ148.H15.95.216	trapeze-rectangle	stereo	longitudinal motion		Snap fractures of varying sizes, overlapping mostly small. >5 per 10mm (area 2). Step terminating bending fracture (area 11)	
WZ148.H15.95.223	backed bladelet fragment	stereo	unknown function		Very small conchoidal fractures. Overlapping and rounded >5 per 10mm (area 2)	
WZ148.H16.105.202	trapeze-rectangle	stereo, high-powered	longitudinal motion	cutting meat/hide	Snap fractures along the edge. Continuous, overlapping (areas 2-3)	Weak generic polish (area 12)
WZ148.H16.111.204	trapeze-rectangle	stereo, high-powered	longitudinal motion		Overlapping snap fractures >5 per 10mm (areas 1-3)	
WZ148.H16.111.206	trapeze-rectangle	stereo, high-powered	longitudinal motion		Snap fractures >5 per 10mm (areas 2-3)	
WZ148.H16.111.210	backed bladelet fragment	stereo, high-powered	longitudinal motion		Snap fractures >5 per 10mm (areas 1-2)	

WZ148.H16.115.200	trapeze-rectangle	stereo, high-powered	unknown function	cutting medium hard material	Step terminating bending fracture 1.6mm (at the corner) (area 1). Conchoidal fracture with step terminations (area 2). Series of overlapping bending and conchoidal fractures with feather hinge terminations >5 per 10mm (areas 10-11)	Polish localized along the edge, continuous and bright (areas 1-2)

Table 75: Kharaneh IV details of use-wear traces resulting from longitudinal, transverse, and unknown functions

Artifact Number	Microlith Type	Magnification	Motion	Material	Evidence (low powered)	Evidence (high powered)
KHIV.AQ40.13.56	inversely retouched bladelet	stereo, high-powered	longitudinal motion		Snap fractures >5 per 10mm (areas 4-5)	
KHIV.AS42.10.1	lunate	stereo, high-powered	longitudinal motion	cutting meat/hide	Small snap fractures >5 per 10mm (area 3)	Weak generic polish (area 12)
KHIV.AQ40.13.2	notched bladelet	stereo, high-powered	longitudinal cutting with hafting damage		Very fine conchoidal fractures with rounding, area 1. Rounding (area 5)	
KHIV.AP36.17.2	obliquely truncated	stereo	twisting motion?		Overlapping conchoidal fractures (area 2)	
KHIV.AP36.45.1	obliquely truncated	stereo	scraping?		Series of conchoidal fractures >5 per 10mm (areas 2-3)	
KHIV.AQ36.3.5	obliquely truncated	stereo	chopping?		Overlapping step terminating bending fractures (areas 1-2, 10-11)	
KHIV.AQ40.13.22	obliquely truncated	stereo, high-powered	transverse motion		Conchoidal fractures, step and hinged >5 per 10mm (areas 1-3)	
KHIV.AR38.11.21	obliquely truncated	stereo	longitudinal motion		Snap fractures >5 per 10mm (areas 1-3)	
KHIV.AR38.11.4	unbacked trapeze	stereo, high-powered	longitudinal motion	heavy butchering	Step terminating bending fracture 1.0mm, angled (area 1). Large step terminating	Very bright polish at the edge of the piece, moving into generic weak polish

					bending fracture, angled, with a few smaller overlying fractures 2.4mm	(areas 11-12)
KHIV.AR38.11.5	obliquely truncated	stereo	longitudinal motion		Mix of conchoidal and snap fractures along the edge >5 per 10mm (areas 1-2)	
KHIV.AS38.12.11	obliquely truncated	stereo	longitudinal motion		Snap fracture along the entire edge >5 per 10mm (areas 1-3, 10-12)	
KHIV.AS38.12.5	obliquely truncated	stereo	longitudinal motion		Small snap fractures >5 per 10mm (area 12)	
KHIV.AS41.10.2	obliquely truncated	stereo	longitudinal motion		Angular snap fractures >5 per 10mm (area 1)	
KHIV.AS42.10.15	obliquely truncated	stereo, high-powered	transverse motion		Series of overlapping conchoidal fractures >5 per 10mm (area 2)	
KHIV.AS42.10.21	obliquely truncated	stereo, high-powered	longitudinal motion	cutting meat/hide	Discontinuous, very small snap fractures, rounding (areas 1-2, 10-11)	Weak generic polish (area 10)
KHIV.AT35.5.3	obliquely truncated	stereo	longitudinal motion		Snap fractures >5 per 10mm (area 2)	
KHIV.AR38.11.12	obliquely truncated and backed	stereo	longitudinal motion		Very small continuous snaps >5 per 10mm (areas 1-3, 10-12)	
KHIV.AS42.10.33	partially backed	stereo	longitudinal motion		Snap fractures >5 per 10mm (areas 2-3)	
KHIV.AP36.17.1	trapeze-rectangle	stereo	longitudinal motion		Small snaps >5 per 10mm (areas 10-12)	
KHIV.AQ36.3.4	trapeze-rectangle	stereo, high-powered	transverse motion		Conchoidal fractures overlapping >5 per 10mm (area 1)	
KHIV.AS42.10.10	trapeze-rectangle	stereo, high-powered	longitudinal motion		Conchoidal fractures, very small >5 per 10mm, continuous (areas 2-3)	
KHIV.AT36.5.1	trapeze-rectangle	stereo	longitudinal motion		Snap fractures >5 per 10mm (areas 10-11)	

KHIV.AQ36.24.1	unbacked trapeze	stereo, high-powered	longitudinal motion		Snap fractures >5 per 10mm (area 1). Conchoidal fractures, very small >5 per 10mm (area 3)	
KHIV.AQ40.13.55	unbacked trapeze	stereo, high-powered	longitudinal motion		Snap fractures >5 per 10mm (areas 2-3)	
KHIV.AR38.11.10	unbacked trapeze	stereo, high-powered	longitudinal motion		Rounding with very small snaps >5 per 10mm (areas 2, 10). Feather terminating bending fractures	
KHIV.AS36.7.5	unbacked trapeze	stereo, high-powered	longitudinal motion	cutting meat/hide	Very small, shallow snap fractures, continuous >5 per 10mm (areas 1, 10)	Weak generic polish (areas 11-12)
KHIV.AS37.14.5	unbacked trapeze	stereo	longitudinal motion		Rounding (area 3)	
KHIV.AS41.10.1	unbacked trapeze	stereo, high-powered	transverse motion		Conchoidal fractures >5 per 10mm step terminating (area 3). Very large feather terminating conchoidal fractures with crushing (areas 10-12)	
KHIV.AS42.10.14	unbacked trapeze	stereo, high-powered	transverse motion		Continuous snaps and conchoidal fractures >5 per 10mm (area 1). Feather terminating conchoidal fractures	
KHIV.AS38.12.1	utilized bladelet	stereo, high-powered	longitudinal motion		Very large, continuous snap fractures >5 per 10mm, some bending fractures (areas 2, 11)	
KHIV.AS42.10.36	varia	stereo, high-powered	transverse motion	scraping hard material	Conchoidal fractures step terminations, >5 per 10mm varying sizes and overlapping	Bright, concentrated polish along the edge, hard contact material. Very localized
KHIV.AP36.17.7	obliquely truncated and backed	stereo	unknown function		Small step terminating bending fractures (areas 2-3). Two large conchoidal fracture (area 10)	

KHIV.AP36.17.8	completely backed	stereo	unknown function		Step terminating bending fracture 2.0mm, perpendicular (area 2). Snap fractures >5 per 10mm (area 3)	
KHIV.AQ40.13.49	obliquely truncated and backed	stereo, high-powered	unknown function		Conchoidal fractures and step terminating bending fractures >5 per 10mm. Snap fractures across piece (area 2-3)	
KHIV.AQ40.13.9	unbacked trapeze	stereo, high-powered	unknown function		Step terminating bending fractures overlapping retouch, continuous >5 per 10mm (areas 1-3)	
KHIV.AR38.11.2	pointed backed bladelet	stereo	unknown function	hard material	Combination of feather terminating and step terminating bending fractures. Also conchoidal fractures >5 per 10mm, overlapping and different sizes (areas 1-3, 8)	polish at the tip, bright and concentrated (area 10)
KHIV.AS42.10.11	completely backed	stereo, high-powered	unknown function		Feather terminating bending fractures x 2 (area 2). Massive feather terminating conchoidal fractures x2 6.7mm (area 10)	
KHIV.AS42.10.19	backed bladelet fragment	stereo, high-powered	unknown function		Step and feather terminating conchoidal fractures (areas 2-3). Small conchoidal fractures (area 12)	
KHIV.AS42.10.23	obliquely truncated	stereo	unknown function		Step terminating bending fractures >5 per 10mm (area 3). Cluster of step terminating bending fractures 1.2mm, >5 per 10mm (area 11)	
KHIV.AS42.10.3	trapeze-rectangle	stereo, high-powered	unknown function		Feather and step terminating bending fractures >5 per 10mm. Irregularly sizes and overlapping, but continuous (areas 1-2). step terminating bending fractures x4, perpendicular (area 3)	polish along the end, bright and localized, probably from hafting using a hard material (area 10)

KHIV.AS42.10.39	obliquely truncated	stereo	unknown function	Snap fractures. Large conchoidal fracture, conchoidal fractures >5 per 10mm (area 2)
KHIV.AS42.10.5	trapeze-rectangle	stereo, high-powered	unknown function	Three small conchoidal fractures with step terminations (area 1). Step terminating bending fractures, overlapping and of different sizes, perpendicular (areas 10-12)
KHIV.AS42.10.8	unbacked trapeze	stereo, high-powered	unknown function	Overlapping conchoidal fractures, feather terminations >5 per 10mm (areas 1-2). Overlapping conchoidal fractures, feather terminations >5 per 10mm (area 11). Step terminating bending fracture 0.6mm (area 12)

Wadi Mataha Low-Powered Photomicrographs

Appendix D Use-Wear Images

This appendix contains a sample of photomicrographs of wear traces taken using from low-powered and high-powered magnification.

Wadi Mataha Low-Powered Photomicrographs

Figure 46: WM-2493. Projectile bard, step terminating bending fracture (ventral surface)

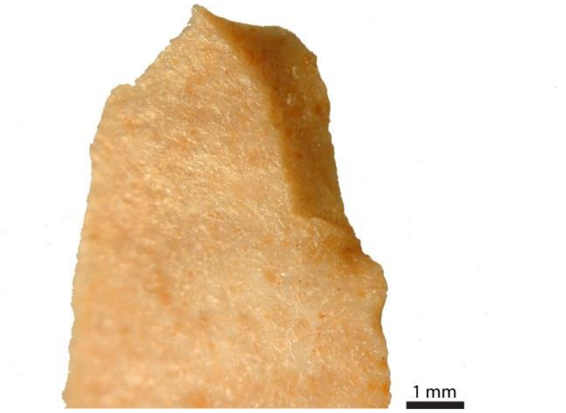

Figure 48: WM-2510. Projectile tip, impact burination

Figure 47: WM-2493. Projectile bard, step terminating bending fracture (dorsal surface)

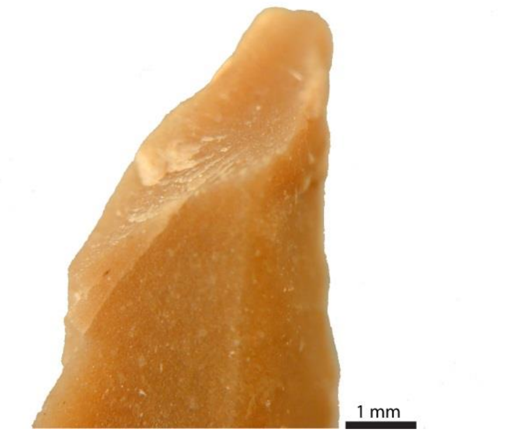

Figure 49: WM-2570. Projectile tip, impact burination

‘Uyun al-Hammâm Low-Powered Photomicrographs

Figure 50: WZ148.G13.29.217. Projectile bard, step terminating bending fracture

Figure 52: WZ148.H15.110.210. Projectile bard, step terminating bending fracture

Figure 51: WZ148.H11.11.201. Projectile bard or transverse, step terminating bending fracture

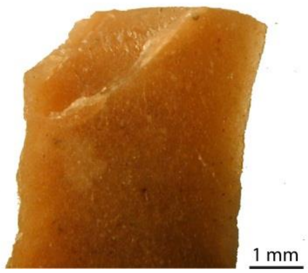

Figure 53: WZ148.H15.110.219. Projectile tip, step terminating bending fracture.

Kharaneh IV Low-Powered Photomicrographs

Figure 54: KHIV.AQ40.13.4. Projectile bard or transverse, step terminating bending fracture

Figure 56: KHIV.AS42.10.2. Projectile bard or transverse, step terminating bending fracture

Figure 55: KHIV.AR38.11.1. Projectile bard or transverse, step terminating bending fracture

Wadi Mataha High-Powered Photomicrographs

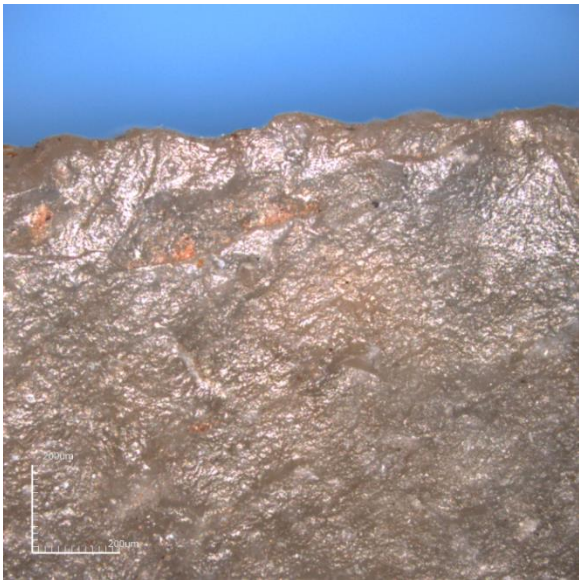

Figure 57: WM-2376 Cutting meat, weak generic polish and rounding

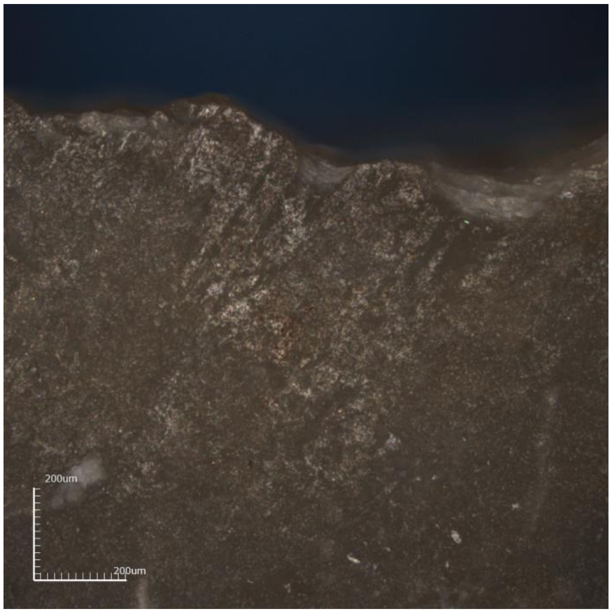

Figure 58: WM-2466 Projectile, angled striations and weak generic polish

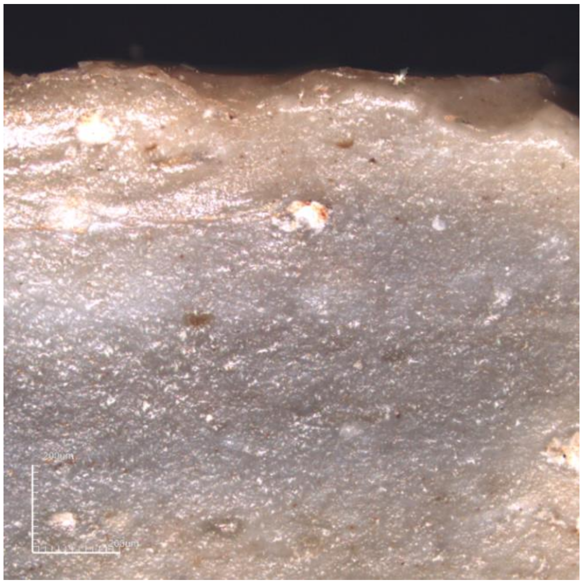

Figure 59: WM-2382 Cutting meat, weak generic polish and rounding

Figure 60: WM-2532 Cutting meat, weak generic polish

‘Uyun al-Hammâm High-Powered Photomicrographs

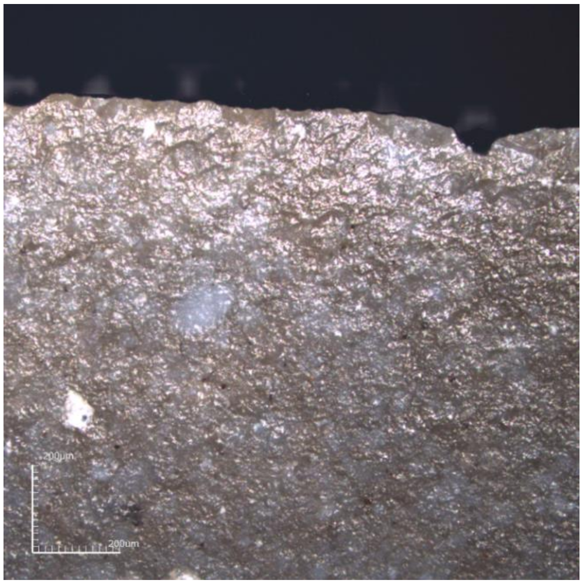

Figure 61: WZ148.G13.29.216 Transverse motion on soft material, weak generic polish

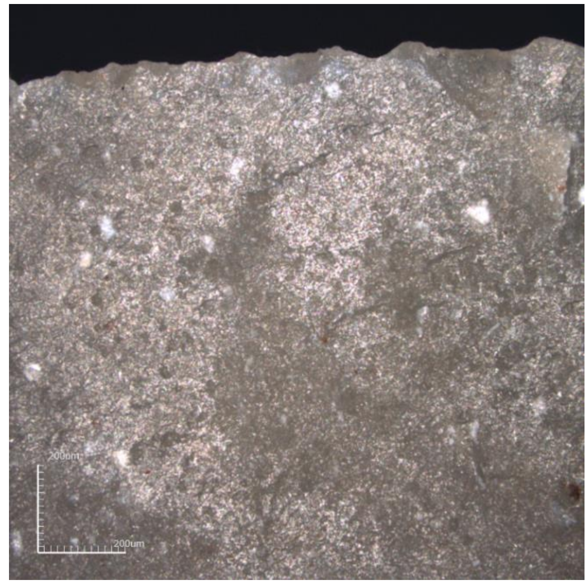

Figure 63:WZ148.G13.30.269 Cutting meat/hide, weak generic polish

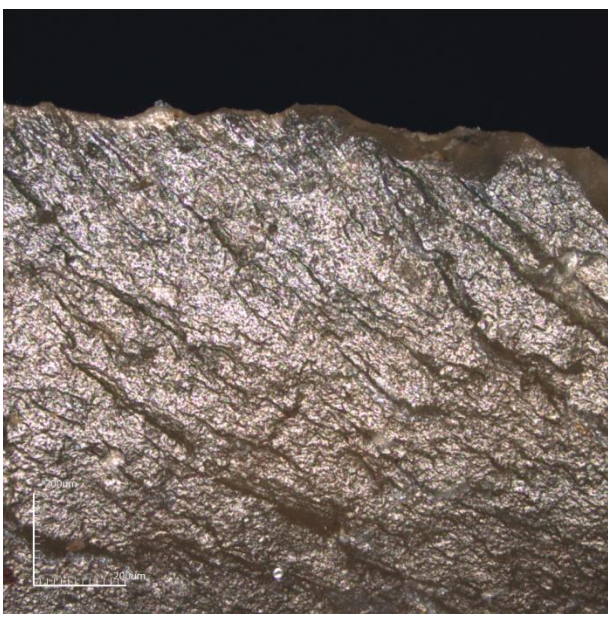

Figure 62: WZ148.G13.39.234 Cutting meat/ hide, weak generic polish.

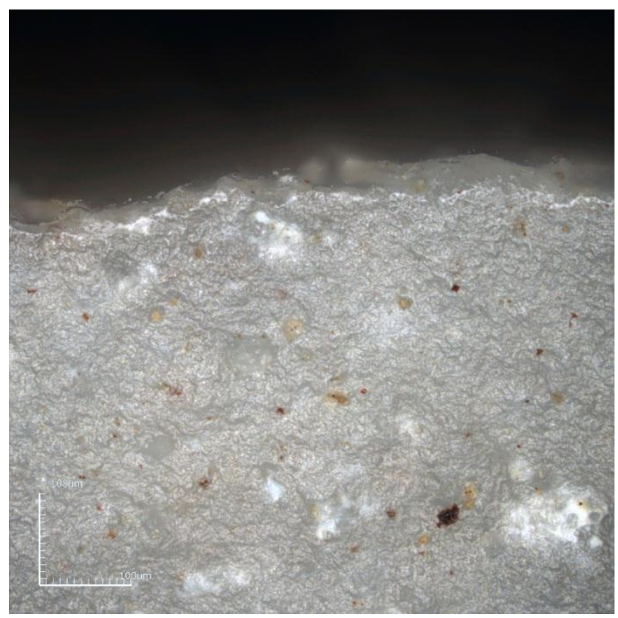

Figure 64: WZ148.H11.20.201 Cutting hard contact material

‘Uyun al-Hammâm High-Powered Photomicrographs

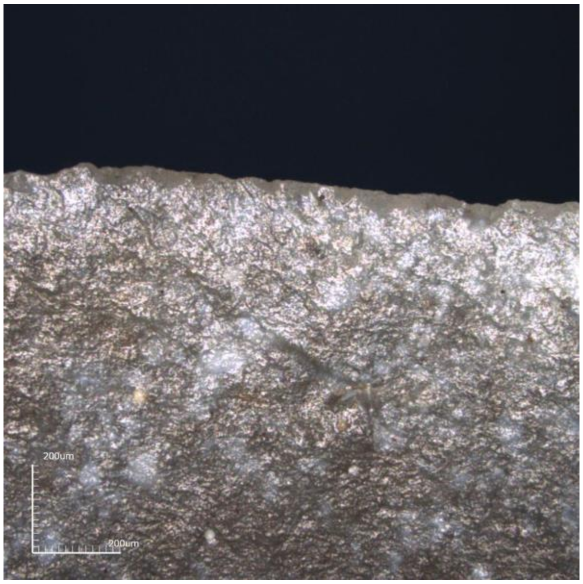

Figure 65: WZ148.H11.20.205 Cutting meat/weak generic polish

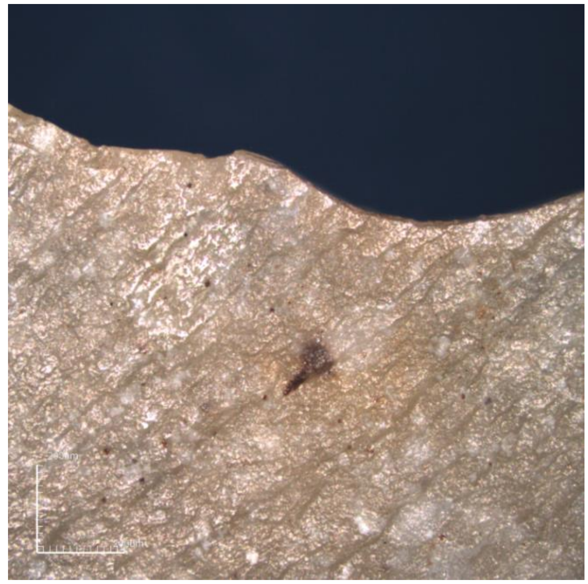

Figure 67: WZ148.H16.105.202 Cutting meat/weak generic polish

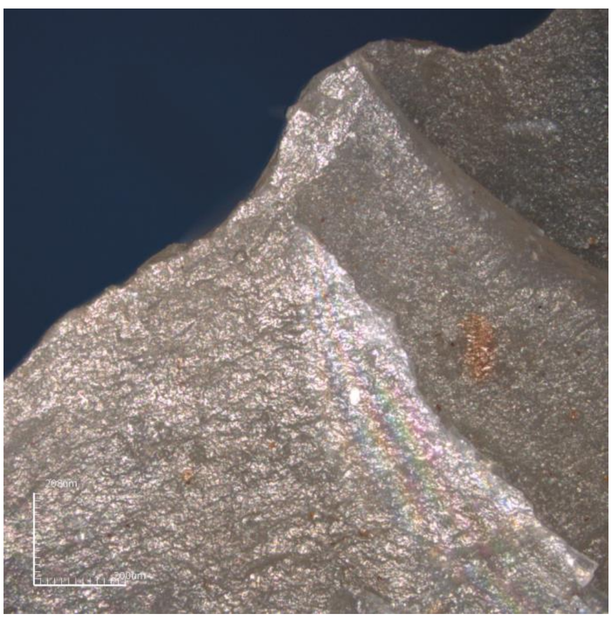

Figure 66: WZ148.H16.105.206 Projectile with weak generic polish

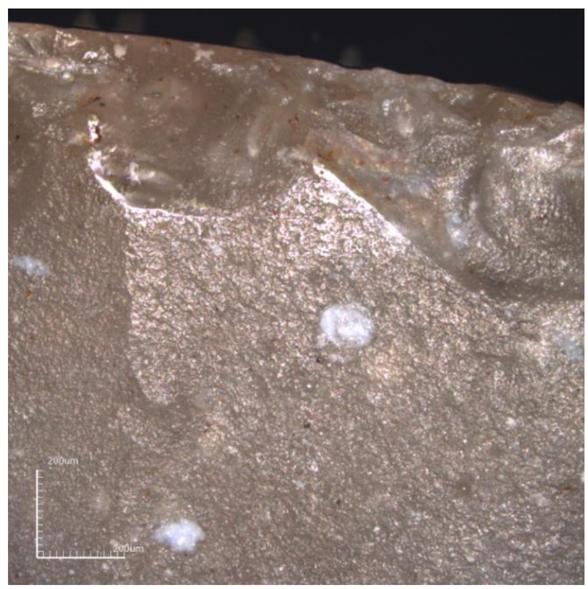

Figure 68: WZ148.H16.115.200 Cutting medium/hard material

Kharaneh IV High-Powered Photomicrographs

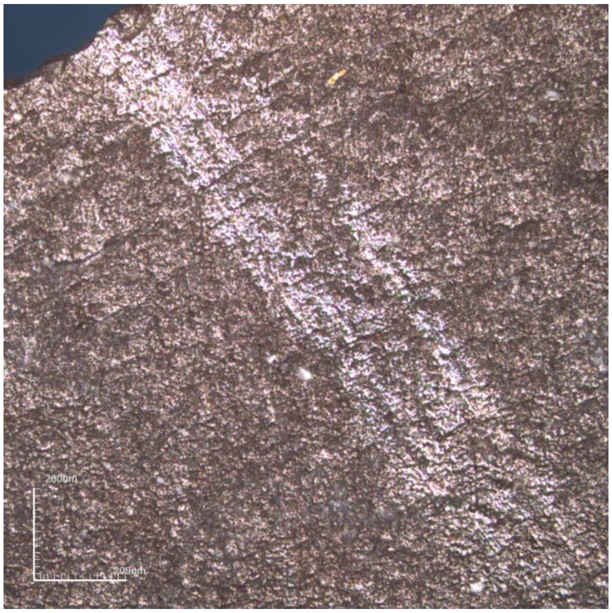

Figure 69: KHIV.AQ36.36.1 Projectile, angled linear polish

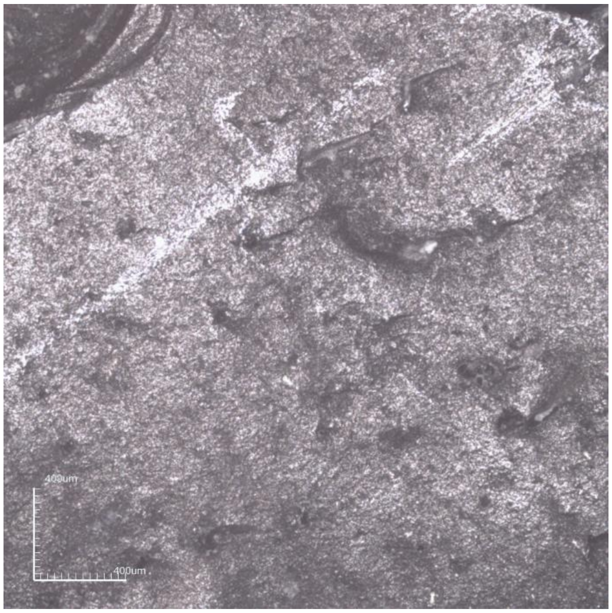

Figure 71: KHIV.AQ40.13.5 Projectile; angled linear polish

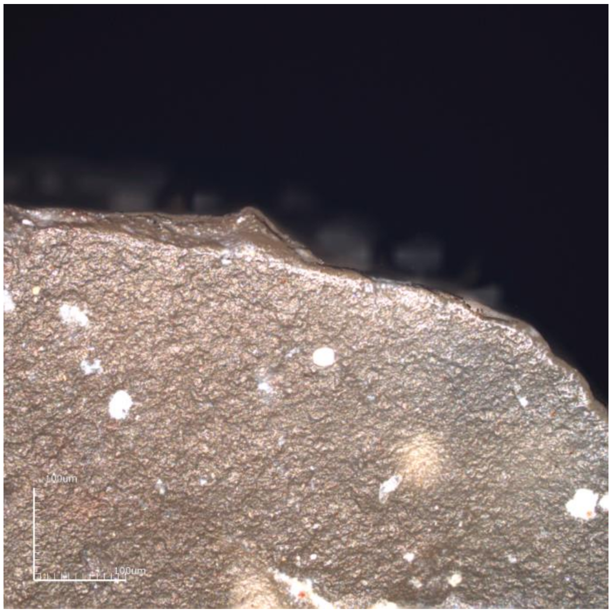

Figure 70: KHIV.AQ40.13.8 Projectile with bright polish (bone contact)

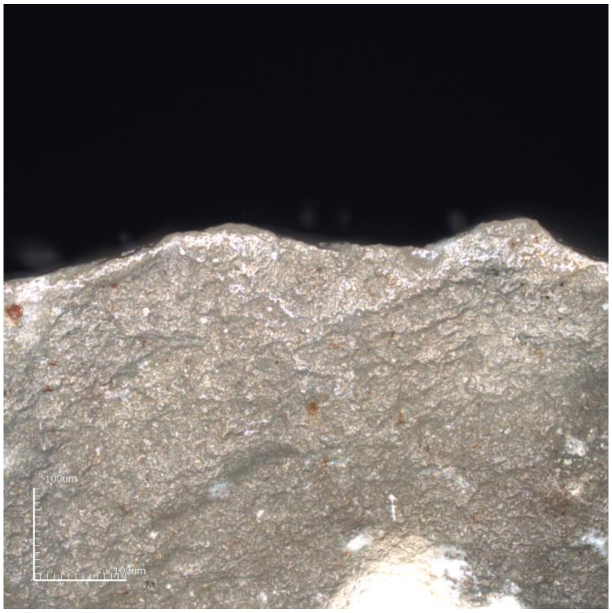

Figure 72: KHIV.AQ40.13.10 Projectile with bright polish (bone contact)

Kharaneh IV High-Powered Photomicrographs

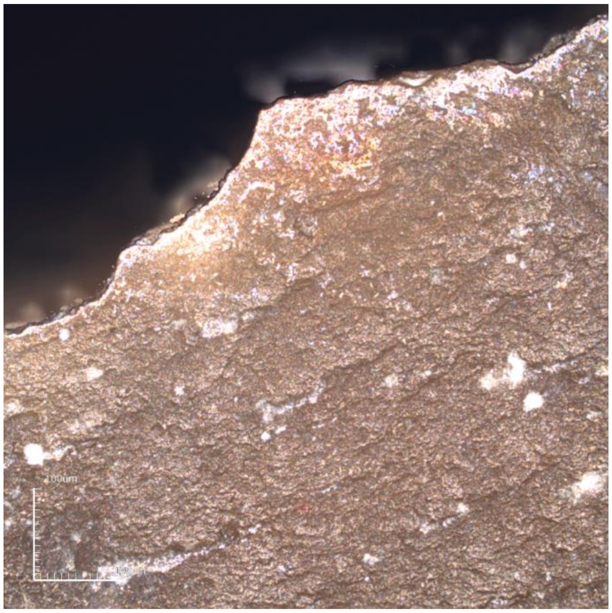

Figure 73: KHIV.AQ40.13.69 Bright localized polish, hard contact material

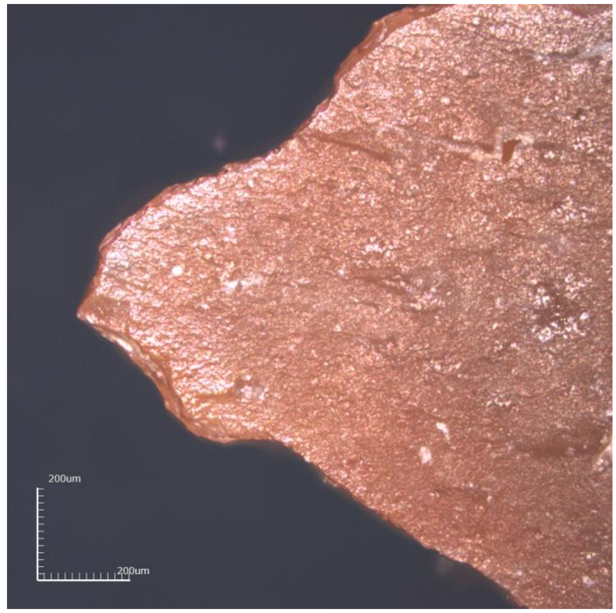

Figure 75: KHIV.AR38.11.2 Unknown function, bright polish at the tip

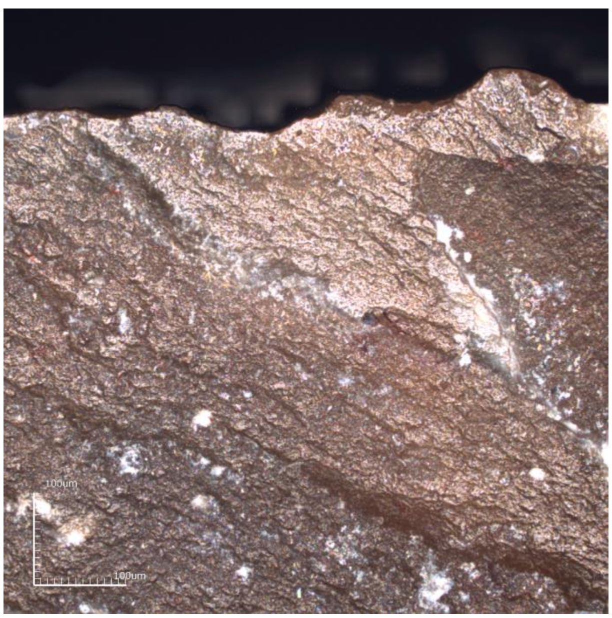

Figure 74: KHIV.AR38.11.4 Heavy butchering Very bright polish at the edge of the piece, moving into generic weak polish

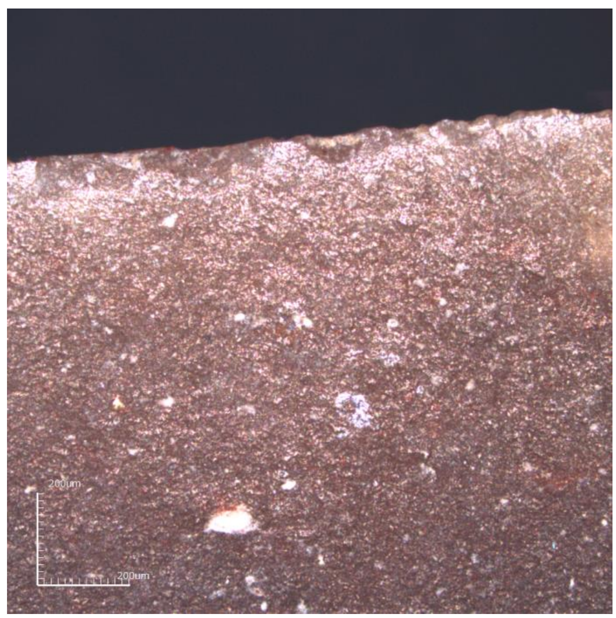

Figure 76: KHIV.AS36.7.5 Cutting meat/hide. Weak generic polish

Kharaneh IV High-Powered Photomicrographs

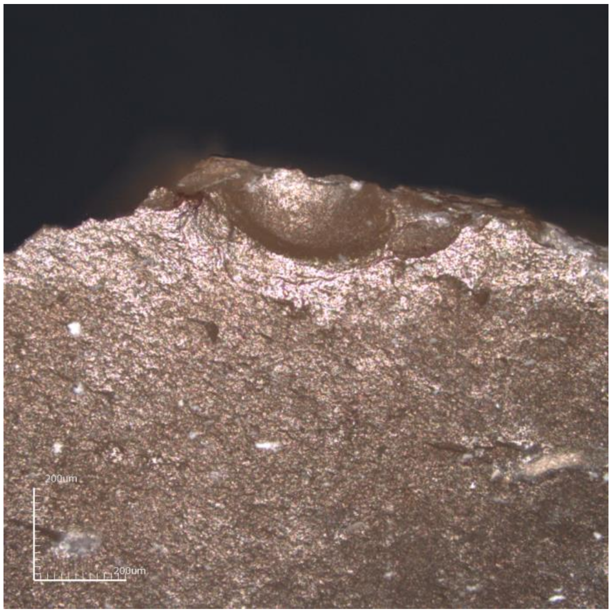

Figure 77: KHIV.AS42.10.2 Projectile with weak generic polish

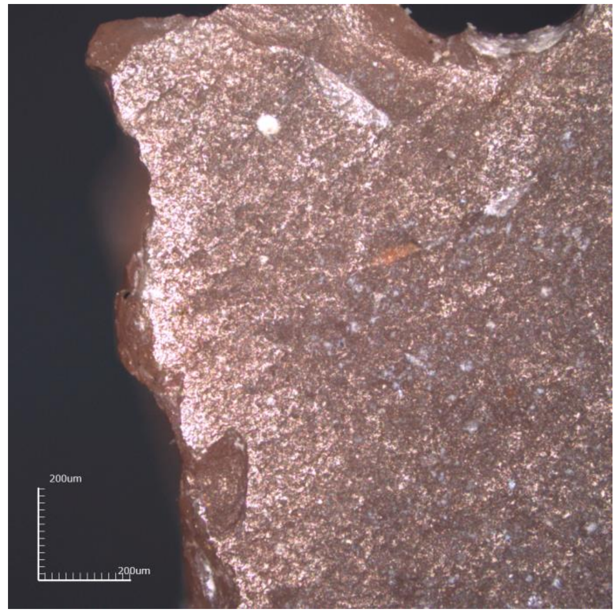

Figure 79: KHIV.AS42.10.3 Unknown function, hafting using a hard material

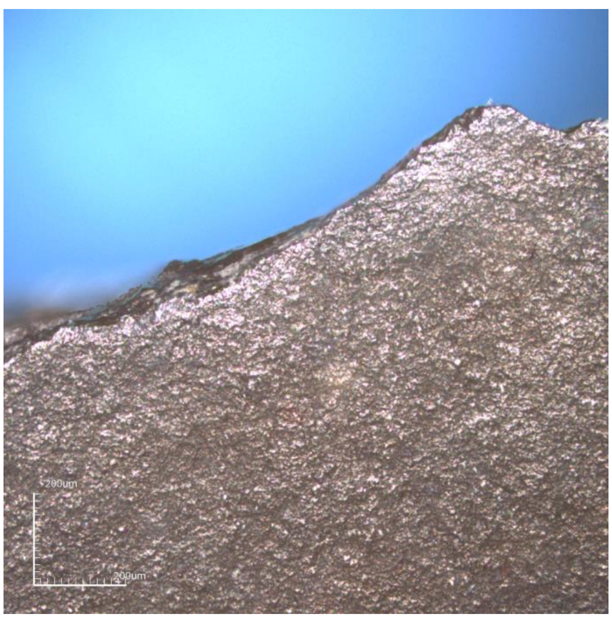

Figure 78: KHIV.AS42.10.6 Projectile with weak generic polish

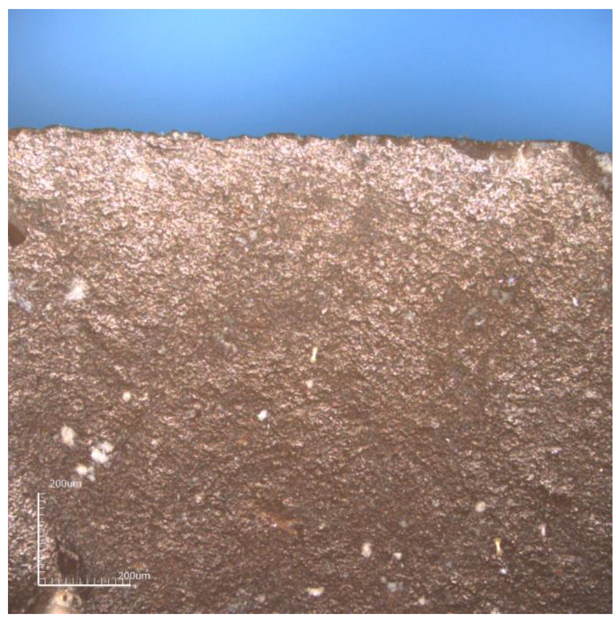

Figure 80: KHIV.AS42.10.21 Cutting meat/hide, weak generic polish

Kharaneh IV High-Powered Photomicrographs

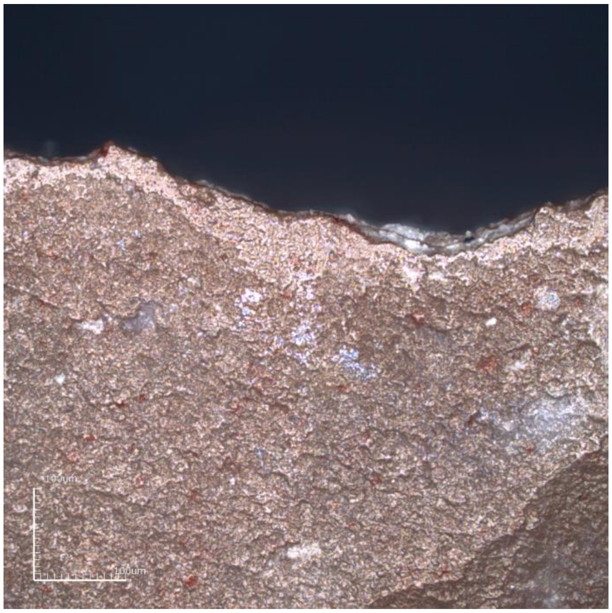

Figure 81: KHIV.AS42.10.36 Transverse motion, bright polish, hard contact material

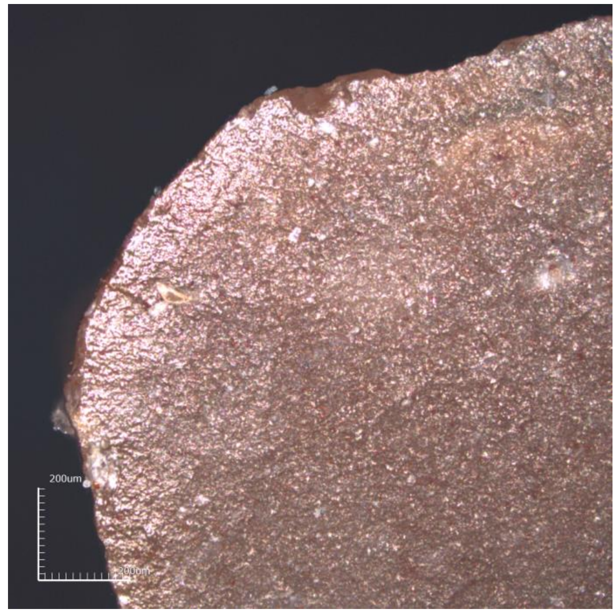

Figure 83: KHIV.AS42.10.36 Transverse motion, bright polish, hard contact material

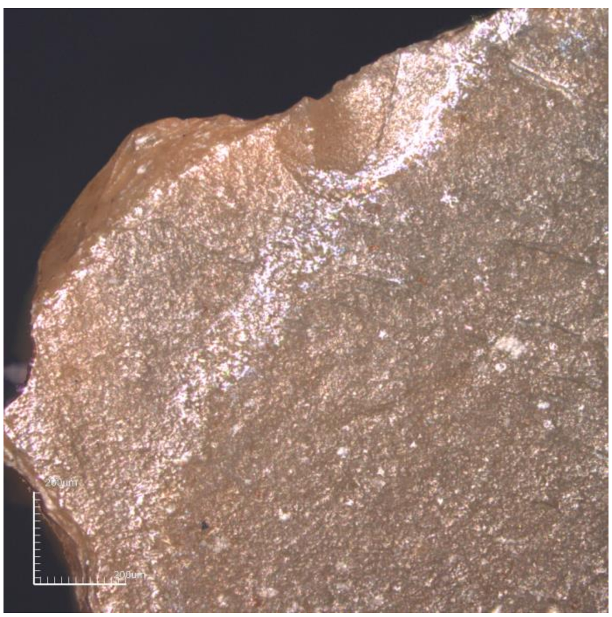

Figure 82: KHIV.AT41.9.3 Projectile with linear polish

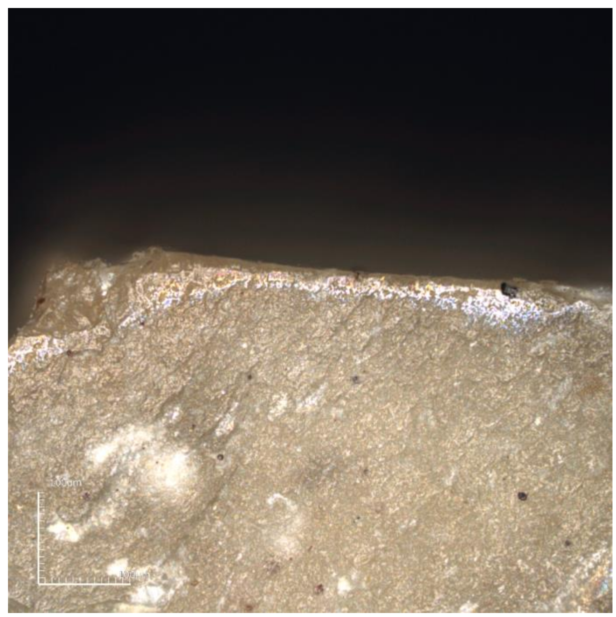

Figure 84: KHIV.AT41.9.6 Projectile with bright polish (bone contact?)