Functional Variation within Middle Paleolithic Ground Stone Tools: Use-Wear Analysis of *ad-hoc* Limestone Tools from Nesher Ramla Units I-II.

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Abstract

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In the southern Levant, ground stone tools (GST) provide insight into early plant food exploitation, butchery, and cognition. Outside of these examples, GST evidence is scarce, particularly for the Middle Paleolithic. An extensive assemblage of GST recovered from Nesher Ramla, an open-air hunting camp in Israel, presents the unique opportunity to study the role of GST within Middle Paleolithic behaviour. Use-wear and residue analysis, together with replication experiments are employed to investigate GST function within a specific period of site use by focusing on GST from the Upper Sequence (Units I-II) which reflects a trend of decreasing site-use intensity. The results indicate that GST were employed for bone breaking and knapping during the final phases of occupation while comparison with Unit V suggests longer occupations involved more diverse and extensive use of GST. GST at open-air sites are also proposed to represent a strategy for intensive exploitation of location-specific resources.

Keywords

Ground Stone Tools, Use-Wear Analysis, Residue Analysis, Southern Levant, Middle Paleolithic, Bone Breaking, Hammerstones, Open-Air Habitation.

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Chapter 1 - Introduction

The discovery of Nesher Ramla, a Middle Paleolithic open-air hunting site in Israel, in 2010 led to the recovery of extensive evidence for human occupation including two hominin fossils, lithics, animal bones, fire remains, and most notably for the purposes of this thesis, a large assemblage of ground stone tools (GST) (Hershkovitz et al. 2021; Zaidner et al. 2014). Previous studies of GST from the southern Levant have provided valuable insights into many aspects of ancient behaviours related to subsistence, technology, and cognition including early plant food exploitation, butchery practices, symbolic expression, and long-term planning (e.g. Alperson-Afil and Goren-Inbar 2016; Assaf et al. 2020; Dubreuil and Nadel 2015; Goren-Inbar et al. 2002; Hovers et al. 2003; Paixão et al. 2021a). Outside of these examples, evidence of early GST is scarce, particularly for the Middle Paleolithic period. The functional analysis of the largest assemblage of GST yet to originate from a Middle Paleolithic site in the southern Levant conducted here contributes to correcting this imbalance.

GST present a diverse range of forms and functions but share the same general characteristic of having been manufactured or used through percussion, grinding, polishing, or some combination of these gestures. Essentially, the term GST can be applied to any form of non-flaked stone tool (Adams et al. 2009; Adams 2014a; Dubreuil et. al 2015; Wright 1992).

Within this important category of technology, the term "*ad-hoc* GST" is applied in this thesis to natural pebbles, cobbles, or blocks that have been collected for expedient use without prior preparation or manufacture. Such tools represent some of the earliest forms documented for GST and present a paradox in terms of their promising research potential and what is actually understood regarding their function(s) (e.g. Arroyo et al. 2020; Arroyo and de la Torre 2016, 2018, 2020; Caruana et al. 2014; de Beaune et al. 2004; Harmand et al. 2015). The earliest forms of GST have also been attributed an important ancestral role within the initial stages of the evolution of technology (de Beaune 2004). Despite this, they remain understudied and associated with a limited range of functional interpretations.

Ad-hoc GST are reported at the oldest Early Stone Age and Lower Paleolithic sites in Africa and the Levant where they have been associated exclusively with percussive motions of use and are implicated in knapping, bone breaking, and nut cracking (Alperson-Afil and Goren-Inbar 2016; Arroyo et al. 2020; Arroyo and de la Torre 2016, 2018, 2020; Assaf et al. 2020; Caruana et al. 2014; Delagnes and Roche 2005; Goren-Inbar et al. 2002; Roche et al. 2018; Shea and Bar-Yosef 1999). In later contexts, *ad-hoc* GST demonstrate a wider range of functions as they were utilized with novel gestures and/ or applied to novel processed materials (Cristiani et al. 2012, 2021; Dubreuil and Nadel 2015; Mercader 2009; Revedin et al. 2010, 2015). By the Middle Stone Age in Africa and the Upper Paleolithic in the Levant and Europe, *ad-hoc* GST were used with an abrasive gesture, or a mix of percussion and abrasion, for hide processing and ochre grinding. These tools also potentially reveal early instances of plant food processing activities that are associated with formal tool types in even later periods (e.g. Cristiani et al. 2012, 2021; Dubreuil and Nadel 2015; Goren-Inbar et al. 2002; Piperno et al. 2004; Revedin et al. 2010, 2015; Van Peer et al. 2003, 2004).

Background

In this thesis, Nesher Ramla serves as a specific context to study the function of *ad-hoc* GST and investigate how these tools fit into Middle Paleolithic lifeways while the southern Levant provides a wider background for examining the significance of activities conducted with GST at Nesher Ramla. Broader discussions of *ad-hoc* GST function and open-air habitation will also rely primarily on evidence from the southern Levant.

The Levant is the geographic region on the coast of the Eastern Mediterranean Sea that forms part of a terrestrial land-bridge between the African and European continents (Shea 2013). The southern Levant, which encompasses Israel, Palestine, Jordan, Syria, and the Sinai region of Egypt, is distinguished within this region for its unique climate and geography (Suriano 2014; Zaidner et al. 2016).

Nesher Ramla is situated on the slopes of the Central Mountain Range of the southern Levant overlooking the coastal plain that borders the eastern coast of the Mediterranean Sea (Zaidner et al. 2014). The Mediterranean imposes a favourable climate on this region that is characterised by high annual rainfall and mild, humid winters (Bar-Matthews et al. 2019). Variation in rainfall amounts over short distances also brings a diverse range of vegetation and fauna in close proximity to Nesher Ramla (Crater Gershtein et al. 2020; Langugut et al. 2011; Miebach et al. 2019; Shea 2003).

The history of occupation at Nesher Ramla (170-80 ka) roughly coincides with the end of the MIS 6 glacial period and spans almost the entirety of the subsequent MIS 5 interglacial period (Zaidner et al. 2014). Fluctuations in water availability and temperature occurred throughout the occupation of Nesher Ramla and caused the spread or retraction of different plants resulting in a mosaic landscape of mixed vegetation types in close proximity to one another (Bar-Matthews et al. 2019; Chen and Litt 2018; Frumkin et al. 2011; Langgut et al. 2011; Miebach et al. 2019).

The Middle Paleolithic (ca. 250-45 ka) marks the peak distribution of the Levantine Mousterian technocomplex in the southern Levant and the predominance of

Levallois flake production systems (Centi and Zaidner 2021; Hovers and Belfer-Cohen 2013; Shea 2013). The habitual use of fire, habitation of caves as base camps, and communal butchery activities represent a related set of behaviours which have their onset in the late Lower Paleolithic and later proliferated during the Middle Paleolithic (Chazan 2009; Shimmelmitz et al. 2014, 2016; Stiner et al. 2009, 2011).

The southern Levant is noted for the habitation of both Neanderthals and anatomically modern humans (AMH) (e.g. Hovers and Belfer-Cohen 2013**;** Shea 2008, 2010). The two populations share similarities in material culture, including lithic industries, and have been proposed to demonstrate behavioural modernity through symbolic behaviour and spatial organization of sites (Alperson-Afil and Hovers 2005; Bar-Yosef Mayer et al. 2009; Hovers and Belfer-Cohen 2013; Hovers et al. 2003; Prévost et al. 2021; Shea 2010).

Towards the end of the Middle Paleolithic, increased demographic pressure within the Mediterranean zone is implicated in a change in land use patterns that prompted a shift in subsistence strategies in response to declining availability of preferred prey items (Hovers 2001; Hovers and Belfer-Cohen 2013; Meignen et al. 2006; Shea 2010). Expansions of diet breadth leading up to the Upper Paleolithic in which lower-ranked resources were incorporated to supplement hunter-gatherer diets are proposed to have included shifting patterns of prey selection and the consumption of plant-food resources (Melamed et al. 2016; Lev et al. 2005; Rosen 2003; Speth 2012, 2013; Speth and Clark 2006; Stiner et al. 1999, 2000).

Nesher Ramla documents a previously unknown mode of open-air habitation as the site is located within a karst-sinkhole (Zaidner et al. 2016). As a result of this unique context, the 8m archaeological sequence displays exceptional preservation for an open-air site (Zaidner et al. 2014, 2016).

This research investigates the role of GST within a specific period of site-use at Nesher Ramla by focusing the functional analysis on pebbles and cobbles originating from the Upper Sequence (Units I-II). The Upper Sequence comprises the latest phases of occupation at the site and is distinguished from the oldest phases of occupation within the Lower Sequence by a change in artifact densities, faunal remains, and the sedimentation rate. The Upper Sequence displays a trend of decreasing artifact density that has been interpreted as a signal for declining site use intensity culminating in the abandonment of the site (Centi and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014, 2018). A shift in species representation within the faunal assemblage of the Upper Sequence indicates that a change in hunting practices may have accompanied this change in site use (Centi and Zaidner 2020; Varoner et al. 2021).

The Upper Sequence GST assemblage is composed of an extensive collection of hundreds of predominantly limestone water-shaped pebbles, cobbles, and blocks which were systematically recovered during excavation (Zaidner et al. 2014). Investigating the function of these objects will provide an independent line of evidence for determining what activities were conducted at Nesher Ramla and what changes to occupation were involved in the shift towards increasingly ephemeral and sporadic visits to the site.

Previously conducted research on the GST from Unit V within the Lower Sequence by Paixão et al. (2021a,b) presents the opportunity to examine change over time in GST function at Nesher Ramla. Unit V, which represents the most intensive phases of occupation is accordingly predicted to display a greater degree of diversity in GST function compared to the Upper Sequence.

In addition to shedding light on the role of GST within the subsistence strategies and technological system at Nesher Ramla, the results of this functional analysis will also be applied to a broader discussion as to what insights can be revealed regarding open-air occupation and Middle Paleolithic patterns of land use in general. Open-air sites represent much of the earliest evidence for hominin occupation until the late Lower Paleolithic when intensive occupation of cave sites as base camps emerged as a widespread behaviour along with the habitual use of fire (Hovers 2017; Sharon et al. 2014). These behavioural innovations may reflect a change in land-use patterns involving other site types during this period. In the Levant, cave and open-air sites are considered complimentary modes of occupation within Middle Paleolithic patterns of mobility and settlement (Hovers 2017; Meignen et al. 2006; Sharon et al. 2014).

The functional analysis conducted in this thesis relies on other traces of use which may be left behind on the surface of tools. A combined approach consisting of use-wear and residue analysis is employed here to reconstruct the life-history of the GST from Nesher Ramla. Residue analysis and use-wear analysis are complimentary to one another as the former is more precise at identifying processed material and the latter is more effective for determining the use area and how materials were processed (Dubreuil et al. 2015; Stephenson 2015).

Use-wear analysis is study of wear that develops as a result of progressive alteration to the surfaces of tools during manufacture, use, and discard. Wear traces, which differ in appearance according to contact material properties and the nature of contact between the tool and the processed material, can be characterised and compared to patterns of wear associated with known use parameters in order to elucidate the context of wear formation (Adams 1988, 2014a; Adams et al. 2009; Dubreuil and Savage 2014; Dubreuil et al. 2015).

Interpretation of the use-wear observed on the GST from Nesher Ramla therefore required the development of an experimental reference collection. An experimental assemblage of seven limestone cobbles were collected near Nesher Ramla and used to perform a series of use-wear experiments in order to provide comparative patterns of use-wear from activities that were identified as having a high potential to have been conducted at the site. The experimental tasks included bone breaking, tendon pounding, hide processing, ochre grinding, and flint knapping among others. These experiments also produced the residues that were used to create the reference collections for the macro and micro residues.

Restrictions on travel as a result of the COVID-19 pandemic prevented access to archaeological assemblage, as a result some adjustments to the research framework originally planned for this thesis were required. In place of the originally planned research framework, analysis of the Upper Sequence GST assemblage makes use of spreadsheets and pictures provided by Laure Dubreuil and Laura Centi (PhD candidate, Hebrew University of Jerusalem) as sources for use-wear data. A database of use-wear traces recorded during preliminary observation of the cobbles was constructed in order to define patterns of related wear trace types while the pictures enabled the description of micropolish characteristics on six artifacts noted to display highly visible sheen.

Thesis Structure

This thesis is divided into six chapters. Following this introduction, chapter 2 presents the research context beginning with the geography and climate of the southern Levant. A discussion of the Middle Paleolithic period then provides the chronological background for a detailed description of Nesher Ramla and its occupational history. This chapter also includes a review of *ad-hoc* pebbles and cobbles in archaeological and ethnographic contexts and highlights behavioural insights gained from previous studies of these tools. Appendix A presents more extensive detail on archaeological and ethnographic *ad-hoc* GST.

Chapter 3 outlines the research framework employed by this thesis including the methodologies for residue and use-wear analysis, multiscale observation, and documentation; as well as the descriptive framework employed. This chapter also describes current theories for use-wear analysis and the history of use-wear research. The protocols for the blind test, which assesses the reliability of the descriptive framework and experimental results, is outlined in this chapter and the results are presented in Appendix B.

Chapter 4 presents the experimental framework and the results of use-wear and residue analysis for the experimental assemblage. The experimental results document the process of wear formation and provide insight into task viability through assessments of efficiency and effectiveness.

Chapter 5 presents the archaeological results from each data set separately beginning with the wear patterns identified through the database and then the micropolish characteristics documented in the pictures of the cobbles with sheen. Functional interpretations for the Upper Sequence GST are proposed based on comparisons with the experimental results and insights from other use-wear literature. The reliability of these functional interpretations is assessed based on other lines of evidence from Nesher Ramla in order to determine the degree of confidence with which each activity can be supported.

Chapter 6 applies the results of the analysis of the Upper Sequence GST assemblage to discussions regarding the role of GST in subsistence and how the abundance and diversity of functional types varied across different levels of site-use intensity. A comparison of GST function between the Upper Sequence and Unit V examines the role of GST within different patterns of occupation at the same site as well as change in GST function over time. The GST from Nesher Ramla are then integrated with GST evidence from other open-air sites in the southern Levant in order to examine Middle Paleolithic patterns of land-use through strategies of raw material provisioning and resource exploitation. This chapter also outlines recommendations for improving the recognition and recovery of *ad-hoc* GST in archaeological contexts, promising avenues for future research, and the research limitations of this thesis.

Chapter 2- Research Context

This chapter presents the chronological and geographic context for the GST assemblage from Nesher Ramla. The Levant provides an interesting backdrop for research as its extensive Lower Pleistocene archaeological record suggests this area was one of the first to be successfully colonized by early hominin groups outside of Africa (Dennel 2003). The route passing through northern Africa, across the Sinai Peninsula and into the Levant has been hypothesized as a terrestrial path for Out of Africa dispersals into Eurasia (Breeze et al. 2016; Petraglia and Alsharekh 2003). The rich archaeological record of the southern Levant documents an extensive history of repeated migrations and occupation by various hominin species spanning some 1.4 million years (e.g. Bar-Yosef 1994; Bar-Yosef and Belfer-Cohen 2001; Bar-Yosef and Belmaker 2011; Belmaker 2009; Belmaker et al. 2002; Dennel 2003; Goren-Inbar et al. 2000; Hovers and Belfer-Cohen 2013; Ronen 2006; Shea 2008, 2010; Shea and Bar-Yosef 1999).

The intent of this chapter is to place the Nesher Ramla GST assemblage within Middle Paleolithic trends in technology and behaviour in the southern Levant as well as to detail the history of a specific category of ground stone technology.

This chapter begins with a brief description of the geology and environment of the southern Levant as well as the history of climatic shifts that occurred throughout the occupation of Nesher Ramla. The Middle Paleolithic period is characterised in terms of subsistence, land-use patterns, social organization, and technological innovations to provide the chronological and behavioural background for Nesher Ramla which serves as a specific context for this research. Details on changing patterns of subsistence and site-use gained from previously conducted research at the site are reviewed as this evidence provides context for the Upper Sequence GST.

Descriptions of the collection, use and discard of *ad-hoc* pebbles and cobbles from archaeological and ethnographic contexts provide the background for the study of GST conducted in this thesis. This is intended to both inform the experimental design by identifying tasks likely to have been conducted with the Upper Sequence GST and highlight insights gained from previous research into *ad-hoc* GST.

2.1 Geography of the Levant

The Levant is a broad geographic region located at the intersection of the Eurasian and African continents that runs along the coast of the Eastern Mediterranean Sea. The Levant extends east to the Euphrates River where regions of extensive desert mark the edge of the climatic influence of the Mediterranean (Bar-Matthews et al. 2019; Shea 2013; Suriano 2014; Zaidner et al. 2016). The region south of the Litani River in Lebanon, the southern Levant, is often distinguished for its unique climatic and topographic features (Suriano 2014; Zaidner et al. 2016).

The southern Levant is bounded to the west by the Eastern Mediterranean Sea where the Mediterranean Coastal Plain meets the shore. Moving east, the landscape rises rapidly as the Mediterranean coastal plain becomes a ridge of hills and reaches a maximum altitude of 1000 MSL (Lisker et al. 2010). This Central Mountain Ridge runs north and south along the western margin of the Jordan Rift Valley and divides the Levant into a coastal lowland zone to the west of the mountains and an interior plateau to the east (Lisker et al. 2010; Shea 2003; Suriano 2014). Nesher Ramla is situated on the western slopes of the Central Mountain Ridge (fig. 2.1) which separate the site from the Dead Sea and its ancient predecessors (Zaidner et al. 2014). The eastern slopes of the ridge descend into the Jordan Rift Valley to the shores and surface of the hypersaline

Dead Sea, the lowest point on the earth's land surface with elevations below -400 MSL (Miebach et al. 2019; Suriano 2014).

Figure 2.1: Location of Nesher Ramla in the southern Levant.

The Jordan Rift Valley, formed around 3-4 Ma by east-west tectonic activity resulting from the northern expansion of the East African Rift, was an important geographic feature of the Levantine landscape for hominin populations as several waterbodies were formed in this region (Shea 2003, 2013; Stein 2001; Torfstein et al 2009). The Paleo-lake Amora was formed where the modern-day Dead Sea exists today and has been dated to the late Pleistocene, around 740 to 70 Ka, making a portion of its existence simultaneous with the occupational history of Nesher Ramla (Lisker et al. 2010; Stein 2001; Torfstein et al 2009; Zaidner et al. 2016). During the early Pleistocene, fresh-water bodies existed in the northern and higher altitude portions of the Jordan Rift Valley and were associated with some of the earliest hominin sites in the Levant such as Gesher

Benot Ya'aqov located on the shore of the paleo-Lake Hula and the 'Ubeidiya Formation (Gaudzinski 2004; Goren-Inbar et al. 2000; Shea 2013; Stein 2001; Torfstein et al 2009).

To the south of the Dead Sea, the coast of the Mediterranean Sea curves west away from the Levant. The Negev Desert in this southern region demonstrates the impact of the Mediterranean Sea on the climate and vegetation of the southern Levant due to the increased precipitation its proximity brings (Bar-Matthews et al. 2019). The following sections discuss the climate of the southern Levant in the present day as well as during the Middle Paleolithic period.

2.2 Climate and Environment of the southern Levant

The Mediterranean Sea has served as the main influence on rainfall conditions in the Levant throughout the Paleolithic and into the modern day. The regions along the coast of the eastern Mediterranean experience heightened rainfall amounts resulting in a Mediterranean climate that is characterised by dry summers and cool humid winters (Bar-Matthews et al. 2019; Chen and Litt 2018; Shea 2003). A drastic drop in annual rainfall amounts occurs moving south away from the sea and towards the Negev Desert which serves as the boundary of the Mediterranean Climate Zone (Bar-Matthews et al. 2019). The influence of other geographic features result in differential annual rainfall amounts throughout the southern Levant. The Central Mountain Ridge imposes rain-shadow desert conditions on the region to the east including the Dead Sea Basin. To the west, the mountains act to trap moisture resulting in increased annual rainfall on the western facing slopes and the Mediterranean coastal plain (Bar-Mathews et al. 2019; Chen and Litt 2018; Miebach et al. 2019; Shea 2003).

Characteristics and Distribution of Phytogeographic Zones

Variation in annual rainfall amounts across the Levant results in the coexistence of four diverse phytogeographic zones each of which support a different array of vegetation and animal life (Chen and Litt 2018; Miebach et al. 2019; Shea 2003). Table 2.1 details the annual rainfall amounts and common elements of vegetation for each zone. Nesher Ramla is located within the Mediterranean phytogeographic zone which extends from the northern regions of the southern Levant to the south along the Mediterranean coast and the Central Mountain Ridge and to the east of the Dead Sea along the highest western slopes of the Jordan Rift Valley.

Phytogeographic Zone	**Annual Rainfall**	**Vegetation**
Mediterranean	> 400 mm	Dominated by woodland vegetation including deciduous oaks (*Quercus ithaburensis* and *Q. libani* at low and high elevations respectively), evergreen oaks (*Q. calliprinos*), terebinth (*Pistacia spp.*), olive trees (*Olea europaea*), and conifers such as Aleppo pines (*Pinus halepensis*).
Irano-Turanian Steppe	100-350 mm	Characterised by dwarf-shrub and herbaceous vegetation such as wormwood (*Artemisia herbaalba*), grasses, and *Pistacia atlantica*.
Saharo-Arabian Desert	<100 mm	Sparse desert vegetation including Amaranthaceae, tamarisk (*Tamarix nilotica*), and goosefoot (Chenopodiaceae).
Sudanian	50-100 mm	Trees and shrubs representing tropical Savanna vegetation such as date palm (*Phoenix dactylifera*), *Acacia tortilis,* and *Balanites aegyptiaca.*

Table 2.1: The phytogeographic zones of the southern Levant with associated rainfall values and vegetation (Chen and Litt 2018; Miebach et al. 2019; Shea 2003).

The Irano-Turanian steppe occurs in the semi-arid and arid regions of the southern Levant between the margins of the Mediterranean and Saharo-Arabian phytogeographic zones. The Saharo-Arabian desert zone is located in the Negev desert and the area surrounding the Dead Sea. Sudanian phytogeographic zones are limited to oases surrounded predominantly by the Saharo-Arabian vegetation within the Jordan Rift Valley (Chen and Litt 2018; Miebach et al. 2019; Shea 2003).

The steep topography of the southern Levant brings diverse ecozones in close proximity to one another (Shea 2003, 2013). Areas where Mediterranean woodland transitions to Irano-Turanian Steppe, known as ecotones, are characterised by a concentration of food resources from both phytogeographic zones (Shea 2003). Ecotones represented attractive areas for hominin occupation due to a reduction of the energy required to locate and obtain a variety of food resources offered by these areas (Shea 2003, 2013). The ranges of phytogeographic zones were altered with important implications for hominin populations as areas of the southern Levant periodically became more or less hospitable while cycling between glacial and interglacial periods.

Paleoclimate and Vegetation of the southern Levant

Throughout the Paleolithic period, climatic conditions, fauna, and vegetation in the southern Levant underwent intermittent change in response to periodic glacial and interglacial cycles that brought shifts in temperature and precipitation amounts on global and local scales (Bar-Matthews and Ayalon 2004; Bar-Matthews et al. 2019; Chen and Litt 2018; Frumkin et al. 2011; Lisker et al. 2010). Differences in water availability for ecosystems in the southern Levant between and within glacial and interglacial periods influenced the distribution of different phytogeographic zones and the expansion and domination of certain vegetation types at the expense of others (Bar-Matthews et al. 2019; Frumkin et al. 2011; Miebach et al. 2019).

Fluctuations in sea level and temperature between glacial and interglacial periods also temporarily transformed certain geographic features of the southern Levant from biogeographic barriers to bridges enabling intermittent biotic interchanges between Africa and Eurasia. During glacial periods, palearctic fauna from Eurasia entered the southern Levant via a northern route through the Taurus and Zagros Mountains. Brief periods of increased humidity in the Sinai and Negev deserts during interglacials enabled the migration of Afro-Arabian fauna (Breeze et al. 2016; Tchernov 1998; Tchernov and Belmaker 2004; Tchernov et al. 1994).

Marine-isotope stages (MIS) distinguish time periods with different climate conditions, sea levels, and glacial ice volume from one another and correspond roughly to alternating phases of the glacial/ interglacial cycle (Shea 2003, 2010). The Middle Paleolithic period of the Levant coincides with MIS7-3, at least two full glacial and interglacial cycles (Hovers and Belfer-Cohen 2013). The occupational sequence at Nesher Ramla has been dated to shortly after the onset of MIS 6 and the end of MIS 5, 170-80 ka (Zaidner et al. 2014, 2018).

MIS 6 Glacial Period (~191-133 ka)

Continuous speleothem deposition throughout MIS 6 in the central and northern regions of the southern Levant suggests that the annual precipitation rate always exceeded ~250mm (Bar-Matthews et al. 2019). Speleothems in the Dead Sea Basin and in the northern Negev Desert indicate that these regions experienced uncharacteristically increased rainfall amounts during MIS 6 such that the boundary of the desert is suggested to have shifted ~30km south relative to its current location (Bar-Matthews et al. 2019; Frumkin et al. 2011; Lisker et al. 2010). In addition, an increased rate of precipitation during MIS 6 is supported by reconstructions of the shores of Lake Amora and Lake Samra (Frumkin et al. 2011; Torfstein et al. 2009).

Lower $\delta^{13}C$ values in speleothem layers dated to185-150 ka suggest that C3 vegetation was more widespread in the early glacial period with C4 vegetation increasing after 150 ka indicating that the later portion of MIS 6 was drier (Bar-Matthews et al. 2017, 2019; Bar-Matthews and Ayalon 2007; Frumkin et al. 2011).

The Dead Sea pollen record reveals an abundance of herbaceous vegetation typical of desert and steppe environments during late MIS 6. Deciduous oaks (*Quercus ithaburensis)* requiring an average of 400mm annual precipitation for growth, were a common element of arboreal vegetation indicating that a temperate climate may have persisted in the Central Mountain Ridge. The mountains would have served as a refuge for a temperate woodland habitat while arid and semi-arid conditions occurred at lower elevations where an open habitat of herbs and grasses persisted (Chen and Litt 2018). The presence of more arid adapted vegetation at lower altitudes brought resources associated with an open habitat into close proximity with occupants of Nesher Ramla providing easy access to a variety of resources and reducing transportation and travel costs to and from different habitats (Chen and Litt 2018).

The time period encompassing the end of the MIS 6 glacial and the onset of the MIS 5 interglacial was marked by unstable climate and significant drying. Increasing aridity around 133 ka resulted in the decline of deciduous oak and conifer dominated woodlands and the spread of open herbaceous drought tolerant vegetation (Chen and Litt 2018). The lithology of Lake Amora reveals sporadic decreases in water levels from high-stand conditions at the MIS 6/5 transition with a negative water balance persisting throughout most of MIS 5 (Frumkin et al. 2011; Torfstein et al. 2019). Rising temperatures towards the end of the penultimate glacial period are indicated by an increase in pistachio trees, which cannot tolerate frost (Chen and Litt 2018).

MIS 5 Interglacial Period (~133-71 ka)

Climatic conditions of the MIS 5 interglacial are characterised by temperatures as least as warm as the region is today (Chen and Litt 2018). Increased rainfall amounts brought on by periodic deluge episodes interrupted the otherwise arid conditions that persisted throughout MIS 5 (Chen and Litt 2018; Langgut et al. 2011; Miebach et al. 2019). These deluge events resulted in phases of peak interglacial conditions within different substages of MIS 5: MIS 5e (~128-120 ka), MIS 5c (~109-100 ka) and MIS 5a (~86-83) (Bar-Matthews et al. 2017, 2019).

Deluge events were associated with an ameliorated climate and the spread of Mediterranean woodland vegetation while more drought-tolerant herbaceous vegetation and open habitats spread when arid or cold conditions persisted. The resulting mosaic landscape was composed of dynamic plant populations with components of Irano-Turanian steppe and Mediterranean woodland vegetation occurring in close proximity to one another (Chen and Litt 2018; Langgut et al. 2011; Miebach et al. 2019). This is supported by the presence of deciduous oak within wood charcoals from Nesher Ramla which suggests the site was in proximity to patches of arboreal vegetation within an environment composed of open-landscape and scattered forests (Allué and Zaidner 2021).

The onset of glacial conditions toward the end of MIS 5 resulted in cooling temperatures accompanied by aridification. These simultaneous decreases in water availability and temperature resulted in the decline of tree species and other components of Mediterranean vegetation (Chen and Litt 2018; Langgut et al. 2011; Miebach et al. 2019; Zaidner et al. 2016).

2.3 The Middle Paleolithic of the southern Levant (ca. 250-45 ka)

This section provides the cognitive, social, and technological context for Nesher Ramla as well as many of the GST examples discussed in section 2.5.1 (fig. 2.2). The archaeological sequence at Nesher Ramla extends from the late early Middle Paleolithic to the end of the late Middle Paleolithic (Zaidner et al. 2014). This review of Paleolithic behaviour and technology will be focused primarily on the Middle Paleolithic but will also include a discussion of behavioural innovations that originated in the late Lower Paleolithic and demonstrate increased complexity in Middle Paleolithic.

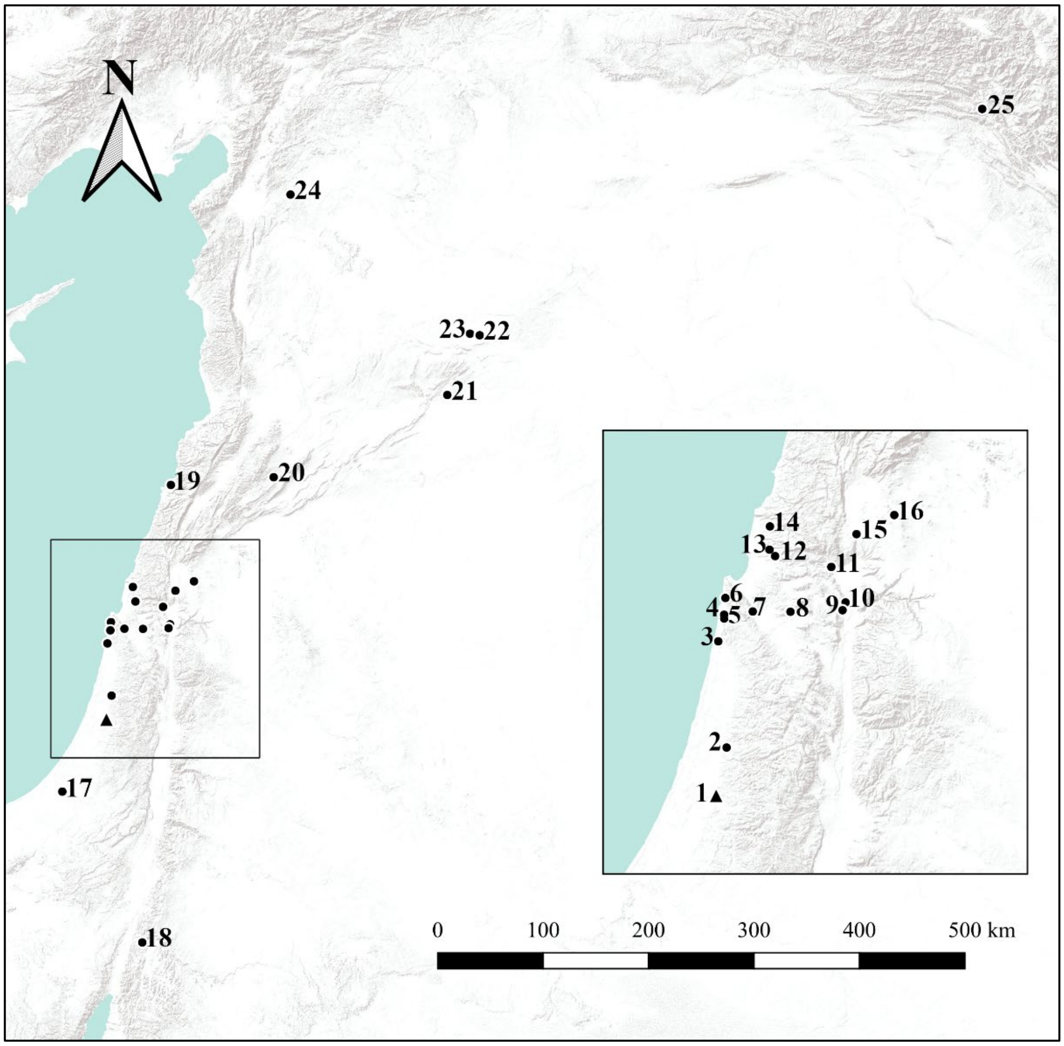

Figure 2.2: Nesher Ramla (1) and other sites mentioned in this chapter. 2: Qesem Cave, 3: Kebara Cave, 4: Skhul Cave, 5: Tabun Cave, 6: Misliya Cave, 7: 'Ein Qashish, 8: Qafzeh Cave, 9: 'Ubeidiya, 10: Ohalo II, 11: Amud Cave, 12: Meged Rockshelter, 13: Hayonim Cave, 14: Manot Cave, 15: Gesher Benot Ya'aqov, 16: Quneitra, 17: Far'ah II, 18: Tor Faraj, 19: Ras El Kelb, 20: Yabrud Rockshelter, 21: Douara Cave, 22: Hummal, 23: Umm el Tlel, 24: Dederiyeh, 25: Shanidar Cave.

The Middle Paleolithic is defined by a technological shift consisting of the decline of Lower Paleolithic bifacial tools and the appearance of the Levantine Mousterian technocomplex in which Levallois flake production systems were the predominant component and reached their peak distribution in the southern Levant (Centi and Zaidner

2021; Hovers and Belfer-Cohen 2013; Shea 2013). The Middle Paleolithic is sometimes subdivided on the basis of behavioural and technological differences into the Early Middle Paleolithic (EMP) ca. 250-130 ka, the Mid-Middle Paleolithic (MMP) which roughly coincides with the MIS 5 interglacial period ca. 130-75 ka, and the Late Middle Paleolithic (LMP) ca. 75-45 ka (Prévost and Zaidner 2020; Shea 2008). The use of these subdivisions of the Middle Paleolithic here will facilitate a discussion of how behaviour and technology shifted within this vast period of time.

The southern Levant in the Middle Paleolithic is most notably characterised by possible cohabitation by AMH and Neanderthals (Akazawa et al. 1995; Bar-Yosef et al. 1992; Been et al. 2017; Hovers and Belfer-Cohen 2013; Hovers et al. 1995; Shea 2008, 2010). In the southern Levant, sites associated with Neanderthals and AMH display a high degree of similarity in material culture including lithic industries. The two populations also demonstrate shared behaviours including intentional burials, mobility, and subsistence (Alperson-Afil and Hovers 2005; Been et al. 2017; Hovers and Belfer-Cohen 2013; Shea 2010). As a result, diagnostic remains are required to securely associate a site with either Neanderthals or AMH (Been et al. 2017). Neanderthal remains dating to the Middle Paleolithic appear at sites such as Tabun, ‘Ein Qashish, Kebara, Amud, and Dederiyeh in the southern Levant (Akazawa et al. 1995; Bar-Yosef et al. 1992; Been et al. 2017; Coppa et al. 2005, 2007; Hovers et al. 1995; Shea 2008). Additionally, human fossils from Nesher Ramla are reported to display a mosaic of Neanderthal and archaic features (Hershkovitz et al. 2021; May et al. 2021). AMH remains dating to MIS 6-5 were recovered at Misliya, Skhul and Qafzeh caves and from later contexts at Manot Cave (Hershkovitz et al. 2015, 2018; Mercier et al. 1993; Shea 2008; Stringer et al. 1989; Vandermeersch and Bar-Yosef 2019).

Continuity and distinction between Lower and Middle Paleolithic behaviour

Sites dated to the late Lower Paleolithic (~420-250/200 ka) reveal the onset of several behaviours which are often assumed to distinguish the Middle Paleolithic from that of preceding periods (Barkai and Gopher 2013; Gopher et al. 2010; Shimmelmitz et al. 2014, 2016; Valladas et al. 2013). Increased occupation of caves as base camps, habitual fire use, and the systematic hunting of prime-age large ungulates represent a possibly related set of behavioural innovations which appeared in the late-Lower Paleolithic and later proliferated during the Middle Paleolithic (Chazan 2009; Hovers and Belfer-Cohen 2013; Kaufman 2002; Rabinovich and Hovers 2004; Shea 2010; Speth 2012; Speth and Tchernov 1998; Stiner 2005, 2009; Stiner et al. 2009, 2011; Yeshurun et al. 2007).

The adoption of caves as preferred base camps ~400 ka and habitual fire use appear to be somewhat related behavioural shifts (Gopher et al. 2010; Sharon et al. 2014). The use of fire in the southern Levant remained sporadic until the late Lower Paleolithic when it is demonstrated at cave sites such as Tabun Cave (Shimmelmitz et al. 2014), Yabrud Rockshelter (Shimmelmitz et al. 2014; Solecki and Solecki 1986), and Qesem Cave (Barkai and Gopher 2013; Gopher et al. 2010; Karkanas et al. 2007; Shahack-Gross et al. 2014).

At Qesem Cave, the concentration of butchering and other processing activities around a centralized hearth enabled inhabitants to experience the full advantages conferred by habitual fire use such as improved social interaction and food processing methods (Barkai and Gopher 2013; Blasco et al. 2014, 2016; Shimmelmitz et al. 2014; Stiner et al. 2009, 2011). The role of hearths as centers for carcass processing and social interaction is proposed by Stiner et al. (2011) to have led to the development of meat-sharing behaviours as a powerful source of social cohesion. At the same time as this shift in subsistence behaviours, the faunal assemblage of Qesem Cave also documents an early occurrence of hunting behaviours associated with the Middle Paleolithic (Blasco et al. 2014; Stiner et al. 2009). Meat sharing may therefore have been part of an overall shift in hunting and subsistence in which prime-age large-bodied ungulates were systematically hunted and meat and marrow-rich skeletal elements were transported to a home base where cooperative butchery and consumption occurred (Blasco et al. 2014, 2016; Stiner 2009; Stiner et al. 2009, 2011).

By the Middle Paleolithic, habitual fire use appears to have expanded as variation in shape, size, and intensity of use are inferred from patterns of ash accumulation (Alperson-Afil and Hovers 2005; Bar-Yosef 1998; Goldberg and Bar-Yosef 1998; Henry et al. 2004; Hovers and Belfer-Cohen 2013; Madella et al. 2002; Meignen et al. 2007; Speth 2006; Weinstein-Evron and Zaidner 2017; Yeshurun et al. 2020) Additionally, the use of pyrotechnology as part of the production sequence for ochre indicates that application to novel materials was part of this increase in complexity (Godfrey-Smith and Ilani 2004; Hovers and Belfer-Cohen 2013; Hovers et al. 2003; Salomon et al. 2012**)**.

The Middle Paleolithic also appears to mark the first appearance of several behaviours attributed to the emergence of behavioural modernity in the Levant including symbolic behaviour and spatial organization of sites into distinct activity areas (e.g. Alperson-Afil and Hovers 2005; Bar-Yosef Mayer et al. 2009; Henry et al. 2004; Hovers and Belfer-Cohen 2013; Hovers et al. 2003; Oron and Goren-Inbar 2014; Shea 2010, 2013; Speth et al. 2012).

Change and Innovation within the Middle Paleolithic: Symbolic Behaviour

The presence of ‘non-utilitarian’ items in the form of ochre and naturally perforated marine shells which have been interpreted as beads, at Skhul and Qafzeh indicate the emergence of symbolic behaviour in the southern Levant by at least the MMP (Bar-Yosef Mayer 2005; Bar-Yosef Mayer et al. 2009; Hovers and Belfer-Cohen 2013; Hovers et al. 2003; Shea 2010; Vanhaeren et al. 2006). Small chunks of ochre have also been reported at Nesher Ramla (Zaidner et al. 2014). Stones incised with linear patterns at Qafzeh, Quneitra, Ras El Kelb, and Manot Cave and engraved aurochs bones from Quneitra and Nesher Ramla provide further evidence for symbolic behaviour through abstract representation (Goren-Inbar 1990; Hovers et al. 1997; Marder et al. 2018; Marshack 1996; Prévost et al. 2021; Shaham et al. 2019; Shea 2010).

Intentional burials with grave goods at Skhul and Qafzeh suggest that mortuary practices were another symbolic behaviour during the MMP (Belfer-Cohen and Hovers 1992; Hovers and Belfer-Cohen 2013; Shea 2010). The characteristics of these burials as well as later burials at Tabun, Kebara, Amud, and Dederiyeh are distinct from African or European burials indicating that mortuary behaviour was a novel innovation within the Levant that persisted throughout MIS 5-3 (Akazawa et al. 1995; Bar-Yosef et al. 1986; Belfer-Cohen and Hovers 1992; Hovers and Belfer-Cohen 2013; Hovers et al. 1995, 2000).

Change and Innovation within the Middle Paleolithic: Spatial Organization

Spatial organization in the context of cave and open-air sites has often been characterised as a behavioural innovation of the LMP (e.g. Alperson-Afil and Hovers 2005; Henry et al. 2004; Hovers and Belfer-Cohen 2013; Shea 2010; Speth et al. 2012). Douara Cave in Syria and Misliya Cave have been proposed to demonstrate spatial organization in the EMP (Nishiaki and Akazawa 2015; Yeshurun et al. 2020). The distribution of lithics, and animal and plant remains at Douara suggests the division of the site into distinct activity areas some of which were centered around a hearth (Nishiaki and Akazawa 2015). Even earlier evidence for intra-site spatial organization in the Lower Paleolithic may be observed at Gesher Benot Ya'qov and Qesem Cave (Alperson-Afil et al. 2009; Blasco et al. 2016; Stiner et al. 2009, 2011).

Evidence for social and technological divisions of sites resulting in differential use of spaces within the same site is more widespread for the LMP (e.g. Alperson-Afil and Hovers 2005; Gilead and Grigson 1984; Henry et al. 2004; Hovers and Belfer-Cohen 2013; Shea 2010; Speth 2006; Speth et al. 2012). At Amud Cave, differential patterns of lithic production and discard were observed between two activity areas indicating that the early and final stages of the reduction sequences for Levallois points were conducted in spatially distinct areas (Alperson-Afil and Hovers 2005). Spatial differentiation of knapping activities or even different stages of lithic production is also reported at Quneitra, Tor Faraj, and Far'ah II (Alperson-Afil and Hovers 2005; Gilead and Grigson 1984; Goren-Inbar 1990a; Henry et al. 2004; Oron and Goren-Inbar 2014).

Other patterns of spatial organization include hearth centered activity areas, middens, burials, and designated areas where subsistence tasks were repeatedly conducted (e.g. Alperson-Afil and Hovers 2005; Bar-Yosef et al. 1992; Gilead and Grigson 1984; Henry et al. 2004; Hovers et al. 1995; Oron and Goren-Inbar 2014; Speth 2006; Speth et al. 2012). At Quneitra, hammerstones and anvils were recovered in association with broken bones indicating that the use of ground stone technology for bone-breaking and marrow extraction was also ascribed to specific areas (Goren-Inbar 1990a,1990b; Oron and Goren-Inbar 2014; Rabinovich 1990**)**.

Change and Innovation within the Middle Paleolithic: Technology

Tools hafted with adhesives through the use of pyrotechnology appear to have emerged during the LMP. Traces of a black organic substance observed on the surfaces of flaked tools and cobbles from Umm el Tlel, Syria have been interpreted as the evidence for the use of bitumen as an adhesive for hafting stone points to vegetal or bone materials. The artifacts, recovered from Mousterian layers dated to 40 and 70 ka, represent the earliest evidence for tools hafted with bitumen (Boëda et al. 1998a, 2008). Further evidence for the use of hafted tools at Umm el Tlel is provided by a Levallois point fragment embedded in the vertebra of a wild ass in layer IV 3b’1. Due to the force required to penetrate the overlying soft tissue and bone this discovery has been attributed to the use of a thrusting spear on a hafted point for hunting (Boëda et al. 1999).

It is however important to note the distinction between hafted tools and hafted tools that were used as projectile weapons as the latter are proposed to represent a much later innovation (Boëda et al. 1999; Shea 2006, 2010). Characteristics of Levallois points from MP contexts indicate that these items were hafted for use as thrusting or hand-cast spears rather than as true projectile weapons (Shea 1988, 2006, 2010). Points indicating use for projectile weapons were not systematically produced in the Levant until after 40-50 ka (Shea 2006).

Change and Innovation within the Middle Paleolithic: Occupation Patterns

Low density lithic and faunal assemblages from EMP sites indicate that occupation was predominantly ephemeral during this time (Hovers 2001; Hovers and Belfer-Cohen 2013; Meignen et al. 2006; Shea 2010). EMP faunal assemblages also demonstrate a reliance on tortoises and prime-age ungulates suggesting that hunting pressures were low enough to sustain intensive exploitation of a narrow range of preferred prey items (Meignen et al. 2006; Stiner et al. 1999, 2000). Overall, the EMP can be characterised by a settlement pattern in which small populations frequently moved around the landscape to exploit seasonal or location-specific resources (Hovers 2001; Hovers and Belfer-Cohen 2013; Meignen et al. 2006; Shea 2010).

Intensified occupation of the Mediterranean climate zone ca. 130 ka has been related to heightened aridity in other areas of the southern Levant. The resulting increase in demographic pressure is proposed to have prompted a change in land use patterns in which group territoriality increased and site use shifted to enable more intensive and efficient use of increasingly small territories (Hovers 2001; Hovers and Belfer-Cohen 2013; Meignen et al. 2006; Shea 2010). Lithic and faunal assemblages in the Mediterranean zone show increased density and interassemblage variability is lower among sites in closer geographic proximity. This suggests a pattern of land-use in the later MP in which occupation remained ephemeral but involved more frequent visits to a smaller number of sites (Hovers and Belfer-Cohen 2013; Goring-Morris et al. 2009; Meignen et al. 2006; Shea 2010).

Change and Innovation within the Middle Paleolithic: Subsistence

Systematic hunting of large and medium-sized prey and prime-age individuals at sites such as Misliya, Hayonim, Amud, and Kebara demonstrate the continuation of hunting behaviours from the Lower Paleolithic throughout the Middle Paleolithic (Chazan 2009; Hovers and Belfer-Cohen 2013; Kaufman 2002; Rabinovich and Hovers 2004; Shea 2010; Speth 2012; Speth and Tchernov 1998; Stiner 2005, 2009; Stiner et al. 2009, 2011; Yeshurun et al. 2007). Changing land-use patterns within the Mediterranean zone also appear to have instigated a change in subsistence strategies toward the end of the Middle Paleolithic. LMP faunal assemblages exhibit shifting patterns of prey selection that have been interpreted as expansions of diet breadth to compensate for the overhunting of large, prime-age ungulates or small and slow prey. These instances of reliance on lower-ranked prey species to supplement the dietary requirements of LMP hunters have also been proposed to represent early trends towards Upper Paleolithic modes of subsistence (Speth 2012, 2013; Speth and Clark 2006; Stiner et al. 1999, 2000).

A potential expansion of diet breadth is supported by the faunal assemblage of Kebara Cave. The decline in the frequency of red deer and aurochs remains at around 60-55 ka is accompanied by an increasing proportion of smaller ungulate species and immature individuals. The intensified exploitation of smaller and younger ungulates is attributed to overhunting of preferred larger-bodied prey forcing smaller, less valuable prey to be relied on to compensate for the loss of preferred prey items. (Speth 2013; Speth and Clark 2006).

Stiner et al. (1999, 2000) propose that a later expansion of diet breadth involved a shift in small game exploitation as a result of rapid population growth. Tortoises, which were preferred by Middle Paleolithic hunters for their ease of capture, are also particularly susceptible to overhunting. The gradual reduction in the body size of tortoises within the faunal assemblages at Hayonim Cave and Meged Rockshelter therefore reveals that increasing hunting pressures during the LMP eventually surpassed the capacity of tortoise populations to sustain themselves. Following this, small and fast prey, such as birds, increase in abundance at these sites beginning in the Upper Paleolithic. This shift to small game species that were lower-ranked due the enhanced difficulty associated with their capture is attributed to the fast repopulation rate of these species which made them more resistant to overhunting (Stiner et al. 1999, 2000).

Hayonim and Meged Rockshelter are both located in the Mediterranean zone. The overhunting of small, slow-moving species in the LMP may therefore have been driven by the concentration of human groups in the Mediterranean zone as proposed by Hovers and Belfer-Cohen (2013) rather than an actual increase in the total population. Either way it appears that changes in subsistence associated with the Upper Paleolithic and later periods are somewhat rooted in the LMP.

In addition to shifts in the exploitation of animal resources, the consumption of plant food resources has also been implicated as part of an early trend toward the broadening of diet breadth that characterises Upper Paleolithic subsistence. Evidence for consumption of plant food resources during the Lower and Middle Paleolithic originates from a range of climatic and environmental contexts and demonstrates variation in the specific plant resources relied upon at different sites (Albert et al. 2000; Goren-Inbar et al. 2002; Henry et al. 2011; Lev et al. 2005; Madella et al. 2002; Melamed et al. 2016; Rosen 2003).

In the Lower Paleolithic, seasonal exploitation and processing of plant food resources is represented at Gesher Benot Ya'aqov. Plants with edible underground storage organs, fruits, and nuts are the most abundantly represented among the 55 plant food taxa identified in the macro botanical remains (Goren-Inbar et al. 2002; Melamed et al. 2016).

Evidence for exploitation of plant foods from Mousterian contexts at Amud Cave, Kebara Cave and Tor Faraj in the form of phytoliths, starch grains, and carbonized plant remains indicate that plant food consumption may have varied between different environments (Albert et al. 2000; Lev et al. 2005; Madella et al. 2002; Rosen 2003). The phytolith assemblage from Amud provides evidence for collection and exploitation of grass seeds in the Irano-Turanian zone (Madella et al. 2002). Kebara, located within the

Mediterranean zone and Tor Faraj, situated near the boundary between the Irano-Turanian and Saharo-Iranian zone (but proposed to have experienced increased moisture during occupation), display more variation in the types of edible plants represented (Albert et al. 2000; Lev et al. 2005; Rosen 2003). The majority of the charred plant remains from Kebara are legumes (Papilionaceae) although nuts, including oak and pistachio, are also represented along with tubers, plants with edible roots, and edible rhizomes such as bulbous barley (*Hordeum bulbosum*) (Lev et al. 2005). Starch grains and phytoliths from Tor Faraj include date palm (*Phoenix dactylifera*), nuts (pistachio), tubers, and roots. The concentration of wild grass seed husk phytoliths around a hearth is also proposed to reflect the collection and consumption of wild grass seeds (Rosen 2003).

Starch grains and phytoliths recovered from samples of Neanderthal dental calculus at Shanidar Cave in Iraq provide direct evidence for plant food consumption during the Middle Paleolithic in the Levant. Starch grains included grass seed starches belonging to the Triticeae tribe with some grains displaying damage patterns attributed to cooking while only date palms could be identified within the phytolith assemblage (Henry et al. 2011).

The low ranking assumed for plant food resources among hunter-gatherers is attributed to the considerable investment in time and effort required to exploit plant resources relative to highly ranked animal resources. The scarcity of evidence for consumption of plant food resources may indicate that this behaviour was rare prior to the Upper Paleolithic and the above examples reflect its origins as part of the overall expansion of diet breadth supported by faunal assemblages from the Mediterranean zone. Considering the variation in temporal and geographic contexts, the scarcity of plant food remains may simply reflect poorer rates of preservation relative to faunal remains (Lev et al. 2005; Melamed et al. 2016). That the nutritional yields of many of the described plant resources benefit from cooking or some other form of processing, which may require GST, provides another potential line of evidence for the study of plant food consumption. A review of plant processing implements from archaeological contexts is presented in section 2.5.1.

Summary

Many of the defining characteristics of the Middle Paleolithic in the southern Levant reflect a great degree of continuity with earlier and later periods (e.g. Chazan 2009; Hovers and Belfer-Cohen 2013; Shea 2010; Shimmelmitz et al. 2014, 2016; Stiner 2009). Several traits assumed to signal the emergence of behavioural modernity in the Middle Paleolithic have origins within the late Lower Paleolithic. Spatial organization and habitual fire use represent two such behaviours that demonstrate increases in complexity in the Middle Paleolithic rather than novel behavioural innovations (e.g. Alperson-Afil and Hovers 2005; Alperson-Afil et al. 2009; Henry et al. 2004; Hovers and Belfer-Cohen 2013; Nishiaki and Akazawa 2015; Shea 2010; Shimmelmitz et al. 2014, 2016; Speth 2006; Speth et al. 2012; Stiner et al. 2009, 2011; Yeshurun et al. 2020). However, non-utilitarian items and burials which provide evidence for symbolic behaviour begin to appear only in the Middle Paleolithic (e.g. Bar-Yosef Mayer et al. 2009; Belfer-Cohen and Hovers 1992; Hovers and Belfer-Cohen 2013; Hovers et al. 2003; Shea 2010; Vanhaeren et al. 2006). Additionally, some forms of Upper Paleolithic subsistence may have been adopted in response to demographic changes occurring in the LMP (e.g. Hovers and Belfer-Cohen 2013; Lev et al. 2005; Melamed et al. 2016; Speth and Clark 2006; Speth 2013; Stiner et al. 1999, 2000).

2.4 Nesher Ramla as a Specific Context for Studying GST Function

Nesher Ramla serves as a specific context to study the trends in subsistence and technology discussed in the previous section through the GST assemblage. The review of other lines of evidence conducted here allows insights from the study of the Upper Sequence GST to be incorporated into a fuller understanding of how these tools fit into the technological system at Nesher Ramla as a whole.

Nesher Ramla is an open-air site located on the slopes of the Central Mountain Ridge that borders the Mediterranean Coastal Plain (Zaidner et al. 2014). The site is situated within the Mediterranean climate zone in close proximity to the steppe environment of the Irano-Turanian zone in the Jordan Valley to the east (Crater Gershtein et al. 2020; Langgut et al. 2011).

The site was discovered in a limestone and chalk quarry by the Israel Antiquities Authority and underwent salvage excavations from 2010 to 2011. These excavations revealed an 8m thick Mousterian sequence containing hominin remains, combustion features, ochre, and extensive assemblages of faunal and lithic artifacts. The sequence displays exceptional preservation for an open-air site which is attributed to the location of the site within a karst sinkhole (Friesem et al. 2014; Zaidner et al. 2014, 2016).

Human occupation at Nesher Ramla occurred within a deep funnel shaped depression that formed as a result of sagging and collapse of chalk bedrock layers into an underground karst void (fig. 2.3a). Over time, the steep walls of the depression acted to trap sediments causing rapid deposition of layers and burial of artifacts with little indication of post-depositional disturbances (Friesem et al. 2014; Tsatskin and Zaidner 2014; Zaidner et al. 2014, 2016). Habitation within a karst sinkhole in the southern

Levant was unknown prior to the discovery of Nesher Ramla and as such, the site reflects a novel form of open-air occupation (Zaidner et al. 2016).

As a result of this unique context, the archaeological sequence at Nesher Ramla displays similarities with open-air and cave contexts while remaining distinct from both. The steep walls protected the artifacts from the aerial weathering processes that affect open-air contexts while the absence of a roof prevented the diagenetic processes associated with cave contexts (Friesem et al. 2014; Zaidner et al. 2014, 2016).

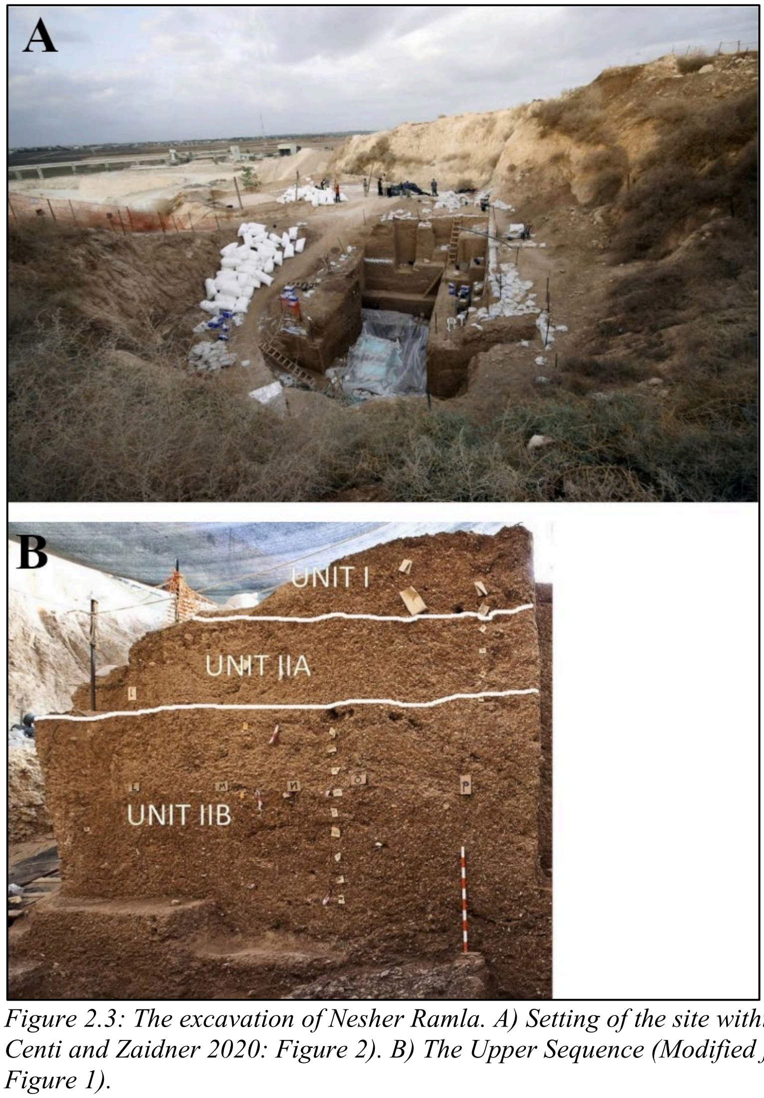

Figure 2.3: The excavation of Nesher Ramla. A) Setting of the site within a karst sinkhole (Modified from Centi and Zaidner 2020: Figure 2). B) The Upper Sequence (Modified from Centi and Zaidner 2020: Figure 1).

The archaeological sequence is located at an elevation of 107.5-99.5 m above sea level (asl) and dated to 170-80 ka by optically stimulated luminescence (OSL). The sequence is divided into six archaeological units which are organized into Upper (fig.2.3B): Units I-II and Lower Sequences: Units III-VI. Unit II is further subdivided into Unit IIA, Unit IIB-Upper and Unit IIB-Lower based on differences in lithic and bone densities. The Upper Sequence displays a trend of decreasing artifact density towards the later phases of occupation (Centi and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014, 2018).

The Lower Sequence is characterised by varying occupation intensity and displays a pattern of alternating artifact density between different units (Centi and Zaidner 2020; Friesem et al. 2014; Zaidner et al. 2014). Combustion features interpreted as hearths and ash discard piles are reported only in the Lower Sequence although the presence of burnt flint in the Upper Sequence suggests the use of fire (Friesem et al. 2014; Pietraszek et al. 2021; Varoner et al. 2021; Zaidner et al. 2014, 2018). Unit VI is distinguished within the Lower Sequence by the presence of two Middle Pleistocene human fossils (Hershkovitz et al. 2021; May et al. 2021; Zaidner et al. 2021).

The variation observed in the densities of lithics and faunal remains throughout the sequence potentially indicates changes to site use between different phases of occupation (Centi and Zaidner 2020; Friesem et al. 2014; Varoner et al. 2021; Zaidner et al. 2014, 2018). Table 2.2 provides a detailed summary of the abundances of faunal and lithic artifacts as well as the general characteristics for each layer.

Nesher Ramla Homo

Nesher Ramla *Homo* is represented by two fossils discovered in Unit VI in association with lithic and faunal remains which have been dated to 140-120 ka by a combination of ESR/U-series, TL, and OSL methods (Hershkovitz et al. 2021; Zaidner et al. 2021). The NR-1 fossil is comprised of a partial right parietal bone and four fragments of a left parietal while NR-2 is a nearly complete mandible with an intact left second molar (Hershkovitz et al. 2021). The two fossils are attributed to a single individual and exhibit morphological characteristics typical of Neanderthals or earlier Middle Pleistocene *Homo* populations. Based on this mosaic of Neanderthal and archaic features, the NR-1 and NR-2 fossils are attributed to a Middle Pleistocene paleodeme that may have contributed to later *Homo* lineages in Europe and Asia (Hershkovitz et al. 2021; May et al. 2021). The term "Nesher Ramla *Homo"* is proposed by Hershkovitz et al. (2021) to describe this population which resided within the Levant from ~420 to 120 ka and potentially includes the fossils from Qesem, Zuttiyeh, and Tabun Caves (Barkai et al. 2013; Friedline et al. 2021; Hershkovitz et al. 2021; Tillier 2005).

Interaction between Nesher Ramla *Homo* and *H. sapiens* is evidenced by the presence of centripetal Levallois technology at Nesher Ramla and contemporaneous contexts at Skhul and Qafzeh associated with *H. sapiens* habitation (Bar-Yosef 1998; Zaidner et al. 2021). Use of the centripetal knapping method represents a shared technological trait between the two populations and potentially indicates that cultural diffusion was one aspect of the interaction between Nesher Ramla *Homo* and *H. sapiens* (Zaidner et al. 2021).

Characteristics of the Lithic Assemblage

Excellent preservation together with the systematic collection of artifacts has resulted in an extensive assemblage of GST consisting of hundreds of pebbles, cobbles, and blocks composed of limestone or flint that have been interpreted as manuports (Zaidner et al. 2014). The manuports are distributed in dense concentrations in association with piles of broken bones in several units although Units IIB, III, and V displayed the highest frequency with about 60 of these concentrations recorded. In Unit IIB, manuports and bones occur as spatially distinct concentrations rather than the superimposed and connected piles observed in Units III and V (Zaidner et al. 2014, 2018).

This research is focused on the manuports recovered from the Upper Sequence in order to study the function of GST within the context of declining site-use intensity. Additionally, research previously conducted on GST from Unit V by Paixão et al. (2021a) enables a comparison between the Upper and Lower Sequences in terms of how site use and GST function changed over time.

The flaked lithic assemblage is characterised by short and broad flakes produced predominately with the Levallois system (Centi and Zaidner 2021; Prévost and Zaidner 2020; Zaidner et al. 2014, 2018). Lithic reduction strategies were consistent throughout the Upper Sequence even as the nature of site use shifted between phases of occupation as centripetal and unidirectional-convergent flaking served as complementary methods of the Levallois flaking system (Centi and Zaidner 2021; Prévost and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014, 2018). However, some variation is demonstrated by a shift from centripetal flaking to unipolar-convergent as the most prevalent method between Unit IIB and Unit IIA (Centi and Zaidner 2021; Varoner et al. 2021; Zaidner et al. 2014).

The manufacture of flaked tools at Nesher Ramla was primarily conducted with nodules of high quality Mishash flint collected from local Senonian outcrops. Eocene flint originating from greater distances was exploited to a lesser degree (Centi and Zaidner 2021; Ekshtain and Zaidner 2021; Prévost and Zaidner 2020). This pattern of raw material exploitation suggests a strategy in which abundant local material was relied upon for the majority of knapping tasks while scarcer, non-local materials were brought by visitors to the site as the components of personal tool kits (Ekshtain and Zaidner 2021; Prévost and Zaidner 2020). The exploitation of predominantly local materials combined with the high frequency of side-scrapers and other butchery tools at Nesher Ramla have been proposed to reflect the function of the site as an ephemeral hunting camp during the final phases of occupation (Centi and Zaidner 2020, 2021; Ekshtain and Zaidner 2021; Groman-Yaroslavski et al. 2021).

Characteristics of the Faunal Assemblage

Initial taxonomic analysis of the Upper sequence revealed an abundance of ungulate faunal remains, predominantly aurochs (*Bos primigenius)*, Mesopotamian fallow deer (*Dama mesopotamica*), and mountain gazelle (*Gazella gazella*). Spur-thighed tortoise (*Testudo graeca)* remains were also present in small amounts. The faunal assemblage demonstrates a general trend of decreasing density within the Upper Sequence. Bones bearing evidence of human modification such as cut marks, burning, or green fracturing also become less frequent towards Unit I (Centi and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014).

The composition of the Upper Sequence faunal assemblage displays a shift in the proportions of ungulate taxa and a simultaneous decline of tortoise remains following Unit IIB. In Unit IIB aurochs, fallow deer, and tortoise represent the most abundant species. Units IIA-I contain a wider variety of ungulate species representing a range of body-class sizes. Small, medium, and large bodied ungulates are represented at relatively similar frequencies in Unit I (Varoner et al. 2021; Zaidner et al. 2014).

The faunal assemblage from Nesher Ramla is unique in that it shows affinities and distinctions with both open-air and cave faunal assemblages. Similarities with open-air sites include the abundance of aurochs and other large ungulate remains whereas small, bodied ungulates are more frequent at cave sites. Resemblance to cave sites is demonstrated by the high density of faunal remains and the presence of tortoises which are typically absent from open-air sites (Crater Gershtein et al. 2020; Zaidner et al. 2014).

Skeletal element proportions of the Unit III faunal assemblage show increased frequencies of ungulate forelimbs, hindlimbs, and heads, which were valued for their high meat and marrow yields, at the expense of axial bones and antlers. Selective transport, which was more drastic in larger bodied ungulates than medium-sized ungulates, provides further support for the interpretation of Nesher Ramla as a campsite occupied specifically for hunting and butchering tasks (Crater Gershtein et al. 2020).

Changes to Site Use

Nesher Ramla is interpreted as a hunting camp where hunters may have utilized the steep walls of the depression to trap prey although evidence for the selective transport of skeletal elements suggests hunting also occurred offsite (Centi and Zaidner 2020; Crater Gershtein et al. 2020; Varoner et al. 2021; Zaidner et al. 2014). Hunting efforts were concentrated predominantly on large and medium-bodied ungulate species, but slow-moving and small prey were also exploited (Crater Gershtein et al. 2020; Varoner et al. 2021). Butchery tasks conducted at the site include dismemberment, filleting, skinning, marrow extraction, and possibly hide working (Crater Gershtein et al. 2020; Groman-Yaroslavski et al. 2021; Varoner et al. 2021).

Changes to site use intensity between different phases of occupation are indicated by variation in the composition and density of the lithic and faunal assemblages (Centi and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014, 2018). Units IIB-Lower, III, and V reflect instances of intensive occupation during which increased quantities of lithics and faunal remains were deposited. Outside of these peaks, site use is suggested to have become more ephemeral based on the deposition of lithic and faunal evidence at lower densities. A chronological trend of decreasing site use intensity within the Upper Sequence is also inferred from artifact densities (Centi and Zaidner 2020, 2021; Varoner et al. 2021; Zaidner et al. 2014, 2018).

Increasingly ephemeral site visits may have begun in Unit IIB-Lower as this layer is characterised by alternation between phases of intensive and ephemeral modes of occupation. Beginning in Unit IIB-Upper, occupation becomes progressively sporadic as visits to the site are less frequent and imported materials and tools decline in frequency (Centi and Zaidner 2020, 2021; Varoner et al. 2021).

Increasingly ephemeral occupation may have also resulted in a more general pattern of site function involving a shift in subsistence behaviours that is potentially demonstrated by the change in species representation between the faunal assemblages of Unit IIB and IIA. Unit IIB indicates the systematic hunting of large and medium ungulates and small game while a wider and more general subsistence strategy in which ungulates from a range of body-size classes were exploited at relatively similar rates is supported after the onset of Unit IIA (Centi and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014).

A potential explanation proposed for the decline in site use intensity and eventual abandonment of Nesher Ramla implicates the unique depositional forces influencing site formation. Slower deposition of layers in Units IIA-I resulted from changes to the morphology of the sinkhole. As the base of the depression widened, the walls became less steep resulting in slower burial of artifacts and the increased frequency of broken items observed in the upper units (Centi and Zaidner 2020; Tsatskin and Zaidner 2014; Zaidner et al. 2014, 2016, 2018). If the steep walls of the depression were indeed what attracted humans to Nesher Ramla for their use in trapping large prey species, then a reduction in their inclination over time may have resulted in a gradual loss of this benefit. This explanation is supported by the increasingly general nature of site use in Units I and IIA as site inhabitants would have had to incorporate smaller ungulate species into their diets to compensate for the reduced effectiveness of the depression walls in trapping large ungulates (Centi and Zaidner 2020).

Unit/ Elevation	**Artifact Densities and Descriptions**	**Characteristics of Site Use**
Unit I 107.3-105.5 masl	*Lithics:* Artifacts are present at low densities. High ratio of burnt items (10.9%). Personal tool-kit components are less frequent. *Faunal remains:* Concentrated piles of complete and articulated bones are abundant and associated with lithic artifacts. Aurochs and Mountain gazelle represent the most abundant taxa. *Additional features:* Ochre is present in 5-15 mm pieces. Pedogenic damage is most frequent in this layer.	Unit I reflects the most ephemeral stage of site use. Visits to the Nesher Ramla appear to become less frequent and intensive prior to abandonment of the site.
Unit IIA, IIB-Upper 105.5-103.7 masl	*Lithics:* Lower density of artifacts and burnt items. Shift from centripetal to unipolar convergent flaking as the predominant method. Retouch and Levallois blanks decline in frequency and expedient technology increases. *Faunal remains:* Fallow deer make up half the NISP, aurochs are also present along with the only specimens of Rhinocerotidae identified at the site.	Site use becomes gradually less intensive. A lack of combustion features may reflect phases of occupation becoming shorter and less frequent.
Unit IIB-Lower 103.7-102.2 masl	*Lithics:* Drastic increase in density of artifacts. Manuports of limestone and chert appear in dense concentrations along with abundant broken bones. Personal tool-kit components are well represented. *Faunal remains:* The NISP is dramatically higher than preceding layers. Aurochs and fallow deer are the most abundant taxa. Increased frequency of tortoise remains. *Additional features*: Chunks of ochre within concentrations of broken bones and manuports.	Occupation patterns may have shifted in this phase to alternate phases of more and less intensive occupation.
Unit III 102.2-101.9 masl	*Lithics:* Increased density of artifacts. Burnt items are relatively abundant (11%). *Faunal remains:* Density increases. Tortoise and	Site occupation intensified and involved extensive use of fire. Short visits focused on hunting and butchering tasks.

	aurochs are the most abundant taxa. Butchery marks on bones reflect dismemberment, filleting, and bone breaking for marrow extraction. *Additional features:* Combustion features include ash lenses and hearths containing carbonized bones.	
Unit IV 101.9-101.6 masl	*Lithics:* Density decreases in this layer. *Faunal remains:* Lower density than the surrounding layers. Bones are not concentrated piles in association with lithic artifacts.	Ephemeral site occupation characterised by lower frequency and intensity of visits.
Unit V 101.6-101.2 masl	*Lithics:* Increased density of artifacts with the highest abundance of manuports. *Faunal remains:* Highest density of remains. Concentrated piles associated with manuports in the center of the living space and along the depression walls. *Additional features:* Concentrations of calcined and carbonized bones interpreted as hearths. Anthropogenic reworking of fire remains in this unit is attributed to intentional sweeping out of hearths or trampling.	Intensive site use that may have involved increased butchery activities.
Unit VI 101.15-99.5 masl	*Lithics:* Lower density than the above layer. *Faunal remains:* Decreased density in this layer. Broken bones do not appear in concentrations with manuports. *Hominin remains:* NR-1: right parietal bone fragment and four fragments of a left parietal. NR-2: mandible with an intact left second molar.	Site use may have been sporadic until the onset of Unit V.

Table 2.2: Change in the abundance and density of artifacts between different phases of site occupation and suggested patterns of occupation for each archaeological unit (Centi and Zaidner 2020, 2021; Crater Gershtein et al. 2020; Friesem et al. 2014; Paixão et al. 2021a; Pietraszek et al. 2021; Prévost and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014,2018).

The GST assemblage of Nesher Ramla can serve as independent avenue for studying changes in site use and other questions regarding the nature of occupation. For example, changes to the intensity of butchery activities over time can be examined if the manuports are connected to bone breaking. Analysis of the GST will also investigate whether the variety of butchery tasks conducted fluctuates with intensity of site use. Previous studies of the Upper Sequence indicate that as the timing of visits became progressively shorter and sporadic, site function is expected to have become more task-specific (Centi and Zaidner 2020; Varoner et al. 2021). It is therefore predicted that the

Upper Sequence GST will also exhibit a trend of decreasing site-use intensity by reflecting a narrower range of activities centered around hunting and butchery towards the latest phases of occupation.

2.5 Archaeological and Ethnographic Evidence for the Use of *ad-hoc* GST

The collection of natural pebbles, cobbles, and blocks for use as *ad-hoc* or minimally modified GST has been described in various archaeological and ethnographic contexts. A review of the broad range of functions documented for these tools is conducted in this section with the intent of aiding the functional identification of the Upper Sequence GST. These descriptions serve as a basis of comparison with GST use at Nesher Ramla and help to identify potential activities for investigation through the experimental program outlined in section 4.2. This discussion also provides details regarding the manner in which GST are collected and discarded and is also focused on what insights into behaviours related to technology, subsistence, and cognition can be gained from analysis of GST.

2.5.1 *Ad-hoc* Pebbles and Cobbles from Archaeological Contexts

This review is primarily centered around GST from sites within the southern Levant but also incorporates details on *ad-hoc* GST in other contexts. Examples from Africa and Europe are included in Appendix A as they reveal some of the earliest functions for *ad-hoc* GST and provide a fuller picture of the extensive range of functions associated with these tools. These functions are grouped into three categories of behaviour: technology, subsistence, and symbolism although these are not strict classifications as certain functions or processed materials are noted to overlap between different categories. This discussion is also organized chronologically in order to detail the emergence of novel behaviours and functions associated with *ad-hoc* GST.

Basalt and phonolite cobbles and blocks are identified among the earliest known tools dated to 3.3 Ma at Lomekwi in Kenya where they are associated with knapping and additional pounding tasks (Harmand et al. 2015). At other Early Stone Age (ESA) sites in African, *ad-hoc* pebbles and cobbles have been interpreted as both active and passive implements that were employed in nut cracking, multiple knapping techniques, and bone breaking among other percussive tasks (e.g. Arroyo and de la Torre 2016, 2018, 2020; Arroyo et al. 2020; Caruana et al. 2014; Delagnes and Roche 2005; Roche et al. 2018). In later periods, *ad-hoc* GST were also used to process a variety of materials with an abrasive gesture and provide some of the earliest evidence for plant food processing in Africa, Europe, and the southern Levant (e.g. Cristiani et al. 2012, 2021; Dubreuil and Nadel 2015; Goren-Inbar et al. 2002; Piperno et al. 2004; Revedin et al. 2010, 2015; Van Peer et al. 2003, 2004).

Technology

Ad-hoc GST from archaeological contexts have predominantly been associated with the production or maintenance of other forms of technology. Knapping accounts for the majority of the functional interpretations reviewed here. The prevalence of knapping hammerstones is in part attributable to the ubiquity of evidence for flaked tool production in the archaeological record as well as the conspicuous use-wear formed as a result of contact with hard stone material. *Ad-hoc* pebbles and cobbles were employed in a variety of knapping methods and could also serve as multipurpose tools with other applications (e.g. Arroyo and de la Torre 2018; Arroyo et al. 2020; Barsky et al. 2015; Cristiani et al. 2012; Harmand et al. 2015). Hide processing tasks including cleaning, softening, and treatment with ochre represent other technology-related functions for *ad-hoc* GST (Cristiani et al. 2012, 2021; Dubreuil and Nadel 2015; Shimmelmitz et al. 2021).

Ad-hoc hammerstones are represented at several Lower Paleolithic sites in the southern Levant, including the early Acheulian site of Hummal and the Acheulian sites of ‘Ubeidiya and Gesher Benot Ya’aqov (Alperson-Afil and Goren-Inbar 2016; Goren-Inbar et al. 2002; Hauck 2010, 2011; Shea and Bar-Yosef 1999; Wegmüller 2015). Variation in the morphology and distribution of the pits observed on basalt hammerstones at Gesher Benot Ya’aqov was suggested to reflect their use in bifacial knapping in addition to nut cracking based on comparisons with experimental tools (Goren-Inbar et al. 2002).

The multiuse nature of basalt percussive tools at Gesher Benot Ya’aqov was also mirrored by the complex life histories of the limestone assemblage. Limestone cobbles, which were transported to the site from fluvial deposits were classified into two categories of percussors. Knapping percussors, *percuteurs de taille,* were characterised by flat or globular morphologies. The second category, *Percuteurs de concassage*, displayed damage from heavy blows against a hard surface resulting in morphologies unsuitable for knapping. Percussors demonstrated a complex life cycle composed of at least three separate stages of use that were discernable by a progressive decrease in size, loss of cortical surface, and increase in the frequency of scars between each stage. The first stage involved forceful and repeated strikes which eventually resulted in accidental breakage. In the second stage, broken percussors were modified into chopping tools or *percuteurs de concassage* for bone breaking. In the final stage, chopping tools were modified into cores for the removal of flakes. This proposed life cycle demonstrates the degree to which long-term planning influenced the use of expedient technology at Gesher Benot Ya’aqov as the selection of cobbles for use as percussors would have required consideration of the functional requirements of every potential stage of the tool’s life cycle (Alperson-Afil and Goren-Inbar 2016).

Ad-hoc pebbles and cobbles associated with hide processing tasks were employed with an abrasive gesture or a combination of percussion and abrasion. A basalt pebble from the Epipaleolithic site of Ohalo II was identified as an active hide processing implement and displayed use-wear consistent with an abrasive gesture (Dubreuil and Nadel 2015). Additionally, a cobble composed of dolomite from the Acheulo-Yabrudian complex of Tabun Cave may provide evidence for the use of *ad-hoc* pebbles and cobbles for the abrasion of a soft material such as hide during the late Lower Paleolithic ca. 350 ka B.P. Properties of the processed material were elucidated through comparisons to experimental tools used to abrade a variety of materials although a secure identification of the processed material itself was limited to characterizing it as a soft material (Shimmelmitz et al. 2021).

Subsistence

Ad-hoc pebbles and cobbles have been associated with food processing tasks involving both plant and animal material. Identified plant processing activities include nut cracking and grinding or pounding of a variety of vegetal materials while the use of *ad-hoc* tools for processing animal materials is best represented by bone breaking.

The consumption of plant food resources in the Lower and Middle Paleolithic of the southern Levant is evidenced by macroplant remains, starch grains, and phytoliths recovered from a select few sites (e.g. Goren-Inbar et al. 2002; Madella et al. 2002; Melamed et al. 2016; Lev et al. 2005; Rosen 2003). Tools implicated in the processing of plant foods in the southern Levant are even less represented in Lower and Middle Paleolithic contexts than physical plant remains although this may be attributable to a lack of recognition in the absence of formalized tool forms (Dubreuil and Nadel 2015; Goren-Inbar et al. 2002; Piperno et al. 2004).

Nut cracking is often characterised as the oldest function for percussive technology that originated in the common ancestor to hominins and chimpanzees and represents shared behaviour between humans and several non-human primate species (Arroyo et al. 2021; Boesch and Boesch 1982; de Beaune 2004; Mercader 2007). The archaic nature of nut cracking behaviours is supported by active, and passive implements from Early Stone Age contexts in Olduvai Gorge and West Turkana which have been associated with this behaviour (Arroyo et al. 2020; Arroyo and de la Torre 2016, 2018; de la Torre et al. 2013; Delagnes and Roche 2005). *Ad-hoc* tools used for processing plant foods through grinding or mixed gestures are reported at later contexts in Africa, Europe, and the southern Levant (Barton et al. 2012; Cristiani et al. 2021; Dubreuil and Nadel 2015; Mariotti Lippi et al. 2015; Mercader 2009; Revedin et al. 2010, 2015).

Nut cracking has been identified in the southern Levant at Gesher Benot Ya'aqov by the presence of seven edible species of nuts with hard shells which require hammering to be cracked open for consumption along with an extensive collection of 54 pitted objects at the site. The deep pits, characterised by smooth and rounded interiors, observed on the center of pitted basalt objects were similar to those that resulted from nut cracking experiments (Goren-Inbar et al. 2002).

A basalt slab from Ohalo II provides evidence for sporadic processing of plants in the southern Levant during the Upper Paleolithic (Dubreuil and Nadel 2015; Piperno et al. 2004). The basalt slab was interpreted as a lower implement used to process non-oily plant material in pounding and grinding tasks although the minimal development of wear traces indicates it was not used extensively (Dubreuil and Nadel 2015). Starch grains recovered from the surface of the basalt slab indicate it was exclusively used to process cereals, predominantly wild barley (*Hordeum*), but other Poaceae grains are represented (Piperno et al. 2004).

Bone breaking for marrow extraction is documented at several Lower and Middle Paleolithic sites in the southern Levant by percussion marks and breakage patterns observed on the bones themselves in addition to the stone implements used to break them (Alperson-Afil and Goren-Inbar 2016; Assaf et al. 2020; Blasco et al. 2014, 2016; Rabinovich and Hovers 2004; Rabinovich et al. 2008; Speth 2012; Speth and Clarke 2006; Stiner 2005; Stiner and Tchernov 1998; Stiner et al. 2009, 2011; Yeshurun et al. 2007).

Two different forms of potential *ad-hoc* bone breaking implements are identified at Gesher Benot Ya'aqov although the functional interpretation of these tools is not supported by comparison with experimental tools. Limestone *Percuteurs de concassage* displaying dull edges and extensive damage were associated with bone breaking. This interpretation was supported by the presence of an elephant skull with extensive percussion damage attributed to marrow extraction along with fragmented bones of other large mammals including bovids, rhinoceros, and hippopotamuses (Alperson-Afil and Goren-Inbar 2016). Basalt anvils with a distinctive thin morphology have been identified as potential bone breaking implements based on the determination that they were not employed in bipolar knapping, however more investigation is required to definitively connect these anvils with bone breaking (Goren-Inbar et al. 2015).

Symbolic Behaviour

In addition to practical applications such as hide treatment, hafting, or medicine (e.g. Cristiani et al. 2021; Dubreuil and Grosman 2009; Wojcieszak and Wadley 2019), the processing of ochre has also been associated with symbolic behaviour (Cristiani et al. 2012; Hovers et al. 2003). Ochre lumps from many contexts bear signs of scraping and crushing and a variety of preparation methods involving heat transformation, scraping with lithic tools, and reduction into powder through grinding have been proposed (Henshilwood 2011; Hovers et al. 2003; Salomon et al. 2012). The tools used for preparing and/or storing ochre provide insight into production sequences for ochre products in different contexts and investment into producing non-utilitarian items.

The use of *ad-hoc* tools for ochre processing is documented in Africa at several Middle Stone Age (MSA) sites and in the Middle Paleolithic site of Qafzeh Cave in the southern Levant (Henshilwood 2011; Hovers and Belfer-Cohen 2013; Hovers et al. 2003; Rosso et al. 2016; Van Peer et al. 2003, 2004; Wojcieszak and Wadley 2019).

A Levallois core from Qafzeh Cave was interpreted as an implement that was recycled and employed for grinding and storing ochre based on the presence of ochre stains within the negative of a flake scar. The opportune use of a concave surface on this core is reported to be similar to the use of concavities on the surfaces of Upper Paleolithic grinding stones for preparing and storing ochre and provides another potential application for *ad-hoc* ochre grinding tools (Hovers et al. 2003).

Flexibility and Opportunism Demonstrated by Archaeological ad-hoc GST

The above examples demonstrate a range of functions for the use of *ad-hoc* GST. Knapping hammerstones, and other applications for *ad-hoc* pebbles and cobbles reflect both flexibility and specialization. In some instances, efforts to acquire tools may be minimized by using the same implement for tasks with similar parameters while in others task efficiency and performance may be improved by selectivity for particular morphological or raw material characteristics. Differences in raw material, morphological, or size characteristics between functional categories of tools indicates that an understanding of task parameters still governed the selection of expedient tools. The operational sequence for limestone percussors at Gesher Benot Ya'aqov provides insight into the cognitive abilities of hominins including the capacity for long term planning and contingency through a predetermined yet dynamic procedure for transforming one tool form into another (Alperson-Afil and Goren-Inbar 2016).

The degree of specialization of expedient tools can also provide some indication of the importance of different modes of subsistence especially in instances where superior quality non-local material was preferred for certain tasks over locally available material (e.g. Alperson-Afil and Goren-Inbar 2016; Pop et al. 2018). Investigating subsistence through *ad-hoc* tools may be useful for exploring the origins of subsistence activities that are associated with more conspicuous formal tool types in later contexts. Use-wear and residues on *ad-hoc* stone tools used to process plant foods represent alternate lines of evidence that are not hindered by poor preservation to the same extent as plant remains. These tools also offer further insights into the manner by which plant foods were incorporated into diets and can provide some idea of the investment in labour and time required for their exploitation. Although scarce, the available evidence for early plant food processing tools in the southern Levant reinforces studies of plant food remains which suggest that early plant food consumption may have been more widespread than previously assumed (Dubreuil and Nadel 2015; Goren-Inbar et al. 2002; Madella et al. 2002; Melamed et al. 2016; Lev et al. 2005; Piperno et al. 2004; Rosen 2003).

The use of *ad-hoc* tools for ochre storage and production can reflect either flexibility or specialization. In some cases, the selection of tools for ochre production appears to be opportunistic, making use of available material by recycling different forms, while in others an apparently mundane unprepared pebble or cobble can be a component of a highly specialized tool kit (Henshilwood 2011; Hovers et al. 2003; Rosso et al. 2016; Van Peer et al. 2003, 2004; Wojcieszak and Wadley 2019).

2.5.2 Ethnographic Accounts for the Use of *ad-hoc* Pebbles and Cobbles

The ethnographic accounts for the use of *ad-hoc* pebbles and cobbles discussed in this section are derived predominantly from the Human Relations Area Files (eHRAF World Cultures) and include a diverse range of cultural and geographic contexts. Despite the fact that details on the implements themselves are often minimal, these accounts are valuable in that they provide descriptions of actual use as well as the context in which collection, use, and discard occurred. These accounts are organized by the material that was processed and further subdivided by the action employed. A more extensive presentation of ethnographic accounts appears in Appendix A.

Animal matter

The ethnographic accounts document the use of *ad-hoc* pebbles and cobbles to process a variety of animal materials including bone, hide, and whole animal carcasses (e.g. Binford 1978; Jochelson 1905; Kluckhohn et al. 1971; Leechman 1951; McGee 1895; Schroth 1996). Tasks related to subsistence included bone breaking and comminution for access to marrow and pounding of dried meat or small animals (e.g. Binford 1978; Jochelson 1905; Leechman 1951; Osgood 1970). Tendon pounding, hide processing, and bone abrasion were conducted for the production of tools and other objects (e.g. Barrett 1952; Hilger 1957; Jochelson 1905, 1925) and bone breaking occasionally conferred an additional benefit of providing bone fragments for tool production (Osgood 1970).

Tasks related to subsistence were conducted exclusively with a striking gesture within the reviewed descriptions (e.g. Lee 1979; Leechman 1951; Schroth 1996). Pebbles and cobbles used in bone breaking demonstrated little selectivity other than for suitable sizes and morphologies. These tools were typically fist-sized with a rounded or narrow shape which ensured a secure and comfortable grip during use (Binford 1978; Jochelson 1905; Lee 1979). Available descriptions of wear on bone breaking implements are limited to pecking damage (Lee 1979) and a gradual change towards a pestle-like morphology (Honigmann 1981). Elongated pebbles were selected for pounding whole carcasses of small animals and displayed battering on the ends in one account (McGee 1895; Scroth 1996).

Processing of animal matter for non-subsistence related tasks involved a wider range of actions. Abraders composed of rough volcanic rocks such as pumice or andesite were used to polish bone or ivory (Jochelson 1925; Laughlin 1980). Pumice whetstones were also used to grind and polish flaked bone for the production of retouchers and to repair these tools when the tips broke or split (Jochelson 1925).

Accounts of hide processing also attest to a preference for rocks of abrasive quality including pumice or sandstone (e.g. Barrett 1952; Dening 1930 as cited by Rodnick 1938; Ewers 1945; Forde 1949; Hatt 1969; Hilger 1957; Kluckhohn et al. 1971). *Ad-hoc* pebbles and cobbles, often acquired opportunistically from the immediate area, were used for abrasion during several stages of hide processing: defleshing (Kluckhohn et al. 1971; Ridell 1960), the application or removal of treatment substances (Ewers 1945; Hilger 1957; Riddell 1960), and softening (e.g. Hatt 1969; Ewers 1945; Kluckhohn et al. 1971; Laughlin 1980; Schroth 1996). Some accounts indicate that pounding also was also part of the softening process (Kluckhohn et al. 1971; Schroth 1996; Spier 1933), initial skinning (McGee 1895; Riddell 1960), or used to remove hair from the hide (Kluckhohn et al. 1971). Tendons were also typically processed by pounding to separate the fibers for use as threads or ropes (Denys 1908; Jochelson 1925). McGee (1895) describes the severing of tendons through abrasion over the edge of a quartzite cobble.

Bone breaking, tendon pounding, the pulverising of small animals, and occasionally, hide processing involved the use of a secondary stone surface that served as an anvil (Jochelson 1905; McGee 1895; Lee 1979; Leechman 1951; Schroth 1996; Spier 1933). Typically, the anvils employed in these tasks were also not prepared prior to use and selected for their naturally flat surfaces (Jochelson 1905; Schroth 1996; Spier 1933).

Plant Material

The ethnographic accounts for the processing of plant materials with *ad-hoc* pebbles and cobbles discussed here predominantly relate to subsistence. Nut cracking, especially of acorns, is the predominant task detailed although seeds, berries, roots, maize, and garlic were also pounded (e.g. Barrett 1952; Jochelson 1905; Kluckhohn et al. 1971; Marlow 2010; McGee 1895; Schroth 1996; Shoemaker 2017). Extraction of the edible kernels of acorns and other nut species required cracking with a hard hammerstone and usually involved placement on a stone anvil (Barrett 1952; Gayton 1948; Kluckhohn et al. 1971; Lee 1979). Acorns could serve as a supplement to diets during times of crop shortages or in response to increased demographic pressure (Cohen 1977; Mortensen et al. 1993). Mesquite seeds were processed by a combination of crushing and grinding with a quartzite pebble (McGee 1895). In many accounts, the selection of pebbles and cobbles for pounding plant material prioritized convenience through the collection of locally available rocks of suitable sizes and shapes (Ertug-Yaras 2002; Marlow 2010; Shoemaker

2017). Descriptions for plant processing implements demonstrate a preference for elongated morphologies for pounding tasks (Ertug-Yaras 2002; Shoemaker 2017).

Ad-hoc GST were also used in plant processing tasks unrelated to subsistence. Descriptions of wood abrasion include the sharpening of digging sticks and the use of pumice abraders for polishing arrows, harpoon shafts, canoe hulls, paddles, and bowls (Laughlin 1980; LeBar 1964; Schroth 1996). In another account, a quartzite pebble was used to chop trees by pounding the wood at a weak point and for removing the thorns of ocotillo stems (McGee 1895).

Stone Material

Ethnographic accounts for the application of *ad-hoc* pebbles and cobbles to stone material describe the production or maintenance of stone tools and objects (Barrett 1952; Jochelson 1925; Linton 1923; Marlow 2010; Radcliffe-Brown 1922) as well as the production of pigments (Jochelson 1925; McGee 1895). Tasks related to the former predominantly involved a percussive gesture. Unprepared pebbles and cobbles were used as hammerstones to knap obsidian, chert, and quartz (Barrett 1952; Radcliffe-Brown 1922). River cobbles were used to resharpen the surfaces of grinding slabs through pecking (Marlow 2010). Water-worn cobbles of basalt were employed as hammerstones for manufacturing adzes and displayed battering damage on their ends (Linton 1923). Jochelson (1925) describes the production of stone lamps and sinkers with two types of hammerstone that were distinguished based on differences in morphology, size, and raw material. The first type, composed of oblong boulders recovered from the shore, was employed for heavy strikes during the initial shaping of stone lamps. The hardness of the material for this hammerstone type was selected based on properties of the material to be processed. The second type had an egg-shaped or discoidal morphology and was employed in lighter strikes and enabled finer handling during final shaping.

Accounts of *ad-hoc* pebbles and cobbles used to polish and sharpen stone tools and objects describe the use of an abrasive gesture (Jochelson 1925; LeBar 1964). A series of andesite whetstones was used to polish stone implements in multiple stages by employing polishing stones composed of increasingly fine material (Jochelson 1925).

Pigment production for paint was conducted through a combination of percussion and abrasion (Jochelson 1925; McGee 1895). Hematite was crushed with oval-shaped stones that served as both active implements as well as anvils (Jochelson 1925).

Flexibility and Opportunism Demonstrated by Ethnographic ad-hoc GST

In many accounts, acquisition of *ad-hoc* tools consisted of collecting pebbles and cobbles of suitable size, morphologies, or raw material for the task at hand from the immediate area (e.g. Barrett 1952; Ertug-Yaras 2002; Jochelson 1925; Linton 1923; Marlow 2010; Schroth 1996; Shoemaker 2017). The expedient nature of these tools is also demonstrated by the ease at which they could be discarded following completion of a task or abandonment of a site and replaced as needed (Marlow 2010; Shoemaker 2017).

McGee (1895) describes the transport of pebbles and cobbles that reveals a greater investment into ad-hoc tools than characterised by other ethnographic accounts. Rocks ranging in size from boulder to pebble-sized were collected from the beach for a variety of purposes. The decision to transport these implements once the task at hand had been completed depended on factors such as the size of the implement, the availability of similar materials at the destination, as well as anticipation of the requirements of future tasks. Smaller rocks were transported into areas where similar material was scarce while larger rocks were left upon abandonment of a site. Some of these smaller implements were retained as a highly valued component of a personal toolkit. One such tool consisted of a quartzite pebble that displayed battering on the edges and remnant bits of fat and flesh clinging to the surface. This pebble was observed to have a range of functions that included several tasks for processing a horse carcass, processing plant material, severing cords of hair by abrasion, pounding and grinding ochre for face paint, and driving away nuisance animals. The presence of polish on the lateral edges of this pebble were interpreted as the result of extensive handling.

2.6 Chapter Summary

This chapter has established the context for the GST assemblage studied in this thesis within the broader trends of the Middle Paleolithic of the southern Levant and within the technological system of Nesher Ramla. The southern Levant served as an attractive destination for hominin migrations throughout the Paleolithic due to its favorable geographic location and Mediterranean climate (Bar-Matthews et al. 2019) and therefore represents an important context for the study of GST evolution and use in the Middle Paleolithic. Nesher Ramla is situated within this region on the western slopes of the Central Mountain Ridge in the Mediterranean climate zone (Langugut et al. 2011; Zaidner et al. 2014). The site location experiences heightened rainfall amounts due to the Mediterranean Sea and is dominated by Mediterranean woodland vegetation although ecotones bring a variety of resources into close proximity (Chen and Litt 2018; Miebach et al. 2019; Shea 2003).

The history of occupation at Nesher Ramla coincides roughly with the last half of the MIS 6 glacial period and the MIS 5 interglacial during which drastic changes to climate and water availability occurred. The resulting landscape around Nesher Ramla was a dynamic mix of Mediterranean woodland and Irano-Turanian steppe vegetation (Chen and Litt 2018; Langgut et al. 2011; Miebach et al. 2019).

An overview of the Middle Paleolithic describes the behavioural context for Nesher Ramla and many of the *ad-hoc* GST described in section 2.5.1. The Middle Paleolithic is characterised by continuity in behaviour, technology, and subsistence between the preceding Lower Paleolithic and the subsequent Upper Paleolithic. Increased movement into and occupation of the Mediterranean zone by populations ca. 130 ka resulted in changing land-use patterns characterised by heightened group territoriality and more intensive exploitation of resources within smaller territories (Hovers and Belfer-Cohen 2013; Shea 2010). Consumption of plant food resources is among the Upper Paleolithic subsistence behaviours identified as having an early onset during the LMP (e.g. Goren-Inbar et al. 2002; Henry et al. 2011; Lev et al. 2005; Melamed et al. 2016).

Analysis of the Upper Sequence GST will reveal how these tools fit into the pattern of changing site-use at Nesher Ramla that is demonstrated by the lithic and faunal assemblages. The composition and density of archaeological layers reflects a gradual trend of decreasing intensity of occupation towards the upper-most units. Morphological change to the depression represents a potential explanation for the decline in usefulness of the site and its ultimate abandonment (Centi and Zaidner 2020; Zaidner et al. 2014; 2016).

Insights provided by the review of *ad-hoc* pebbles and cobbles from archaeological contexts in Africa, Europe, and the southern Levant demonstrate a variety of functions related to technology, subsistence, and symbolic behaviour (e.g. Alperson-Afil and Goren-Inbar 2016; Arroyo et al. 2020, Arroyo and de la Torre 2016, 2018, 2020; Barksy et al. 2015; Cristiani et al. 2021; Dubreuil and Nadel 2015; Goren-Inbar et al.

2002; Hovers et al. 2003; Revedin et al. 2010, 2015; Titton et al. 2018). The acquisition and use of these tools appears to have been influenced by a combination of flexibility and specialization. The review of ethnographic accounts reveals a similar diversity of functions. These accounts provide details on the collection of *ad-hoc* pebbles and cobbles and their application to animal, plant, and stone materials for purposes related to subsistence, technology, and symbolic behaviours (e.g. Binford 1978; Jochelson 1905; Kluckhohn et al. 1971; Schroth 1996).

Chapter 3 - Research Framework and Methodology

This chapter outlines the methods of analysis and documentation applied to both the archaeological and experimental tools beginning with the protocol and theories for each methodology. This is followed by a description of the equipment and methods employed for observing and documenting residue and use-wear evidence. The final section outlines the protocol for the blind test conducted on the experimental tools.

A modified approach for use-wear analysis serves as the basis for the functional interpretation of the Upper Sequence GST assemblage although several additional lines of evidence are used to support these proposed functions. An experimental assemblage of *ad-hoc* limestone pebbles provides a comparative data set for interpreting the use-wear traces observed on the archaeological tools. The functional analysis conducted on the experimental tools includes residue analysis in addition to use-wear analysis.

3.1 Methods of Analysis

Functional analysis is concerned not just with reconstructing use, but all phases of the life history of an artifact including design, manufacture, use, reuse, and discard. This approach investigates decisions made at each stage in order to reveal how a particular artifact was incorporated into a larger technological system as a solution to a particular problem or set of problems (Adams 2014a; Adams et al. 2009; Dubreuil et al. 2015). This thesis employs several different methods of analysis that together enable a functional analysis of the Upper Sequence GST.

The GST from Nesher Ramla are expedient and altered predominantly through use. However, a few factors influencing their design can still be recognized. The raw material composition, size, shape, and weight of the rocks selected may provide some indication of the tasks they were selected for (Adams 2014a; Adams et al. 2009; Dubreuil et al. 2015). The assessments of task viability and efficiency included in the experimental results in Chapter 4 will elucidate some of the characteristics that may have been desirable in *ad-hoc* GST used to perform each of the experimental tasks.

A combined approach of use-wear analysis and residue analysis was originally intended to investigate the use stage of the life cycle of the Upper Sequence GST although these approaches can also be applied to other life stages. Descriptions of use-wear traces characterize alterations to the surface of a tool during use in relation to both contact material properties and the motion of use. Use-wear analysis may also aid in identifying instances of reuse or multiple-use based on the number of use areas or the presence of different patterns of use-wear on the same tool (Adams 2014a; Adams et al. 2009; Dubreuil et al. 2015). Residue analysis serves as a complimentary approach to use-wear analysis in that the former can identify processed material with greater accuracy and the latter can identify the use area as well as the manner in which material was processed (Cristiani and Zupancich 2021; Stephenson 2015).

Limitations on the Analysis of the Archaeological Assemblage

Due to restrictions imposed on international travel for research imposed by Trent University in response to the COVID-19 pandemic, I was unable to travel to the Hebrew University of Jerusalem, Israel where the archaeological assemblage is stored. As a result, my research plan was altered in order to account for the fact that I was not able to conduct use-wear analysis or residue analysis on the archaeological assemblage using the originally planned protocols. Instead, a modified approach for use-wear analysis was adapted to make the best use of data on the Upper Sequence GST that were actually available to me.

The use-wear data employed originate from two different sources. Each source has its own advantages and disadvantages and was used in a slightly different manner in order to enable even the most basic functional interpretations of the GST.

The first source is a database constructed from two excel spreadsheets in which wear trace observations were recorded during the initial examination of artifacts recovered from the Upper Sequence by Laura Centi and Laure Dubreuil. From this database, the relative frequency for each type of wear on the assemblage was determined and separate wear patterns were identified based on the presence of different wear traces in association with one another. My hypothesis is that any differences between wear pattern characteristics reflect differences in gesture and/ or processed material properties. Functional interpretations for the identified wear patterns will be limited to proposals of a range of activities that may account for the wear pattern in question.

The second source of archaeological data is a collection of pictures and accompanying descriptions of six cobbles that were taken by my research supervisor, Laure Dubreuil. These cobbles were selected from the assemblage to be photographed based on the presence of highly visible sheen on each of their surfaces. The pictures document the sheen present on each artifact at various scales enabling detailed descriptions of the micropolish characteristics. These characteristics are then compared to the experimental results in order to identify any tasks that can potentially account for the sheen observed on the Upper Sequence GST.

The protocols for residue and use-wear analysis outlined in the proceeding sections were still applied as planned to the experimental assemblage. The residues sampled from the experimental tools were used to produce a reference collection of the materials processed and the methods through which they were processed. This, in addition to descriptions of use-wear data on the experimental assemblage, contribute to the available pool of data on residues and use-wear and have some value for future research efforts.

3.1.1 Residue Analysis

The protocol for residue analysis employed in this thesis was modified from Cristiani and Zupancich (2021) and Stepheson (2015) and makes use of observations at low and high magnifications. The intended result of using multiple scales of observation is to characterize different aspects of residues at each scale which are divided into macro residues and micro residues. Macro residues were observed *in-situ* at low magnification and described in terms of distribution, morphology, and appearance using the terms outlined in section 3.2.3. Micro residues were observed at high magnification with and without the aid of Picro-Sirius Red (PSR) biochemical staining. The benefits of each method of observation are further detailed in section 3.2.1.

Biochemical staining works by colouring a target component of a substrate via chemical reaction in order to visually isolate this component and increase birefringence when viewed under cross-polarized light. Since PSR selectively stains collagen, this procedure was used only on the residue samples extracted from the surface of the experimental tools used to process animal material. With PSR staining the three most common types of collagen in the archaeological record can be identified and distinguished from one another: Type I: fibres, Type II: hyaline and elastic cartilage and Type III: reticulin fibers and fibrillar collagen (Stephenson 2015).

Residue samples were collected and prepared for observation using the procedure developed by Stephenson (2015). Residues were extracted by placing 20-µl droplets of ultrapure water on several locations on each tool surface and leaving them adequate time to soak into the matrix. A second pipette was then used to repeatedly inject and extract another 20-μl of ultrapure water into the matrix in order to loosen and extract residues. Once extracted, the sample was placed in a microcentrifuge tube for storage. One droplet of the extracted sample was placed on to a glass slide, covered to prevent airborne contamination and allowed to dry for one day.

The PSR solution was prepared by adding 0.05 g Sirius red F3B to a 50 ml saturated aqueous solution of picric acid and then diluted by adding one-part PSR solution to three-parts deionised water. One drop of the diluted PSR solution was added to the sample slide with a 230 mm glass pipette and left to dry for one hour.

Once dried, one to two drops of acidified water (5ml glacial acetic acid and 1L distilled water solution) were applied to the slide to wash away any excess PSR solution. A cover slip was then applied to the stained area and a lint-free wipe was used to remove excess liquid. The slide was then placed under a bright-field light microscope for observation using the procedure outlined in section 3.2.1.

3.1.2 Use-Wear Analysis

Wear occurs through the progressive transformation of a surface and results from contact and relative motion between another surface. Use-wear analysis is the examination of the traces of wear on an object that result from manufacture or use of a tool. Use-wear analysis relies on the notion that the appearance of wear traces will differ based on the conditions under which they were formed so that different modes of contact and processed material properties result in the formation of different wear patterns. Interpretation of observed wear patterns is often supported by use-wear experiments which provide wear patterns associated with known use contexts as a basis for comparison (Adams 1988, 2014a; Adams et al. 2009; Dubreuil and Savage 2014; Dubreuil et al. 2015).

History of Use-Wear Analysis

The 1964 English translation of S.A. Semenov's 1957 *Prehistoric Technology* brought awareness of his 20 years of use-wear research to archaeologists in the west. Semenov is credited with developing the first systematic methodology for describing and studying use-wear which incorporated the analysis of experimentally knapped tools for comparative purposes (Semenov 1964). Semenov's work facilitated investigation into tool function and technological change over stylistic classification and inspired the adoption of use-wear analysis on chipped-stone in studies conducted by Keeley (1980), Odell and Odell-Vereecken (1980), Tringham et al. (1974), and Wilmsen (1968) among others.

The success of early use-wear studies conducted outside of the Soviet Union was often undermined by failure to uphold the standards outlined by Semenov including the preparation of translucent artifacts prior to observation so that wear traces would not be obscured. The methodologies employed also served to weaken the legitimacy of results as little care was taken to ensure that microwear actually originated from use rather than manufacturing or post-depositional processes (Keeley 1974). Subsequent efforts to improve methodological standards included the implementation of blind-testing procedures by Keeley and Newcomer (1977) and Odell and Odell-Vereecken (1980). Concern for methodological improvement also resulted in debate regarding the efficacy of low-powered versus high-powered magnification for examination of wear traces in spite of the fact that Semenov (1964) had recognized the complimentary benefits gained by the use of multiple scales of observation (Keeley 1974; Keeley and Newcomer 1977; Odell 1975; Odell and Odell-Vereecken 1980).

The focus of use-wear studies eventually expanded from a focus on chipped-stone implements to investigate the manufacture and function of GST (e.g. Adams 1988, 1989, 2002, 2014a; Adams et al. 2009; Dubreuil 2004; Dubreuil and Grosman 2009; Fullagar and Field 1997; Hamon 2008; Hayden 1987; Mansur 1997; Mills 1993; Mora and de la Torre 2005; Risch 2008, Yerkes 2003). Recent efforts have also been made to develop and promote the use of a standardized framework for describing and analysing use-wear on GST (Adams et al. 2009; Dubreuil et al. 2015; Dubreuil and Savage 2014).

Use-wear studies rely heavily on insights from experiments which have been used not only as a source of comparative use-wear traces and task viability but also to assess the robusticity of frameworks employed for studying use-wear formation and to develop new methodologies. Hamon and Plisson (2008) have performed one of the few blind tests of use-wear analysis on GST. This test enabled the methodology for use-wear analysis employed to be assessed in terms of reliability and accuracy in determining different functional parameters such as processed material or kinetic action.

Experiments performed by Delgado-Raack et al. (2009) involved the use of industrial machines to isolate the mechanical behaviour of rocks during different abrasive tasks from human and environmental sources of variability. This allowed clearly defined petrographic qualities to be related to more abstract characteristics of task performance and raw material preference.

Other methodologies have been employed to integrate use-wear analysis with 3D analysis and surface quantification on experimental tools used to perform bone breaking, knapping, nut cracking, and grinding of vegetal material. These combined approaches provide both qualitative data, in the form of use-wear descriptions, and quantitative data, in the form of measurements of spatial distribution and dimensions, that can be applied for the interpretation of archaeological tools (e.g. Arroyo and de la Torre 2020; Benito-Calvo et al. 2018; Caricola et al. 2018; Caruana et al. 2014; de la Torre et al. 2013; Paixão et al. 2021b; Zupancich et al. 2019).

Current Theories for Use-Wear Analysis

In order to better explain the factors influencing the formation of different wear patterns, Jenny Adams (1988) made use of insights from the field of tribology which studies friction, lubrication, and wear between interacting surfaces in relative motion within industrial contexts (Bhushan 2013). Tribological concepts were applied to research on GST to distinguish four mechanisms of wear that result in damage to ground stone surfaces: adhesive wear, fatigue wear, abrasive wear, and tribochemical wear (Adams 1988; 2014a; Adams et al. 2009). Although each tribological mechanism of wear is associated with a specific wear formation process and different wear traces (table 3.1), these mechanisms can occur simultaneously and influence one another. For example, fatigue wear can destroy wear traces resulting from abrasive wear and the environment created by adhesive, abrasive, and fatigue wear enables the build-up of reaction products from tribochemical wear (Adams 1988, 2014a; Adams et al. 2009). These mechanisms will be discussed in Chapter 4 as part of an attempt to understand the formation processes of the wear traces observed on the experimental assemblage.

Tribological Mechanism	Description	Visible wear traces
Adhesive wear	Attraction between contacting surfaces occurs at the atomic level. Relative movement between the contacting surfaces breaks these molecular bonds causing the release of frictional heat and removal of rock grains from one or both contacting surfaces.	Residues
Fatigue wear	The movement and weight of a contacting surface imposes pressure and stress upon the highest topographic areas of rock grains. Rock grains eventually collapse and become crushed when they are unable to withstand the stress.	Fractures, cracks, pits, frosted appearance
Abrasive wear	Particles removed from contacting surfaces by adhesive and fatigue wear become intermediary abrasive agents when they are dragged across a surface. Asperities that remain attached to a harder contact surface may also be abrasive when moving across a softer contact surface.	Striations and scratches, leveling, grain edge rounding
Tribochemical wear	Interaction between contacting surfaces and the action of other mechanisms of wear allow the build-up of chemical reaction products in the form of film or oxides.	Polish or sheen

Table 3.1: Tribological mechanisms of wear and associated wear traces. Modified from Adams (2009:Table 6.2).

3.2 Methods of Documentation

Prior to performing the experiments, measurements of the dimensions and weight of the experimental tools were recorded using calipers and an electronic scale. The general morphology of the tools was also described. These same measurements were recorded for the Upper Sequence GST assemblage.

Descriptions of use-wear and residues were recorded in a Google Sheets spreadsheet during observation. Multiple observation spots were selected on the surface of each tool to ensure that the same area could be examined at each interval in order to document use-wear development as the experiments progressed. The file numbers for photographs taken were also recorded in this document along with the magnification and corresponding observation spot for easier access when processing the files with the digital focal stacking software.

3.2.1 Methods of Observation

Observation of the experimental tools was conducted prior to performing the experiments to record the characteristics of the surface for later comparison and document the wear patterns already present on many of the cobbles due to environmental and mechanical damage that occurred prior to their collection. Observation occurred at predetermined intervals during each experiment to document the process of wear formation during each activity. Residues were observed after each experiment had reached its target duration and prior to washing the surface for use-wear analysis. Due to the fact that observation of use-wear necessitated washing the surface of the experimental tools, the residues observed on each tool are limited to those that accumulated during the final interval of observation, typically one to two hours of use.

Increasing scales of observation were employed to examine and document use-wear and residues on the experimental assemblage beginning with observation with the naked eyes, macroscopic observation, and finally microscopic observation. These combined scales of observation are complimentary to one another as each scale can be used to observe different aspects and even different types of residues and wear traces (Tables 3.3-3.4) (Adams 2014a; Adams et al. 2009; Cristiani and Zupancich 2021; Dubreuil and Savage 2014; Dubreuil et al. 2015; Stephenson 2015). Observation of residues and use-wear traces employed essentially the same procedures and equipment at the naked eye and macroscopic stages of observation. At the high magnification stage, the two procedures diverged as each required different pieces of equipment.

Observations made with naked eyes enable a discussion of whether or not certain activities can be recognized without the use of macroscopic and microscopic observation. This may have important implications for identifying *ad-hoc* GST in archaeological contexts as activities performed with naturally shaped pebbles and cobbles may go unrecognized due to the absence of conspicuous wear. Descriptions recorded at this stage included the distribution and gross appearance of any residues or wear traces visible without microscopic aid.

Macroscopic observations at low-power magnification were conducted with a Nikon SMZ 1000 stereomicroscope with magnification from 8× to 80×. The distribution of residues can be more accurately defined at this scale. Descriptions of the morphology, texture, colour and identified structures within residues under low magnification may also allow for a more complete understanding of how their appearance and distribution are influenced by the manner in which they were deposited during use (Cristiani and Zupancich 2021). For observations of use wear, low-power magnification is best used to identify the dimensions of the use area; kinetic motion; and traces from adhesive, abrasive, and fatigue wear (Adams et al. 2009; Dubreuil and Savage 2014).

High magnification observation of residues was conducted with a brightfield transmitted light microscope with magnifications of 100× to 400×. Staining with PSR and polarizing filters were used together to further increase contrast and enhance the visibility of collagen structures. Staining also enhances birefringence under cross-polarized light as light waves pass through collagen fibers and attached elongated dye molecules at different speeds. The result is a double refraction, or birefringence, of two polarized light waves with perpendicular planes which are then combined to produce a single image (Robinson and Davidson 2021; Rottenfusser et al. 2021; Stephenson 2015). Under cross-polarized light different types of collagen display birefringence of varying intensity and colours (Stephenson 2015).

Microscopic observations of use-wear traces were conducted with a Nikon Eclipse LV-150 compound metallographic microscope at magnifications of 50× to 500×. Differential Interference Contrast (DIC) microscopy was used to enhance contrast and improve the visibility of micropolish relief (Murphy et al. 2021). High-power magnification lends itself best to observations of tribochemical wear as differences in reflectivity and other characteristics of micropolish are more easily discerned although damage to individual grains, linear traces, and abraded areas can also be observed (Adams et al. 2009; Dubreuil and Savage 2014).

3.2.2 Photographic Documentation

Photography was used alongside the descriptive framework to document use-wear patterns on the experimental assemblage. Pictures were also taken before experiments were initiated and during the set intervals of use-wear analysis.

Pictures at the unaided eye level of observation wear were taken with a Nikon D3200 camera and a Nikon 18-55mm f/3.5-5.6 lens. This was done to document visible changes to the surface of tools and built-up residues as tasks progressed. A Cannon EOS T2i camera with a Diagnostic Instruments DD20NLT 2.0X adapter lens affixed to the stereomicroscope and metallographic microscope was used to take pictures of use-wear at macroscopic and microscopic scales of observation. An OMAX USB 3.0 camera with an OMAX A3RDF50 0.50X fixed reduction lens affixed to the brightfield transmitted light microscope was used to take high magnification pictures of the residues.

The pictures taken with the microscopes provide a helpful visual context for conceptualizing descriptions of residues and use-wear traces. However, increased magnification also serves to narrow the depth of field and limit the area of an image that can be in focus at once. This problem is heightened at higher magnifications or when photographing surfaces with varying topographic relief.

Helicon Focus 7.6.6 digital focus stacking software was used to address this issue and ensure clear and focused images of use-wear patterns. To enable digital focus stacking, multiple photographs were taken manually of each area by slowly rolling through the focus and taking photographs at regular intervals. The single composite image produced by the software had a larger depth of field so that most if not all of the subject was in focus.

3.2.3 Descriptive Framework

This thesis makes use of a standardized framework in order to describe the way tools are used to perform work. The typology of percussion proposed by Leroi-Gourhan (1971 as cited by Stroulia 2010) consists of a hierarchical scheme to differentiate between all the potential ways tools can be used although some of these terms are not applicable to the tools in question. Table 3.2 lists the terminology employed in this thesis for describing tool use.

Position of tool during use:
Active
Passive
  Application of force:
  Percussion
  Abrasion
  Mixed
    Direction of force:
    Perpendicular
    Oblique

Table 3.2: Hierarchy of descriptive terms for tool use.

At the highest level of this hierarchy, tools can be categorized as active or passive implements depending on their position relative to the processed material during work. Three main modes of percussion are distinguished by the how force is applied to the processed material: thrusting percussion (percussion), resting percussion (abrasion), or a combination of thrusting and resting percussion (mixed). These categories are further subdivided by the direction in which force is applied in, either a perpendicular or oblique motion, and further still by the nature of contact between the active area of the tool and the processed material which can be linear, punctiform, or diffuse (de Beaune 2004; Leroi-Gourhan 1971 as cited by Stroulia 2010).

Residues

The terminology for describing residues, outlined in table 3.3, is adapted from Cristiani and Zupancich (2021) and Stephenson (2015) and makes use of some of the same parameters used to describe the use-wear traces (Adams et al. 2009; Dubreuil and Savage 2014; Dubreuil et al. 2015).

Macro Residues	
Distribution Pattern of accumulation on the surface.	*Powder* *Film* *Crust* *Amorphous compound*
Structures Substances identified under low magnification.	*Collagen fibers* *Collagen tissues* *Hair* *Fat*
Characteristics	
Density	Isolated spots, extends over surface, limited to use area.
Incidence	Situated on high or low topography, associated with use-wear.
Appearance	Colour, texture, transparency, reflectivity.
Margins	Sharp or diffuse.
Alterations	Compressed, twisted, mud-cracked appearance.
Linear features	Present or absent.
Features	Collagen, fat, bone.
Micro Residues	
Structures Substances identified under high magnification**.**	*Collagen fibers* *Collagen tissues* *Fat* *Blood vessels*
Characteristics	
Density	Isolated or clustered.
Appearance	Parallel, twisted, folded, wavy, macerated, random.
Birefringence*	High, medium, low.
Birefringence pattern*	Yellow birefringence, yellow-orange birefringence, yellow-green birefringence.
Banding patterns*	Present or absent.

Table 3.3: Descriptive terms for macro and micro residues (Cristiani and Zupancich 2021; Stephenson 2015).
**Visible under cross-polarized light*

Characteristics of macro residues observed under low magnification are reported by Cristiani and Zupancich (2020) to be strongly influenced by alterations to the surface topography during use as well as the gesture used. At high magnification, micro residues observed include identifiable collagen structures and the characteristics of collagen residues under various types of polarized light (Cristiani and Zupancich 2021; Stephenson 2015).

Use-Wear

The terminology employed to describe use-wear in this thesis is modified from Adams et al. (2009), and Dubreuil and Savage (2014), and Dubreuil et al. (2015) to fit the characteristics of the experimental tools. Table 3.4 defines the wear traces observed in use-wear analysis and the parameters used to characterise them.

This framework divides the description of different use-wear traces by increasingly finer scales of observation, beginning with macroscopic observation of overall modifications to the surface topography to the various types of wear traces visible under microscopic observation.

Macroscopic	**Topography**	The morphology of the surface observed macroscopically in plan view.
	Flat	The topography is uniform across the surface with few peaks.
	Sinuous or rounded	The topography varies with rounded edges on peaks and a gradual decline into interstices.
	Uneven or rugged	Peaks are rough with a steep decline into interstices.
Microscopic	**Microtopography**	The irregularity of a surface that can be discerned when it is observed microscopically in plan view.
	Regular	The distance between high and low areas of topography is consistent across the surface.
	Irregular	The distance between high and low areas of topography varies greatly across the surface.
Use-wear types		
	Leveling	Removal of volume from high topography that eventually produces homogeneous areas.
	Distribution	Loose, covering, or concentrated.
	Density	Separated, closed, or connected.
	Incidence	Occurrence on high or low topography.
	Morphology	Flat, sinuous, or rounded appearance under macroscopic observation.
	Texture	Rough or smooth.
	Pits	Small areas of concavity due to removal of material from the surface.
	Distribution	Loose, covering, or concentrated.
	Density	Loose scattering, closed or dense pattern with no overlap, or connected pattern with overlap.
	Orientation	longitudinal, transverse, or oblique.
	Depth	Fine or superficial and wide or deep.
	Pit shape in plan view	Irregular, circular, triangular, starlike, or comet shaped.
	Pit shape in cross-section	U-shaped or V-shaped.
	Microfractures	Fractures or cracks on the surface. Extensive microfracturing results in a frosted appearance.
	Distribution	Loose, covering, or concentrated.
	Density	Separated, closed, or connected.
	Orientation	Longitudinal, transverse, or oblique.
	Depth	Fine or superficial and wide or deep.
	Edge rounding	Removal of material from the edges of topographic relief resulting in reduced roughness.
	Occurrence	Present or absent.
Linear Traces Wear traces that reflect the direction of movement.		
	Scratches	Observed macroscopically and wider than striations.
	Striations	Observed microscopically and narrower than scratches.
	Distribution	Loose, covering, or concentrated.
	Density	Separated, closed, or connected.

Incidence	Occurrence on high or low topography and relative depth.
Disposition	The arrangement of linear traces relative to one another: random, concentric, parallel, oblique, or perpendicular.
Relative length	Long traces extend across the surface while short extend partially across.
Longitudinal morphology	Continuous or intermittent.
Transverse morphology	U-shaped or V-shaped.
Micropolish Altered reflectivity of a surface observed under high-power magnification.	
Microtopographic context	Where micropolish occurs on the surface: on high or low topography or leveled areas.
Distribution	Loose, covering, or concentrated.
Density	Separated, closed, or connected.
Morphology in cross-section	Flat, domed, sinuous, irregular.
Texture	Rough, fluid, or smooth.
Margins	Sharp or diffuse.
Vertical extension	How deep micropolish extends into low topography.
Opacity	Transparent, translucent, or opaque.
Brightness	High, medium, or dull.
Interruptions	Wear such as linear traces, leveling or pits that interrupt the extent of micropolish.
Associated wear	Wear such as linear traces occurring with micropolish.

Table 3.4: Descriptive framework and defined terminology for use-wear. Modified from Adams et al. (2009), Dubreuil and Savage (2014), and Dubreuil et al. (2015).

Functional Typology

The Upper Sequence GST will be sorted into a typology as part of their functional interpretation. The typology employed incorporates insights and definitions from typologies constructed to describe other assemblages of GST but was developed specifically to suit an assemblage composed predominantly of *ad-hoc* implements. Types are therefore defined by the hypothesized function of the artifacts rather than form. The exception to this is choppers which are characterised by a prepared edge.

The different functional types, outlined in table 3.5, were chosen based on results of the analysis of the archaeological assemblage as well as the experimental tasks. Each functional type is associated with particular wear characteristics. Distinction between types also reflects a combination of gesture, processed material, and the intended task outcome. For example, hammerstones and pounders are both active tools employed for striking with a percussive gesture, but they are distinguished by the use of hammerstones to work stone material for knapping and pounders for working animal or plant materials. Where this information is available, the location of wear on specific aspects of the surface will also be taken into account when sorting the Upper Sequence GST into functional types.

Type	Position	Function	Associated experiment
Hammerstone	Active	Percussion against flint or other stone material.	Flint knapping
Pounder	Active	Percussion against animal or plant materials.	Bone breaking, bone comminution, tendon pounding, and acorn hulling.
Abrader	Active/ passive	Used with an abrasive gesture to shape or alter objects through removal of material from the surface.	Abrasion of bone (dried and fresh), antler, shell, and wood.
Polisher	Active/ passive	Used with an abrasive gesture to alter or polish the surface of objects. Distinguished from abraders by the increased appearance of sheen.	
Hide-processing stone	Active	Used to work and soften animal hide. Distinguished from abraders by their exclusive application to hide.	Hide cleaning and hide softening (dried and tanned).
Handstone	Active	Reduce materials via grinding and crushing to a powder or paste. Paired with a lower, stationary implement.	Ochre grinding
Chopper	Active	Rocks with an edge produced by flaking.	Bone breaking

Table 3.5: Functional typology for the Upper Sequence GST. Modified from Adams (2014a) and Wright (1992).

3.3 Framework for the Blind Test

The blind test assesses the reliability of the experimental results with two main objectives. The first was the recognition of use wear on *ad-hoc* GST with and without the aid of microscopic observation in order to determine if the tasks performed in the experimental framework result in alterations to the surface that are visible to the naked eye. This may provide some insight on how to improve the recognition of potential *ad-hoc* GST in archaeological contexts so they can be recovered for further examination.

The second objective was to assess the reliability of the descriptive framework for use-wear employed in this thesis and the replicability of the use-wear results. This was done by determining the rate of consistency at which two researchers observing the same tool identified the same wear traces and chose the same terms to describe each wear trace identified. An additional benefit of this assessment is that it can reveal some of the potential factors, such as subjectivity and experience levels, that may influence the interpretation of use-wear patterns.

The blind test was performed by Nicholas Stevenson who has two years of experience with the methods of use-wear analysis and had some awareness of the experiments performed but not how each experimental tool had been used.

The blind test consisted of use-wear analysis of the experimental assemblage by the blind tester using a predetermined descriptive framework that was familiar to both researchers. The use-wear descriptions were recorded in a Google Sheets document. The objective of this analysis was to identify whether or not the face had been used and if so, whether the use area could be recognized without microscopic examination, and to estimate the nature of the processed material and the kinetic motion when possible. The results of the blind test are presented in Appendix B.

3.4 Chapter Summary

The functions of the GST from the Upper Sequence of Nesher Ramla are investigated in this thesis through a combined approach comprised of residue and use-wear analysis. Due to travel restrictions preventing access to the archaeological tools, the use-wear and residue analysis methodologies outlined in this chapter are applied only to the experimental assemblage. In place of the intended analysis of the Upper Sequence

GST, preliminary descriptions and photographic documentation are used instead to define patterns of associated wear traces and micropolish characteristics. In Chapter 5, these patterns are compared to the experimental results to provide an albeit limited interpretation of the archaeological assemblage.

The blind test component will assess the reliability of the methodology outlined in this chapter and identify potential factors influencing the interpretation of use-wear.

Chapter 4 - Experimental Framework and Results

This chapter outlines the experimental framework and the results of use-wear analysis on the experimental assemblage. The use-wear patterns associated with the experimental tasks serve as a basis of comparison for interpreting the general patterns of wear described on the archaeological assemblage in Chapter 5. The description of the experimental assemblage includes pre-existing wear types which were documented prior to conducting the experiments. This is followed by a presentation of the experimental framework and results. The experimental results are grouped by processed material and include assessments of task viability. Use-wear descriptions begin with a discussion of whether the task in question results in alterations to the surface visible at the naked eye level.

4.1 The Experimental Assemblage

The experimental assemblage is composed of seven waterworn limestone cobbles which were collected from a ploughed field near Nesher Ramla that had once existed as an ancient shoreline as well as a riverbed adjacent to the site. Every cobble was assigned a unique number. Additionally, each face of the cobbles was numbered individually as different faces of the same tool were employed in multiple experiments. Implements are therefore referred to both by tool number and face number. For example, S1F1 refers to face 1 on stone 1.

The analytical framework for the experimental assemblage began with observation and documentation of residues at low magnification before they were collected using the method outlined in section 3.1.2. The tools were then washed using soap and water by scrubbing lightly with a toothbrush prior to conducting use-wear analysis.

Pre-Existing Wear

Pre-existing fractures were noted on stone 3 and 4 from the experimental assemblage. On S3F4 and S3F5, the fractures were 2.4 cm and 1.6 cm in length, respectively. The fracture on S4F1 measured 1.6 cm in length.

Two types of wear were observed during the initial examination and documentation that was conducted prior to each experiment. Intensive effort was exerted to detail the distribution and characteristics of these wear patterns in order to prevent them from being mistakenly interpreted as use-wear resulting from any of the experimental tasks. The most conspicuous wear type consisted of mechanical damage from tilling in the form of metallic residues adhered to the surfaces of the tools. The second type of wear is a reflective sheen which is attributed to exposure to environmental processes and referred to as environmental polish. Both types of wear were noted on each of the experimental tools to a varying degree. The following sections describe these wear types and their appearance.

Metallic Residues

Metallic residues were easily observed at all scales of observation as a brown or rust-coloured discolouration. To the naked eye, these residues had a slight reflectivity and appeared in curved, randomly oriented patterns on flat surfaces or were concentrated along natural edges on the cobbles. Under microscopic examination, the brown or rust coloured discolourations are associated with an accumulation of a metallic substance. In areas where the build-up of these residues is thin, they are translucent and lighter in colour and appear to merely stain the surface of the rock. Thicker accumulations are opaque, darker in colour, and display topographic relief. Under high-power observation, an opaque and highly reflective micropolish appears on thick metallic residues (fig. 4.1).

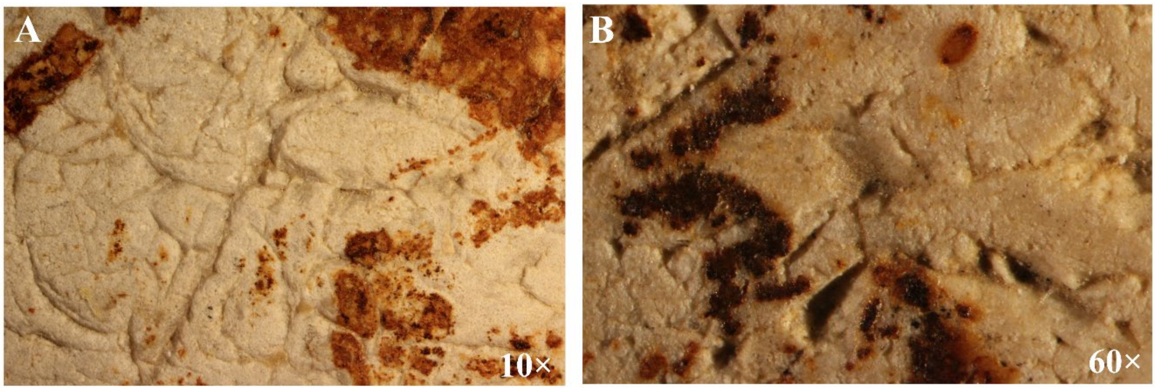

Figure 4.1: A-B) Metallic residues on the surface of the experimental tools.

Environmental Polish

Rocks exposed to wind are weathered by eolian abrasion in which particles contact and move across exposed surfaces (Ugalde et al 2015). Rocks in fluvial environments are also eroded by abrasion and attrition (Charlton 2008). The results of these weathering processes include rounding of sharp topography and polish (Charlton 2008; Ugalde et al 2015). Environmental polish may be distinguished from use polish by its distribution. Environmental polish is expected to be distributed randomly over surface of a pebble or concentrated on raised ridges and edges which would have been most likely to come in contact with particles passing over the rock surface. Some general characteristics can be used to describe the majority of the environmental polish on the experimental assemblage although some idiosyncratic variation was noted in a few locations. Examples of the environmental polish with both unique and generic characteristics are documented in figure 4.2.

The environmental polish has a relatively even distribution on the experimental tools rather than being confined to a specific location or face as would be expected with use polish. Macroscopically, environmental polish occurs predominantly around the margins of higher topographic areas and within the bases of pre-existing fractures in thin, dull, or moderately reflective patches with diffuse margins. The texture is typically rough but appears more fluid in thick accumulations (Fig 4.2A). Stone 6 displays a unique micropolish that covers the entire surface and appears moderately reflective to the naked eye (Fig 4.2B). This micropolish has a typically rough texture and diffuse margins but is distinguished by its translucency and distribution over both low and high topography.

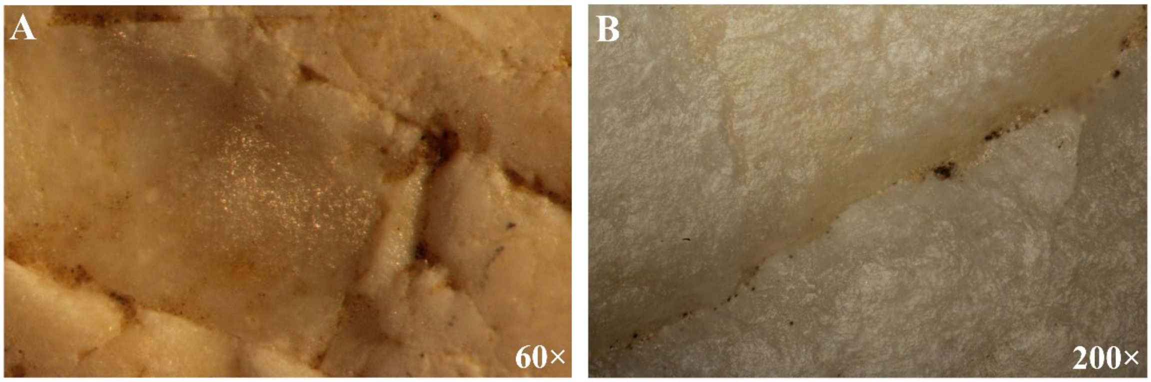

Figure 4.2: Environmental polish on the surface of the experimental tools. A) Typical appearance of environmental micropolish. B) Unique distribution of the polish on stone 6.

4.2 Experimental Framework

The archaeological and ethnographic evidence discussed in section 2.5 indicate that waterworn cobbles and pebbles were used as *ad-hoc* tools for processing animal, plant, and stone material for a variety of tasks including food processing and tool production. The experiments performed for this thesis aim at shedding light on the nature of use-wear on *ad-hoc* implements as well as the process of wear formation during each of the investigated tasks. Proposals regarding the potential function of the Upper Sequence GST are strengthened by assessments of task viability which were enabled by having performed these tasks personally as a novice as well as ethnographic accounts of more experienced tool users. Table 4.1 presents a basic description of the task completed in each experiment including the duration of the experiment, and the gesture involved.

The observation intervals were originally set at 30 minutes but later adjusted based on the speed of wear formation or task progression.

Experiment/ Tool	**Material/ Gesture**	**Task description**	**Duration**
1 S1F1	Bone/ Percussion	*Bone breaking:* long bones of cow, deer and moose were broken open for marrow extraction.	4:30 *Observation at:* 00:30, 1:00, 1:30, 2:30, 3:30
2 S4F1	Bone/ Percussion	*Bone comminution:* long bone ends were pulverised into small fragments.	4:00 *Observation at:* 1:00, 2:00, 3:00
3 S3F3	Bone/ Abrasion	*Bone abrasion (dried):* a dried sheep metapodial was abraded into a point.	1:00
4 S3F1	Bone/ Abrasion	*Bone abrasion (fresh):* fresh bone fragments were abraded into a point.	1:00
5 S7F1	Antler/ Abrasion	*Antler abrasion:* a piece of antler was abraded into a point.	2:00 *Observation at:* 1:00
6 S5F1	Tendon/ Percussion	*Tendon pounding:* dried cow tendons were pounded on a stone anvil until separated into thin fibers.	1:00
7 S5F4	Hide/ Mixed	*Hide cleaning (fresh):* a deer hide was worked in order to remove remnant bits of flesh.	2:00
8 S5F4	Hide/ Mixed	*Hide softening (dried):* a dried deer hide was rubbed in order to soften it.	2:00
9 S3F2	Hide/ Mixed	*Hide softening (tanned):* a tanned sheep hide was rubbed in order to soften it.	4:00 *Observation at:* 2:00
10 S7F2	Shell/ Abrasion	*Shell abrasion:* shells were abraded in order to sharpen the edges and smooth the surface.	2:00 *Observation at:* 1:00
11 S3F5	Plant/ Abrasion	*Wood abrasion:* wood from a sugar maple tree was abraded to remove bark and smooth the material.	2:00 *Observation at:* 1:00
12 S2F2	Plant/ Percussion	*Acorn hulling:* acorns were cracked on a stone anvil in order to extract the kernel without crushing it.	2:15
13 S6F1	Flint/ Percussion	*Flint knapping:* pieces of flint were knapped with a hammerstone in order to produce flakes.	2:00 *Observation at:* 1:00
14 S2F2	Ochre/ Mixed	*Ochre grinding:* pieces of ochre were crushed and ground into a powder.	2:00 *Observation at:* 1:00

Table 4.1: The experimental framework.

4.3 Experimental Results

4.3.1 Bone Breaking

A cobble with a naturally rounded extremity (S1F1) was selected from the experimental assemblage to perform the bone breaking experiment. This selection was based on the results of previous experiments conducted by Assaf et al. (2020), Benito-Calvo et al. (2018), and Titton et al. (2018) which indicate that concentrating the force of the strike on a protruding edge or rounded extremity tool surface is an effective strategy for bone breaking.

A collection of long bones composed of femurs, tibias, a metacarpal, and a fused radius and ulna originating from moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), and cow (*Bos taurus*) were prepared by defleshing although the periosteum was not removed. Breakage proceeded by leaning the bone against a stone anvil in order to hold it in place at an angle for striking. The bones were struck with hard blows roughly perpendicular to the long axis and concentrated on an area of the shaft adjacent to the epiphysis until the bone was sufficiently broken to allow for extraction of the marrow.

The experimental tool proved to be an effective hammerstone for bone breaking. Smaller bones such as a deer metapodial required less than three minutes of striking to fracture the bone extensively enough. Larger cow femurs were broken sufficiently after 10 to 20 minutes. In some instances, the epiphysis was even broken off completely. The advantage conferred by a small, protruding striking surface over a wide, flat striking surface is demonstrated by the results of the bone comminution experiment (section 4.3.2).

Residues

Reminant pieces of flesh and bone adhere to the surface of the tool and are concentrated around the impact point (fig. 4.3A). The main impact point is clear of built-up material visible to the naked eye suggesting that it had been pushed to the surrounding area by subsequent strikes. The entire surface of the tool appears to be coated in a glossy, oily film. The oils present between the gloves worn during the experiment and the surface of the tool are discussed in section 4.3.12 for their potential in influencing the formation of grip polish that appeared where the tool had been handled during the experiment.

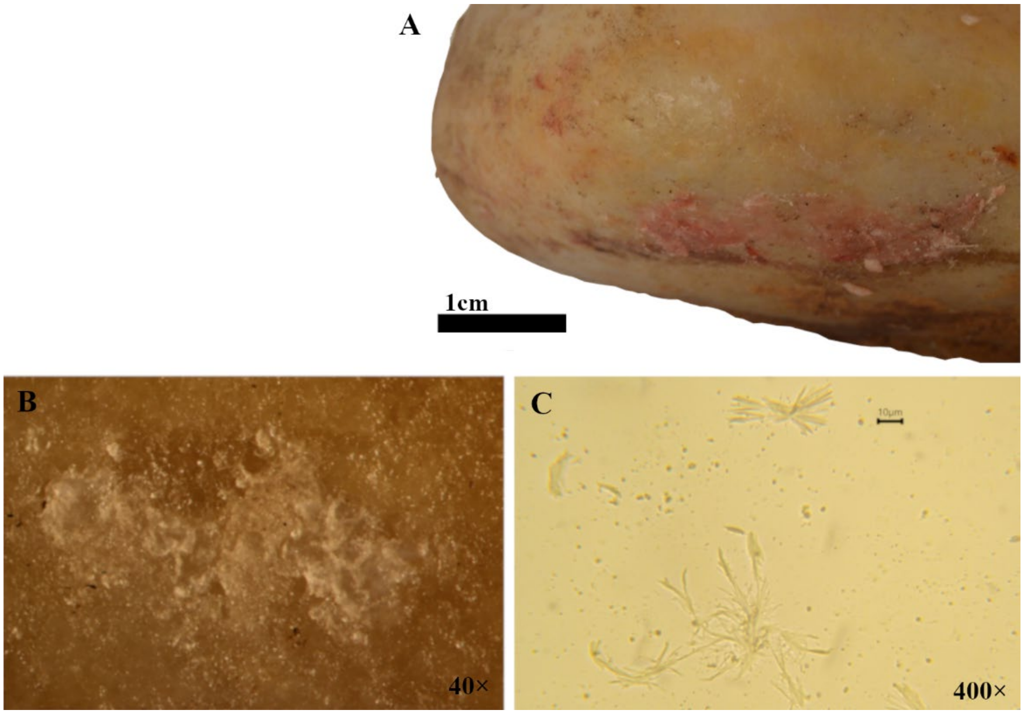

Figure 4.3: Residues on the surface of S1F1 after 60 minutes of bone breaking. A) Residues surrounding the use-area and thin, reflective film coating the surface. B) Oily macro residues with visible fat structures. C) Clusters of twisted collagen fibers.

Macro residues consist of a greasy, transparent film with moderate reflectivity (fig. 4.3B). This film covers the surface but its reflectivity is brightest on smooth areas of high topography. Amorphous compounds ranging from transparent to opaque and white in colour are also built-up within pits created by impacts or distributed randomly across the surface in smaller isolated patches. At around 20× magnification, compressed bone fragments, fat, collagen tissues, and fibers can be discerned within these compounds. Compared to the macro residues described on passive sandstone bone splitting tools by Cristiani and Zupancinch (2021), the macro residues formed on limestone appear greasier and lack a mud-cracked quality. The film is also more extensive over the tool surface and fluid in texture, likely reflecting the relatively smoother surface of the limestone material.

Micro residues from bone breaking include clusters of twisted collagen fibers and macerated collagen tissues (fig 4.3C).

Use-Wear

As the experiment progressed, a darker discolouration appeared on the impact point and gradually spread to adjacent areas and along the protruding ridge. To the naked eye, this discoloured area appears smoother relative to the surrounding surface. Upon completion of the experiment, very small (>3mm) reflective spots are visible on and around the active area. Aside from these spots, the use area is inconspicuous to the naked eye indicating that higher power observation would likely be required to identify bone breaking wear on cobbles in an archaeological context (fig. 4.4).

The results of this experiment appear to be in line with the slow development of wear reported by other bone breaking experiments (Assaf et al. 2020; Benito-Calvo et al. 2018; Paixão et al. 2021b; Titton et al. 2018). Changes to the topography of the surface through a combination of leveling with fractures and removals constitute the most significant wear traces associated with bone breaking. The discoloured areas visible to the naked eye correspond at 40× magnification to a removal of the outer, lighter coloured layer of the surface of the rock so that the darker interior is exposed. In areas where wear is less extensive, and in transition areas between the used and unused surface, the low topography retains a lighter colouring relative to the high topography.

Initially, the topography became more sinuous with rounded edges on peaks. As leveling progressed, the high topographic areas were gradually flattened and smoothed (fig. 4.5A). These leveled areas then became increasingly irregular as repeated hard impacts resulted in microfractures and removal of material from the surface. Circular pits with u-shaped bases appeared and progressively became wider and more irregular in

Figure 4.4: The active area (circled) on S1F1 after 270 minutes of bone breaking.

shape as the margins were worn down. Additional microfractures and pits appeared as leveling eventually spread from the main impact point outward. These pits are characterised by bright reflective patches and rough, irregular bases. The margins are rounded with a frosted appearance due to extensive microfracturing.

After around 210 minutes of use, the presence of a thin and translucent micropolish was noted on leveled areas and surrounding the margins of grain fracture areas (fig.4.5B). The micropolish has a rough texture and is thicker on areas of high topography and thinner where it extends into low topography.

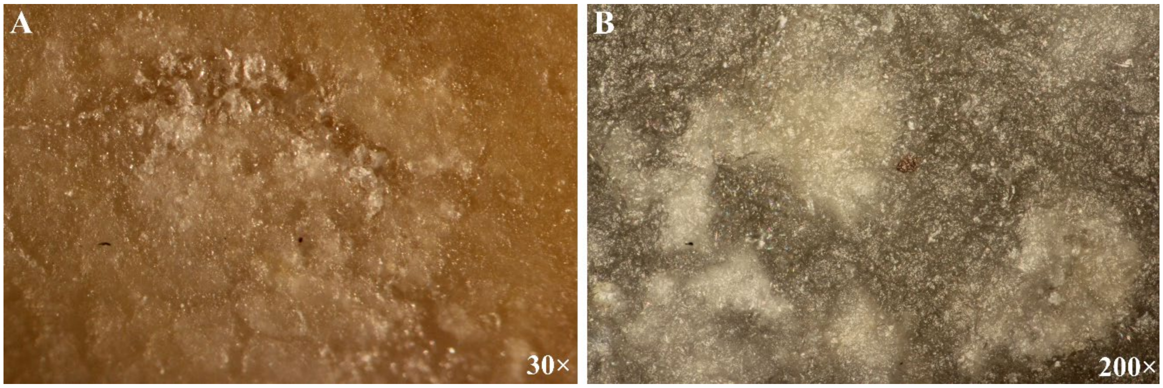

Figure 4.5: Use-wear associated with bone breaking. A) Leveling and pits with frosted margins. B) Distribution of micropolish on high and low topography.

4.3.2 Bone Comminution

A cobble with flat surfaces (S4F1) was selected from the experimental assemblage for bone comminution as it was estimated this would provide the most effective striking surface for the task requirements. The experimental and ethnographic literature offered minimal insights as to what shape or size rocks would provide the most effective tool other than indications of weight, which exceeded all those of the experimental assemblage, and that the bones should be placed on a stone anvil for processing (Binford 1978; Costamagno 2013; Leechman 1951; Morin 2020; Morin and Soulier 2017; Pasda and Odgaard 2011; Schroth 1996). This experiment is intended to investigate whether the higher oil content of cancellous bone or the more intensified fragmentation of the bones affected the formation of wear.

Where bone breaking is predominantly targeted at marrow stored in the medullary cavities of long bones, the bone comminution experiment was targeted at the cancellous bone within the epiphyses of long bones. The bone comminution experiments followed the bone breaking experiments to make use of the left-over epiphyseal ends. The epiphyses were placed on a stone anvil and struck with the hammerstone using roughly perpendicular blows until the bones were reduced to fragments between 1-2 cm in size or they been reduced into a flattened cake composed of small fragments and finer bone paste.

The experimental tool was eventually able to reduce several epiphyses to the intended level of fragmentation although this took between 30 and 40 minutes in some cases, considerably longer than reported in other experiments (Morin 2020; Morin and Soulier 2017). The extra time required to complete this experiment can possibly be explained by the small size of the hammerstone employed or the selection of a flat striking surface. The lower weight of this implement would have reduced the strength of the impact while the flat striking surface would have resulted in the force of the strike being diffused over the entire surface rather than concentrated in a single location. Together, these factors would have reduced the ability of the hammerstone to break down the structure of the bones. It is therefore concluded that although the experimental tool was ineffective at bone comminution, the extremities or flat surfaces of larger rocks may have been more effective at this task.

Residues

After 60 minutes of bone comminution, residues are visible to the naked eye as patches of crushed bone and flesh and a reflective, greasy film that coats the entire surface of the tool (fig. 4.6A). The build-up of remnant bits of bone and flesh during bone comminution is less extensive than during bone breaking. Patches of bone and flesh are limited to areas of low topography or the edges of the tool face and are more compressed in appearance (fig. 4.6B). The greasy film is thicker and has an increased reflectivity in comparison to the bone breaking experiment.

Under low power magnification, the macro residues accumulated in low topography can be characterised as amorphous compounds of fat, flesh, and crushed bone (fig. 4.6C). These residues have an oily and reflective appearance that matches the greasy film on the surrounding rock surface. It is difficult to identify the different constituents of a particular patch due to the degree to which they have been compacted. Individual structures from fat, or collagen tissues can be distinguished based on differences in colour and transparency. Bone comminution unsurprisingly produced similar micro residues to bone breaking although fewer clusters of twisted collagen fibers were noted. The collagen tissues appear in isolated clumps with a macerated appearance (fig. 4.6D).

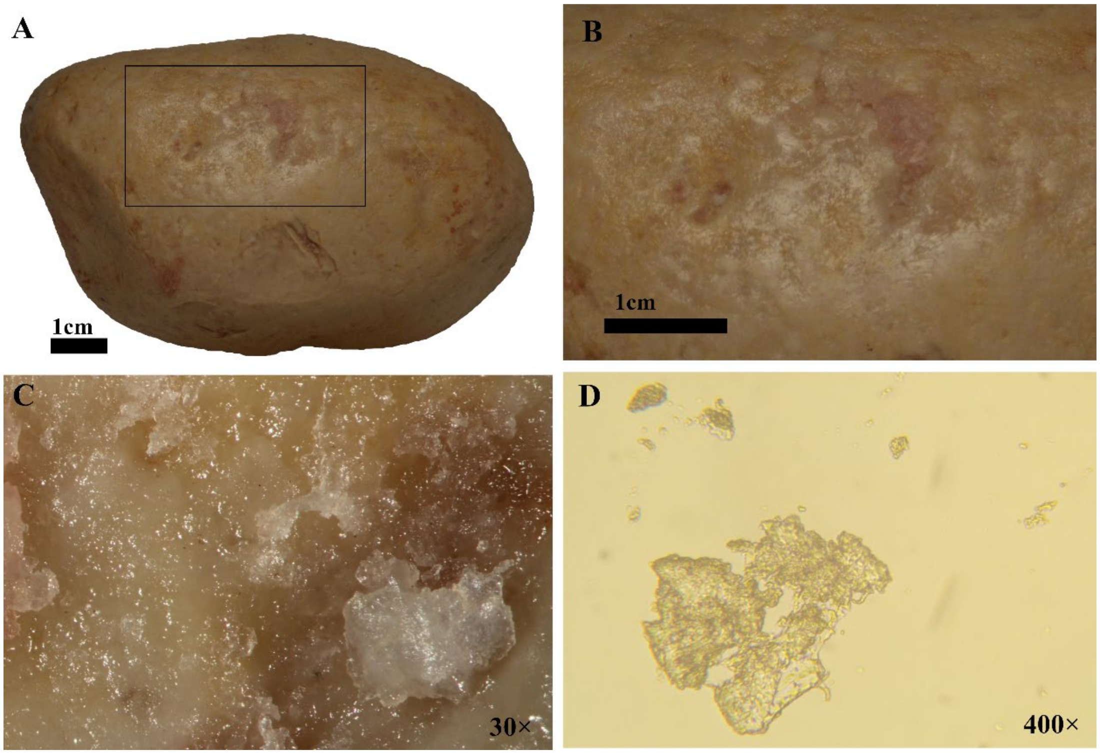

Figure 4.6: Residues on the surface of S4F1 after 60 minutes of bone comminution. A) Greasy film coating the tool surface. B) Crushed bone and flesh built-up in low topography. C) Fat within amorphous compounds. D) Collagen tissue micro residues.

Use-Wear

Alterations to the surface of the experimental tool that were visible to the naked eye developed at a faster rate than that of the wear observed following the bone breaking experiment (fig. 4.7). After one hour had elapsed, the topography appeared smoothed and rounded relative to the unused surface. At two hours, a moderately reflective sheen appeared on the smoothed and rounded portions of the face and spread as larger areas of the surface topography were altered. The association of smooth and rounded surface topography and sheen may be useful for identifying cobbles potentially used in bone comminution prior to observation with higher power magnification.

Under macroscopic observation, alteration of topography is extensive with many features of the surface having been obliterated. The high topography is leveled resulting in flat and smooth homogenous areas with rounded margins between areas of low topography (fig. 4.8B). The distance between topographic highs and lows is reduced. Some areas of low topography are also leveled although less extensively as the surfaces are more sinuous than flat (fig. 4.8A).

Figure 4.7: Smooth and reflective surface of S4F1 after 240 minutes of bone comminution.

An opaque and moderately reflective micropolish was first noted on leveled areas of high topography but extended into topographic lows after 120 minutes (fig. 4.8C). The micropolish has a fluid texture and sinuous morphology in most occurrences and a flatter appearance where it has accumulated more extensively. Linear traces are present in some areas of micropolish as short, parallel groups on leveled topographic highs that are randomly oriented to one another. In other areas, the linear traces appear as longer, isolated marks with micropolish pooled in the base.

Use-wear traces associated with bone comminution appear to be part of a related process beginning with initial leveling. Micropolish and associated linear traces appear on these altered surfaces and spread as more areas of the surface are leveled. The scarcity of microfractures and removal of material from the surface observed in the bone breaking experiment may be due to the use of the flat surface of S4F1 as the force of each strike was diffused across a larger area.

The rapid development and accumulation of micropolish may be attributed to the persistence of leveled areas during bone comminution. The increased presence of within bone oils in cancellous bone compared to compact bone is also a potential factor in micropolish development.

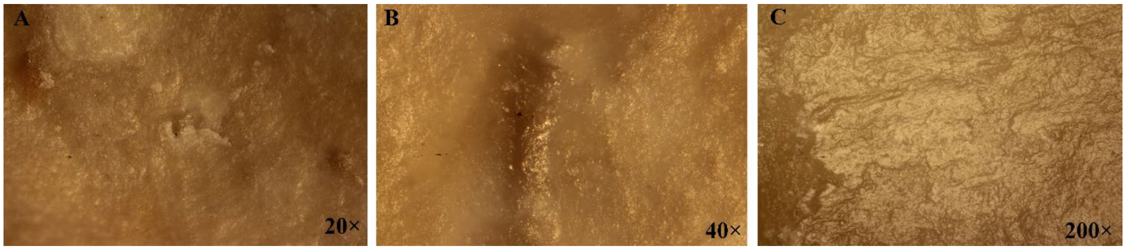

Figure 4.8: Use-wear associated with bone comminution. A) Leveling of the high and low topography. B) Rounded margins between high and low topography. C) Extensive and highly reflective micropolish.

4.3.3 Bone Abrasion

Previous bone abrasion experiments have reported that the process of wear formation may differ between dry and fresh bone due to the increased presence of oils in fresh bone (Adams 1989, 2002, 2014b; Hamon 2008). Dried and fresh bone abrasion experiments were performed in order to document differences in the formation and appearance of use-wear associated with both substances.

Stone 3 was selected to abrade both dried and fresh bone for its rougher surface compared to the rest of the experimental assemblage. A broken, dried sheep metapodial was abraded using S3F3 for the dried bone abrasion experiment. A fragment of a deer metapodial produced in the bone breaking experiment was abraded with S3F1 for the fresh bone abrasion experiment. In both experiments, the bones were abraded using a reciprocal motion with the experimental abrader serving as a passive implement that was held in one hand for greater stability. The bones were held at an angle to the surface of the tool and abraded with the aim of shaping the broken end into a fine point.

The tool proved to be ineffective at both tasks as abrasion initially proceeded slowly. However, a buildup of bone particles within the interstices between high topography gradually reduced the amount of material that was removed from the bone until shaping of the bones ceased entirely. As a result, the decision was made to abandon the bone abrasion experiments after just one hour had elapsed.

Dried Bone

Residues

Residues from the dried bone accumulated as a white, powder within low topography across the surface but are especially built-up within the pre-existing fracture on the surface (fig. 4.9A). Macro residues include a white, opaque powder that is accumulated so extensively in low topography as to bring it level with the high topography (fig. 4.9B).

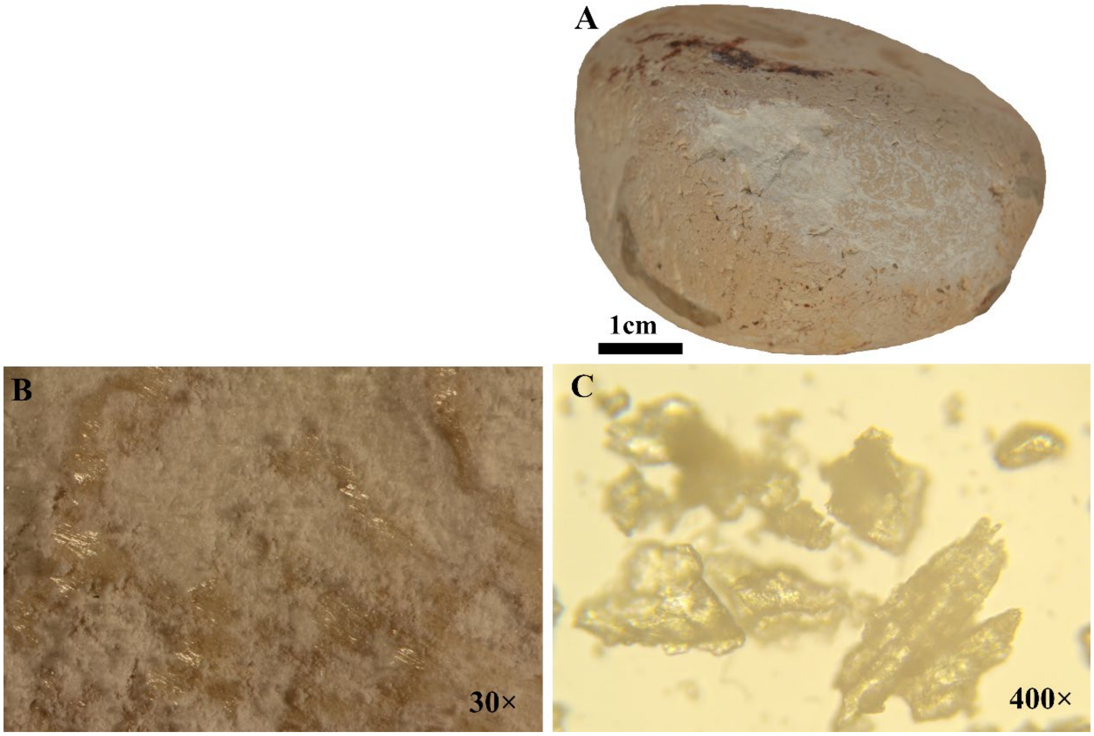

Figure 4.9: Residues on the surface of S3F3 after 60 minutes of dried bone abrasion. A) Appearance at the naked-eye level. B) Reflective macro residues on high topography and powder within low topography. C) Collagen tissue clusters.

A highly reflective film resulting from the compression of the powder macro residues occurs on some areas of high topography with short, parallel striations. Linear traces also appeared within accumulations of bone residue in low topography. Micro residues from dried bone consisted of collagen tissues with a macerated appearance (fig. 4.9C).

Use-Wear

Changes to the surface of the experimental tool resulting from abrasion of dried bone are concentrated predominantly around the pre-existing fracture on the surface (fig. 4.10). Removal of material from the surface is marked by lighter areas where the interior of the rock has been exposed. These lighter discoloured areas are characterised by a rounding of the high topography which results in a sinuous and irregular texture. Although S3F3 proved to be ineffective at the task of bone abrasion, the presence of leveling and rounded edges discernable to the naked eye may serve as useful criteria for recognizing wear from abrasive tasks without the aid of higher power observation.

Figure 4.10: The surface of S3F3 after 60 minutes of bone abrasion.

Under macroscopic observation, the surface topography appears sinuous as topographic peaks are rounded and smooth while the low topography retains its original texture (fig. 4.11A). Rounding of the topographic peaks is extensive around the fracture and slight on other areas of the surface. No linear traces were observed after the residues were removed through washing.

Micropolish development is limited compared to micropolish resulting from abrasion of fresh bone (fig. 4.11B). Small patches of opaque micropolish with a texture ranging from rough to fluid appear on a few areas of high topography.

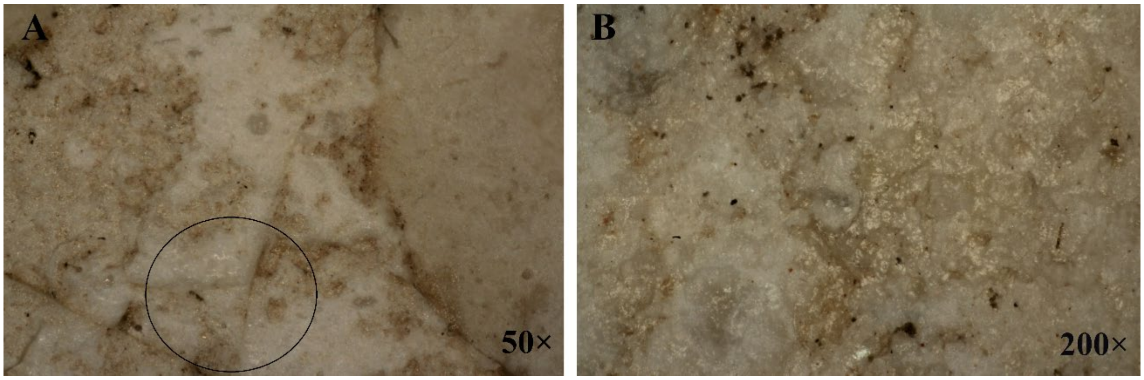

Figure 4.11: Use-wear associated with abrasion of dried bone. A) Sinuous and rounded high topography with reflectivity (circled) due to leveling. B) Rough patches of micropolish.

Fresh Bone

Residues

Residues from fresh bone abrasion are indistinguishable to the naked eye from those resulting from dried bone abrasion (fig. 4.12A). With low-power magnification, the opaque, white powder macro residues from fresh bone have a more compressed appearance (fig. 4.12B). The reflective film resulting from the compression of bone macro residues on high topography that was observed following dried bone abrasion is also present on the fresh bone abrasion tool. In addition, this film is also scattered across the surfaces of bone macro residues accumulated in low topography indicating that fresh bone macro residues are more easily compressed. Micro residues from fresh bone include collagen tissues similar to those associated with dried bone. Fresh bone micro residues can be distinguished from those associated with dried bone by the presence of isolated and twisted collagen fibers (fig 4.12C).

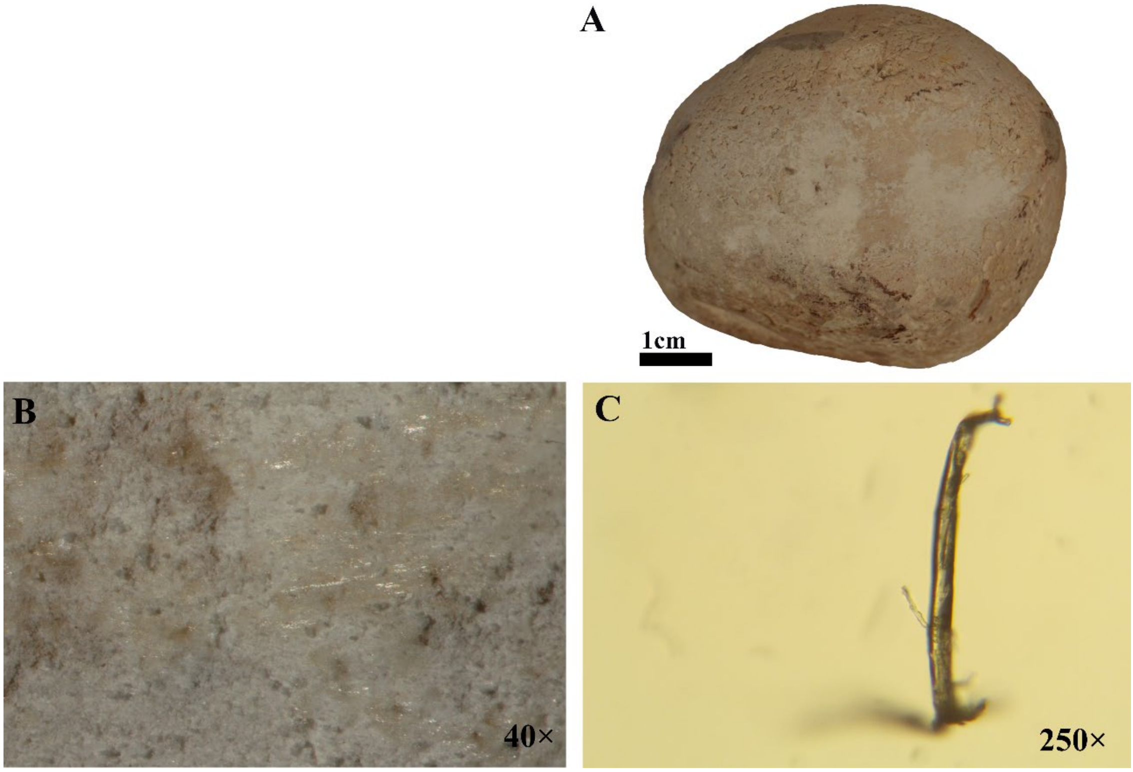

Figure 4.12: Residues on the surface of S3F1 after 60 of fresh bone abrasion. A) Appearance at the naked-eye level. B) Compressed powder macro residues. C) Collagen fiber micro residues.

Use-Wear

Abrasion of fresh bone resulted in alterations to the surface that are easier to recognize with the naked eyes than abrasion of dried bone (fig.4.13). Removal of material from the surface of the rock exposed the lighter interior in separated patches with smooth and flat topographies. In some locations, only the high topography is altered with some of the original surface remaining intact on low topography. Linear traces or sheen were not observed on these leveled areas. The best indication of use visible at the naked eye level of observation appears to be the occurrence of leveling limited to certain areas of one surface of the rock.

Figure 4.13: Alteration of the surface of S3F1 after 60 minutes of bone abrasion.

Under low power magnification, the leveled surfaces have a slightly rough texture compared to the smoother original surfaces. Where leveling is less extensive, more features of the low topography remain intact, and the surface is sinuous. Faint linear traces are noted on a smooth leveled surface as a single cluster of short and very shallow parallel striations (fig. 4.14A).

Leveled areas appear slightly reflective. A thin, moderately reflective, and opaque micropolish was observed on high topography and within the depressions formed by linear traces. The micropolish has a rough to fluid texture and is oriented directionally in some locations (fig. 4.14B).

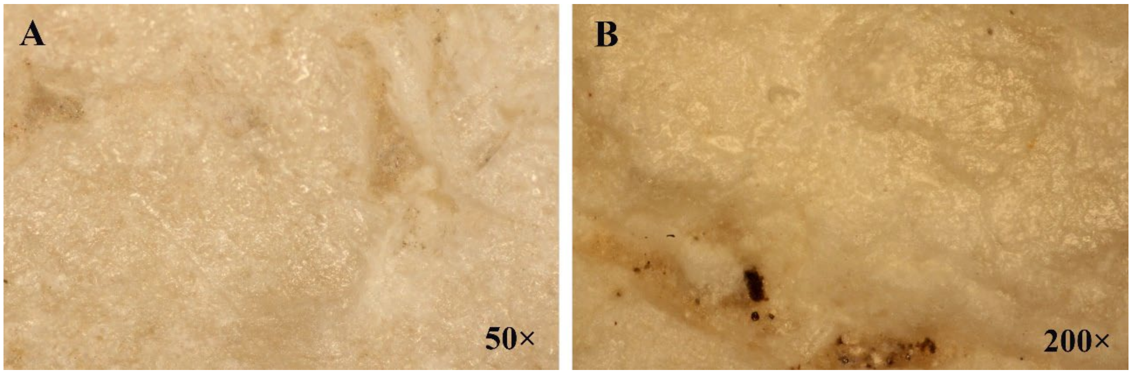

Figure 4.14: Use-wear associated with abrasion of fresh bone. A) Rough surface due to leveling. B) Thin micropolish on high topography.

4.3.4 Antler Abrasion

Stone 7 (F2) was selected to abrade piece of antler from a white-tailed deer with the intent of shaping it into a fine point. The experimental abrader was held in one hand and used as a stationary passive implement while the antler was abraded with a reciprocal motion.

Initially, the task proceeded slowly with very little material removed from the antler. After 30 minutes with almost no progress, the experiment was altered so that the antler was soaked for a period of at least 24 hours prior to each time it was abraded. This decision was based on observations by Bergman (1987) that soaking antler prior to working improves the flexibility and ease of shaping. Soaking the antler improved the speed of task progression somewhat. After 120 minutes of abrasion, rough spots on the antler resulting from gnawing by rodents had been smoothed and the point had been slightly narrowed. Despite the efficiency gained through prior soaking of the antler, the abrader can still be considered to be ineffective for this task.

Residues

Residues from antler abrasion included a white, opaque powder trapped within areas of low topography. Slightly reflective parallel linear features are also visible to the naked eye on the smooth areas of high topography (fig. 4.15A). Under low power observation, these linear features correspond to a heavily compressed film that is similar in appearance to an opaque, highly reflective micropolish with a rough texture (fig. 4.15B). In some areas of low topography, the accumulated white powder macro residues have a fibrous appearance. Antler micro residues consist of collagen tissues and twisted collagen fibers that occur in isolated or clustered distributions (fig. 4.15C).

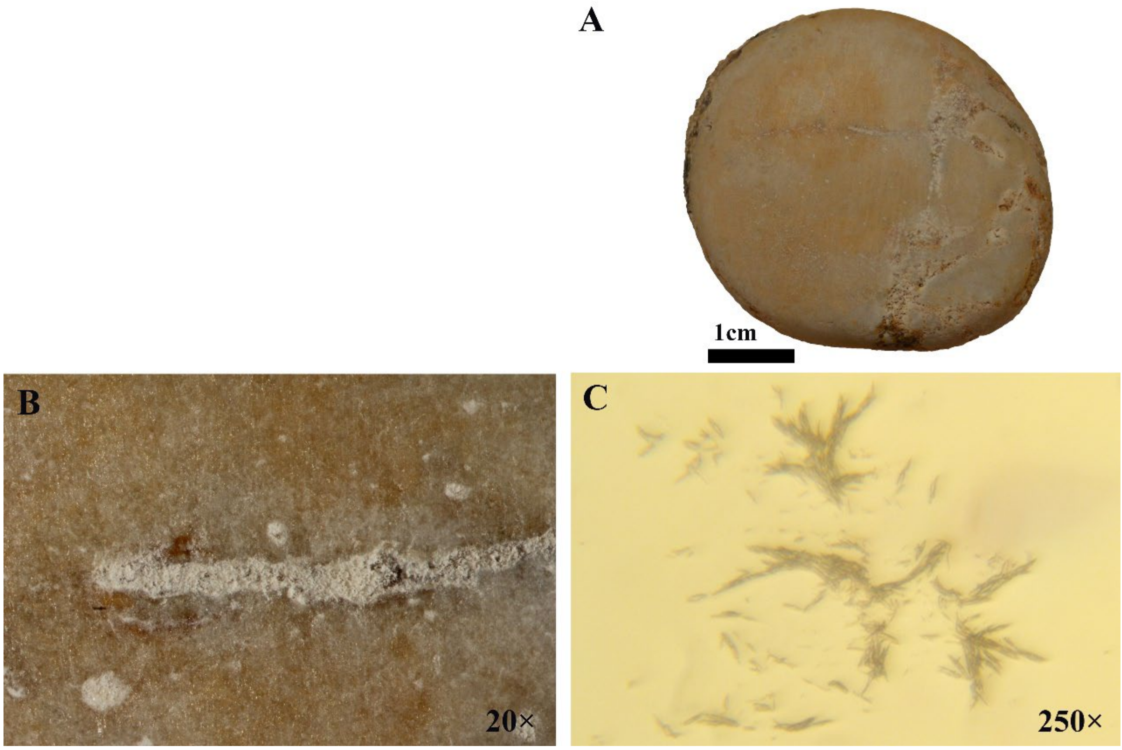

Figure 4.15: Residues on the surface of S7F2 after 60 minutes of antler abrasion. A) Directionality of residues visible to the naked eyes. B) Powder macro residues built up in low topography and a compressed, reflective film on high topography. C) Clusters of twisted collagen fibers.

Use-Wear

Antler abrasion was not associated with any alteration to the surface of the experimental tool that could be discerned with the naked eyes (fig. 4.16). Antler abrasion tools may therefore be difficult to detect in the absence of contextual evidence.

Figure 4.16: The surface of S7F2 after 120 minutes of antler abrasion.

Alteration to the topography was observed to progress slowly under low-power magnification. After 120 minutes of antler abrasion, the surface appears sinuous due to slight leveling of the high topography (fig. 4.17A). Pre-existing spots of damage to the surface that displayed a frosted appearance were obliterated by leveling. Removal of material due to leveling occurred in separated areas distributed loosely across the surface. These areas display small reflective spots due to microfractures and a slightly rugged topography.

Hamon (2008) reports similar results for antler abrasion experiments performed with quarzitic sandstone. Despite the use of rocks of better abrasive quality, use-wear formation for these experiments was limited to grain modification and partial leveling of the surface. Slow development of use-wear for different rock types used to abrade antler may therefore be more reflective of the hardness of the processed material rather than the quality of the abrader material.

Micropolish associated with antler abrasion is loosely distributed in small, isolated patches on high topography (fig. 4.17B). This translucent micropolish is moderately reflective, rough textured and displays parallel linear traces.

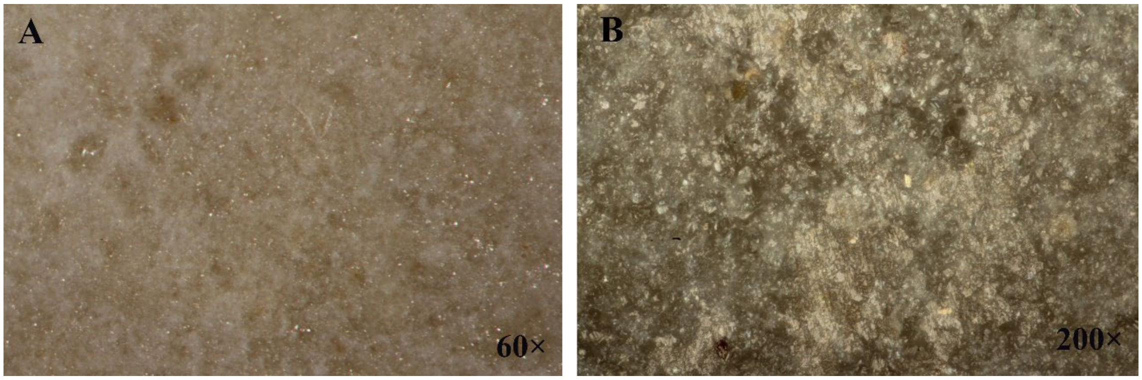

Figure 4.17: Use-wear associated with antler abrasion. A) Small reflective microfractures and sinuous high topography due to leveling. B) Parallel linear traces within micropolish.

4.3.5 Tendon Pounding

The tendons used in this experiment were collected from cow bones prior to their use in the bone breaking experiment and allowed to dry for a period of two weeks. Once dried, the tendons were placed on a stone anvil and struck with a rock from the experimental assemblage (S5F1) with the aim of separating the dense bundles of fibres into thinner and flatter pieces.

Initially, hard strikes were required to break down the tough structure of the bundled tendons. Increasingly lighter strikes were required in order to avoid severing the individual fibres as the tendons gradually thinned out. The experimental tool proved to be capable of separating the tendons into thin and flattened strips while preventing the strips from being severed. This experiment was only conducted for 60 minutes due to a lack of unprocessed tendons to continue the experiment.

Residues

Residues from tendon pounding built-up predominantly within the areas of low topography on the main point of impact during use (fig. 4.18A-B). Macro residues consist of a compact opaque powder that ranges in colour from white to pinkish or beige in heavily compressed patches (fig. 4.18C). Individual tendon fibers can be discerned where the residues were less intensively compressed. Tendon pounding micro residues included collagen tissues and thick collagen fibers that appeared in twisted clusters (fig. 4.18D).

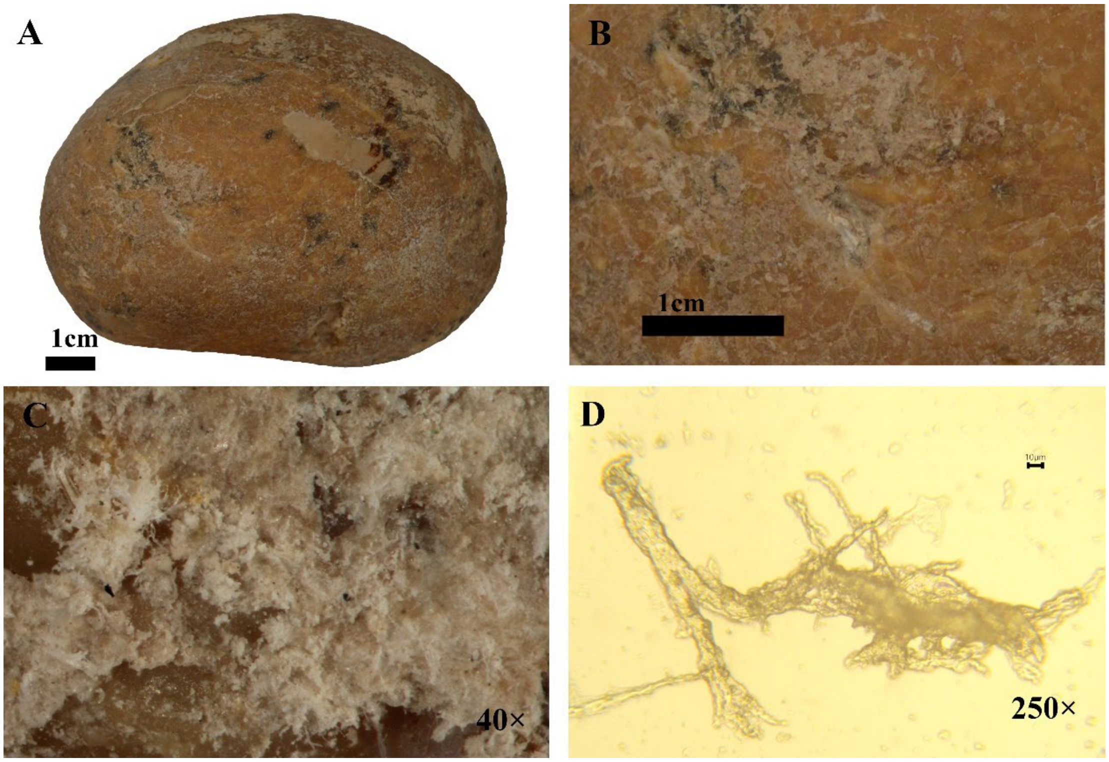

Figure 4.18: Residues on the surface of S5F1 after 60 minutes of tendon pounding. A-B) Appearance at the naked-eye level. C) Compressed powder macro residues with discernable collagen fibres. D) Clusters of twisted collagen fiber micro residues.

Use-Wear

Large areas of extracted material resulting from fractures are discernable to the naked eye following tendon pounding (fig. 4.19). The margins of these extractions remained irregular and sharp as continued use resulted in more removal of material from the margins rather than existing removals becoming crushed or rounded on the margins. The limitation of extensive damage to one location on the surface of the rock may serve as a potential indicator of use in archaeological contexts and could provide effective criteria for identifying pebbles that should be put aside for microscopic observation.

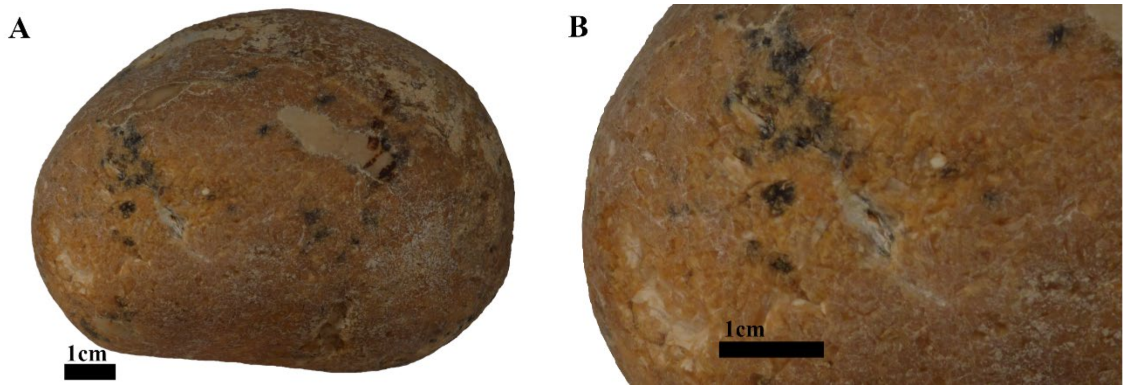

Figure 4.19: A-B) The experimental tendon pounding tool after 60 minutes of use.

As the experiment proceeded, the topography became increasingly irregular and appears uneven and rugged under low-power magnification. Removal of material from the surface exposed the darker of the interior of the rock. The margins and bottoms of the resulting cavities remained rough and became deeper and wider as more material was fractured off. In areas where extractions are less extensive, the flat topographic highs are leveled with rounded edges or have a frosted appearance due to crushing of surface material (fig. 4.20A).

As with other tendon pounding experiments that were conducted with sandstone implements, the irregular and rugged surface observed on S5F1 is attributed to increased contact between the active and passive tools (Cristiani and Zupancich 2021; Zupancich and Cristiani 2020). In other percussive experimental tasks, such as bone breaking, the processed material absorbs some of the force of the strike and reduces the likelihood of contact between the hard surfaces of the pounder and the anvil although accidental strikes may still occur.

Tendon pounding also resulted in a moderately reflective, opaque, and sinuous micropolish with a texture that ranges from rough to fluid in thicker patches (fig. 4.20B). This micropolish is distributed loosely on flatter areas of high topography in connected patches with diffuse margins and is thinner where it extends into areas of low topography.

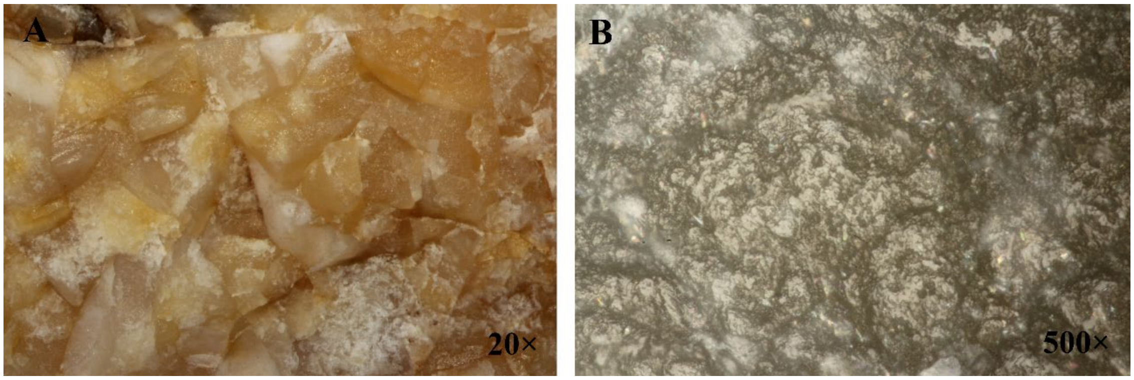

Figure 4.20: Use-wear associated with tendon pounding. A) Rough, irregular topography resulting from fractures and crushing. B) Patches of moderately reflective micropolish on leveled high topography.

4.3.6 Hide Processing

Three different hide processing experiments were performed in order to determine if the condition of hide at different stages of treatment affects the formation and appearance of use-wear. The first experiment consisted of cleaning a fresh hide from a white-tailed deer. A large implement (S5F4) was selected from the experimental assemblage to scrape the flesh and fat that remained on the inside of the hide following skinning. The hide was then allowed to dry for a period of eight weeks. After drying, the hide was softened with the same experimental tool in order to make it pliable. The final hide processing experiment also consisted of hide softening. This experiment was conducted with a different experimental tool (S3F2) that was used to rub a dried and tanned piece of sheep skin.

All three experiments were performed by moving the experimental tool in a reciprocal back and forth motion across the surface of the hides. During the hide cleaning experiment, pieces of flesh were sometimes struck at angle in order to aid their removal from the surface of the hide. When the dried fresh hide was worked, it was also sometimes struck with blows to the surface in order to help break up the fibers. During softening of the tanned hide, the hide was bent around the edge of a stone anvil to help break up the fibres.

The experimental tool proved to be ineffective for hide cleaning as the rounded and blunt surface of the cobble made removal of adhered pieces of flesh difficult and time consuming. After two hours of work had elapsed, only a small portion of the hide had been cleaned and additional effort with a knife was required in order to prepare the hide for drying. When employed in hide softening, the same experimental tool was only able make a small portion of the hide become slightly more pliable while the majority of the hide remained rigid. The experimental tool used to soften the dried and tanned sheep skin demonstrated a similar degree of success. Although this experiment was conducted for four hours, only a small portion of the skin had become somewhat pliable. The ethnographic literature reviewed in section 2.5 indicates that hide softening with a natural pebble can be a lengthy task that may require up to eight hours of work (Kluckhohn 1971). It may be then that the minimal degree of progress made in hide softening is more reflective of the extensive time requirements of this task than the ineffectiveness of these implements at hide softening.

Hide Cleaning

Residues

Hide cleaning resulted in a glossy and oily film that coats the entire surface of the tool. Accumulated fat and flesh are also visible to the naked eye within a pre-existing cavity and an area of the surface that is rougher due to adhered concretions (fig. 4.21A). Under macroscopic observation, spots of translucent or opaque amorphous compounds are distributed across the use area in small spots or built-up within low topography. Fat or tissue structures can occasionally be identified within these compounds (fig. 4.21B).

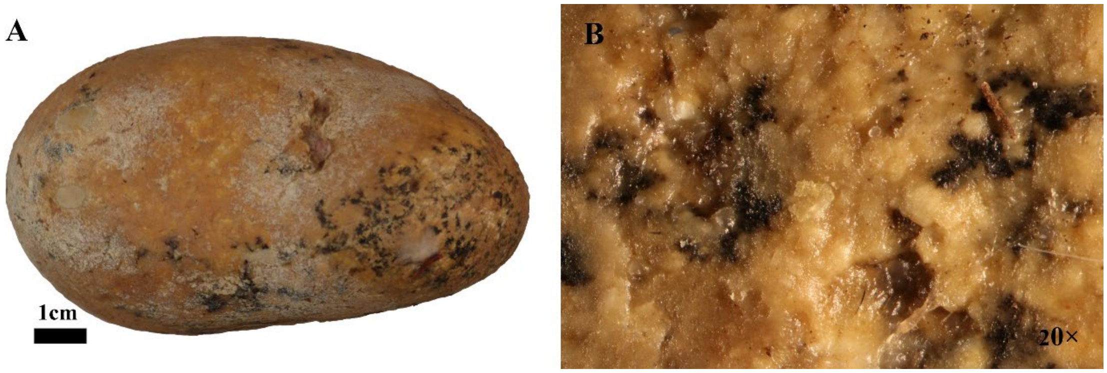

Figure 4.21: Residues on the surface of S5F4 after 120 minutes of hide cleaning. A) Discolouration of the tool surface. B) Bits of flesh trapped in topographic lows.

Use-Wear

After 120 minutes of hide cleaning of elapsed, a colour change occurred over the entire surface of the experimental tool as oils from the hide covered the rock during use (fig. 4.22). No other change to the surface can be discerned to the naked eye.

Figure 4.22: The surface of S5F4 after 120 minutes of hide cleaning

Under low-power magnification, the discolouration noted on the surface corresponds to leveled portions of high topography where the whitish exterior layer of the rock has been removed to expose the darker interior. Leveled surfaces are smooth and connected to one another across the surface. Where leveling is extensive, the light exterior surface remains only on the margins of cracks on the surface and in low topography (fig. 4.23A).

Hide cleaning resulted in the development of a translucent and highly reflective micropolish with a rough to fluid texture that appears flatter where the buildup is more extensive (fig. 4.23B). The micropolish is scattered across leveled areas of high topography in separate patches with well defined borders. In some instances, short, parallel groups of linear traces are observed in micropolish deposits.

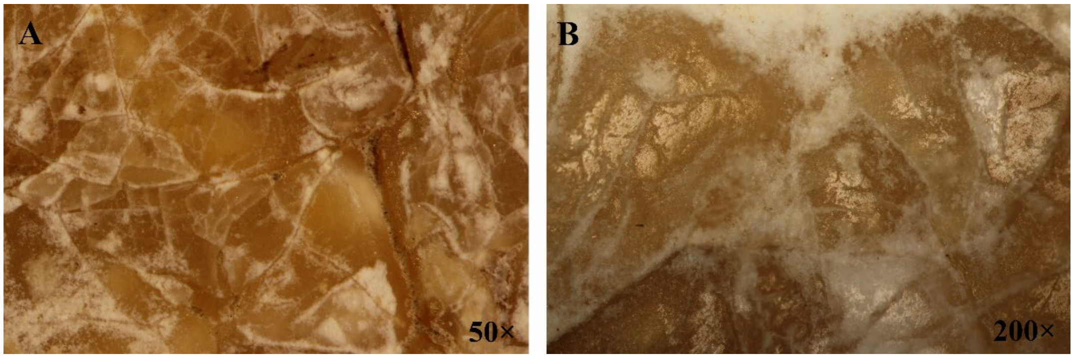

Figure 4.23: Use-wear associated with hide cleaning. A) Exposed rock interior due to leveling. B) Patches of micropolish on flat, leveled high topography.

Softening Dried Hide

Residues

Hide softening resulted in a film of oils on the surface similar to that observed after hide cleaning although this coating is thinner, and the surface is less reflective as a result (fig. 4.24A). Remnant pieces of fat or fibres are observable under low power magnification within patches of oily compounds that are distributed across the surface in isolated spots (fig. 4.24B). In areas of low topography, macro residues are built up more extensively as compressed, fibrous crusts. An oily film with a dull and rough appearance formed predominantly on areas of high topography. The limited distribution of residues following hide softening compared to hide cleaning likely reflects the decreased presence of oil and moisture within dried hide relative to fresh hide as well as the fact that dried hide is a much harder and less pliable contact surface.

Hide processing micro residues were collected from S5F4 after the experiments had been completed and the tool had been washed. As a result, the collected micro residues, which consisted of clustered and twisted collagen tissues, are associated with both hide cleaning and hide softening (fig. 4.24C).

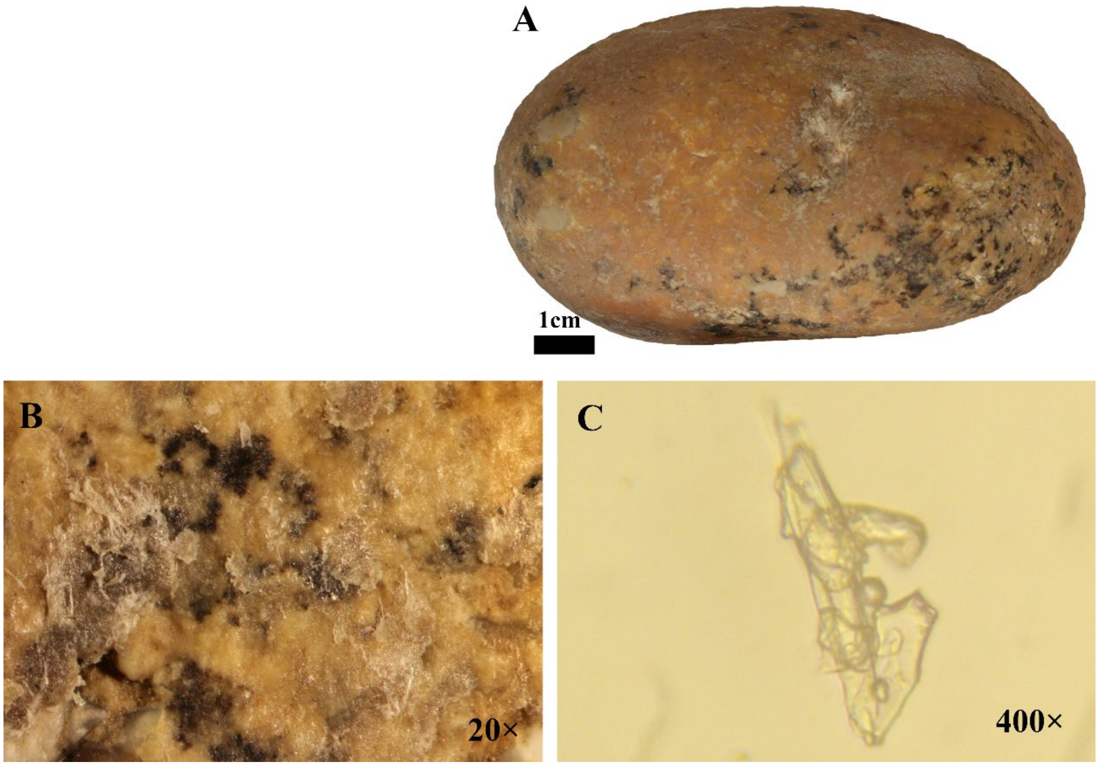

Figure 4.24: Residues on the surface of S5F4 after 60 minutes of hide softening. A) A slightly reflective, oily film coating the surface. B) Fibrous hide macro residues. C) Twisted collagen micro residues.

Use-Wear

Hide softening results in the spread of the same discolouration described in the hide cleaning experiment although it is more uniformly distributed across the surface of the experimental tool (fig. 4.25). One spot of hard material that had been encrusted to the surface of the rock was removed during this experiment but no other modification to the surface topography of the rock could be observed. A small area of reflectivity is also noted on the surface.

The increased discolouration of the experimental tool corresponds to more extensive leveling of the topography under macroscopic observation. Leveled surfaces are smooth compared to the original surface of the rock although the topography is not regularized. The margins and peaks of high topography are rounded rather than flattened in homogenous zones (fig. 4.26A).

Figure 4.25: The surface of (S5F4) after 120 minutes of hide softening.

Micropolish with a similar appearance to that associated with hide cleaning developed more extensively during the hide softening experiment. The same texture, ranging between rough and fluid, along with well-defined boundaries characterizes the hide softening micropolish. The distribution of this micropolish has expanded so that patches of micropolish are connected over high topography (fig. 4.26B). Linear traces occur as isolated and deep striations or as groups of short, parallel striations. The separate groups of striations appear randomly oriented relative to one another.

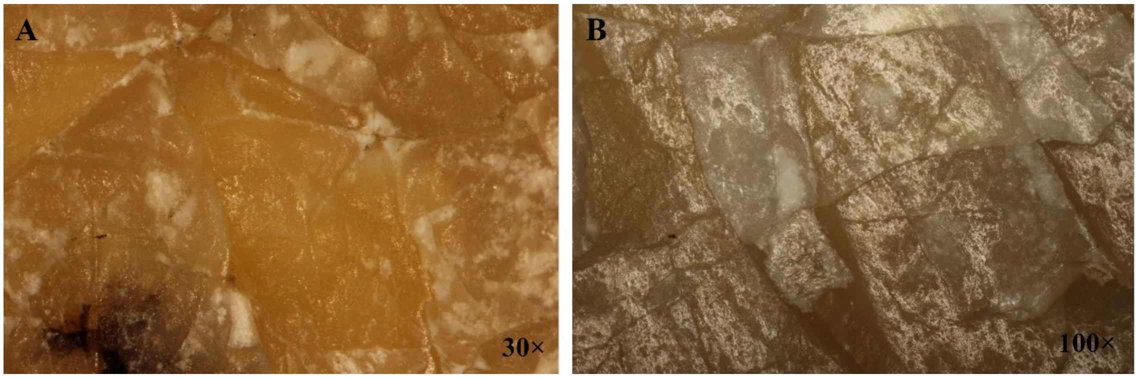

Figure 4.26: Use-wear associated with dried hide softening. A) Smooth, rounded high topography due to leveling. B) Randomly oriented linear traces within micro polish.

Softening Tanned Hide

Residues

A dark, translucent film developed on the most projecting part of the use area where contact with the surface of the hide would have been the most intense (fig. 4.27A). Within this area, the residues fill the low topography and cover areas of high topography where the accumulation is thickest. Under macroscopic observation, the film is highly reflective and translucent across areas of high topography (fig. 4.27B). In areas of low topography, the built-up film is opaque and has a compressed, mud-cracked appearance. Linear features are visible within the residues as parallel groups that vary in length and orientation. Micro residues from tanned hide included clusters of collagen fibers that were thinner than those from the deer hide in addition to collagen tissues with a macerated appearance (fig. 4.27C).

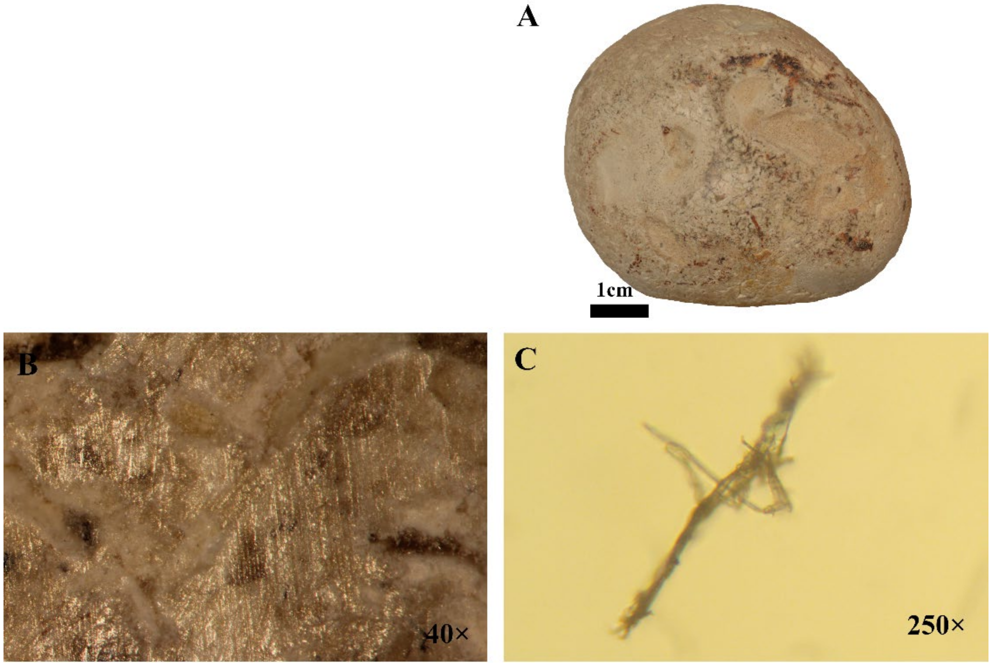

Figure 4.27: Residues on the surface of S3F2 after 120 minutes of hide softening. A) Appearance at the naked-eye level. B) Highly reflective, compressed film covering the topography and associated striations. C) Twisted collagen fiber micro residues.

Use-wear

A small area of darker discolouration is present on the highest portion of the use surface (fig. 4.28). This discolouration is faint compared to the discolouration of the experimental tool used in the previous two hide processing experiments as it is limited to the margins surrounding high topographic areas which retain the lighter colouring of the original surface.

Figure 4.28: The surface of (S3F2) after 240 minutes of hide softening.

The presence of this dark discolouration between areas of high topography, rather than on the high topography itself, is the result of edge rounding which has removed the lighter exterior surface and exposed the darker interior only on the margins of high topography. Leveling has modified the high topography less extensively; the surfaces are flat and smooth and wearing away of the original white exterior surface appears to be proceeding from the margins inward (fig. 4.29A).

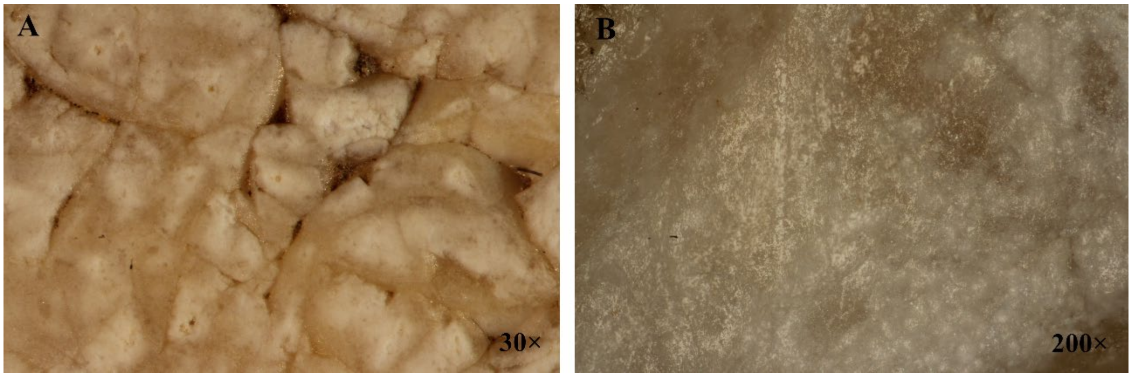

Figure 4.29: Use-wear associated with softening tanned hide. A) Rounded edges of leveled high topography. B) Thin, rough micropolish formation.

A thin, opaque micropolish is present on leveled areas of the high topography in a loose and separated distribution and more extensively on topographic margins in a concentrated distribution (fig. 4.29B). The micropolish formed during abrasion of the tanned hide is thinner and less reflective than the micropolish developed during abrasion of the dried deer hide despite of the fact that abrasion of the tanned hide was conducted for twice as much time. Due to this thinner build-up of micropolish, the texture is rough in appearance. Where the micropolish has accumulated more extensively, it is associated with linear traces and has a fluid texture.

4.3.7 Shell Abrasion

S7F1 was used to abrade shells with the intent of smoothing the exterior texture. The tool was used as a passive implement and held in one hand while the processed shell was abraded in a reciprocal motion with the other hand. Task progression was predictably slow, given the smooth texture of the tool surface. After 120 minutes had elapsed, a small portion of one shell had been slightly smoothed. Together with the absence of shell at the site, the ineffectiveness of limestone for abrading shell indicates this task was not likely to have been conducted with the Upper Sequence GST.

Residues

Shell abrasion resulted in the accumulation of opaque, white powder residues within spots of low topography on the surface. On the flat and smooth areas of high topography, the residues have been compressed into a rough film that is reflective to the naked eye and oriented in parallel linear traces (fig. 4.30A).

Macroscopically, the powder residues are distributed over the use area in isolated spots of low topography (fig. 4.30B). The film located on high topography appears to be composed of compressed powders. This moderately reflective film is rough textured and displays roughly parallel linear features. In some instances, patches of powder macro residues have been so heavily abraded and compressed that the reflectivity of the film on high topography extends to these spots.

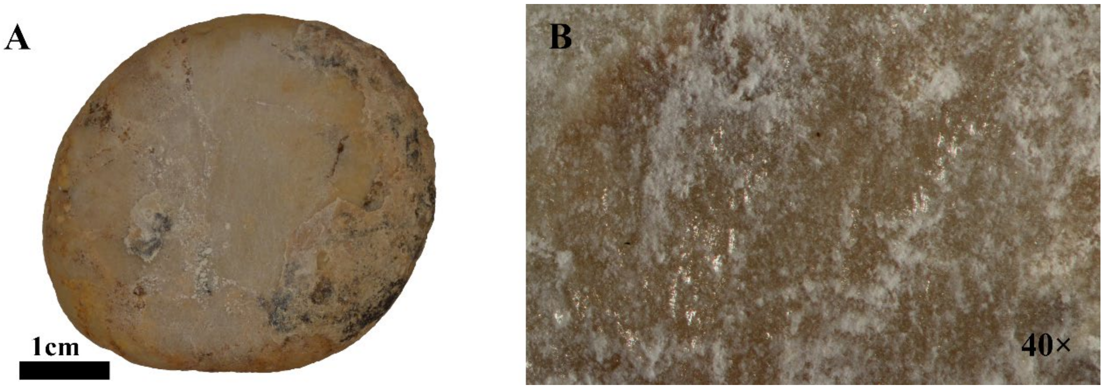

Figure 4.30: Residues on the surface of S7F1 after 60 minutes of shell abrasion. A) Reflective shell residues at the naked-eye level. B) Reflective film with a linear orientation.

Use-Wear

After 120 minutes of shell abrasion, the only indication of use that could be noted was the presence of a rough reflectivity oriented in parallel lines corresponding to the direction of use across the surface (fig. 4.31). No alteration of the surface topography could be discerned with the naked eye.

Figure 4.31: The surface of S7F1 after 120 minutes of shell abrasion.

Under low-power magnification, the reflectivity corresponds to leveled areas of high topography that cover the use area in connected patches (fig. 4.32A). Leveling of the surface was slight as indicated by the sinuous appearance and rough texture of the high topography. The orientation of the patches relative to one another, along with the presence of reflective linear features within larger individual patches, conveys directionality.

Shell abrasion resulted in the formation of a highly reflective micropolish on leveled areas in separated patches with sharp margins. Under high-power magnification, the micropolish is sinuous and ranges from rough and translucent to fluid and opaque in thicker deposits. Groups of parallel linear traces can easily be discerned in each patch of micropolish (fig. 4.32B).

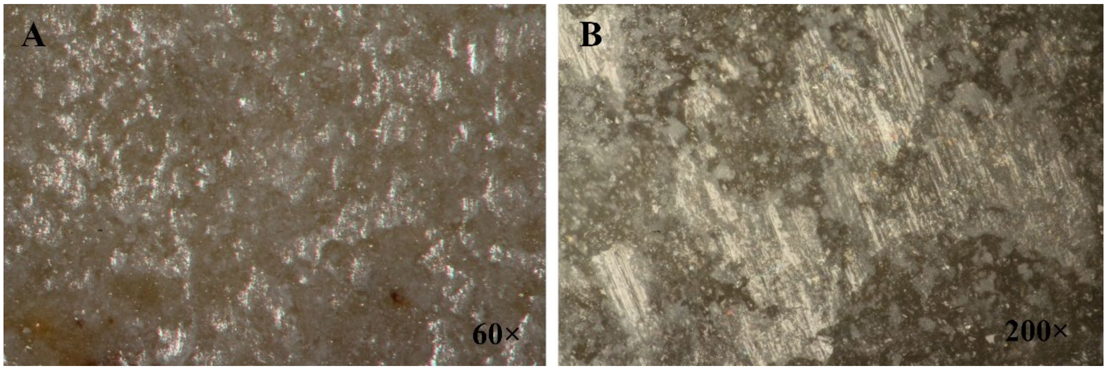

Figure 4.32: Use-wear associated with shell abrasion. A) Rough, reflective leveled patches of high topography. B) Parallel linear traces within highly reflective micropolish.

4.3.8 Wood Abrasion

S3F5 was used to abrade a fresh branch from a sugar maple (*Acer saccharum*) with the aim of removing the bark and smoothing the surface. Initially, bark was removed from the surface at a surprisingly fast pace and protrusions on the surface were worn down with minimal force. After around 20 minutes of work, the progress of bark removal began to slow gradually due to the buildup of wood residues on low topography. Given the limited effectiveness of the experimental tool, it is likely that if wood abrasion or shaping occurred at Nesher Ramla, certain flaked stone tool types or rocks with more abrasive properties would have represented more desirable alternatives for completing these tasks.

The experimental framework originally included a dried wood abrasion experiment that was intended to compare residues and use-wear between fresh and dried wood. Due to the paucity of use-wear results for the fresh wood abrasion experiment, the decision was made to abandon the dried wood abrasion experiment.

Residues

Wood abrasion resulted in a dark, glossy film that appeared predominantly on smooth, flat areas of high topography and accumulated in areas of low topography (fig. 4.33A). Under low-power magnification, the film has a mud-cracked appearance. On high topography, the film is slightly reflective and translucent with a faint directionality. In low topography, wood macro residues have accumulated in dark, opaque patches of film with a fibrous texture (fig. 4.33B).

Figure 4.33: Residues on the surface of S3F5 after 60 minutes of wood abrasion. A) Glossy film coating the use-area. B) Wood macro residues with a mud-cracked appearance and linear traces.

Use-Wear

The distribution of wood residues correspond to a darker discolouration of the high topography that persisted after the surface had been washed (fig. 4.34). This discolouration contrasted with some areas of low topography where the removal of material had exposed the lighter interior of the rock. Aside from residues that remained trapped between rock grains following washing, the discolouration of a single surface of the rock is the strongest indication of use as wood abrasion appeared to result in very little use-wear formation.

Figure 4.34: The surface of S3F5 after 120 minutes of wood abrasion.

Very little topographic change could be observed under low power observation. Leveling appeared to be limited to locations where some material had already been removed from the surface prior to this experiment. In these areas, the leveled surface is sinuous and smooth. Areas of high topography that had almost certainly come into contact with the processed material during the experiment did not appear to be leveled and instead retained their original texture (fig. 4.35). This is suggested to be due to the accumulation of wood residue on topographic highs that protected the surface from abrasion.

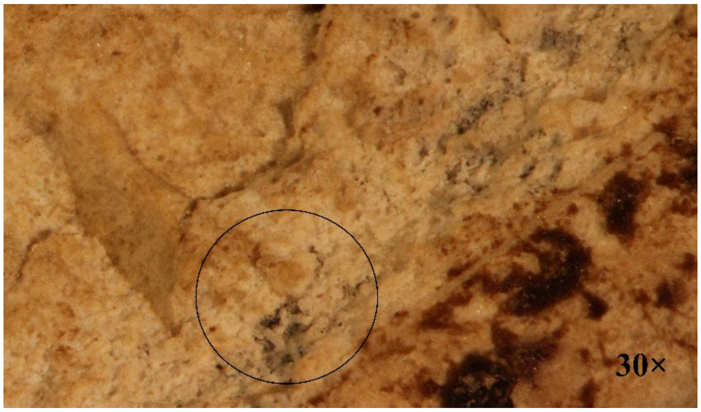

Figure 4.35: Use-wear associated with wood abrasion. A small area where material was removed from the surface due to leveling is circled.

Wood abrasion was not associated with the formation of micropolish. The micropolish that was documented prior to performing the experiment was instead attributed to environmental polish based on its rough texture, opacity, and reflectivity. In addition, this micropolish appeared predominantly on low topography that could not have possibly come into contact with the wooden branch.

4.3.9 Acorn Hulling

An experimental tool (S2F2) was used to crack acorns collected from Red Oak trees (*Quercus rubra*). Acorns were placed on a stone anvil and struck with the flat face of the experimental tool in order to crack the shell so the edible kernels inside could be removed. Successful extraction of the kernel required a very light strike that was just forceful enough to crack the shell of the acorn while avoiding crushing the kernel so it could be removed intact. The experimental tool was effectively used to hull acorns at a steady rate while also enabling control over the force of the strike. This experiment was originally intended to include grinding of the extracted kernels on the same anvil. However, this was prevented by a lack of a sufficient supply kernels for processing as most were rotten upon extraction.

Residues

Residues from acorn hulling consist of a thin, transparent film concentrated in the middle of the tool surface with diffuse margins (fig. 4.36A). Under macroscopic observation, the film is slightly reflective, fibrous in texture, and has a compressed appearance (fig. 4.36B). The macro residues are primarily concentrated in the center of the use area accumulated within the cracks of low topography in addition to small, isolated patches on high topography.

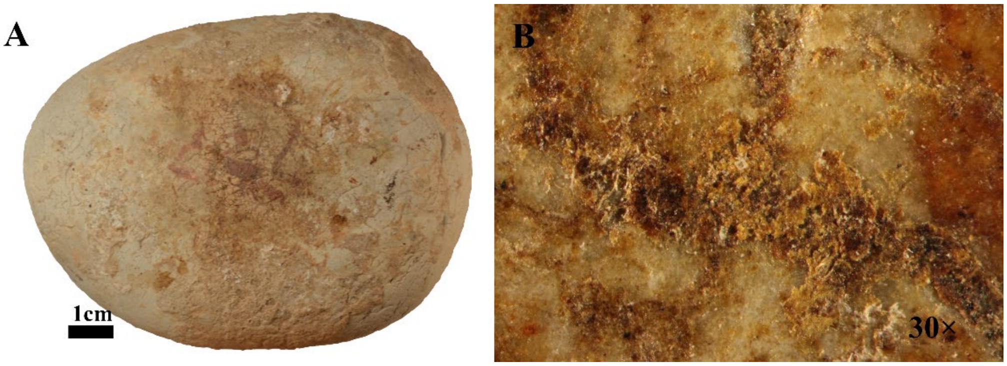

Figure 4.36: Residues on the surface of S2F2 after 135 minutes of acorn hulling. A) Thin, transparent film corresponding to the area of the surface in contact with the acorns. B) Compressed macro residues within topographic lows.

Use-Wear

After 135 minutes of acorn hulling, the sole alteration to the surface is the appearance of a slight, dark discolouration concentrated within a small portion of the use-surface (fig. 4.37). This discolouration is lighter than that reported on the wood abrasion tool (S3F5) and its distribution roughly matches that of the acorn residues that built up on the surface during the experiment.

Figure 4.37: The unaltered surface of S2F2 after 135 minutes of acorn hulling.

Under macroscopic observation, use-wear traces associated with acorn hulling were not identified. Pre-existing impact marks were noted on the surface in addition to an opaque, rough micropolish on low topography. This is environmental polish and unrelated to acorn hulling.

Acorn hulling is an outlier among the percussive experiments performed in that use-wear formation was not detected (fig. 4.38). The relatively brittle material combined with the light strikes necessary for this task are likely the reason for the absence of wear traces present on the tool. In addition, risk of accidental contact with the harder surface of the anvil is minimal compared to the bone comminution and tendon pounding tasks.

Figure 4.38: Pre-existing impacts and crushed grains on the surface of S2F2 after 135 minutes of acorn hulling.

4.3.10 Flint Knapping

S6F1 was used to knap pieces of Onondaga chert. In addition to a striking gesture, the tool was also used to prepare the striking surface through abrasion. The experimental tool proved to be an effective hammerstone that withstood the force of the strikes required for flake removal without breaking. The cobble also enabled reasonable control over the location and size of removals. Any problems encountered with the quality and accuracy of the final products are therefore reflective of my own inexperience at knapping.

Use-Wear

Flint knapping resulted in extensive alteration of the surface of the experimental tool and an easily discernable use area as the lighter interior surface of the rock was exposed. Removal of material from the surface reflects both the intense striking gesture and the hard processed material. The use area is also characterised by irregular and rugged topography (fig. 4.39). Dark scratches from flint abrasion with a linear orientation were also observed on the surface surrounding the impact marks.

Figure 4.39: Alteration to the surface of S6F1 after 120 minutes of flint knapping.

As the experiment progressed, the topography became increasingly irregular and rugged as impact marks deepened. Areas of extracted material are irregularly shaped with crushing visible around the margins of some removals (fig. 4.40A). The interior of deeper removals is smooth while shallower removals have rougher pits. Areas of high topography are characterised by dark, reflective flint traces scattered across sharp peaks in a random orientation. The transition between the impact area and the surrounding original surface is sharp and marked by a shift to smooth, flat topography and a change in colour. Flint traces are more extensive in these surrounding areas and are often randomly oriented in linear patterns. Isolated impact marks with irregular shapes and rough bases in these areas are shallow relative to the main impact area.

A translucent and moderately reflective micropolish developed in association with the adhered flint (fig. 4.40B). The texture of this micropolish ranges from rough where the build-up is thin and fluid in slightly thicker accumulations. Groups of short, parallel linear traces were noted on even isolated patches of micropolish that appear on topographic peaks.

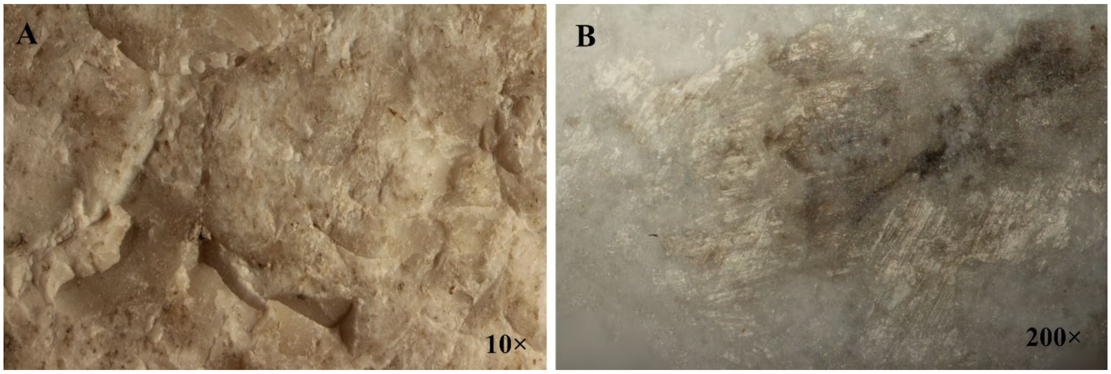

Figure 4.40: Use-wear associated with flint knapping. A) Rough, irregular topography with impact marks. B) Micropolish with randomly oriented groups of linear traces.

4.3.11 Ochre Grinding

S2F2 was repurposed for ochre grinding following the poor results of the acorn hulling experiment. Chunks of ochre sourced from Ontario and Israel were placed on a stone anvil and processed with a combination of crushing and grinding. The experimental tool proved effective at ochre grinding. Initially, the ochre chunks were struck with blows perpendicular to the surface of the anvil in order to break them up into smaller fragments and crush them. The fragments were then ground with a reciprocal back and forth motion until they had been completely reduced to a fine powder.

Residues

Ochre residues are easily observed on the surface of the tool in the form of a reddish-brown powder (fig. 4.41A). This powder evenly coats the smooth high topographic areas of the use area and is built up within low topography. Macro residues on the high topography consist of a slightly reflective thin film of compressed powder. Thicker spots of moderately reflective film with linear features are scattered over the surface in isolated spots. Dark clumps of uncompressed powder also appear in small concentrations on the surface (fig. 4.41B).

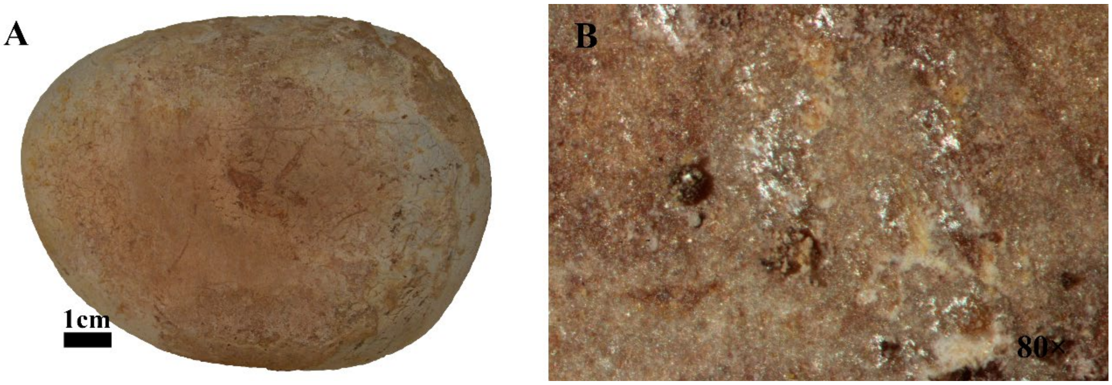

Figure 4.41: Residues on the surface of S2F2 after 60 minutes of ochre grinding. A) Ochre residues coating the use-area. B) Crushed, reflective macro residues on high topography.

Use-Wear

The most notable change to the surface of the experimental tool following ochre grinding is the reddish-brown stain that marks the boundaries of the use area (fig. 4.42). Leveled areas, characterised by smooth, flat surfaces and regularized topography, can also be easily discerned with the naked eyes.

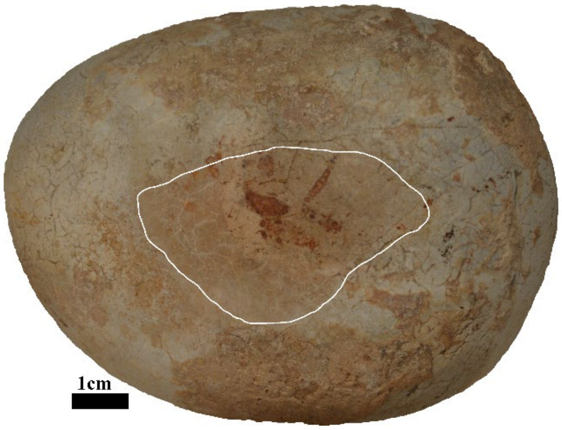

Figure 4.42: Leveling and discolouration (outlined) on the surface of S2F2 after 120 minutes of ochre grinding.

Under macroscopic observation, the leveled areas appear flat with rounded margins and are darker than the original surface due to exposure of the interior of the rock. Small reflective spots and short parallel striations are also noted on the leveled surfaces. In some instances, the striations are similar in colour to the ochre due to the presence of trapped residues within the striations even after washing (fig. 4.43A).

Ochre grinding resulted in the formation of a moderately reflective opaque micropolish with a texture that ranged from rough to fluid (fig. 4.43B). The micropolish is distributed across the high topography in connected patches with diffuse margins. Linear features can be discerned within larger patches of micropolish.

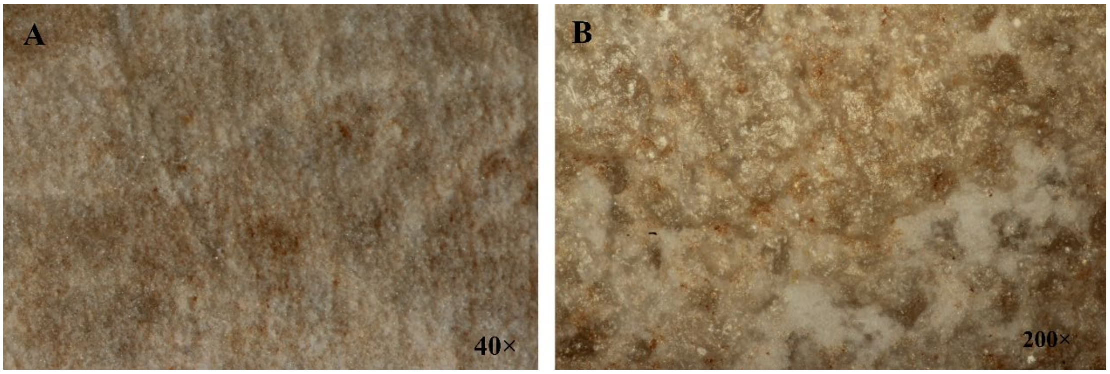

Figure 4.43: Use-wear associated with ochre grinding. A) Parallel striations and reflective patches on leveled areas. B) Patches of moderately reflective micropolish with linear traces.

4.3.12 Grip Polish

Bone breaking and bone comminution were associated with the development of reflective areas where the tools had been grasped with silicon gloves during the experiments. During these experiments, the entire tool become coated in oils from the processed bones. The presence of oils made it difficult to maintain a solid grip during use and as a result, the tool slipped around in my hand or slipped out of my hand completely at several points in each experiment. I hypothesize that the formation of grip polish results from the interaction between oils coated on the surface and contact between the glove and the surface of the tool. Grip polish from these bone processing tasks is therefore proposed to be an additional potential explanation of the presence of sheen on the archaeological pebbles discussed in section 5.3.

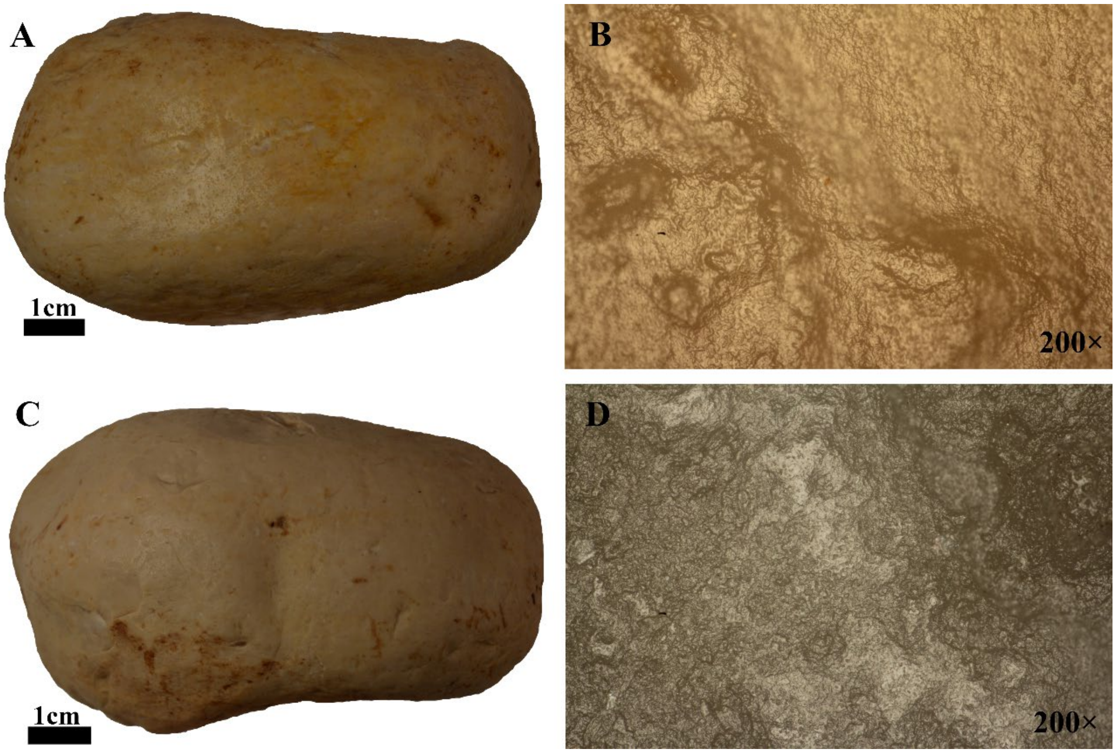

Figure 4.44: Grip polish associated with bone comminution. A-B) Position of thumb during use on S4F4. C-D) Position of fingers during use S4F3.

The grip polish formed during bone comminution is the most extensive of the two tasks (fig. 4.44). The locations where the tool had been gripped during use appear smooth and highly reflective to the naked eyes. Under low-power magnification, the polish is associated with sinuous and smooth leveled areas. With high-power magnification, micropolish on the grip areas is characterised as opaque and highly reflective with diffuse margins and a rough texture where accumulations are thin and fluid where they are more extensive.

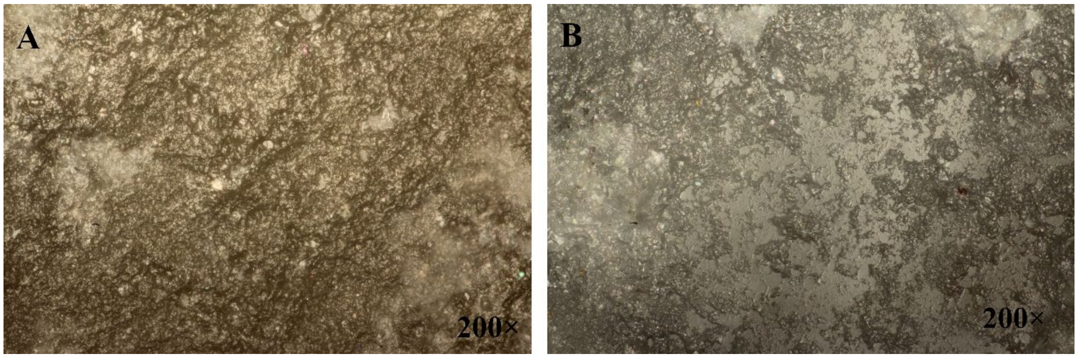

Figure 4.45: Grip polish associated with bone breaking. A) Position of palm during use on S1F2. B) Position of thumb during use on S1F3.

The grip polish formed during bone breaking was less extensive and not visible to the naked eyes. Under high-power magnification, the polish is translucent and moderately reflective. The texture of this micropolish ranges from rough to fluid on S1F2 (fig. 4.45A) while it is flat on S1F3 (fig. 4.45B).

4.4 Synthesis

This analysis of the experimental assemblage has revealed some potential sources of influence on task viability, use recognition, and the appearance or formation of use-wear and residues for *ad-hoc* GST. The following discussion also briefly summarizes the experimental results in relation to how they are applied to the analysis and interpretation of the Upper Sequence GST in Chapter 5. A condensed summary of the experimental results is also presented in tables 4.2 and 4.3.

	Macro Residues		**Micro Residues**
Experiment	**Distribution/ structures**	**Structures/ appearance**	**Structures/ appearance**
Bone Breaking S1F1	Film, amorphous compounds.	Bone fragments, fat, collagen tissues and fibers. Greasy, opaque/ transparent, moderately reflective.	Collagen tissues/ fibers. Clustered, twisted.
Bone Comminution S4F1	Film, amorphous compounds.	Crushed bone, fat, collagen tissues. Greasy, translucent, highly reflective.	Collagen tissues/ fibers. Clustered, macerated.
Bone Abrasion (dried) S3F3	Powder, film.	Opaque, white, linear traces, film is slightly reflective.	Collagen tissues. Clustered, compressed.
Bone Abrasion (fresh) S3F1	Powder, film.	Opaque, white, compressed, film is slightly reflective.	Collagen tissues/ fibers. Clustered, twisted, compressed.
Antler Abrasion S7F2	Powder, film.	Opaque, white, linear features, fibrous. Film is compressed and highly reflective.	Long thin, collagen fibers.
Tendon Pounding S5F1	Powder	Collagen fibers. Opaque, compressed, white/pink.	Collagen tissues/ fibers.
Hide Cleaning (fresh) S5F4	Film, amorphous compounds.	Fat, collagen tissues. Greasy, translucent/ opaque, moderately reflective.	Collagen tissues/ fibers. Clustered, twisted.
Hide Softening (dried) S5F4	Film, amorphous compounds, crust.	Fat, collagen fibers. Greasy, fibrous, compressed, slightly reflective.	Collagen tissues/ fibers. Clustered, twisted.
Hide Softening (tanned) S3F2	Film.	Translucent/ opaque, highly reflective, compressed, mud-cracked. Linear features.	Collagen tissues/ fibers. Clustered, twisted.
Shell Abrasion *S7F1*	Powder, film.	Translucent/ opaque, white, film is compressed and slightly reflective. Linear traces.	
Wood Abrasion (fresh) S3F5	Film	Slightly reflective, brown, mud-cracked, fibrous.	
Acorn Hulling S2F2	Film	Transparent, slightly reflective, fibrous, compressed.	
Ochre Grinding *S2F2*	Powder, film.	Reddish-brown, Opaque, slightly reflective, compressed, moderately reflective. Linear features.	

Table 4.2: Summary of the experimental residue results.

Experiment	**Topography**	**Grain Alterations**	**Linear Traces**	**Micropolish**
1. Bone Breaking S1F1	Irregular, rugged.	Leveling, Pits and extraction, edge rounding		Translucent, dull, rough, sinuous. Diffuse margins.
2. Bone Comminution S4F1	Topographic highs: flat, smooth. Topographic lows: sinuous and smooth.	Leveling. High topography: flat, smooth. Low topography: sinuous, smooth.	Short, randomly oriented, parallel groups associated with micropolish on high topography. Long, isolated traces within micropolish.	Opaque, moderately reflective, fluid, sinuous/flat. Diffuse margins.
3. Bone Abrasion (dried) S3F3	Sinuous. Rounded, smooth peaks.	Leveled high topography. Sinuous and smooth.		Opaque, dull, fluid/rough. Diffuse margins.
4. Bone Abrasion (fresh) S3F1	Flat, rough.	Leveling, High topography: flat/sinuous, rough.	Short, shallow striations on leveled surface. Micropolish accumulated within.	Opaque, moderately reflective, rough/fluid. Diffuse margins.
5. Antler Abrasion S7F2	Sinuous, smooth.	Leveling: smooth, rounded topographic peaks. Reflective extractions.	Parallel groups of short linear traces within micropolish.	Translucent, moderately reflective, rough. Sharp margins. Linear traces.
6. Tendon Pounding S5F1	Irregular, rugged.	Extractions. Topographic highs have rounded or crushed edges.		Opaque, moderately reflective, sinuous, rough/fluid. Diffuse margins.
7. Hide Cleaning (fresh) S5F4	Flat/sinuous, smooth.	Leveling: flat, smooth.	Short, shallow parallel groups within micropolish.	Translucent, highly reflective, fluid, flat. Sharp margins.
8. Hide Softening (dried) S5F4	Flat/ sinuous, smooth. Rounded peaks.	Leveling: Rounded topographic peaks, smooth, flat.	Isolated, deep, and short, parallel, shallow randomly oriented groups associated with micropolish.	Opaque, highly reflective, fluid/ rough, flat. Sharp margins. Linear traces.
9. Hide Softening (tanned) S3F2	Sinuous, smooth.	Grain edge rounding. Leveling: flat, smooth.	Short, parallel, shallow within micropolish.	Opaque, moderately reflective, rough/fluid, flat. Diffuse margins.
10. Shell Abrasion S7F1	Sinuous, rough.	Leveling: sinuous, rough, reflective.	Reflective patches oriented in linear pattern.	Translucent and rough/ opaque and fluid, highly reflective. Sharp margins. Linear traces.
11. Wood Abrasion (fresh) S3F5	Sinuous, smooth	Leveling: sinuous and smooth.		

12. Acorn Hulling S2F2	No alteration.			
13. Flint Knapping S6F1	Irregular, rugged.	Extractions, crushing, impact marks.	Randomly oriented, short, parallel groups within micropolish.	Translucent, moderately reflective, rough/ fluid. Sharp margins. Linear traces. Associated with flint residues.
14. Ochre Grinding *S2F2*	Flat, rough.	Leveling of high topography. Reflective spots.	Short, parallel striations.	Opaque, highly reflective, rough/ fluid. Diffuse margins. Linear traces.

Table 4.3: Summary of the experimental use-wear results.

With the exception of acorn hulling and wood abrasion, the use-wear patterns documented on the experimental assemblage proved to be adequate for distinguishing between different processed material properties and the gesture involved, if not the actual activity the tool was employed in. Differences in the characteristics and distribution of wear observed on the experimental tools reflect a combination of processed material properties and the manner in which the material was processed.

The degree with which use-areas can be discerned with naked-eye observation depends partially on the gesture involved in use, processed material properties, and the extent of use. Percussive gestures combined with mineral or hard animal materials tended to result in the most conspicuous use-areas. For abrasive or percussive tasks involving soft or resilient materials, the hardness and oil content of the processed material properties demonstrated the most influence on wear visibility. The latter factor may account for the difference in the visibility of the use-areas on the bone breaking and bone comminution tools. Recognition of *ad-hoc* tools in archaeological contexts is therefore expected to favour those used for flint knapping, tendon pounding, ochre grinding, and abrasion of shell or other hard materials.

Observation at regular intervals allowed different stages of wear formation to be observed. This enabled a better understanding of how the formation of different wear traces were related to one another. Percussive tasks can result in abrasive wear if the processed material is oily and soft enough that the topography is regularized and smoothed. This in turn provides an adequate surface and environment for tribochemical wear to form.

Documentation of environmental polish and pre-exiting alterations during initial observation of the tool surfaces not only helped to distinguish these traces from use-wear but also demonstrated the types of damage that may occur on archaeological GST in addition to use-wear. This is an especially helpful insight for analysis of *ad-hoc* tools that may have no explicit use-areas where wear traces could be reasonably expected to appear.

In terms of viability, the tools were demonstrated to be generally more effective at tasks involving a percussive gesture than an abrasive one. Abrasion of bone, antler, wood, and shell proved unlikely functions for the Nesher Ramla assemblage on the basis of poor task efficiency. Ochre grinding, which was conducted through a combination of percussion and abrasion, was the single abrasive task to be conducted successfully with the experimental assemblage.

The appearance and distribution of residues observed on the experimental tools reflected the manner in which the material had been processed. In some instances, residues were noted to affect the development and characteristics of wear. During the experiments in which bone or wood were abraded, the accumulation of residues not only reduced the efficiency of the tool but also acted to protect low topographic areas from wear. Of all types of wear, micropolish was particularly influenced by the presence of oily residues. Tasks in which fresh bone or hide were processed were associated not only with more extensive micropolish formation but also increased reflectivity and more widespread distributions compared to dried bone or hide.

Micro residues appeared relatively similar to one another although some differences in characteristics may reflect either the nature of the processed material or the manner in which it was processed. Fresh bone micro residues included collagen fibers which were not observed within the dried bone micro residues. There was no difference in the types of collagen structures identified in micro residues between bone processed through percussion and abrasion although collagen tissues were more abundant in bone processed with a percussive gesture.

Chapter 5 - Archaeological Results and Interpretation

This chapter presents the results of analysis of the Upper Sequence GST assemblage. The results for each source of data are presented separately and interpreted through comparison with the experimental results and other use-wear literature. The various functions proposed for the Upper Sequence GST are then assessed through contextual and independent lines of evidence from the site to determine how likely each is to have been conducted at Nesher Ramla. The Upper Sequence GST are also sorted into a typology based on the interpretation of identified wear patterns and micropolish characteristics in order to discuss the diversity of functional types for each unit as well as the Upper Sequence overall.

5.1 Database Description

The database is constructed from two excel spreadsheets which were produced during preliminary analysis of the artifacts, each with different strategies for data collection and documentation. The particular attributes of each spreadsheet have their own advantages as to the unique discussions they enable.

The spreadsheet recorded by Laure Dubreuil includes 98 artifacts originating from Units IIA and IIB. The strategy for selecting objects for analysis was mostly random although some were purposefully selected due to the presence of highly visible sheen on their surfaces. This spreadsheet contains the greatest level of detail as observations were conducted at low and high magnification in addition to the naked eye level. Descriptions of wear include characteristics and their distribution over the surface of the artifact for some of the observations. The high level of detail recorded for this spreadsheet enables a discussion regarding the frequency of multiple-use tools as well as the appearance of each wear pattern on various parts of the surface.

The other spreadsheet was produced by Laura Centi, whose PhD research focused on the flaked stone assemblage from Unit V. This spreadsheet records the characteristics for 419 items recovered from the center of the site. Observations of wear traces were conducted only at the naked eye level and the details recorded were limited to the types of wear observed on each artifact. As this spreadsheet contains every cobble recovered from within a defined area in the center of the site, it is possible to examine how relying on only observations done without microscopic aid affects the recognition of different types of wear and potential use in an archaeological context.

The two spreadsheets were integrated into a single database with the intent of investigating the functions of GST from the Upper Sequence as a whole. Distinct wear patterns are identified by the presence of different types of wear in association with one another. This is to account for differences in recorded details between the two sources of data and to make use of the largest data set possible. The largest of the spreadsheets did not include details regarding the characteristics of wear traces while the smaller spreadsheet was more detailed but only included consistent details on the distribution rather than on the characteristics of wear. This strategy was therefore implemented in order to standardize the data from the two sources.

Functional interpretations of the identified wear patterns are supported by comparison with the experimental results and insights from other use-wear literature. Each wear pattern will be associated with particular gestures, raw material properties, and where appropriate, specific tasks that can account for the wear pattern in question.

As three of the cobbles with sheen were also recorded in the database, functional interpretations for these objects rely on information from both datasets. These cobbles are discussed in detail in section 5.3. The other three cobbles with sheen were also added to the database and associated with different wear patterns based on descriptions of micropolish and other wear types.

5.2 Results: Identified Wear Patterns

The GST from the Upper Sequence are composed predominantly of limestone although three flint items were also recorded. Table 5.1 summarizes the attributes of the artifacts from the Upper Sequence.

A total of 139 items were included in the database. Artifacts were excluded from counts if wear could not be definitively associated with use rather than post-depositional processes and were therefore labelled "use indeterminate". Objects identified as flakes were also excluded from this analysis. Objects identified as choppers and cores were included as some were noted to display use-wear (N=10). Analysis of choppers from Unit V has also implicated these objects in bone breaking (Paixão et al. 2021a). Nine items were identified as choppers with edges prepared for use by flaking. The rest of the artifacts were interpreted as *ad-hoc* tools that were not prepared prior to use.

	Unit I	**Unit IIA**	**Unit IIB**	**Total**
Unit of origin	9	81	49	139
%	6.47	58.27	35.25	100.00
Raw material				
Limestone	9	80	47	136
%	100.00	98.77	95.92	97.84
Flint		1	2	3
%		1.23	4.08	2.16
Broken	2	31	10	43
%	22.22	38.27	20.41	30.94

Table 5.1: Attributes of the Upper Sequence GST assemblage.

A total of 183 separate areas with wear traces were identified within the recorded spreadsheet data and sorted into five unique wear patterns (table 5.2). The frequencies of wear types were counted by the number of times they appeared on individual use areas so that a given tool could contribute multiple counts for a particular wear trace. This was done to account for the potential of artifacts with multiple functions to have more than one use area so each use area could be analysed independently.

It should also be noted that although the development of more than one type of use wear within the same location on an artifact may be the result of the same activity, this may not be the case for every instance of co-occurring use wear traces. The possibility that two or more unrelated activities resulted in wear formation on the same area of the tool's surface must therefore be acknowledged. Interruption or alteration of one type of use wear by another may indicate when a subsequent activity has been conducted with a previously utilized part of a tool.

Fatigue wear, which is related to a percussive gesture in the experimental results, is the predominant wear mechanism represented the assemblage (table 5.3). Tasks with an abrasive gesture are represented by various types of abrasive and tribochemical wear. Tasks requiring a combination of abrasion and percussion are indicated by the appearance of fatigue wear and either abrasive or tribochemical wear, or the presence of all three types of wear traces.

Wear Pattern One

The experimental results indicate that percussion against a hard or resilient material results in an irregular and rugged topography with extracted material, crushing, impact marks, pits, and occasionally, reflective spots produced by microfractures. The presence of flake removals may indicate a more intense strike force. Another explanation may be that artifacts with flake removals served as cores at one point in their life history.

Wear Pattern	**Description**	**Functional Interpretation**	**Frequency**		
1	Any combination of impact marks, flake removals, crushing, chipping, pitting, or reflective spots.	Striking of a hard material. *Flint knapping, tendon pounding.*	Unit I	7	
			Unit IIA	79	
			Unit IIB	45	
			Total	131	71.59%
2	Fatigue wear such as impact marks, chipping, or crushing associated with abrasive wear or sheen.	Striking and possibly abrasion of a hard or resilient, oily material. *Bone breaking, tendon pounding, flint knapping.*	Unit I		
			Unit IIA	21	
			Unit IIB	4	
			Total	25	13.66%
3	Striations	Abrasion of hard material.	Unit I		
			Unit IIA	11	
			Unit IIB		
			Total	11	6.01%
4	Sheen associated with abrasive wear.	Abrasion of a hard or oily material. Striking of an oily material. *Bone comminution, hide softening (dried/ tanned).*	Unit I	3	
			Unit IIA	10	
			Unit IIB	1	
			Total	14	7.65%
5	Sheen	Abrasion of a pliable or resilient, oily material. *Hide softening (dried/ tanned), grip polish.*	Unit I	1	
			Unit IIA	1	
			Unit IIB		
			Total	2	1.09%
			Total	183	100.00%

Table 5.2: Description and functional interpretation of wear patterns identified in the archaeological assemblage.

The rough, irregular topography and crushing observable on the experimental tendon pounding tool can all be accounted for by wear pattern one. The majority of percussive wear observed following the tendon pounding experiment was attributed to increased contact between the anvil and the surface of the tool as the tendon bundles separated and flattened. The presence of micropolish does complicate this association, however. Given that the micropolish was observed after just 60 minutes of work, it is unlikely that this pattern could reflect even short periods use, but it is also possible that continued use would eventually obliterate any micropolish. Tendon pounding is therefore more confidently associated with wear pattern two although wear pattern one remains a potential alternative.

The results of the flint knapping experiment also demonstrate many similarities to wear pattern one, with the exception of the striations that were noted on some parts of the use area. If some of the artifacts bearing wear pattern one were indeed used for flint knapping, it may be that these tools were not used to prepare the striking surface with abrasion, or the striations were obliterated by fatigue wear from subsequent strikes with the hammerstone.

Wear Pattern Two

Experiments in which oily materials were worked with a percussive gesture resulted not only in the expected fatigue wear traces, but also the development of leveled surfaces that display sheen or striations in some instances. The presence of fatigue wear in association with smoothed surfaces and/ or sheen is therefore hypothesized to reflect bone breaking or tendon pounding. Bone comminution represents another potential activity that could account for wear pattern two if concentrating the force of the strike in a narrower use area would result in the development of impact marks and other types of fatigue wear.

Development of leveling and pits during the bone breaking experiment were noted to be parts of a related process in which the capacity of the surface to withstand the force of strikes was gradually diminished until leveled areas of topography began to collapse. Leveling and microflakes are reported on other bone breaking experiments performed with limestone cobbles by Assaf et al. (2020). However, the absence of smoothing or leveling reported by Benito-Calvo et al. (2018) on experimental bone breaking tools composed of quartzite and basalt suggests that the appearance of abrasive wear in association with fatigue wear may vary between different raw materials.

As the tendon pounding experiment was only performed for one hour, it is unclear if continued use would have served to eliminate or extend the slight leveling of the surface that was observed. As such, it is not possible to associate leveled surfaces with either more intensive or sporadic use in tendon pounding. In tendon pounding experiments performed by Cristiani and Zupancich (2021), the surfaces of sandstone implements appeared slightly abraded. Fractures and micropolish are also reported on these tools suggesting that the formation of abrasive and fatigue wear during tendon pounding is somewhat consistent across different raw materials.

Flint knapping, which resulted in fatigue wear and linear traces, is also associated with wear pattern two. The striations observed on the extremities and faces of artifacts in association with impact marks are described in the database as separated with most oriented parallel to sub-parallel although some examples are randomly oriented.

Insight from other stone knapping experiments suggests the appearance of fatigue wear in association with striations may vary based on raw material properties and knapping techniques. Striations were reported on gabbro pebbles employed in pressure flaking experiments by Robitaille and Briois (2019). Striations and other linear traces were not noted on limestone cobbles employed in direct percussion in stone knapping experiments performed by Titton et al. (2018) or in bipolar knapping experiments performed by Roda Gilabert et al. (2012).

Although bone breaking, tendon pounding, and flint knapping are associated with the same pattern of associated wear traces, it may be possible to distinguish between these three tasks based on specific wear criteria. Flint knapping can be identified by the presence of linear traces, which were not associated with either bone breaking or tendon pounding. The micropolish on the experimental flint knapping tool also has sharper margins and is more restricted in its distribution on high topography compared to the micropolish observed on the tools used to work animal materials.

The distinction between the latter two tasks relies on differences in the extent of wear formation as both are associated with fatigue wear and smoothed topography. The bone breaking experiment resulted in minimal fatigue wear visible to the naked eyes in the form of small reflective spots. In contrast, the experimental tendon pounding tool displays extensive fatigue wear with a rough, irregular topography at the naked eye level while leveled, smooth surfaces are only visible under low-power magnification.

Wear Pattern Three

Wear pattern three does not appear to match any of the experimental results. The striations observed on cobbles bearing this wear pattern are typically distributed in separate or closed groups with parallel orientations and in one instance they are randomly oriented. Linear traces on the experimental assemblage are only observable under low or high-power magnification, with the exception of the shell abrasion tool on which reflective spots are oriented in the direction the shell moved across the surface. In every instance in which striations or other linear features are observed on the experimental tools, they are also associated with micropolish or situated on leveled surfaces rather than occurring in isolation.

Evidence from other use-wear experiments provides some indication of the processed material properties that can potentially account for wear pattern three. Striations appeared as isolated traces on greenstone abraders used to smooth limestone and on limestone tools used to stamp dried hide and limestone with ochre although the latter experiment also resulted in the formation of ochre residues (Cristiani et al. 2012). The appearance of striations without other associated wear types is therefore hypothesized to reflect the abrasion of a hard and possibly non-oily material.

Wear Pattern Four

Sheen associated with abrasive wear is the most common wear pattern to be associated with an abrasive gesture. This wear pattern appeared only on artifacts that were identified as multiple-use tools with the exception of a core that was employed as an abrader on a separate face.

Wear pattern four was observed on several of the experimental tools that were used for dried bone, antler, and shell abrasion; all three of the hide processing tasks; ochre grinding; and bone comminution. On each of these tools, the sheen and striations were also associated with leveled surfaces. The overall scarcity of leveling on any of the cobbles bearing wear pattern four (N=3) is somewhat surprising given that leveled surfaces were associated with many of the experimental tasks. Leveling may have been particularly difficult to recognize during preliminary analysis of the Upper Sequence GST without an experimental assemblage to serve as a reference point for the appearance of leveled surfaces on limestone specifically.

The efficacy, or lack thereof, of the dried bone, antler, and shell abrasion; and hide cleaning tools indicate these tasks can be ruled out as potential functions for the Upper Sequence GST with a fair degree of certainty. Ochre grinding is also an unlikely function given that ochre residues were not recorded on any of the artifacts in the database. Wear pattern four is therefore associated with softening of dried or tanned hide and bone comminution.

Bone comminution can be distinguished from hide processing by the presence of highly conspicuous and extensive leveling which reflects the percussive gesture involved in this task. The micropolish associated with bone comminution shares many characteristics with the micropolish from both hide softening tasks including opacity, moderate reflectivity, and a flat morphology. However, hide softening micropolish displays a more conspicuous directionality as a result of the abrasive gesture used to work both the dried and tanned hide. Dried hide processing resulted in a flat or sinuous topography with a larger distribution than the sinuous leveled areas on the tanned hide softening tool. As dried hide is more oily than tanned hide, the former is associated with thicker micropolish development which had sharp margins compared to the diffuse margins of the latter.

The presence of sheen in association with abrasive wear has also been reported for use-wear experiments in which basalt implements were used to soften hide and abrade shell, stone, and dried bone (Dubreuil 2002, 2004). Experiments in which plant materials including wild barley, hulled wheat, legumes, nuts, wild grass grains, and fresh and dried acorns were ground also resulted in sheen associated with leveled surfaces and striations (Cristiani and Zupancich 2021; Dubreuil 2002; Paixão et al. 2021b). Together, the above examples indicate that wear pattern four can generally be related to the abrasion of a hard and/or oily material or percussion against a resilient or soft and oily material.

Wear Pattern Five

Artifacts with isolated sheen are relatively uncommon; a single cobble with wear pattern five is recorded in Units I and IIA each. Wear pattern five may be related to grip polish or the softening of dried or tanned hide. Striations on the hide softening tools are uncommon and appear to develop only after extensive use suggesting that this wear pattern could reflect short periods of use for either task.

		Associated Wear Traces*										
		IM	**FR**	**Pt**	**Cr**	**Ch**	**RS**	**Rn**	**Str**	**Sh**	**Lv**	**Count**
Wear Pattern	**1**	✓										56
		✓				✓						23
		✓			✓							15
		✓	✓									12
			✓									6
						✓						5
					✓	✓						4
		✓	✓			✓						3
							✓					1
		✓					✓					1
		✓			✓		✓					1
			✓		✓							1
		✓	✓		✓							1
			✓			✓						1
				✓	✓							1
	2	✓							✓			16
		✓									✓	2
				✓					✓			2
		✓			✓				✓			1
		✓			✓	✓			✓			1
		✓			✓						✓	1
			✓			✓					✓	1
						✓		✓				1
	3								✓			11
	4								✓	✓		10
										✓	✓	3
									✓	✓	✓	1
	5									✓		2
												N=183

*Table 5.3: Patterns of associated wear traces recorded on the Upper Sequence assemblage***.** **IM: impact marks, FR: flake removals, Pt: pits, Cr: crushing, Ch: chipping, RS: reflective spots, Rn: rounding, Str: striations, Sh: sheen, Lv: leveling.*

The grip polish observed on the experimental bone breaking and bone comminution tools is attributed to a combination of oils present on the surfaces of the tools and abrasive movement between the tool surfaces and the gloves worn during the experiments. Grip polish therefore presents an additional factor to consider when identifying potential bone breaking or bone comminution tools.

As the identification and differentiation of wear patterns was informed by previous research and the experimental results, this division may have been biased by what wear traces were expected to appear together. It should be noted then that the identified wear patterns potentially over or underestimate functional variation in the Upper Sequence. Over division of wear traces into separate patterns may result from attributing sets of associated traces to different functions when in fact they are related to a single function that results in variety of wear types. For example, wear patterns one and two are differentiated by the presence or absence of abrasive wear and or tribochemical wear but may simply reflect a single task, such as flint knapping, for which the formation of sheen and striations is possibly inconsistent. Underestimation of functional diversity in the assemblage may have resulted from the unintentional grouping of unrelated wear types into a single pattern. Wear pattern four may actually encompass multiple tasks as indicated by the high frequency of sheen associated with abrasive wear in the experimental results.

Wear patterns characterised by the presence of fatigue wear traces are the best represented throughout the Upper Sequence (table 5.2). However, it is unclear whether this is because tasks involving an abrasive gesture were conducted less frequently with the Upper Sequence GST or if less conspicuous types of wear are underrepresented in the database. Two factors that may have undermined the recognition of less conspicuous or minimal wear traces are that the preliminary observations were conducted without the aid of an experimental reference collection and that one of the spreadsheets was recorded without microscopic observations. These factors are necessary to consider as the ability to compare the unused and used surfaces of the experimental tools proved to be extremely effective for identifying inconspicuous wear traces and because multiple scales of observation were required to identify and document the complete range of use-wear present on many of the tools. The following discussion attempts to better clarify the influence of scale on the accuracy of use recognition and the visibility of different types of wear.

Scale and Reliability of Use Recognition

Of the 419 items included on the spreadsheet which recorded only observations at the naked eye level, 24.82% (N=104) had discernable wear traces that could be confidently associated with use. This relatively low rate of use recognition for objects from this subset of the Upper Sequence assemblage indicates that reliance on only naked eye observations may hinder use recognition. In contrast, of the 471 cobbles, pebbles, and boulders of non-local origin recovered from Unit V of Nesher Ramla, 39.28% (N=185) were identified as used in the multi-scale use-wear analysis conducted by Paixão et al. (2021a).

Recognition of specific wear types appears to favour fatigue wear which is identified on 92.31% (N=96) of the used objects while striations are recorded on 18.27% (N=19) of items and sheen is noted on 2.88% (N=3). The prevalence of fatigue wear traces can potentially be attributed to function as well as the differential visibility of wear traces, however the extent to which each of these factors influenced the abundances of wear types is unclear.

The experimental results provide some insights regarding the influence of observational scale on wear recognition. The majority of experimental tasks were noted to result in the development of wear visible to the naked eyes. A variety of wear traces are observable although fatigue wear, such as pits and fractures, is generally more conspicuous than abrasive or tribochemical wear. The visibility of abrasive or tribochemical wear also appears to be more heavily influenced by scale as linear traces, sheen, and leveling were either more extensive or only observable under low or high-power magnification.

Another insight from the experimental results is that the visibility of wear generally increased the longer the tools were used. This observation may be self-evident, but it is still crucial to acknowledge when examining an assemblage of *ad-hoc* tools which may have been used for only a short period before being discarded.

Alternatively, the observation of abrasive and tribochemical wear, albeit to a lesser extent than percussive wear, on the experimental assemblage may suggest that the high frequency of fatigue wear recorded in the spreadsheet is more reflective of function than differential visibility at the naked eye level. If this subset of the Upper Sequence assemblage had a similar level of functional diversity as the experimental assemblage, a more even representation of wear trace types would be expected.

5.3 Results: Cobbles with Sheen

This section describes characteristics of the micropolish observed on the six cobbles that were noted to have sheen visible to the naked eye. The resulting descriptions are sufficiently detailed as to enable a reliable comparison with micropolish documented on the experimental tools and for potential functions of the cobbles to be proposed.

The cobbles are composed of limestone and were recovered from every unit of the Upper Sequence (table 5.4). Most of the cobbles displayed sheen in multiple locations on their surfaces. Separate patches of micropolish on the same artifact were organized into 12 different zones to be analysed individually as some idiosyncratic variation in micropolish characteristics was noted between different zones. For brevity, the cobbles are referred to by "NRQ" followed by the first four digits of the label they were catalogued under.

Unit of origin	Count	%
Unit I	2	33.33
Unit IIA	3	50.00
Unit IIB	1	16.67
Total	6	100.00

Table 5.4: Distribution of cobbles with sheen in the Upper Sequence.

One cobble (NRQ-3184) was classified as a multiple-use tool based on the presence of micropolish zones with different functional interpretations. Micropolish zones on three of the cobbles (NRQ-3409, NRQ-3190, and NRQ-3195) displayed similar characteristics indicating that more than one area of cobble had been used for the same task. These cobbles were classified as single-use tools. The results of this analysis are summarized in table 5.5.

Micropolish localization	Micropolish Characteristics	Associated Wear	Functional Hypothesis
Artifact: NRQ-3184-Sp.77-80 -Unit I			
Zone 1: Extremity (fig. 5.1)	*Distribution:* high topography, concretions *Appearance:* opaque/ translucent, highly reflective, rough, flat/sinuous *Margins:* defined *Linear traces:* parallel	Leveling, groups of parallel striations	Abrasion of hard material.
Zone 2: Extremity opposite zone 1 (fig. 5.6:A-B)	*Distribution:* Extends into low topography *Appearance:* opaque, dull/moderately reflective, rough/fluid, sinuous *Margins:* diffuse		Contact material is oily and resilient/ pliable. *Bone breaking, grip polish.*
Artifact: NRQ-3001-Sp.59-62 -Unit I			
Zone 1: Flat surface on end (fig. 5.6:C-D)	*Distribution:* extends into low topography *Appearance:* opaque, moderately reflective, rough/fluid, sinuous/domed *Linear traces:* parallel *Margins:* diffuse	Deep, scratches, parallel striations	Working oily and resilient/ pliable material. *Bone breaking.*

Zone 2: Extremity opposite zone 1	N/A*	Leveling	Abrasion
Artifact: NRQ-3409-#9-Sp.117 -Unit IIA			
Zone 1: Extremity (fig. 5.2:A-B)	*Distribution:* high topography, concretions *Appearance:* opaque, highly reflective, rough/fluid, sinuous/domed *Linear traces:* parallel *Margins:* defined	Interrupted by flake removals, parallel striations	Abrasion/ percussion of hard material. *Flint knapping.*
Zone 2: Extremity opposite zone 1 (fig. 5.2:C-D)	*Distribution:* high topography, concretions *Appearance:* opaque, highly reflective, rough, flat/sinuous. *Linear traces:* parallel *Margins:* defined	Leveling, parallel striations	Abrasion/ percussion of hard material. *Flint knapping.*
Artifact: NRQ-3195-Sp.97-100 -Unit IIA			
Zone 1: extremity opposite impact marks and flake removals (fig. 5.3:A-B)	*Distribution:* high topography *Appearance:* opaque, highly reflective, rough/fluid, sinuous/flat *Linear traces:* parallel *Margins:* Defined	Parallel striations and deep scratches	Abrasion/ percussion of hard material. *Flint knapping.*
Zone 2: flat face (fig. 5.3:C-D)	*Distribution:* high topography *Appearance:* opaque, highly reflective, rough/fluid, sinuous/flat *Linear traces:* parallel *Margins:* Defined	Parallel striations	Abrasion/ percussion of hard material. *Flint knapping.*
Artifact: NRQ-3190-Sp.93-96-#18 -Unit IIA			
Zone 1: extremity (fig. 5.4:A-B)	*Distribution:* high topography *Appearance:* opaque, highly reflective, rough/fluid, sinuous/flat *Linear traces:* parallel *Margins:* defined	Leveling, groups of parallel striations.	Abrasion/ percussion of hard material. *Flint knapping.*
Zone 2: convex face (fig. 5.4:C-D)	*Distribution:* high topography *Appearance:* opaque, highly reflective, rough/fluid, sinuous *Linear traces:* parallel *Margins:* defined	Parallel striations	Abrasion/ percussion of hard material. *Flint knapping.*
Zone 3: face opposite zone 1 (fig. 5.4:E-F)	*Distribution:* high topography *Appearance:* opaque, highly reflective, rough/fluid, sinuous *Linear traces:* parallel *Margins:* defined	Deep, parallel groups of scratches and striations.	Abrasion/ percussion of hard material. *Flint knapping.*
Artifact: NRQ-2889-#11-Sp.116 -Unit IIB			
Zone 1: Edge near pointed extremity (fig. 5.5:A-B)	*Distribution:* some extent into low topography *Appearance:* opaque, highly reflective, rough/fluid, sinuous *Linear traces:* parallel *Margins:* defined	Leveling, parallel striations.	Abrasion of hard material.

*Table 5.5: Summary of the micropolish characteristics on the cobbles with sheen. *No pictures available.*

No pictures were available for zone 2 on NRQ-3001 which prevented an adequate description of the micropolish characteristics. As a result, this micropolish zone can only be associated with abrasion.

The characteristics for the rest of the micropolish zones indicate roughly similar functions as the wear patterns. Flint knapping represents the most frequently proposed functional interpretation (N=8) while two zones are associated with bone breaking and one with grip polish.

The majority of the micropolish on the Upper Sequence GST appears to reflect the abrasion of a hard, possibly mineral material. Contact with a hard material is indicated by the distribution of the micropolish in patches on high topography. In most instances, this micropolish is associated with leveling and/or striations and the texture ranges from rough to fluid with a sinuous or flat morphology depending on the degree to which it has accumulated.

Similar micropolish characteristics were observed following the flint knapping and antler and shell abrasion experiments. The micropolish associated with these tasks is also oriented linearly with sharp margins that are abruptly cut-off at the edges of topographic highs. Shell abrasion micropolish displays linear traces with a high degree of similarity to those within the archaeological micropolish suggesting that the cobbles displaying this micropolish pattern were used in an abrasive gesture.

The micropolish associated with flint knapping in particular has many shared characteristics with this pattern of micropolish. On NRQ-3409, NRQ-3195, and NRQ-3190 (figs.5.2-5.4) impact marks, flake removals, and other types of fatigue wear are also present on at least one area of the surface but are not explicitly associated with the micropolish in some instances. These cobbles are therefore interpreted as flint knapping implements that may have been used on different surfaces for flaking and abrasion of the striking surface.

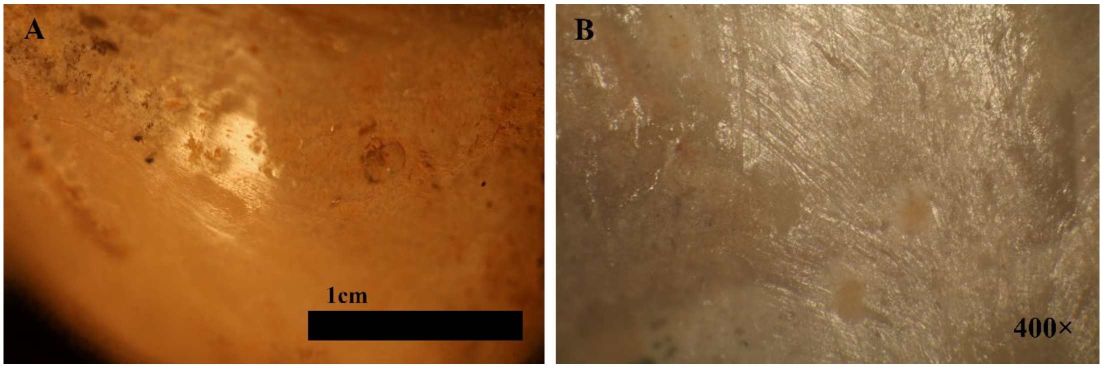

Figure 5.1: Distribution and appearance of micropolish on NRQ-3184 (zone 1). A) Highly conspicuous sheen on high topography and concretions. B) Rough micropolish with randomly oriented striations.

The lack of fatigue wear on other cobbles displaying these micropolish characteristics (figs.5.1 and 5.5) indicates that they may have been used for an alternative task with similar functional parameters. One potential function that may account for this micropolish pattern is the abrasion or polishing of other stone objects. Stone abrasion experiments conducted with basalt or quartzite tools were associated with micropolish development in association with leveling and linear traces (Dubreuil 2002, 2004; Stepanova 2019).

Experiments in which dry plant materials were ground were also noted to result in micropolish characteristics which reflected the abrasion of a hard material. The associated striations and sharp margins of the micropolish are reflective of contact between the hard surfaces of the active and passive grinding tools while the low oil content of the processed material would have also prevented or limited micropolish formation from extending into low topography (Cristiani and Zupancich 2021; Dubreuil 2002, 2004; Paixão et al. 2021b).

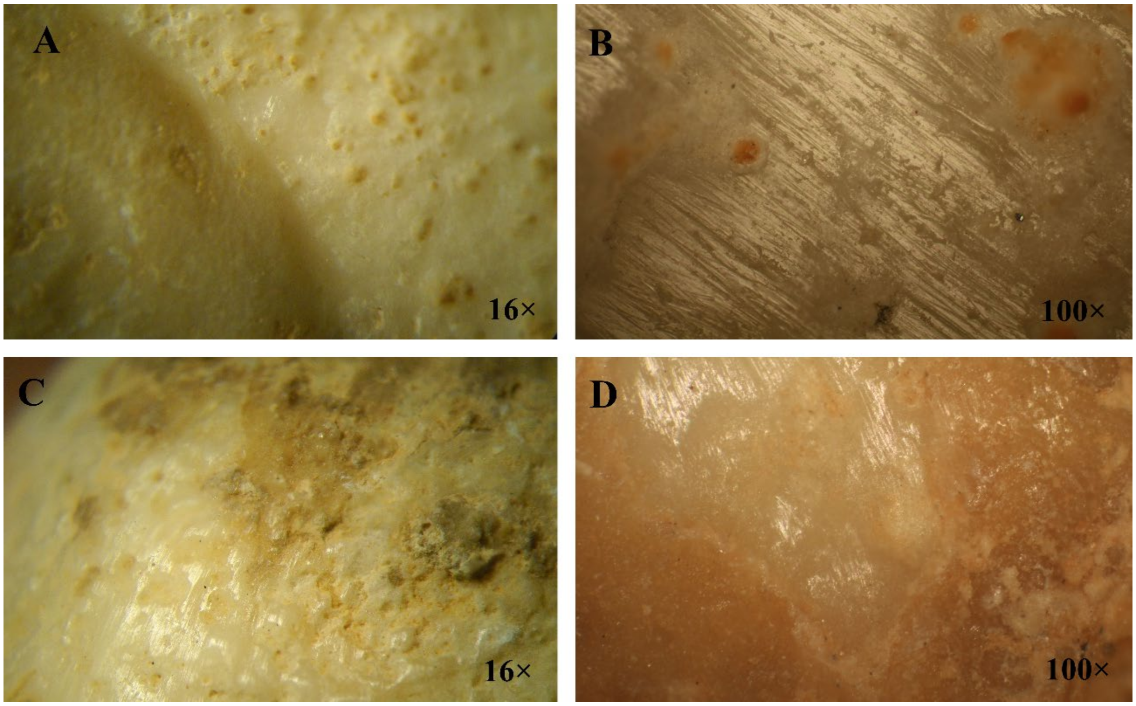

Figure 5.2: Distribution and appearance of micropolish on NRQ-3409. A) Flake removal which cuts through the micropolish on zone 1(B) suggesting it occurred after micropolish development. C) Reflectivity on levelled topography of zone 2. D) Patches of rough micropolish on zone 2.

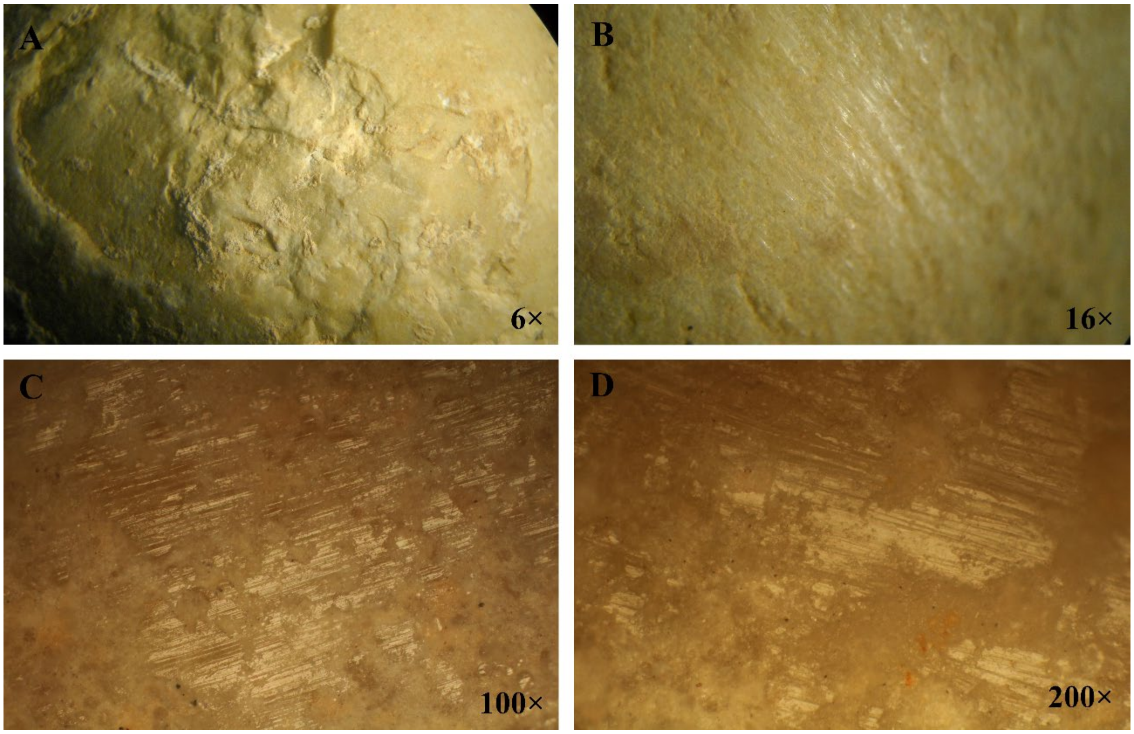

Figure 5.3: Distribution and appearance of micropolish on NRQ-3195. A) Flake removals opposite zone 1. B) Deep conspicuous striations on zone 1. C) Rough micropolish with parallel striations on zone 1. D) Patches of rough to fluid micropolish on zone 2.

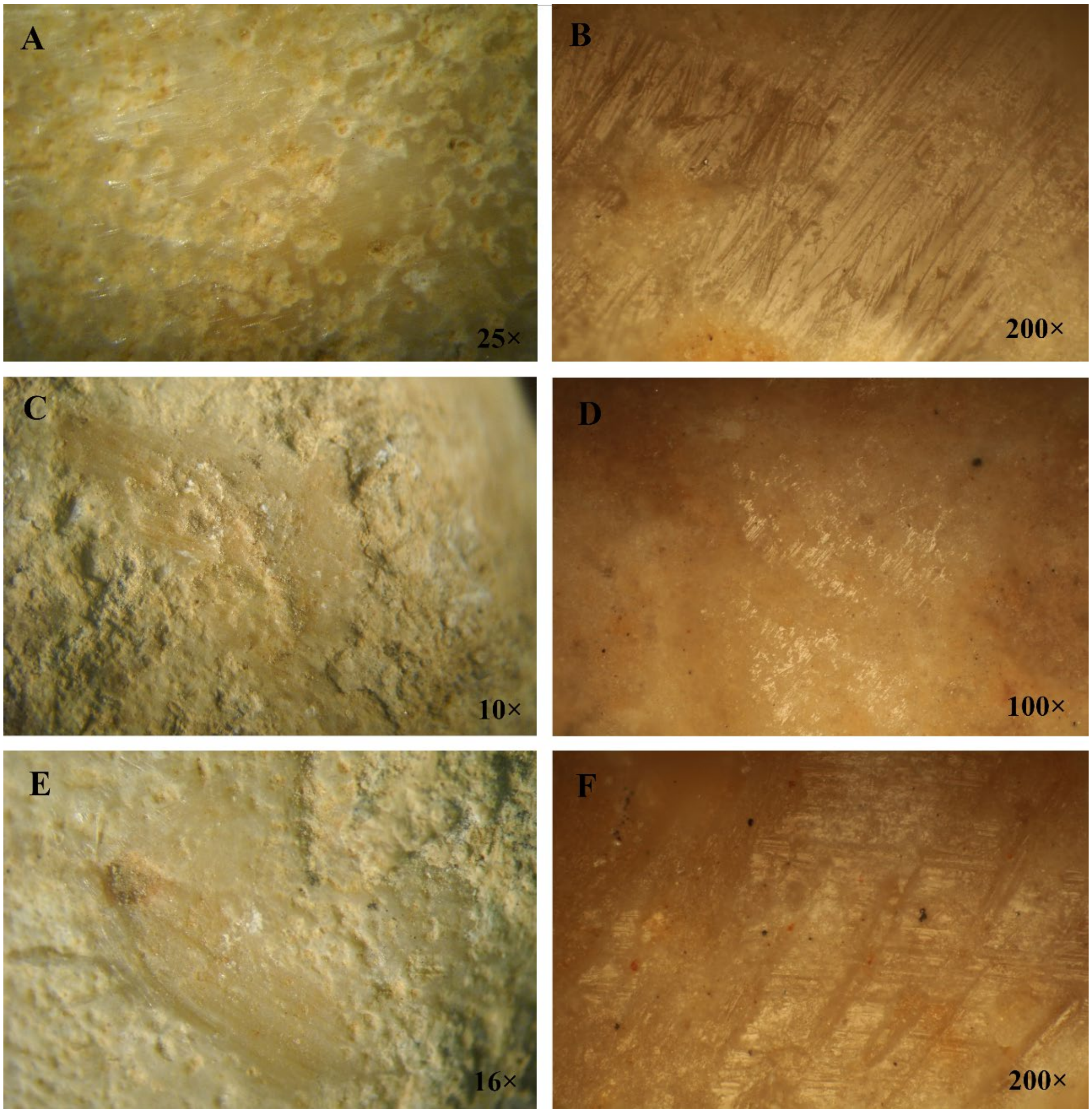

Figure 5.4: Distribution and appearance of micropolish on NRQ-3190. A) Extensive levelling of high topography on zone 1. B) Flat micropolish with striations on zone 1. C) Impact marks and crushing adjacent to zone 2. D) Rough micropolish on zone 2. E) Abraded surface of zone 3. F) Micropolish associated with deep, wide scratches in zone 3.

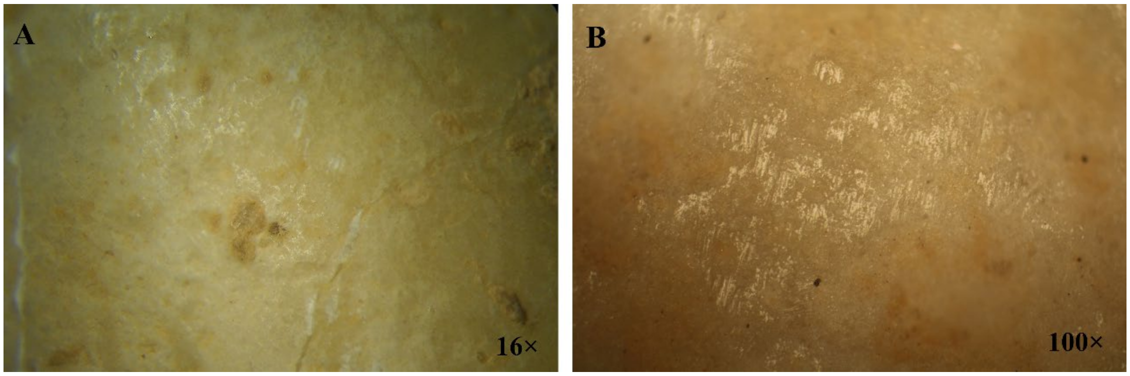

Figure 5.5: Distribution and appearance of micropolish on NRQ-2889. A) Slight reflectivity of high topography. B) Rough micropolish with parallel striations.

Ochre grinding represents another promising task involving the abrasion of a hard material. Unfortunately, the rough, irregular appearance and diffuse, scattered distribution of the experimental ochre grinding polish contrasts heavily enough with the archaeological micropolish as to rule it out as a potential function.

The micropolish on NRQ-3184 (zone 2) and on NRQ-3001 (zone 1) displays unique characteristics compared to the rest of the assemblage. The diffuse margins and extension into low topography suggest that this micropolish can be attributed to contact with an oily and resilient or pliable material. Micropolish on the experimental tools employed in bone breaking, bone comminution, fresh bone abrasion, tendon pounding, and the softening of tanned hide thins as it extends into low topography resulting in margins that are difficult to define. Both cobbles are therefore associated with working animal material although each has a slightly different interpretation.

The micropolish on NRQ-3184 (zone 2) has a relatively rougher texture and lacks linear traces. Of all the experimental tasks, bone breaking and dried hide softening have the most common micropolish characteristics with NRQ-3184 including a rough texture and a limited distribution when viewed under low magnification (Fig 5.6B). Dried hide softening can be confidently ruled out as a potential function due to the defined margins of the micropolish associated with this task. The grip polish observed on the bone breaking tool also bears a high degree of similarity to the micropolish on NRQ-3184. The location of this micropolish on the opposite end of the cobble as the micropolish associated with the abrasion of hard material provides further support for this interpretation.

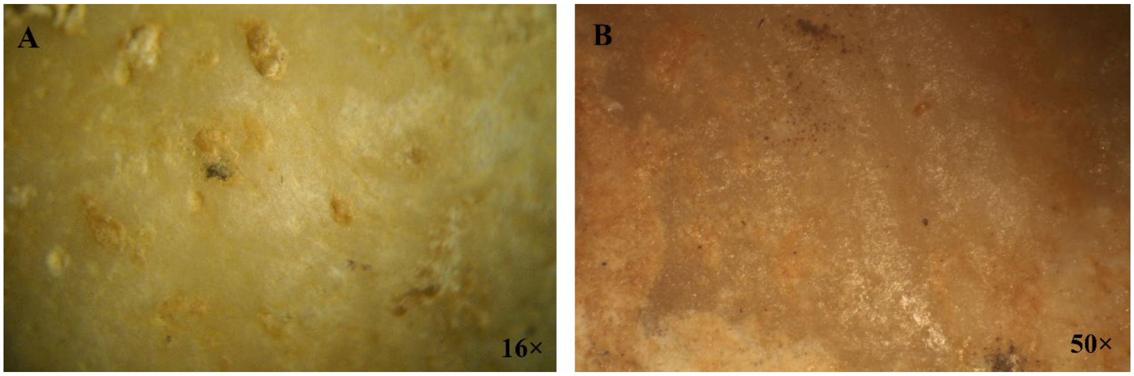

Figure 5.6: Distribution and appearance of micropolish on NRQ-3184 (zone 2) associated with bone breaking and/or grip polish. A) Minor reflectivity and levelling of the surface. B) Rough micropolish which extends into low topography.

The micropolish on NRQ-3001 is distinguished from NRQ-3184 zone 2 by a more fluid texture and the presence of deep, parallel, or isolated striations (fig. 5.7A-B). Based on the presence of these striations, the micropolish characteristics for NRQ-3001 may reflect an abrasive gesture. Fresh bone abrasion and dried hide softening provide the closest parallels although neither task matches well enough to be considered a convincing interpretation. The micropolish from fresh bone abrasion is too thin and the striations are too faint while the boundaries of the dried hide softening micropolish are sharp rather than diffuse. Grip polish can also be ruled out by the depth and abundance of the striations.

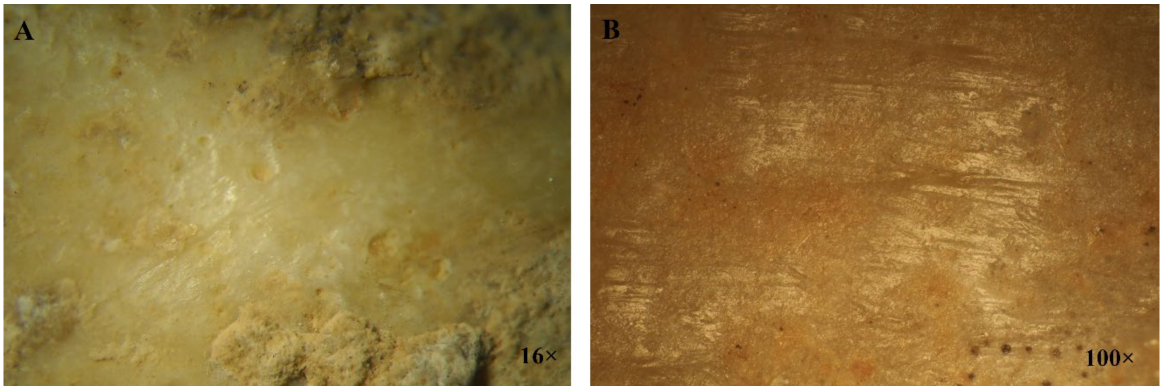

Figure 5.7: Distribution and appearance of micropolish on NRQ-3001 (zone 2) associated with bone breaking. A) Levelled surface with striations. B) Fluid micropolish with parallel striations.

Insights from other bone breaking experiments indicated that the micropolish on NRQ-3001 may be related to bone breaking. Striations were reported on experimental limestone bone breaking implements by Assaf et al. (2020) and Paixão et al. (2021b) suggesting that the development of linear traces may be variable depending on the amount of friction between the bone and the tool and possibly, the duration of use. The absence of fatigue wear in association with the micropolish on NRQ-3184 and NRQ-3001 may indicate shorter periods of use although the extensive development of the micropolish on NRQ-3001 makes this unlikely.

5.4 Analysis: Functional Interpretation of the Upper Sequence GST

In general, comparison between the experimental and archaeological results indicates that the experimental program can account for much of the use-wear on the Upper Sequence GST. Due to the nature of the archaeological use-wear data, proposing functional interpretation is still somewhat complicated as four of the wear patterns are associated with more than one potential function. Which of these proposed tasks were actually conducted is unclear, as it is not possible to distinguish between them with the available data. For wear pattern three, interpretation was limited to a general indication of the gesture and processed material properties with some additional functions proposed based on insights from the use-wear literature. Again, without in-depth descriptions of the wear trace characteristics, is difficult to further scrutinize the potential of any of these functions.

The pictures of the cobbles with sheen document the micropolish characteristics at multiple scales with an adequate level of detail as to support more concrete functional interpretations. Despite this, two of the cobbles present micropolish characteristics that have evaded a specific interpretation.

The following discussion is intended to clarify and strengthen the functional interpretations of the Upper Sequence GST by assessing the likelihood for each proposed task to have actually occurred at Nesher Ramla. This discussion makes use of other lines of evidence from the site, such as the flaked stone and faunal assemblages, and takes into consideration the specific behavioural context in which the GST would have been employed. Each potential task is assigned a degree of confidence based on a combination of use-wear and additional independent evidence. Tasks with a *strong* degree of confidence are supported by both use-wear and independent physical evidence and fit the current understanding of site use. A *moderate* degree of confidence is assigned to tasks that are supported by use-wear evidence and could reasonably be proposed to have been conducted at Nesher Ramla. Independent evidence for these tasks is either indirect or absent. Tasks with a *weak* degree of confidence are not necessarily supported by use-wear evidence and are instead included in this discussion for their potential to account for some of the currently unidentified wear patterns or micropolish characteristics.

Of all the potential functions for the Upper Sequence GST, only bone breaking and flint knapping can be proposed with a *strong* degree of confidence (table 5.6). Previous research efforts have already provided adequate evidence to support the occurrence of these tasks at Nesher Ramla. Percussion marks and a high frequency of green fractures on long bones from the Upper Sequence are related to bone breaking for marrow extraction (Varoner et al. 2021). Identified reduction sequences, as well as the presence of cores and knapping products, in the flaked stone assemblage indicate the nature and frequency of knapping activities throughout the Upper Sequence (Centi and

Zaidner 2020; Varoner et al. 2021). The use-wear results for the Upper Sequence GST not only provide additional, independent evidence for both bone breaking and flint knapping at Nesher Ramla but also identify the implements these tasks were likely conducted with.

Function	**Supporting Evidence**	**Confidence**
Bone breaking	*Use-wear:* wear pattern two, micropolish characteristics for NRQ-3184(zone 2), and NRQ-3001(zone 1). *Faunal:* presence of percussion marks on long bones.	Strong
Flint knapping	*Use wear:* wear patterns one and two, micropolish characteristics for NRQ-3409, NRQ-3195, and NRQ-3190. *Lithic:* cores and reduction sequences are present throughout the Upper Sequence	Strong
Tendon pounding	*Use-wear:* wear patterns one and two.	Moderate
Hide softening (dried/tanned)	*Use-wear:* wear patterns four and five, micropolish characteristics on NRQ-3184(zone 2), and NRQ-3001(zone 1) show some similarities.	Moderate
Bone comminution	*Use-wear:* wear patterns two and four.	Weak
Plant grinding	*Use-wear:* wear pattern four and micropolish on NRQ-3184 (zone 1) and NRQ-2889. *Other:* evidence for Middle Paleolithic plant consumption outlined in section 2.3.2.	Weak
Stone abrasion/ polishing	*Use-wear:* wear pattern three and micropolish on NRQ-3184 (zone 1) and NRQ-2889.	Weak

Table 5.6: Summary of functional interpretations and supporting evidence for the Upper Sequence GST (Centi and Zaidner 2020; Varoner et al. 2021).

Use-wear analysis may also provide evidence for yet unknown activities at Nesher Ramla. Wear patterns one and two are consistent with tendon pounding. Wear patterns four and five are consistent with softening dried or tanned hide while the micropolish characteristics for NRQ-3184 (zone 2) and NRQ-3001 (zone 1) are only somewhat consistent with dried hide softening. Evidence for processed materials, which tend to have poor preservation for these tasks, is absent from Nesher Ramla. Tendon pounding and hide processing are therefore proposed as functions for the Upper Sequence GST with a *moderate* degree of confidence.

Bone comminution is proposed with a *weak* degree of confidence to account for wear patterns two and four. Bone comminution, relative to bone breaking, represents a much more intensive method of extracting fat and nutrients from bone in terms of both time and effort. Cancellous bone must be extensively pulverised to produce sufficiently small fragments which are then boiled in water in order to render the grease (Binford 1978; Costamagno et al. 2013; Morin 2020b; Morin and Soulier 2017; Stiner 2003).

Stiner (2003) outlines three criteria for recognizing bone grease rendering in archaeological contexts: abundant heat-scarred rocks, the presence of pitted anvils, and extensive fracturing of fresh bone, especially cancellous bone. Of the former two criteria, only burnt flints are reported in the Upper Sequence, and the pattern of fracturing on cancellous and compact bone for the Upper Sequence has not been adequately described in order to indicate whether or not bone grease rendering has occurred (Allué and Zaidner 2021; Varoner et al. 2021; Zaidner et al. 2014). Additionally, the earliest evidence for bone grease rendering does not appear in Europe until the late Middle Paleolithic/ early Upper Paleolithic (Castel 2017; Costamagno 2013; Morin 2020b; Stiner 2003).

However, bone comminution may have been conducted for other purposes such as fuel or consumption of the bone fragments themselves (Castel 2017; Costamagno 2013; Morin 2020b; Morin and Soulier 2017). Burned bones at Nesher Ramla have been related to cooking or accidental burning rather than use as fuel (Allué and Zaidner 2021; Crater-Gershtein et al. 2020; Varoner et al. 2021). Still, the possibility remains that cancellous bone was pulverised for direct consumption.

Polishing or abrading of stone objects and plant processing represent two tasks identified from the use-wear literature for their potential to account for wear patterns three and four as well as the micropolish characteristics on NRQ-3184 (zone 1) and NRQ-2889. Neither of these tasks are currently indicated to have been conducted at Nesher Ramla although plant remains are associated with especially poor preservation in open-air settings. It is also possible that any polished or shaped stoned objects may have simply been transported from the site by the inhabitants. The presence of numerous GST which have evaded a convincing functional interpretation at Nesher Ramla highlights the potential of these two tasks for future use-wear analyses.

Typology

The classification of different functional types is based on a combination of gesture, processed material, and when possible, the task(s) each type may have been employed in. The overlap in wear characteristics noted between abraders, polishers, hide-processing stones, and handstones prevented these functional types from being distinguished with the available data. Artifacts bearing wear patterns 3, 4, and 5 are therefore classified as abraders which now serves as a generic category encompassing all tools associated with an abrasive gesture including hide softening, plant grinding, and stone abrasion or polishing. Similarly, all artifacts which were associated with a percussive gesture other than flint knapping are classified as pounders. Functional interpretations for pounders therefore include bone breaking, bone comminution, or tendon pounding.

Artifacts were considered multiple-use tools if they had two or more use-areas with different functional interpretations. Multiple-use tools are distinguished from tools which display two or more use-areas reflecting the same function. These tools are considered to have a single function as they indicate the use of more than one area of the surface for the same task. Most hammerstones have only one use-area although one artifact was noted to display four separate concentrations of fatigue wear traces. The abraders and pounders display only one use-area. Table 5.7 summarizes the distribution and abundances of different functional types throughout the Upper Sequence.

Type	Unit I	Unit IIA	Unit IIB	Total	%
Hammerstone	7	45	41	93	66.91
Pounder		12	4	16	11.51
Abrader		4		4	2.88
Chopper			3	3	2.16
Multi-use Tools					
Hammerstone/ Abrader		8		8	5.76
Pounder/ Abrader	2	2	1	5	3.60
Hammerstone/ Pounder		4		4	2.88
Chopper/ Abrader		2		2	1.44
Chopper/ Pounder		2		2	1.44
Chopper/ Hammerstone		1		1	0.72
Chopper/ Hammerstone/ Abrader		1		1	0.72
				139	**100.00**

Table 5.7: Frequencies of functional types identified within the Upper Sequence.

Hammerstones associated with flint knapping are by far the most abundant functional type represented in the assemblage. Pounders and abraders are represented to a much lesser extent, but still appear throughout the Upper Sequence. The diversity of multiple-use tool types indicates that any one functional type could potentially be employed for a variety of secondary uses. The abundance of multiple-use tools is low (N=23) for the whole Upper Sequence compared to single function tools (N=116).

The majority of choppers are multiple-use tools that also served as hammerstones, pounders or abraders. Use of choppers as hammerstones or pounders was conducted with the extremity opposite of the prepared edge while the face or extremity was exploited for use as an abrader.

For both single-use and multiple-use tools, the distribution of wear on the surface demonstrated a fairly consistent pattern that reflected the requirements of the task at hand. Wear traces indicating that an artifact had been used as an abrader at some point in its life history appear primarily on flat or convex surfaces on the faces of tools and occasionally, on the edges and extremities. Percussive wear indicating use as hammerstones or pounders appears on a variety of locations but is predominantly observed on the edges and extremities of tool surfaces.

Based on the results of the faunal and chipped stone tool assemblage, a trend of decreasing functional diversity towards Unit I was expected for the Upper Sequence GST (Centi and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014, 2018). However, Unit IIA demonstrates the greatest functional diversity with every functional type aside from choppers represented. Unit I displays the lowest functional diversity, which is unsurprising given the relatively low artifact count for this unit.

5.5 Summary

Despite its limitations, this analysis of the Upper Sequence assemblage indicates that cobbles were collected and transported to Nesher Ramla for use in a variety of functions. The identified patterns of wear for this assemblage predominantly reflect the processing of hard or resilient materials with a percussive gesture and the processing of oily and pliable materials through abrasion.

Analysis of the micropolish characteristics enabled more confident interpretations of abrasive wear. The micropolish on a majority of the cobbles displayed a high degree of similarity to one another and was hypothesized to reflect the abrasion of a hard, possibly mineral, material. When these micropolish characteristics were accompanied by fatigue wear on another surface of the cobble, they were related to flint knapping and stone abrasion or plant material grinding when fatigue wear was absent. Although no definitive functional interpretation could be proposed for two of the micropolish zones, they have been cautiously related to bone breaking and/or grip polish.

Flint knapping, which resulted in the most conspicuous wear during the experimental program was unsurprisingly the best represented task with 107 potential hammerstones identified. Bone breaking, bone comminution, and tendon pounding were identified as possible functions for the pounder functional type. Abraders are also represented throughout the sequence and may have been employed for hide softening, stone abrasion, or plant grinding. The abundance and diversity of multiple-use tool types indicates that the boundaries between functional types were flexible rather than strict.

The use-wear results for the Upper Sequence are in line with the results from Unit V as well as indications of site use from other lines of evidence that interpret Nesher Ramla as a hunting camp (Centi and Zaidner 2020; Paixão et al. 2021; Zaidner et al. 2014). Flint knapping and bone breaking activities are supported by use-wear evidence from the Upper Sequence and other carcass exploitation tasks including hide softening, tendon pounding, and bone comminution were also proposed with varying degrees of confidence. The significance of the functional variation demonstrated by the Upper Sequence assemblage, which is associated with a pattern of declining site use intensity, is discussed in the following chapter.

Chapter 6 - Discussion and Conclusions

This chapter begins with a summary of the experimental results and outlines their application in this thesis and contribution to the current body of use-wear data. Potential functions for the Upper Sequence GST relate to technology or subsistence and include knapping, bone breaking, tendon pounding, and hide processing. Wear patterns and micropolish characteristics that have evaded a convincing functional interpretation suggest that additional, yet to be identified tasks may have been conducted at Nesher Ramla.

The functional interpretations proposed for the Upper Sequence GST are relevant for understanding how GST fit into technological and subsistence behaviours at Nesher Ramla. The trends of artifact density and diversity displayed by the GST and flaked stone assemblages from the Upper Sequence are compared to elucidate the changing role of GST during the final stages of occupation. The frequency of bone breaking implements in particular, reveals the role of GST within subsistence at Nesher Ramla through a shift in the pattern of prey selection.

A comparison of GST function between the Upper Sequence and Unit V of Nesher Ramla is then conducted in order to investigate the dynamic role of GST within different patterns of site-use.

A review of GST evidence from Nesher Ramla and other open-air sites analyses these implements through a framework of raw material provisioning strategies proposed by Kuhn (1992). The intent of this is to examine the role of open-air habitation within patterns of land-use through insights into raw material economy and resource exploitation strategies provided by the study of GST function.

In order to encourage research efforts into the study of early GST, this chapter also outlines some recommendations for improving the recognition of *ad-hoc* GST in archaeological contexts that can employed together with an adaptive sampling strategy. This approach is intended to maximize the accuracy and efficiency of research efforts as the sampling strategies for recovery and analysis are selected to best fit the assemblage and research goals at hand.

The final conclusions for this thesis are then presented along with some suggestions for future research into *ad-hoc* GST and an acknowledgement of the research limitations.

6.1 Summary and Application of the Experimental Results

The experimental program and results can account for much of the wear recorded on the Upper Sequence GST and enables functional interpretations to be proposed for many of these artifacts. The descriptions of residue and use-wear characteristics presented in Chapter 4 also expand the pool of available use-wear data for a variety of tasks and contribute to the study *ad-hoc* and limestone GST specifically. This can potentially aid in analyses and functional interpretations of similar tools in the future and demonstrates the replicability of the results of previous use-wear analyses.

The experimental results indicate that pebbles and cobbles employed as *ad-hoc* tools for different tasks can be reliably distinguished by different characteristics of use-wear and to a lesser extent, residues. The gesture involved in use, processed material properties, and the duration of use represent some of the strongest factors identified for their potential to influence the formation and appearance of use-wear and residues.

Percussive tasks are primarily associated with fatigue wear, such as impact marks, pitting, and crushing. However, when applied to oily and resilient processed materials, percussion can also result in the formation of abrasive wear and micropolish development.

For tasks which required an abrasive gesture, the hardness and oil content of the processed material properties influenced the formation of specific types of abrasive wear as well as the appearance and distribution of micropolish. Abrasion of hard, dry materials such as shell and antler resulted in rougher abraded surfaces with more extensive linear traces while micropolish development was limited to the highest areas of the surface topography. When softer and oilier materials, such as hide, are abraded, the leveled surfaces tend to be smoother and flatter. The micropolish associated with these types of materials extends further into areas of low topography on the surface resulting in margins that are difficult to define.

Associating different experimental tasks with specific use-wear characteristics requires observation at multiple scales. The descriptive framework for use-wear traces employed in this thesis (table 3.4) sufficiently encompassed the variation in the appearance of wear traces that were observed under low- and high-power magnification. In fact, this framework was precise enough to distinguish bone breaking from bone comminution which differed only by the type of bone processed in each task.

Unsurprisingly, for all experiments which resulted in discernable wear traces, the distribution and intensity of wear development was noted to increase with the duration of use. Observation at set intervals enabled documentation of the process of wear development and revealed how certain types of wear can influence the formation of other wear. For example, the appearance of micropolish was often preceded out of necessity by the development of leveled surfaces which provided an adequate environment for tribochemical wear formation.

Attributes of macro residues (those observed under low magnification) differ based on their presence on high or low topography. Macro residues on high topography are often distributed as a thin film while powders and amorphous compounds tend to build up in the lower areas between topographic highs. Individual structures of collagen, blood, or fat can be discerned more frequently within these thicker accumulations. The distribution of macro residues was also noted to have an influence on wear formation. Macro residues accumulated in low topography were noted to protect these areas from wear formation, especially during abrasive tasks. For both bone abrasion experiments, and the wood abrasion experiment, the build up of residues from the processed materials also gradually reduced the abrasive capacity of the tools and progress eventually ceased until the residues were removed by washing.

Microscopic observation may be particularly effective for identifying residues with a minimal presence as would be expected in most archaeological contexts. However, micro-residues (observed under high magnification) display overlapping appearances between different processed materials and/or gestures which may prevent their distinction. Collagen tissues were observed following all of the bone processing experiments and show only slight variation in modification between different gestures. For example, a twisted appearance is not a consistent attribute of abraded bone micro residues. There was some distinction however between micro residues from fresh bone, which included both collagen fibers and tissues, and dried bone, which contained only collagen tissues. Additionally, all three hide processing tasks were associated with the same micro residue structures and characteristics.

Observations at the naked eye level reveal that the recognition of *ad-hoc* GST in archaeological contexts may be biased in favour of tools employed with a percussive gesture for working hard and/or oily materials. Experiments with these parameters include flint knapping, tendon pounding, and bone comminution all of which are associated with highly conspicuous wear traces and alteration of tool surfaces that can be more easily discerned without microscopic aid than experiments involving an abrasive gesture and/or softer processed materials. Some recommendations are presented in section 6.4 to help account for this disparity.

Assessments of task viability served as an additional criterion for narrowing down the most likely functional interpretations as certain experiments could be immediately ruled out on the basis of poor efficiency. The experimental tools proved most effective for percussive tasks and were ineffective for the majority of tasks involving an abrasive gesture such as antler, bone, and shell abrasion.

For the tasks which were successful, the viability assessments also provided some indication as to the morphology, size, and working surface properties that are most effective for each task and may be intentionally selected for.

Hide softening and other abrasive tasks were most efficient when conducted with flat or slightly rounded faces on the experimental tools. This provided a large surface area for working a larger portion of the processed material at once and prevented any one specific area of the surface from being worn down rapidly and losing its abrasive quality as a result.

Bone breaking, bone comminution, tendon pounding, and flint knapping were all found to be most effective when conducted on rounded edges or protrusions on the surface of a tool. This appears to concentrate the force of strikes within a small area and enable finer control over where force is directed on the processed material. A sharper edge would have been particularly ineffective for tendon pounding, as many of the fibers would have been severed accidentally. For percussive tasks in general, a sharp edge may possibly undergo fractures and other damage at a higher rate as the strikes would progressively wear away at a pre-existing break faster than an intact cortical surface.

The presence of wear consistent with bone breaking on at least two choppers from Nesher Ramla does however contradict this logic. These artifacts demonstrate that a sharp edge would not only be selected for bone breaking, but that this was one of a few tasks into which time and effort were invested to produce curated tools.

Limestone spheroids and subspheroids from Qesem Cave also demonstrate the use of manufactured edges for bone breaking. These artifacts are especially interesting as they appear to have been transported to the site as finished products specifically for use in bone breaking regardless of their original intended function (Assaf et al. 2020). Experiments by Assaf et al. (2020) and Yustos et al. (2015) suggest that the manufactured blunt edges of spheroids and subspheroids are effective for bone breaking. However, the possibility remains that these artifacts were selected for their composition of high-quality limestone, which is absent from Qesem Cave and its immediate surroundings, rather than for their manufactured forms. Evidence for bone breaking also appears in almost every level of the site while spheroids and subspheroids were recovered from only a few contexts indicating they were not the only implements used for bone breaking by inhabitants (Assaf et al. 2020; Barkai and Gopher 2016). Some potential experiments are outlined in section 6.2.1 that are intended to elucidate the relative efficiencies of different surfaces for bone breaking.

6.2 GST Function in the Upper Sequence and Behavioural Significance

Use-wear analysis of the Upper Sequence assemblage indicates that GST were an integral component of the technological system at Nesher Ramla throughout the final phases of occupation and shifting patterns of site use. Based on context and insights into the functions of *ad-hoc* pebbles and cobbles from archaeological and ethnographic contexts, the predicted functions for the Upper Sequence GST included bone breaking, flint knapping, hide processing, and ochre grinding. Of these tasks, bone breaking and flint knapping are proposed to have been conducted at Nesher Ramla with a strong degree of confidence, hide softening with a moderate degree, while the possibility of ochre grinding was ruled out. Tendon pounding was also identified as a potential function and supported with a moderate degree of confidence. Bone comminution and plant grinding represent additional potential functions that are proposed with a weak degree of confidence for their potential to account for yet unidentified wear patterns and/or micropolish characteristics.

Hammerstones are the most frequent functional type identified throughout the Upper Sequence indicating that GST primarily served technological purposes through use in producing flaked stone implements. Bone breaking is the only subsistence task to be confidently associated with the Upper Sequence GST.

It was also predicted, based on the flaked stone and faunal assemblages, that the Upper Sequence GST would exhibit a pattern of decreasing artifact density and diversity. This trend was generally observed with some surprising deviation in Unit IIA.

Although the occurrence of bone breaking and flint knapping can be reasonably supported through other lines of evidence (Centi and Zaidner 2020; Varoner et al. 2021), identification of the specific tools these activities were conducted with has provided additional insights into behaviours and decisions surrounding their use. The following discussions examine the functions of the Upper Sequence GST in light of what they reveal about changes to site function and in particular, subsistence.

6.2.1 Patterns in Artifact Density and Functional Type Diversity

The frequencies of GST recorded in each unit (table 5.7) show some deviation from the trend of decreasing artifact density that characterizes the flaked stone assemblage (Centi and Zaidner 2020). Hammerstones and all other functional categories of GST increase following the onset of the Upper Sequence in Unit IIB and are most abundant in Unit IIA. Unit I, however, does display a sharp decline in the diversity and abundance of functional types in the final phases of occupation prior to site abandonment.

The most apparent discrepancy between the two lithic assemblages is the abundance and variety of GST functional types within Unit IIA which contrasts the sharp decline in artifact density displayed by the flaked stone assemblage of the same unit. Following Unit IIB, the flaked stone assemblage is characterised by reduced knapping activities, an increased proportion of local Mishash flint at the expense of imported raw materials, and a heavier reliance on expedient reduction strategies (Centi and Zaidner 2020; Ekshtain and Zaidner 2021). This shift in the composition of the flaked stone assemblage, together with declining artifact density, has been related to increasingly sporadic and task-specific habitation at Nesher Ramla during occupation of Units IIA and I (Centi and Zaidner 2020).

Conversely, the variety and quantities of functional types in Unit IIA appears to be reflective of longer phases of occupation involving a greater range of activities. Extended stays at Nesher Ramla may have included additional carcass exploitation tasks such as tendon pounding, hide processing, or bone comminution. The occurrence of these activities at Nesher Ramla is supported only by the resemblance of certain wear patterns with the experimental results. The absence of other evidence for hide working and tendon pounding at the site may simply be attributable to the perishable nature of hide and tendons relative to bone or mineral materials. In addition, other artifact categories currently do not provide clear indications of any additional functions for GST including bone comminution (Allué and Zaidner 2021; Centi and Zaidner 2020; Crater-Gershtein et al. 2020; Varoner et al. 2021; Zaidner et al. 2014). It is therefore possible that whatever tasks were conducted involved processing perishable materials.

Another explanation for the increased functional diversity in Unit IIA is the intensification of tasks conducted with GST regardless of the length of visits to the site. If GST were used more frequently, this would have the effect of increasing the chance that any one cobble would be selected for use more than once. Such repeated and indiscriminate use of cobbles would result in the variety and abundance of multiple-use tools recovered from Unit IIA.

The recovery of the majority of choppers (66.67%) from Unit IIA demonstrates an investment into manufactured tool forms that can be argued to support either scenario. The presence of curated GST forms poses a contrast to the expedient nature of flaked tools from this unit. Alternatively, choppers may signal an intensification of whatever tasks they were employed in, specifically bone breaking.

It remains ambiguous as to whether the abundance and diversity of GST in Unit IIA is due to an expansion of GST function to incorporate new tasks or the result of more intensive use of GST for the same core functions, namely flint knapping and bone breaking. Given its cohesion with artifact categories which indicate increasingly narrow and task-specific site function, the latter scenario seems more likely. Section 6.2.2 further investigates the role of GST in subsistence at Nesher Ramla by examining this potential intensification of bone breaking activities within the context of shifting patterns of prey selection.

6.2.2 The Role of GST in Subsistence

The Upper sequence GST reveal the importance of bone breaking for marrow extraction within the subsistence strategy at Nesher Ramla. Cobbles with potential bone breaking use-wear are noted in all units of the Upper Sequence with the vast majority occurring in Unit IIA (84.00%). The presence of potential bone breaking tools throughout the Upper Sequence suggests this activity persisted as part of the butchery process into the final phases of occupation at Nesher Ramla. Even the single pounder/abrader within Unit I is noteworthy given that only nine cobbles from this unit were analysed.

The relative abundance of bone breaking tools between different units of the Upper Sequence may however reflect changes in the frequency of bone breaking activities over time. The increase in bone breaking implements in Unit IIA occurs around the same time as a shift in subsistence between Unit IIB and IIA during which bone breaking is proposed here to have served as a risk reduction strategy by ensuring a consistent dietary supplement.

Characteristics of the faunal assemblage indicate that bone breaking was part of a complex multi-step butchering procedure at Nesher Ramla. Skeletal element frequencies for Unit III reflect the differential transport of meat and marrow-rich bones from large ungulates while ungulates of smaller body-sizes classes were transported in a more complete state. Once on site, butchery tasks appear to have been consistently relegated to specific areas (Crater-Gershtein et al. 2020). The presence of manuports within spatially isolated concentrations of broken animal bones within Unit IIB indicates that butchery tasks were also subject to some level of spatial organization during at least one later phase of occupation (Zaidner et al. 2014).

Bone breaking has been documented at other Middle Paleolithic sites throughout the southern Levant (e.g. Rabinovich and Hovers 2004; Speth 2012; Speth and Clarke 2006; Stiner 2005; Stiner and Tchernov 1998; Yeshurun et al. 2007). The importance of bone breaking within Middle Paleolithic subsistence strategies is illustrated by the influence of anticipated marrow yields on hunting and butchery practices (Speth 2012). Differential transport of skeletal elements to Amud, Kebara, and Misliya caves, and away from ‘Ein Qashish, favoured elements with high marrow utility indices. Selectivity was more intense for bones of ungulates from larger body-size classes which have both larger marrow reserves and higher transport costs (Hovers et al. 2014; Rabinovich and Hovers 2004; Speth 2012; Speth and Clarke 2006; Yeshurun et al. 2007). Systematic hunting of prime-aged individuals, as demonstrated by faunal assemblages at Misliya, Hayonim, Amud, and Kebara caves, would have also increased the amount of marrow procured from each kill (Rabinovich and Hovers 2004; Speth and Tchernov 1998; Stiner 2005; Yeshurun et al. 2007).

Bone marrow represents a particularly valuable resource for dealing with seasonal nutritional stress. In ungulates and other animals, bone marrow acts a reserve of body fat that is metabolized when all other fat stores have been exhausted (Bar-Oz and Munro 2007; Brink 1997; Speth and Spielman 1983; Stiner 1991). Proposed evidence for the accumulation of long bones for delayed extraction and consumption of marrow at Qesem Cave has been interpreted as a risk reduction strategy in anticipation of seasonal declines in resource availability (Blasco et al. 2019).

Bone breaking for marrow extraction is also documented as part of routine butchery activities conducted by ethnographic hunter-gatherer groups from a variety of climatic contexts (e.g. Binford 1978; O'Connell et al. 1988,1992; Pasda and Odgaard 2011). Compared to lean meat, marrow is less metabolically expensive to digest and richer in both calories and essential fatty acids (Brink 1997; Speth and Spielman 1983). Analysis of bone marrow yields from modern populations of mountain gazelles revealed that despite undergoing seasonal variation in marrow fat content, healthy individuals could still be exploited as a consistent source of dietary fat (Bar-Oz and Munro 2007). Bone breaking can therefore provide a critical source of dietary fat for supplementing nutritional or caloric deficiencies resulting from increased consumption of high-protein lean meats during seasonal times of dietary stress in which plant foods, fish and other alternative sources of fat and carbohydrates are severely depleted (Speth and Spielman 1983).

Given the importance of bone marrow for subsistence, it is not surprising that bone breaking remained a constant part of butchery activities through changing patterns of site use and subsistence at Nesher Ramla when in fact, it may have increased in importance. An overall change in the nature of site use around the onset of Unit IIA is proposed to have involved a shift in prey selection from large ungulates and slow-moving small prey to a more general strategy that incorporated ungulates of smaller body-sizes (Centi and Zaidner 2020). Bone marrow would represent an important nutritional resource within either strategy. In Unit IIB, bone breaking would have related to the exploitation of large ungulates in order to extract the greatest nutritional yield for the lowest expenditure of time and energy. During occupation of Units IIA and I, the supplement of dietary fat and nutrients provided by bone marrow would have eased the stress of relying on lower-ranked ungulate species.

The drastic increase in bone breaking implements in Unit IIA may reflect an expansion of diet breadth in response to reduced availability of preferred resources. A similar expansion of diet breadth proposed at Kebara Cave also involved the exploitation of ungulates with a wider range of subsistence values and occurred during the LMP, although at a slightly later date, 60-55 ka (Speth and Clark 2006; Speth 2013). This hypothetical diet breadth expansion at Nesher Ramla potentially relates to the overall trend of shifting land use patterns and subsistence strategies which was associated with the LMP in Chapter 2 although a more in-depth analysis of the Upper Sequence faunal assemblage is necessary to support this idea. An alternative explanation for the shifting pattern of subsistence in Unit IIA, which implicates morphological change to the karst sinkhole in prompting an overall change in site use, is discussed in section 6.4.2.

6.3 Comparison with Unit V

The comparison of use-wear results between the GST from the Upper sequence and Unit V conducted here has two objectives. The first is to investigate how GST fit into different patterns of occupation within the same site. This discussion also takes the opportunity to examine change in the function of GST over time at Nesher Ramla as the two assemblages are derived from distinct periods of site use and separated by thousands of years. Unit V, dated to early MIS5, represents a peak in site use intensity during some of the earliest phases of occupation while the mid-late MIS5 units of the Upper Sequence encompass the final phases of occupation and the ultimate abandonment of the site (Allué et al. 2021; Tsatskin and Zaidner 2014; Zaidner et al. 2021).

The second intent of this comparison is methodological in nature and concerns the practical elements of research design. Experiments by Paixão et al. (2021b) were performed with a mechanical device which enabled consistency in movement as well as the force applied during use. This extra degree of precision, relative to experiments performed manually, represents an additional variable to be considered. Determining the effects, if any, of the manner in which experimental tasks were conducted on the formation or appearance of wear traces is therefore a necessity for ensuring the applicability of the Unit V results for comparison with those of the Upper Sequence.

Both the mechanical approach favoured by Paixão et al. (2021b) and the manual set-up employed in this thesis are associated own their own advantages and disadvantages. Mechanized experiments enable greater control over task parameters and ideally ensure better consistency between the results of experiments performed by different researchers. The finer details that can be recorded in mechanical experiments also lend themselves well to quantitative analyses of use-wear such as GIS and 3D surface quantification (Delgado-Raak et al. 2009; Paixão et al. 2021b).

Manual experiments represent a more actualistic approach in that conducting the tasks personally provides enhanced insight into the required investments of time and energy. The results of experiments conducted manually can also be expected to better encompass the range of variation in the force applied or angle of motion that surely occurs over the course of even short periods of use by human tool users. This variation includes increased fatigue wear formation during the tendon pounding experiment that was attributed to accidental contact between the active and passive tool. A similar effect on wear formation was reported for other percussive experiments (Cristiani and Zupancich 2021; de la Torre et al. 2013; Titton et al. 2018). An additional, unintended benefit of manual experiments is discovery of grip polish as potential explanation for the micropolish observed on at least one of the Upper Sequence GST.

Despite the differences in analytical application discussed above, the two experimental approaches display broadly similar results for bone breaking and flint knapping which are the two common tasks between both experimental programs (Paixão et al. 2021a,b). The results of the dried acorn grinding experiment reported by Paixão et al. (2021b) were also discussed in Chapter 5 as they indicated that some of the yet unidentified micropolish characteristics and wear pattern may be attributable to grinding acorns or another dry plant material.

The duration of the experiments was recorded differently in each set-up as Paixão et al. (2021b) recorded the number of strikes, while in this thesis the experiments were conducted in set intervals of time. As the longest duration of a mechanical bone breaking experiment, a total of 970 strikes, would amount to a rate of less than 4 strikes per minute if conducted for the full length of the manual bone breaking experiment (270 minutes), the manual experiments can therefore be considered to reflect more extensive use in the following comparison of the use-wear results.

Use-wear formed during flint knapping and bone breaking displays the same characteristics to the naked eyes and under low-power magnification whether the experiments are conducted manually or with a mechanical device. Some differences between the manual and mechanical use-wear results are however perceptible at high magnification and at all scales of observation for residues. Micropolish from the mechanical flint knapping experiment has a flatter texture and covers the surface in a connected pattern where micropolish from the manual flint knapping experiment has a fluid texture and is distributed in loosely connected patches. Bone breaking micropolish is built-up more extensively following the mechanical experiment and has increased reflectivity and a domed morphology in contrast to the dull, sinuous micropolish formed during the manual experiment. Residues are also less extensive following the manual bone breaking experiment and consist of collagen fibers and tissues when observed under high magnification. The distribution and increased build-up of micropolish in the mechanical experiments may be reflective of the manner in which the tasks were performed. A mechanical device would ensure that the same location on the tool came in contact with the processed material with greater accuracy and consistency resulting in wear formation and residues concentrated within a smaller use area. However, it remains possible that another unidentified variable can account for the discrepancies noted between the results.

Consistency in the descriptive framework as well as experimental assemblage composition between the two experimental programs means that bone breaking and flint knapping can be discerned based on the same criteria. Not only does this demonstrate reproducible results for this method of analysis but also the reliability of comparisons made between the results for Unit V and the Upper Sequence.

Consideration must be given to the methods of functional interpretation employed for each assemblage and the depth of comparisons that can accurately be made between the two. As analysis of the Unit V GST assemblage was completed as intended with examination and documentation of use-wear at all scales of observation, any functional interpretations could be made with greater refinement and confidence than for the Upper Sequence GST. This difference serves to undermine the depth to which comparisons between the two assemblages can be made in terms of the frequencies and proportions of different functional types. As such, the comparison conducted below focuses on the function of GST within patterns of declining site use and peak site use intensity.

The typology employed by Paixão et al. (2021a) defines functional types based on the types of wear present and does not distinguish pounders from hammerstones (N=108) as a separate functional type displaying impact marks. The typology employed in this thesis distinguishes hammerstones through their association with flint knapping while pounders are associated with all other percussive tasks. Abraders (N=11) and choppers (N=10) are the other two types in common with the Upper Sequence. Identification of a pebble pestle (N=1) was based on the presence of wear with varied characteristics on the same object. Anvils (N=22), which were characterised by the concentration of use-wear within the centre of the tool surfaces, represent another functional type unique to Unit V.

Hammerstones associated with flint knapping are the most abundant functional type (N=65) constituting 35.14% of artifacts bearing use-wear and are identified by impact marks reflective of contact against a hard mineral material. The presence of similar impact marks on a large portion of the anvils (45.45%) suggests these tools were also utilised for the same task or a similar one. It is interesting that only one hammerstone displays micropolish consistent with abrading hard mineral material. Based on the experimental results of Paixão et al. (2021b) as well as this thesis, micropolish would be expected on a larger portion, if not all hammerstones. This type of micropolish is noted predominantly on abraders which are associated with abrasion or retouch given the absence of impact marks (Paixão et al. 2021a).

Hammerstones from Unit V associated with working hard animal material, possibly bone or antler, are also identified although at a lower frequency (11.35%). Impact marks or micropolish consistent with bone breaking are observed on every functional type making this the second-most common (17.30%) functional interpretation for the Unit V GST (Paixão et al. 2021a).

A small portion of the assemblage, a single hammerstone and abrader, have micropolish that does not show an adequate resemblance to any of the experimental results or the unidentified micropolish characteristics on the cobbles with sheen from the Upper Sequence (Paixão et al. 2021a,b). The defined margins of this micropolish bear a slight resemblance to the micropolish from the manual dried hide softening experiment suggesting an additional unknown function for GST from Unit V involving abrasion of an oily material. Alternatively, this micropolish has also been attributed to post-depositional processes by Paixão et al. (2021a). The variable characteristics, which are consistent with the appearance of the environmental polish noted on several of the experimental tools, provide additional support for this interpretation.

The representation and frequencies of functional types in the Upper Sequence and Unit V suggest that GST function was more or less consistently related to technology and subsistence throughout the occupation of Nesher Ramla. Flint knapping and bone breaking retained their importance as Nesher Ramla continued to function as a hunting camp at which activities were centered around procuring and processing game from the beginning of site occupation until its final stages and ultimate abandonment.

The Unit V assemblage does however reflect greater functional diversity, specifically in the form of anvils and a pebble pestle. Unit V is characterised as one of the most intensive phases of occupation evidenced by the presence of an *in-situ* hearth, burned bones and other combustion features as well as the highest density of bones and artifacts at the site (Friesem et al. 2014; Pietraszek et al. 2021; Zaidner et al. 2014). This mode of occupation may have involved a broader range of activities, either related or unrelated to butchery, that were conducted with GST. Hide softening represents just one task that would fit this scenario and possibly account for the unexplained micropolish characteristics observed on two artifacts. Extensive accumulations of bones with anthropogenic modifications, and flaked stone as well as the presence of anvils could also reflect more intensive flint knapping and bone breaking activities within Unit V.

The general role of GST at Nesher Ramla appears to have remained stable for most of the history of occupation during which the site was consistently exploited as a hunting camp. As part of an adaptive strategy, GST function underwent slight alterations throughout the Upper Sequence. Other artifact categories demonstrate shifts in subsistence, raw material provisioning and site use intensity at the onset of Unit IIA (Centi and Zaidner 2020; Varoner et al. 2021). This is mirrored by the GST of the Upper Sequence which are characterised by a narrowing of function as flint knapping and bone breaking were the primary tasks conducted. Intensive occupation of Unit V involved a broader range of tasks conducted with GST and possibly more extensive bone breaking or flint knapping activity.

6.4 Insights into Open-Air Occupation

Analysis of the GST from Nesher Ramla has provided insights into subsistence and other behaviours that are relevant for understanding the final stages of site occupation. These insights also prompt some broader discussion as to what they can reveal about open-air occupation. The status of Nesher Ramla as an open-air site, although in a unique setting, is also a critical factor to consider in assessing potential causes for the change in site function demonstrated by the Upper Sequence GST and other lines of evidence.

Open-air locations are the setting for diverse range of activities, many of which can only be conducted outside the confines of caves or rockshelters, such as hunting or raw material procurement. Open-air sites also document human habitation and behaviour in a variety of habitats and display differences in lithic assemblage composition compared to cave sites (e.g. Ekshtain et al. 2012; Gilead 1980; Hovers 2017; Hovers and Belfer-Cohen 2013; Sharon and Oron 2014; Sharon et al. 2014). Under conditions with fast deposition of layers, rapid burial of open-air sites can produce a high-resolution record of daily activities (Hovers 2017; Sharon and Oron 2014; Sharon et al. 2014). Studies of Middle Paleolithic residential mobility and land-use patterns indicate that cave and open-air sites represent complimentary modes of occupation in the Levant. When considered together as related components of an overall settlement system, cave and open-air sites better encompass the full range of hominin activities and land-use patterns than either type alone (Ekshtain et al. 2019; Hovers 2017; Hovers and Belfer-Cohen 2013; Meignen et al. 2006; Sharon et al. 2014).

Despite these benefits, open-air sites have been understudied due in part to the fact that they typically yield fewer hominin remains and smaller assemblages than cave sites as well as lingering perceptions of open-air sites as representing short-term habitations (Hovers 2017). As a result, open-air occupation is typically characterised by limited activities centered around a location-specific function. For the Middle Paleolithic this type of habitation includes hunting camps: Nahal Mahanayeem Outlet (Sharon 2018; Sharon and Oron 2014), Quneitra (Goren-Inbar 1990a; Oron and Goren-Inbar 2014), Far’ah II (Gilead 1980; Gilead and Grigson 1984) and lithic workshops: Wadi Zark’aMa’in 2 (Bisson et al. 2014), Givat Rabi East (Ekshtain et al. 2012), Sede Ilan

(Barkai and Gopher 2009), Mount Pua (Barkai and Gopher 2011; Barkai et al. 2002), Sasa and Site 164 (Gopher and Barkai 2014; Barkai et al. 2006).

However, other open-air sites, including Nesher Ramla, reflect more complex, and variable modes of occupation (Centi and Zaidner 2020; Hovers 2017; Sharon et al. 2014). The long Middle Paleolithic sequences at Umm el Tlel and Hummal demonstrate dynamic patterns of site function which vary from ephemeral hunting camps to longer or repetitive habitations with more diverse tasks (Boëda et al. 1998, 2001; Griggo et al. 2011; Hauck 2010, 2011; Le Tensorer et al. 2007; Meignen et al. 2006). At Hummal, these changes in site-use intensity have been attributed to fluctuating water levels with the length or frequency of occupation increasing during wetter periods (Hauck 2011). ‘Ein Qashish has been interpreted as a seasonally occupied camp at which hunting and initial processing of ungulates occurred. The lithic assemblage, which reflects a diversity of functions and mixed raw material provisioning strategies, suggests that ‘Ein Qashish was occupied for short periods as a general habitation site (Ekshtain et al. 2019; Hovers et al. 2008, 2014; Malinsky-Buller et al. 2014).

GST are reported at a few open-air sites in the Levant, typically in small numbers (N<10), with the exception of the larger assemblages from Quneitra and Nesher Ramla (Ekshtain et al. 2019; Gilead 1980; Goder-Goldberger et al. 2020; Goren-Inbar 1990a; Griggo et al. 2011; Hauck 2010; Zaidner et al. 2014). The GST from Quneitra, Far’ah II, and one level of Umm el Tlel (VI1a0) include limestone and basalt artifacts that have been interpreted as hammerstones and anvils employed in bone breaking and knapping based on superficial observations of wear and close proximity to concentrations of broken animal bones (Gilead 1980; Goren-Inbar 1990a,b; Griggo et al. 2011; Oron and Goren-Inbar 2014). These attributes can also be applied to GST present in contexts reflecting more general modes of habitation. This indicates that GST function related strongly to the location-specific tasks conducted at hunting camps but that these tools were also utilized within more general function sites. From these examples, the use of GST for bone breaking appears to be a consistently important component of the butchery process during both the initial processing and consumption of hunting kills (Boëda et al. 2001; Ekshtain et al. 2019; Gilead and Grigson 1984; Griggo et al. 2011; Hauck 2010; Meignen et al. 2006; Rabinovich 1990), as well as later processing that occurred at locations where high value skeletal elements were transported (Boëda et al. 1998, 2001; Meignen et al. 2006).

6.4.1 GST Function within Open-Air Modes of Land-Use

The following discussion incorporates GST evidence from Nesher Ramla and other open-air sites from the Levant (fig. 6.1) with the goal of shedding light on the role of open-air occupation within Middle Paleolithic patterns of land-use. Lithic assemblages at open-air sites are particularly useful for examining land-use patterns through raw material economies and typo-technical characteristics (e.g. Binford 1979; Ekshtain et al. 2012, 2014; Gopher and Barkai 2014; Hovers 1990; Kuhn 1992). Residential mobility, raw material availability, and anticipated needs represent just some factors influencing the composition of lithic assemblages which in turn reflect the lithic provisioning strategy implemented to manage these contingencies (Kuhn 1992).

Provisioning of place and provisioning of individuals represent two alternative, but not mutually exclusive, strategies for ensuring technological requirements are met (Kuhn 1992). Provisioning of places is demonstrated at sites supplied with raw material or tools and lithic assemblages composed predominantly of local materials. This strategy is typical of residential camps with longer occupations and predictable technological requirements (Ekshtain et al. 2014; Hauck 2011; Kuhn 1992).

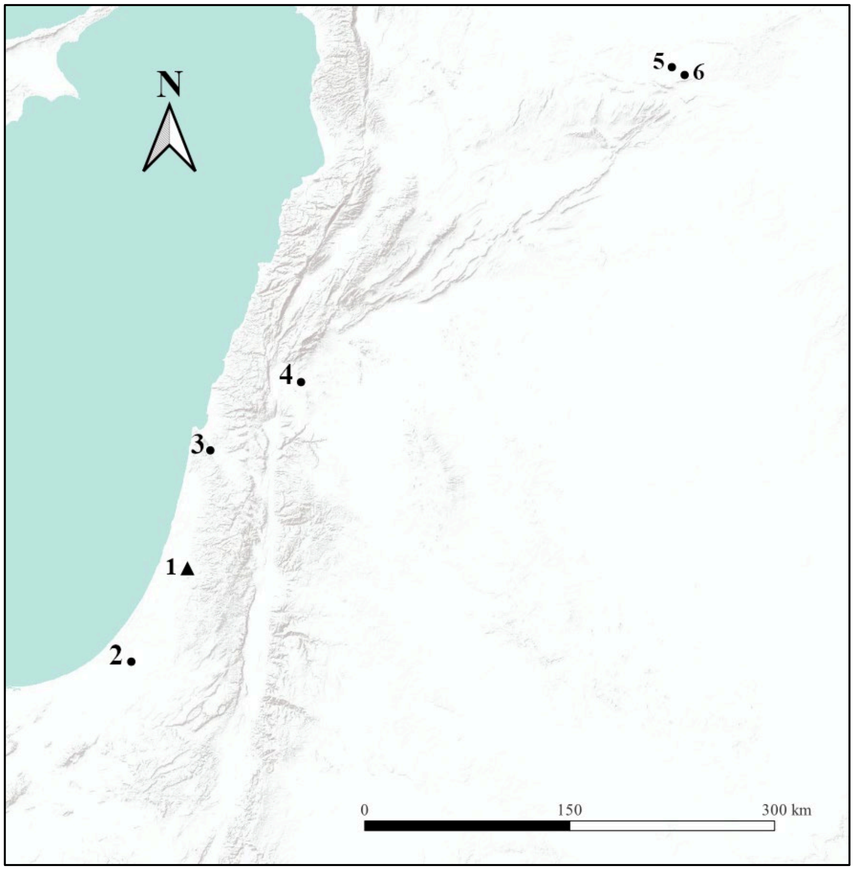

Figure 6.1: Open-air sites with GST in the Levant: 1. Nesher Ramla, 2. Far'ah II, 3. 'Ein Qashish, 4. Quneitra, 5. Umm el Tlel, 6. Hummal.

The provisioning of individuals strategy is characteristic of short-term occupations of task-specific sites and high residential mobility. As part of this strategy, personal toolkits composed of a limited number of tools and cores are retained as insurance against the uncertainty of future needs or opportunities for raw material procurement (Binford 1979; Kuhn 1992). Many caves and open-air sites in the Levant exhibit a mixed or fluctuating pattern of raw material provisioning in which both strategies were relied upon to some extent demonstrating that land-use patterns included complex raw material economies (e.g. Ekshtain et al. 2012, 2014, 2017; Griggo et al. 2011; Hauck 2011; Hovers and Belfer-Cohen 2013; Meignen et al. 2006; Varoner et al. 2021).

Analyses of raw material exploitation are typically focused on characteristics of flaked stone artifacts (e.g. Druck 2020; Ekshtain et al. 2012, 2014, 2017; Finkel et al.

2019; Hovers 1990; Varoner et al. 2021; Wilson et al. 2016). GST are scarce in the Middle Paleolithic and few the examples reviewed above display little variation as they are uniformly expedient tools composed of local raw materials. However, examining the function of GST through this framework can still provide some valuable insight into the nature of open-air occupation within settlement patterns.

At open-air sites, GST were procured from alluvial deposits or outcrops located within short distances from the site and were almost always used without any prior preparation. GST from Nesher Ramla, Far'ah II, Quneitra, Umm el Tlel and 'Ein Qashish GST were recovered in association with concentrations of broken bones or lithics indicating they were discarded immediately after use. Adequate raw material for new GST could then be obtained from similar sources upon moving to a different location as the excessive cost of transporting GST would likely overrule any benefits gained given the large sizes and weights of these tools relative to the rest of the lithic assemblages (Ekshtain et al. 2019; Goder-Goldberger et al. 2020; Goren-Inbar 1990a,b; Griggo et al. 2011; Hauck 2010; Zaidner et al. 2014). This suggests that inhabitants did not anticipate or at least plan accordingly for a shortage of raw materials for future GST use as would be expected in a provisioning of individuals strategy.

Overall, this expedient procurement, use, and discard of GST at open-air sites is strongly reflective of the provisioning of sites strategy. Within this strategy, the large sizes and lack of evidence for transport of GST to and from open-air sites exhibits some resemblances with Binford's (1979) definition of site furniture which incidentally includes large stones employed as hammers and anvils. Such implements may be "installed" for specific activities that are regularly conducted at a site. For inhabitants, these tools constitute a permanent or semi-permanent feature of the site that can be exploited in subsequent phases of occupation.

This classification could apply to GST recovered *in-situ* near concentrations of lithics or broken bones. GST employed as a form of site furniture would serve as a fixed point around which bone breaking or flint knapping activities were organized and result in the previously mentioned spatial patterning for these activities. Limestone objects from ‘Ein Qashish display reworked edges and potential use areas that would fit a designation of site furniture particularly well as efforts to shape these objects reflect their anticipated reuse during seasonal returns to site (Ekshtain et al. 2019).

Site furniture is also noted to have a tendency to be recycled up through successive phases of occupation as it is intentionally recovered upon returns to the site (Binford 1979). This phenomenon is possibly reflected within the long sequences at Hummal and Umm el Tlel, although it may be difficult to convincingly identify. Bone breaking and flint knapping are consistently represented through time at these sites, but GST are not accounted for in each phase of occupation. Alternatively, the presence of potential GST throughout the sequence at Nesher Ramla (Crater Gershtein et al. 2020; Paixão et al. 2021a; Zaidner et al. 2014) suggests that even after repeated occupations, efforts to uncover previously used or cached GST were unnecessary given the ease with which fresh tools could be procured, possibly from the same location.

An alternative classification that might better suit the ephemeral context in which most GST are recovered is situational gear (Binford 1979). As the name implies, situational gear is procured for specific purposes in response to, rather than in anticipation of, technological requirements.

This strategy for acquiring raw material for GST is especially well suited for the pattern of land use demonstrated by the majority of open-air sites. Regardless of site function, open-air occupation was frequently situated near paleolakes, streams, springs, or other water bodies that could be exploited by inhabitants and had the additional benefit of concentrating prey at these locations making them ideal for hunting (Boëda et al. 1998, 2001; Ekshtain et al. 2019; Goren-Inbar 1990b; Griggo et al. 2011; Hovers et al. 2008, 2014). The use of GST as situational gear that were acquired as needed upon successful hunts would also have been facilitated by close proximity to water as the vast majority of the raw material they were composed of originated from alluvial deposits (Ekshtain et al. 2019; Goder-Goldberger et al. 2020; Goren-Inbar 1990a; Griggo et al. 2011; Hauck 2010).

This strategy for provisioning of sites with GST appears to be the most appropriate definition for GST from Nesher Ramla and the majority of the sites discussed within this framework. Modified limestone pieces from ‘Ein Qashish may be best defined as situational gear with the potential to become site furniture (Binford 1979; Ekshtain et al. 2019). GST are generally more frequent in contexts interpreted as short-term hunting camps rather than longer habitations (Ekshtain et al. 2019; Gilead 1980; Goder-Goldberger et al. 2020; Goren-Inbar 1990a; Griggo et al. 2011; Hauck 2010; Zaidner et al. 2014). The use of GST at these sites would have increased the yield from each individual carcass, either through bone breaking or knapping to produce required butchery tools. Overall, the function of GST from open-air sites, regardless of the mode of occupation, appears to demonstrate a low cost, expedient strategy for intensifying the exploitation of resources at a particular location. This strategy would have been especially beneficial at hunting camps as it does not require increasing the length of site visits.

A review of the limited evidence for GST at open-air sites, including the majority of those from Nesher Ramla, has revealed that these tools were expediently acquired and used for bone breaking or flint knapping (Ekshtain et al. 2019; Gilead 1980; Goder-Goldberger et al. 2020; Goren-Inbar 1990; Griggo et al. 2011; Hauck 2010; Zaidner et al. 2014). The GST from Nesher Ramla are somewhat unique among these examples in that they display a wider range functional variation beyond these two tasks. If the Upper Sequence GST were indeed used to complete additional carcass exploitation tasks, this would indicate slight differences in the organization of technology.

6.4.2 GST Function at Nesher Ramla Through the Lens of Open-Air Occupation

The previous discussion relied on GST evidence from open-air sites in order to gain insight into the role of GST within the organization of technology at Nesher Ramla as well as within open-air occupation in general. Studying GST function in the context of open-air occupation also has relevance for understanding the change in function demonstrated by the Upper Sequence GST during the final phases of site occupation.

A trend of decreasing artifact density signals a decline in site-use intensity throughout the Upper Sequence that has been interpreted as a response to change in the morphology of the site. Evidence from GST and other artifact categories indicate this change in site use involved a narrowing of activities as the site was increasingly occupied as a hunting camp for shorter durations (Centi and Zaidner 2020; Zaidner et al. 2014, 2016, 2018).

The influence of morphology on site function is most apparent when considering how occupation of a karst sinkhole would have differed from the typical settings of open-air locales in proximity to bodies of water. Crater-Gershtein et al. (2020) relates the abundance of aurochs and tortoise in the faunal assemblage of Unit III to prolonged stays at Nesher Ramla which enabled additional hunting and butchery activities. Exploitation of large ungulates and slow-moving, small prey is also reflected in the faunal assemblage of Unit IIB. This pattern of prey selection is distinct from those of other open-air sites, where faunal assemblages are predominantly composed of large ungulates, and cave site faunal assemblages, at which tortoises and small ungulates tend to be better represented (Centi and Zaidner 2020; Crater-Gershtein et al. 2020). Occupation of a karst sinkhole may therefore have enabled a unique form of open-air habitation that included extensive butchery and incorporation of lower-ranked prey items in the diet. (Zaidner et al. 2014).

Even if this was not always the mode of occupation, for example during Units IV or VI which indicate lower site use intensity, repeated occupation of Nesher Ramla over thousands of years can also be explained by the unique morphology of the site (Zaidner et al. 2014). Field camps, which serve as short-term task-specific sites within hunter-gatherer settlement systems, tend not to be located relative to previous visits unless they are near resources with static locations (Binford 1980). The karst sinkhole would have acted as a distinctive and constant feature of the landscape that was reoccupied by humans returning to the area for the protective benefits it conferred.

The relationship between site morphology and function can be further examined through the proposed impact of changes to the structure of the karst sinkhole on site-use intensity following Unit IIB. The composition of the GST assemblage as well as other artifact categories indicate that change to the sinkhole morphology over time eventually began to hinder the unique mode of occupation that had originally been supported by sinkhole (Centi and Zaidner 2020; Varoner et al. 2021). Over time, sediment deposition and erosion of the depression walls caused the sinkhole to gradually become shallower and wider. This process reduced the steepness of the depression walls and diminished their capacity for trapping prey. A shift towards shorter and more sporadic phases of occupation subsequently occurred and the range of activities conducted at the site narrowed (Centi and Zaidner 2020; Tsatskin and Zaidner 2014; Zaidner et al. 2016).

As a result, the pattern of site-use at Nesher Ramla became increasingly typical of open-air hunting sites until visits to the site ceased entirely (Centi and Zaidner 2020; Hovers 2017; Varoner et al. 2021). This change in site use would have included the shift in subsistence from exploitation of large ungulates and tortoises to exploitation of ungulates with a broader range of body-size classes at the onset of Unit IIA. The proposed increased frequency of bone breaking activities as a risk reduction strategy in Unit IIA can therefore be attributed to a change in hunting patterns in response to decreasing lengths of occupation rather than the declining availability of preferred resources. Although the site may have gradually declined in importance, the surrounding area may have continued to be exploited after the abandonment of Nesher Ramla through more ephemeral settlements.

6.5 Improving the Recognition and Recovery of GST

The extensive assemblage of GST from Nesher Ramla is the only one of its kind dated to the Middle Paleolithic. It may be that such a large assemblage is a novelty of habitation in a karst sinkhole. However, the exceptional preservation of these artifacts and their systematic collection, are also unique among Middle Paleolithic GST assemblages. Although GST may have been somewhat rare in the Levant during the Middle Paleolithic, the scarcity of these artifacts can also be attributed in part to pedogenic processes at other open-air sites as well as a tendency to be overlooked by research efforts.

Vaquero and Romagnoli (2018) propose that an unequal focus on curated technology over expedient technology is attributable to the presumed advantage of curated technology for studying behaviour. An additional factor proposed for the underrepresentation of *ad-hoc* GST in archaeological research is that their recognition may be hindered by a lack of formalized or manufactured types as well as processing of materials that leave minimal or no detectable use-wear traces (Arroyo and de la Torre 2018; Pop et al. 2018). Encouraging more in-depth studies of these tools can only go so far as long as bias in the recognizability of GST favours those with conspicuous forms and/or use-wear.

In many cases, as with those reviewed in section 6.4, GST are identified based on superficial observations of wear and/or their association with other artifacts. This evidence usually constitutes the sole basis of functional interpretations for GST. Without the use of additional methods, such as multiscale use-wear analysis or comparison with experimental reference collections, this type of approach risks limiting both the recognition of GST in archaeological contexts and the accuracy of functional identifications.

This does not imply that every likely pebble or cobble encountered at a site should always be collected for intensive use-wear analysis in order to be sure nothing has been missed. The following recommendations are intended to balance both efficiency and accuracy when combined with an adaptive sampling strategy for optimizing the study of GST. This approach first attempts to determine the size and distribution of the population, a term which refers to a collection of analytical units within a defined area of study (Binford 1964). These two factors are the basis for selecting which sampling strategy should then be employed for the recovery and analysis of potential GST.

Assessments of potential GST should begin by considering raw material composition. Rocks employed as *ad-hoc* GST are often composed of local material acquired from within a short distance of the site (e.g. Barksy et al. 2015; Ekshtain et al. 2019; Goder-Goldberger et al. 2020; Goren-Inbar 1990a; Griggo et al. 2011; Hamon 2008) with the exception of some materials procured on-site or from longer distances (Alperson-Afil and Goren-Inbar 2016; Assaf et al. 2020; Cristiani et al. 2012; Rosso et al. 2016). Intentionally transported items may also stand out from the background sediment due to their relatively large sizes (Roche et al. 2018). Additionally, the presence of distinctive patinas on the surfaces of shaped stone balls from Qesem Cave has been attributed to their transport from a different environmental setting for opportunistic use as *ad-hoc* tools (Assaf et al. 2020). The presence of transported raw materials does not necessarily guarantee they were used but can still indicate objects that should be selected for further examination. Imported material may be a particularly useful characteristic for identifying GST with less conspicuous use-wear formation.

The presence of conspicuous use-wear that can be discerned upon initial examination is another useful attribute for recognizing potential GST in archaeological contexts. The experimental results presented here and in other literature (Arroyo et al. 2016; Benito-Calvo et al. 2018; Cristiani et al. 2012; de la Torre et al. 2013; Paixão et al. 2021b; Roda Gilabert et al. 2012; Titton et al. 2018) suggest that a percussive gesture and a hard processed material are the task parameters typically associated with highly visible use-wear traces such as impact marks and pits. Striations and polish may also be more prominent on tools used to abrade hard and/or oily materials (Adams 1988, 1989, 2002; Dubreuil 2004; Robitaille and Briois 2019; Roda Gilabert et al. 2012). Identification of use-areas can therefore include some initial predictions regarding the gesture of use and processed material properties although this should not replace multi-scale observations and a proper comparative basis for interpreting use-wear.

The context of potential GST can provide an indication of use regardless of the presence of conspicuous use-areas. Cobbles, pebbles, blocks, and other rock morphologies observed in association with concentrations of broken bones and knapping waste at a number of sites have been interpreted as bone breaking and flint knapping implements, respectively, on the basis of this association (Ekshtain et al. 2019; Gilead 1980; Goder-Goldberger et al. 2020; Goren-Inbar 1990a,b; Griggo et al. 2011; Hauck 2010). Additionally, the distribution exhibited by potential GST and processed materials at some sites has been related to spatial organization of tasks performed with GST (Cristiani et al. 2012; Ekshtain et al. 2019). GST recovered in pairs from Olduvai Gorge indicates these items were used together as active and passive implements (Arroyo and de la Torre 2020; Leakey and Roe 1994). The distribution of potential GST can also be used to discern the spatial structure of the population by revealing interrelationships between different elements within the overall technological system or pattern of site use (Binford 1964).

Any one of the above characteristics alone can be used to identify potential GST that should be collected for further analysis. The presence of transported materials together with the spatial distribution of these objects may be an effective means of recognizing GST with no discernable wear traces. Although most of these characteristics are already used to identify and interpret GST, this approach should be implemented with the intent of alleviating some of the bias in recognition of potential GST.

Once a reliable estimate of the size and distribution of the population has been obtained, optimal strategies for the collection and analysis of potential GST can be determined. Ideally, every potential GST should at the very least be collected and analysed. In situations with very large populations or intense time constraints, it may be necessary to implement a strategy for selecting a sample of the population for recovery or analysis that is sufficiently representative of the entire population. In order to ensure this, the sample must be large enough to encompass an adequate amount of variation that exists within the total population. For populations that appear to display a wide range of variation in GST function and/or form, a larger sample will be required to ensure sufficient representation (Binford 1964).

Random sampling constitutes the most robust method for preventing bias in sampling as each artifact has an equal chance of being selected and artifacts are selected independently of one another. In stratified sampling, the population is divided by a meaningful attribute into different classes which are then sampled from separately. This strategy would prove particularly useful for investigating spatial organization by sampling GST from different areas of a site as separate classes and examining the degree of functional variation between each class (Binford 1964). Raw material composition and morphology represent other interesting attributes to investigate for their relationship with function through stratified sampling.

The sampling strategy originally planned for the analysis of the Upper Sequence and recommended here is a mixed strategy of random sampling with the intentional selection of additional artifacts based on the presence of promising use-wear. While less robust than purely random sampling, the benefit of a mixed strategy is that it can direct the focus of research efforts towards objects with the highest potential of having actually been used.

6.6 Conclusions

Studies of GST from Lower Paleolithic contexts in the southern Levant have provided insight into early technology, subsistence practices, and cognition (e.g. Alperson-Afil and Goren-Inbar 2016; Assaf et al. 2020; Goren-Inbar et al. 2002; Hovers et al. 2003). Due to the scarcity of GST evidence for the Middle Paleolithic, these tools have been understudied and their role within Middle Paleolithic lifeways is currently poorly understood. The analysis of an assemblage of *ad-hoc* GST from Nesher Ramla conducted in this thesis has helped to shed light on the role of GST in Middle Paleolithic behaviour including patterns of subsistence, site-use, and residential mobility.

Pebbles, cobbles, or blocks employed as *ad-hoc* tools without any prior shaping or preparation constitute some of the earliest forms of GST and may also represent an important ancestral stage in the evolution of more complex stone tool types (e.g. Arroyo and de la Torre 2016, 2018, 2020; Arroyo et al. 2020; Caruana et al. 2014; de Beaune et al. 2004; Harmand et al. 2015). *Ad-hoc* GST at Early Stone Age and Lower Paleolithic sites in Africa and the Levant were apparently exclusively used in percussive gestures for knapping, bone breaking, and nut cracking (e.g. Alperson-Afil and Goren-Inbar 2016; Arroyo and de la Torre 2016, 2018, 2020; Assaf et al. 2020; Goren-Inbar et al. 2002; Roche et al. 2018; Shea and Bar-Yosef 1999). In later contexts, the functions of *ad-hoc* GST appear to have expanded as abrasive or mixed gestures were applied to a variety of novel plant, animal, and mineral materials (e.g. Cristiani et al. 2012, 2021; Dubreuil and Nadel 2015; Hovers et al. 2003; Mercader 2009; Revedin et al. 2010, 2015).

The experimental program was therefore designed with the goal of filling in the knowledge gap regarding the function of Middle Paleolithic *ad-hoc* GST from the southern Levant. Activities were selected for investigation based on previous studies of archaeological *ad-hoc* GST, ethnographic accounts for the use of these tools, and contextual evidence from Nesher Ramla that supports the occurrence of flint knapping, bone breaking, and possibly, other carcass exploitation tasks.

The experimental results proved useful, not just for functional identification of the Upper Sequence GST, but also for their contribution to the pool of use-wear data for *ad-hoc* and/ or limestone GST which may aid studies of similar tools in the future. Insights from the examination of the experimental tools at various scales of observation were also applied in this chapter to identify attributes which can improve the recognition of *ad-hoc* GST in archaeological contexts. These attributes can be integrated with an adaptive sampling approach for recovering and analyzing GST in order to reduce bias in research efforts which may favour *ad-hoc* GST with highly conspicuous wear.

The blind test results also contributed to this discussion by revealing the degree to which different factors affect the recognizability of use-areas and use parameters. Identification of used surfaces and use parameters represent the least successful portion of the blind test although this appears to be more reflective of flaws in the design of the protocols themselves. The most problematic of these flaws is the failure to account for unfamiliarity on the part of the blind tester with the specific raw material and processed materials. Some recommendations are outlined in Appendix B which can help address this issue and further improve the robusticity of the protocols. Despite problems with the design of the protocols, the blind test results displayed a high degree of consistency in the identification and characterization of wear traces and demonstrate the reliability of the experimental use-wear results for interpreting the functions of the Upper Sequence GST.

In light of restrictions on international travel which prevented me from analysing the Upper Sequence GST in person, a modified approach for use-wear analysis was developed to make the most effective use of the data that were actually accessible to me. This modified approach consisted of two separate methods of analysis for each available source of use-wear data.

The database which consisted of extensive, but preliminary, observations recorded for cobbles recovered from the Upper Sequence was used to identify patterns of associated wear traces. These wear patterns were then compared to the experimental results and other use-wear literature in order to identify a range of tasks which may result in the appearance of the same suite of use-wear traces.

The pictures and accompanying notes for six cobbles bearing highly visible sheen enabled detailed descriptions of the micropolish and other wear traces on these items. The micropolish characteristics were then interpreted based on the experimental results and other use-wear literature in terms of gesture, processed material, and for many artifacts, the actual tasks they were used in.

Functional interpretations for the Upper Sequence GST suggest that these tools were intentionally collected and transported to Nesher Ramla for use in flint knapping, bone breaking, and potentially other carcass exploitation tasks. Integration of GST evidence with other artifact categories at the site revealed a strategy of intensive land-use that exploited the unique morphology of the site. The GST from the Upper Sequence generally follow the trend of gradually declining site-use intensity and artifact density with the exception of Unit IIA. Two opposing explanations for this variance have been proposed. The first is that GST functional diversity may have expanded to accommodate additional carcass exploitation tasks such as hide processing, tendon pounding, or bone comminution despite indications of decreasing site visit duration (Centi and Zaidner 2020; Varoner et al. 2021). The second, and better supported explanation relates the apparent increase in functional diversity to indiscriminate and intensive use of GST for the core tasks of bone breaking and flint knapping as visits to the site became increasingly short and sporadic (Centi and Zaidner 2020).

This shift in site-use has been attributed to morphological change to the karst sinkhole during the later phases of occupation at Nesher Ramla. As the sinkhole was gradually filled in over time, the walls also became less steep (Tsatskin and Zaidner 2014; Zaidner et al. 2016). Without this unique feature to encourage longer phases of occupation, the pattern of site-use became increasingly typical of open-air occupation (Centi and Zaidner 2020; Hovers 2017; Varoner et al. 2021). This included a shift in subsistence from the exploitation of large ungulates and slow-moving small prey to a more general pattern in which ungulates with wider range of body-size classes were hunted as tortoises declined in importance (Centi and Zaidner 2020; Varoner et al. 2021; Zaidner et al. 2014). Although bone breaking appears to have been an important part of the butchery process throughout the history of occupation, the fat and nutrients within bone marrow would have represented a particularly valuable dietary supplement when lower-ranked ungulate species were relied upon more frequently. The increased frequency of knapping and bone breaking in Unit IIA is therefore proposed to reflect more intensive butchery activities which were prompted by a shift in subsistence as well as the overall pattern of site use.

Comparison with the GST from Unit V supports the notion that GST function was relatively consistent but also varied somewhat with the mode of occupation. Unit V exhibits one of the most intensive phases of occupation with high densities of artifact deposition matched by an increased diversity of GST functional categories (Allué et al. 2021; Tsatskin and Zaidner 2014; Zaidner et al. 2021).

This relationship between site function and GST function is observed at other open-air sites where GST are present. When examined through a framework of raw material provisioning strategies and technological organization, GST from open-air sites typically reflect the provisioning of sites with situational gear (Binford 1979; Kuhn 1992). Adequate raw material could often be acquired from the surrounding area or the site itself for producing flaked tools or for bone breaking as needed upon successful hunts. The GST at Nesher Ramla and other open-air sites are sites are proposed to represent an expedient strategy for intensive exploitation of location-specific resources.

6.6.1 Recommendations for Future Research

Wear pattern three and the micropolish characteristics on two of the Upper Sequence GST have so far evaded convincing functional interpretations although estimates of the gesture and processed material properties were possible. A few tasks with similar parameters, which are outside the scope of the experimental program, have already been identified and are suggested here for their potential to account for the unidentified wear on the Upper Sequence GST.

Abrasion or polishing of stone objects may account for wear pattern three or the micropolish characteristics indicating abrasion against a hard mineral material (Dubreuil 2004; Stepanova 2019). No stone objects bearing evidence of abrasion or polishing have been reported at Nesher Ramla, so it is unclear what purpose this sort of task would have served at the site. Alternatively, the formation of polish on grabbro pebbles employed in retouch experiments by Robitaille and Briois (2019) and on various tools used to grind dried plant materials present other promising avenues of research (Cristiani and Zupancich 2021; Dubreuil 2002, 2004; Paixão et al. 2021b).

GST have served as proxies for investigating early consumption of plant food resources in the southern Levant, Africa, and Europe (e.g. Barton et al. 2012; Cristiani et al. 2021; Dubreuil and Nadel 2015; Goren-Inbar et al. 2002; Mercader 2009). Limited evidence from Middle Paleolithic sites suggests that a variety of plant foods were consumed prior to the intensive consumption and domestication of plant foods described by the Broad-Spectrum Revolution hypothesis during the Upper Paleolithic (Albert et al. 2000; Flannery 1969; Goren-Inbar et al. 2002; Henry et al. 2011; Lev et al. 2005; Madella et al. 2002; Melamed et al. 2016; Rosen 2003). The tools used to process these early plant resources may have been expedient and lacked a recognizable form if this consumption was sporadic enough at first as to not justify an investment in time and effort for shaping or preparing these tools for use. Cracking and grinding of pistachio nuts and acorns and grinding of legumes, edible roots and tubers, and wild cereals such as wheat (*Triticum* sp.), barley (*Hordeum* sp.), and goat grass (*Aegilops* sp.) represent some promising options for plant processing experiments conducted with *ad-hoc* tools.

A dolomite cobble from Tabun Cave reported by Shimmelmitz et al. (2021) suggests that there are other, yet to be identified, abrasive functions for *ad-hoc* GST. Use-wear on the Tabun Cave cobble has been related to the abrasion of a soft material. Some similarities can also be noted between the dull, rough micropolish on this implement and the experimental tool used for dried bone abrasion in this thesis. The presence of rounded topography and levelling in association with this micropolish suggests that contact with dried bone through a percussive gesture could result in the wear pattern observed on the Tabun Cave abrader. Storage of dried bone for delayed marrow consumption, which has been documented at Qesem Cave, represents another subsistence behaviour that could be investigated through dried bone breaking experiments (Blasco et al. 2019).

Additional bone breaking experiments should be conducted to examine the relative efficacy of different surfaces including naturally rounded surfaces, the blunt edges of spheroids or subspheroids, and the sharp edges of choppers. These experiments will enable an examination of the investment demonstrated by the use of manufactured tools for bone breaking at sites such as Nesher Ramla, Qesem Cave, and Olduvai Gorge where bone breaking is already proposed to have been conducted with other implements including *ad-hoc* tools (Arroyo and de la Torre 2016, 2018; de la Torre et al. 2013; Mora and de la Torre 2005; Paixão et al. 2021a).

The GST evidence from open-air sites discussed in section 6.4 suggests that these tools were used expediently for intensive exploitation of location-specific resources. An in-depth analysis of GST from multiple open-air sites would permit a critical assessment of this proposal by identifying and comparing the functions of GST from different types of open-air habitations with a greater degree of confidence. Such an analysis could also incorporate GST evidence from cave sites in order to examine GST function across the full range of Middle Paleolithic patterns of settlement.

6.6.2 Limitations

As I was prevented from analyzing the Upper Sequence GST through the originally intended protocols for use-wear and residue analysis, this represents the most obvious research limitation for this thesis. Extensive considerations were made as to the optimal means of accounting for this. I was fortunate to have access to preliminary data and photographs provided by Laure Dubreuil and Laura Centi as alternative sources for use-wear data. Consolidation of these sources into a single database has enabled at least some level of analysis of the Upper Sequence GST although functional interpretations were accordingly limited. Functional interpretations therefore consist of the range of tasks identified from the experimental results and other use-wear literature that can potentially account for the wear patterns recorded on the Upper Sequence GST. Identification of flint knapping and bone breaking as functions for the GST are also supported by independent evidence (Centi and Zaidner 2020; Varoner et al. 2021).

Sample size presents an additional limitation as an unknown proportion of the Upper Sequence GST were recorded in the database or photographed. Originally, I had intended to analyse the entire assemblage or as large of a sample as possible in light of any time constraints. A larger sample size would more accurately represent the whole assemblage. Analysis of the entire assemblage would also have provided a more concrete indication of the frequency of each functional type and the proportion of used to unused objects. Information regarding the distribution and frequency of functional types in different areas of the site would have also permitted an investigation as to whether tasks conducted with GST were subject to spatial organization.

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Appendix A - *Ad-hoc* GST from Archaeological and Ethnographic Contexts.

A.1 *Ad-hoc* GST use in Africa and Europe (Organized by Chronology and Region).

Context	Description	Basis for interpretation	Source
ESA African contexts			
West/ East Turkana, Kenya			
Lomekwi 3, 3.3 Ma Lomekwian	Multiuse tools include worked cobbles and other artifact categories that were employed in both pounding and flaking tasks as anvils, cores, or active implements.	Comparison with other ESA anvils and experimental reference assemblage.	Harmand et al. 2015
Lokalalei 2C 2.3 Ma Oldowan	Cobbles collected from local outcrops for use as knapping hammerstones. Pitted stones associated with nutcracking. Cores reused for percussion.	Use-wear analysis and comparison with an experimental reference assemblage	Arroyo et al. 2020
Kokiselei 1 1.79 Ma Oldowan	Fractured cobbles associated with bone breaking or nut cracking. Active percussion implements reused as cores.		
Kokiselei 4 1.76 Ma Early Acheulian	Knapping hammerstones re-used as cores.		
Naiyena Engol 2 c.1.8-1.7 Ma Oldowan	Reused core and pitted object used as anvils for bipolar knapping.	Observation under low and high-power magnification.	Delagnes and Roche 2005; Roche et al. 2018
Koobi Fora ~1.6 Ma Oldowan	Basalt cobbles identified as knapping hammerstones.	3D surface analysis and experimental reference collection.	Caruana et al. 2014
Olduvai Gorge, Tanzania			
Beds I and II 1.84-1.48 Ma Oldowan	Indiscriminate use of quartzite blocks as anvils or active implements for bone breaking and or nut cracking.	Low magnification observation and spatial analysis of wear. Experimental reference collection.	Arroyo and de la Torre 2016; de la Torre et al. 2013; Mora and de la Torre 2005
HWK EE 1.7 Ma Oldowan	Pitted stones and cobbles employed as hammerstones and anvils for bipolar knapping. Other cobble morphologies and anvils associated with bone breaking or nut cracking. Percussive tools were reused as cores.	Low magnification observation of wear.	Arroyo and de la Torre 2018
EF-HR 1.6-1.5 Ma Acheulian	Large size of cobbles employed as knapping hammerstones related to production of large flakes. Percussive tools were reused as cores.		
Beds III and IV	Pitted stones associated with bipolar knapping and flake splitting.	Low magnification observation, spatial analysis, 3D analysis, and	Arroyo and de la Torre 2020

~1.3 Ma and 0.6 Ma Acheulian		experimental reference assemblage.	
Later African contexts			
Sai Island, Sudan 220-150 ka	Elongated chert pebbles were selected from the local environment for as preferred material for ochre grinding. Quartzite cobbles employed in plant grinding.	Yellow and red ochre adhered to the cobbles. Wear and polish on quartzite cobbles. Phytoliths and starch grains recovered from the quartzite cobbles.	Van Peer et al. 2003, 2004
Ngalue, Mozambique 105-42 ka	Cobbles identified as cores and core tools repurposed as expedient tools for grinding plant food.	*Sorghum* starch grains recovered from the surfaces of stone tools.	Mercader et al. 2009
Bloombos Cave, South Africa ~100 ka	A quartzite core and cobble were part of complex toolkits for ochre production that included bone, charcoal, grindstones, hammerstones, and abalone shells in which ochre was mixed and stored.	Observation of ochre stains and wear related to grinding and percussion on the core and cobble.	Henshilwood 2011
Sibudu rock shelter 71-77 ka	Flat grindstones and an abraded pebble were used for mixing, crushing, and grinding of ochre	Low magnification observation of wear and ochre residues.	Wojcieszak and Wadley 2019
Porc-Epic Cave, Ethiopia ca. 40 ka	Active and passive ochre grinding implements were composed of a variety of different rock types that ranged in origin from the local environment of the site to requiring transport from distances up to 30-50 km. The use of a diverse range of rock types for ochre processing tools reflects efforts to control the colour and granularity of the ochre powder.	Low magnification observation of wear and ochre residues.	Rosso et al. 2016
Haua Fteah Cave, Libya c.31 ka	A limestone cobble with a pecked surface was identified as an upper grinding implement for plant processing.	Low and high-power observation of use-wear and starch grains from Triticeae grasses.	Barton et al. 2018
Europe			
Barranco León, Spain 1.4 Ma Oldowan	Limestone cobbles with rounded morphologies, were selected for knapping. Cobbles with angular fractures were possibly used for bone breaking. Large slab-like morphologies identified as anvils for knapping and bone breaking.	Morphometric analysis and experimental reference collection	Barsky et al. 2015; Titton et al. 2018
Fuente Nueva 3, Spain ca. 1.2 Ma Oldowan	Limestone blocks and cobbles employed as hammerstones and anvils for bipolar knapping. Anvils were associated with bone breaking.	Morphometric analysis and experimental reference collection	Barsky et al. 2015
Neumark-Nord 2/2, Germany 121 ± 5 ka	Hammerstones were identified by globular shapes and smaller sizes relative to anvils, were associated with knapping or bone breaking. Larger cobbles with flat morphologies	Examination of wear under low-power magnification	Pop et al. 2018

	were identified as anvils for knapping or bone breaking.		
Inden-Altdorf, Germany ca.120-100 ka	A sandstone cobble was used to wipe pitch from the sharp edges of hafted tools following hafting procedures.	Observation of wear at low and high magnification. Birch pitch residues.	Pawlik and Thissen 2017
Grotta Paglicci, Italy 32 600 ya	Elongated sandstone cobble used for grinding plants including oat (*Avena*).	Observations at low and high magnification, 3D surface analysis, and starch grains recovered from the surfaces of the tool.	Mariotti Lippi et al. 2015; Revedin et al. 2015
Kostienki 16, Russia 31 904 ± 698-28 087 ± 253 cal BC	Sandstone cobbles identified as grindstones and grinder-pestles for grinding wild plants such as Cattail (*Typha*) and fern (*Botrychium*).	Observations at low and high magnification, and starch grains recovered from artifact surfaces. Comparison with an experimental reference collection.	Revedin et al. 2010
Pavlov IV, Czech Republic 29 482 ± 288-28 985 ± 337 cal BC			
Bilancino, Italy 28 298 ± 301 cal BC			
Dolni Vestonice I, Czech Republic	A flat, elongated sandstone cobble used as active and passive implement for grinding plants such as Poaceae and *Triticum* grasses.	Observations at low and high magnification, 3D surface analysis, and starch grains recovered from artifact surfaces. Comparison with an experimental reference collection.	Revedin et al. 2015
Riparo Dalmeri, Italy 13 400 -12 900 Cal. BP	Limestone and siltstone cobbles employed as hammerstones for knapping and abrasion of cores. Abraded cobbles were identified as polishers for stone abrasion and hide working with and without ochre treatments. A flat, limestone slab was employed as a cutting surface and for grinding ochre.	Observation under low-power magnification and comparison with an experimental reference collection	Cristiani et al. 2012
Font del Ros, Spain 10 400 - 8450 cal. BP	Pitted cobbles of various materials were potentially identified as hammerstones or anvils for bipolar knapping.	Observation under high and low-power magnification and comparison with an experimental reference collection	Roda Gilbert et al. 2012
Romagnano Loc III rockshelter, Italy 9618-5280 cal. BC	Flat pebbles with convex surfaces were identified as active hide processing implements. Pebbles of various materials were identified as hammerstones employed in knapping, bone tool production or working hard animal material. Two pebbles were	Observations at low and high magnification, 3D surface analysis and comparison with an experimental reference collection. Starch grains from oak acorns (*Quercus*	Cristiani et al. 2021

	identified as active and passive tools for grinding plant foods.	*sp.*) and Paniceae grasses, animal tissues, and ochre residues.
Pradestel rockshelter, Italy 8734-5661 cal. BC	A rounded cobble was identified as a passive tool for hide working with ochre. A flat elongated limestone cobble was employed for percussion against hard animal material and retouch. A porphyry cobble with a flat, concave surface was associated with plant grinding	

Table A.1: Summary of functional interpretations for ad-hoc pebbles and cobbles from early African and European contexts.

A.2 Ethnographic Accounts for the Selection, Acquisition, and Use of *ad-hoc* Pebbles and Cobbles (Organized Alphabetically by Author).

Processed Material or Task/ Gesture	**Description of use/ tool**	**Population/ Region**	**Source**
Hide processing *Abrasion*	Rough pumice rocks were used to rub skins during the tanning process.	Pomo, California	Barrett 1952
Nut cracking *Percussion*	Stones used as anvils or hammerstones to crack acorns were selected based on convenience.		
Knapping *Percussion*	Small, unprepared pebbles were used flaking obsidian or chert.		
Bone breaking for marrow *Percussion*	A long narrow stone was used to strike the long bone or held in the hand while the bone is swung down to strike the stone.	Nunamiut, Alaska	Binford 1978
Hide processing *Abrasion*	Buffalo skins were heated by fire and softened by rubbing with a pumice stone.	Fort Belknap Assiniboine, Montana	Dening 1930 as cited by Rodnick 1938
Tendon pounding *Percussion*	Tendons from the spines of moose were pounded to separate them into finer threads.	Acadians, North America	Denys 1908
Pounding plant material *Percussion*	Elongated pebbles were collected from fields and used with wooden mortars to crack nuts and pound garlic.	Anatolia	Ertug-Yaras 2002
Hide processing *Abrasion*	Smooth stones were used to tan buffalo hides by rubbing brains and fat into the skin. Rough stones were used in the final softening stage to vigorously rub hides and break down tissues.	Blackfoot, North America	Ewers 1945
Hide processing *Abrasion*	Buffalo skins were softened by vigorous rubbing with a rough stone until supple.	Blackfoot, North America	Forde 1949
Nut cracking *Percussion*	Acorns were placed on a small flat stone and cracked by striking the tip with a small, hand-sized stone.	Yokuts, California	Gayton 1948
Hide processing *Abrasion*	Pumice stones were be used to soften hides rub the flesh side of hides to breakup fibers.	Amur region and the Bering Strait	Hatt 1969

Hide processing *Abrasion*	Pumice rocks were used in a circular motion to wash off grease and salt and soften the hide following the tanning process. Rubbing stones with finer surfaces, composed of volcanic rock, were used to remove dried liver from the hide.	Araucanian, Argentina	Hilger 1957
Bone breaking for marrow/ pounding dried meat *Percussion*	Naturally smooth stones were selected for pounding meat or cracking bones. Extensive use resulted in the stone taking on a crude pestle-like morphology.	Kaska, North America	Honigmann 1981
Bone breaking for marrow *Percussion*	Water-worn River pebbles were selected to serve together with a large stone anvil as a household bone breaking kit. Bones were pounded with a hammer for marrow extraction or to boil out tallow for lighting.	Karyak, Russia	Jochelson 1905
Tendon pounding *Percussion*	Tendons were pounded with a stone on a flat stone table and combed into fine threads.		
Pounding plant material *Percussion*	Berries and roots were crushed for gruel and pudding with water-worn cobbles collected from riverbanks.		
Bone *Abrasion*	Round whetstones of andesitic lava were used to polish and repair the ground tips of retouchers composed of flaked bone.	Aleutian Islands, Alaska	Jochelson 1925
Production of stone lamps and sinkers *Percussion*	Boulders collected from the seashore were employed as two different types of hammerstones in the production of stone lamps and sinkers. Elongated boulders were employed in heavy strikes during the initial shaping and pecking of stone lamps while hammerstones with round or egg-shaped morphologies were used in lighter strikes for finer chipping and pecking during final shaping.		
Polishing stone implements *Abrasion*	Whetstones composed of andesitic lava of varying coarseness were used to polish and sharpen stone implements.		
Pigment grinding *Mixed*	Oval-shaped stones were used as active implements and anvils for grinding hematite in the production of paint.		
Hide processing *Abrasion/ percussion*	Buckskin was pounded and rubbed with an unworked sandstone cobble for softening. Sheep skin was rubbed to remove any traces of wool remaining after trimming and scraping. The skin originating from the legs was pounded with a stone to aid in softening. These cobbles were collected from the immediate surroundings for use. Hair was also removed from rawhide by pounding with waterworn pebbles through glancing blows. These implements were preferred over sharp adzes as they avoided puncturing the hide.	Navaho, southwestern United States	Kluckhohn et al. 1971

Pounding plant material *Percussion*	The roots of the mountain mahogany were prepared by consumption by pounding with a sharp rock to remove bark before drying. The dried roots were then crushed using a hammerstone.		
Polishing bone, ivory, and wood *Abrasion*	Abraders composed of pumice or scoriaceous lava were used to shape and polish bone, ivory and wooden objects including harpoon shafts and arrows.	Aleuts, Alaska	Laughlin 1980
Hide processing *Abrasion*	Pumice abraders were used to thin and smooth the hides of marine mammals after the fat had been removed.		
Polishing wood *Abrasion*	Pumice stones were collected from the beach for polishing wooden canoe hulls, paddles, and bowls.	Chuukese, Micronesia	LeBar 1964
Grinding and polishing shell and stone *Abrasion*	Objects of shell and stone were ground and polished by rubbing against the surface of large basalt boulders. The location of the boulders along shorelines enabled regular applications of water during grinding.		
Bone breaking for marrow extraction *Percussion*	A fist-sized hammerstone and stone anvil were used to crack long bones for marrow extraction. Neither implement was prepared prior to use and displayed pecking marks from use.	!Kung, Botswana	Lee 1979
Nut cracking *Percussion*	Mongongo nuts were placed on a stone anvil and held between the fingers while 2-5 sharp blows were delivered with a fist-sized hammerstone to crack open the hard shell. These implements were composed of a suitable hard material such as calcrete, were not prepared prior to use and displayed pecking marks from use.		
Bone comminution *Percussion*	The bones of caribou and moose were placed on a stone anvil and smashed with a stone hammer until the fragments were the size of fingernails.	Loucheux, Yukon	Leechman 1951
Stone adze production *Percussion*	Stone adzes were produced using hammerstones composed predominantly of basalt water-worn cobbles that were selected from stream beds and beaches for their ideal size and weight. These tools displayed battering damage on their ends.	Marquesas, Polynesia	Linton 1923
Hide processing *Abrasion*	Flat stones were used in skin dressing to remove flesh and rough stones are employed in the final stages of smoothing.	Assiniboine, North America	Lowie 1909
Pounding plant material, resharpening *Percussion*	Rounded rocks of ideal size and weight were selected for pounding baobab seeds. These implements were often discarded in their use contexts on top of anvils after abandonment of a site and may have been reused by subsequent inhabitants.	Hadza, Tanzania	Marlow 2010

Grinding slab surfaces *Percussion*	Grinding slab surfaces were resharpened by pecking with conveniently acquired river cobbles.		
Personal implements with a range of functions *Percussion Abrasion, Mixed*	Pebbles and cobbles were collected from a beach. Smaller implements were transported into areas where similar material was scarce while larger were left upon abandonment of a site. Once collected, these implements became important personal property that were used for several different tasks rather than being discarded and replaced and displayed damage interpreted as the result of extensive handling. A quartzite pebble displayed battering on the edges, remnant bits of fat and flesh clinging to the surface and polishing on the lateral edges from handling during use. This pebble was used for several tasks for processing of a horse carcass: removing skin from the legs, severing tendons by abrasion, pounding to remove the hoof, and breaking bones for marrow. This pebble was also used for plant processing: crushing and grinding of mesquite beans, pounding a mixture of shelled corn and slack lime, chopping trees and wood by pounding the wood at a weak point, dethorning okatilla stems and other tasks: severing cords of hair by abrasion, fire stone, pounding and grinding ochre.	Seri, North America	McGee1895
Pounding small animal carcasses *Percussion*	Flat, slab-shaped stones were used as anvils for pounding small animal carcasses. Elongated pebbles used for pounding turtles displayed battering on both ends.		
Pounding plant material *Percussion*	A pebble of moderately hard, vesicular material showed slight battering on the edges. Smooth striations and polish appeared with grease spots and stain from plant material.		
Nut cracking *Percussion*	Acorns were crushed using implements labelled "boulders-on-rock" that served as simple querns for the production of bread. Acorns were used to supplement diets during shortages of other crops.	Nomads of Luristan, western Iran	Mortensen and Nicolaisen 1993
Hide processing *Abrasion*	Rough stones were used to soften dried deer hides.	Apache, southwestern United States, Mexico	Opler 1941
Bone breaking for marrow extraction *Percussion*	A rock was used to break open bones for marrow and obtain splinters for producing bone tools.	Ingalik, Alaska	Osgood 1970
Pounding dried meat	A suitable stone was used to soften dried meat by pounding.		

Percussion			
Flaking *Percussion*	Rounded pebbles composed of suitable hard material were used to strike flakes off of quartz pebbles	Andamanese, Andaman Islands	Radcliffe-Brown 1922
Hide processing *Abrasion*	Rough hand-sized stones were used in the initial cleaning process to remove flesh. The same implements were later employed to during the tanning process to clean the tanning lotion off.	Honey Lake Paiute, California	Riddell 1960
Bone comminution *Percussion*	Vertebra from deer and salmon were crushed into a paste.	Maidu, southern California	Schroth 1996
Pounding small animals or meat *Percussion*	Roasted, jerked, or dried meat was pounded on a flat slab with a rock to tenderize or pulverize it. Whole small animals such as mice, lizards and snakes were pounded for making stew. River cobbles composed of granite or slate were selected for use as pestles by the Tübatulabal for their cylindrical morphology without requiring prior shaping.	Ute, Paiute, Luiseño, Southern Paiute, Goshute, Serrano, Cupeño, Cahuilla, Diegueño, Chemehuevi, Gabrielino, Tübatulabal, Modoc, Yuma, Yokuts, Kawaiisu, and Owens Valley Paiute, southern California	
Hide processing *Percussion, abrasion*	Stones were used during hide processing to pound the hide and softening was conducted with rubbing stones.	Costanoan, Salinan, Chumash, Gabrielino, desert Diegueño, Yuma, and Chemehuevi, southern California	
Nut cracking *Percussion*	Acorns were placed on a flat rock and struck with a convenient smaller rock in order to crack the hull and extract the edible kernels.	Luiseño, southern Diegueño, southern California	
Wood *Abrasion*	Digging sticks were sharpened by rubbing with a stone.	Ute, Southern Paiute and Karok, southern California	
Pounding plant material *Percussion*	River cobbles were selected for their elongated shape and used without modification for pounding maize and other plant materials. These implements were preferred over shaped tools for percussive activities for their ease of replacement.	Marakwet County, northwest Kenya	Shoemaker 2017
Hide processing *Percussion*	Tanned deer hides were placed on flat rocks and pounded with stones for softening.	Yuman of the Gila River, southwestern United States	Spier 1933
Nut cracking *Percussion*	Dried acorns were cracked on pitted anvil stones with a hammerstone.	Foothill Yokuts, California	Spier 1978

Table A.2: Ethnographic accounts of various uses for unprepared pebbles and cobbles.

Appendix B - Results of the Blind Test

A total of 16 different tool surfaces were analysed in the blind test. Due to time constraints, only experiments 1-3, 6, and 12 had been conducted at the time of the blind test. The tools employed in the rest of the experiments are therefore marked unused to reflect this. The results of the blind test are summarized in tables B.1-B.5.

Recognition of Use-Areas and Use Parameters

The blind tester was able to correctly identify 43.75% of the tool surfaces as used or unused. The rate of accuracy was the same for naked eye and microscopic observation although there were some differences in which particular surfaces were identified as used between the two methods. In one instance (S2F1), microscopic observation resulted in the identification of a previously unrecognized use area. A potential use area identified on S1F3 with naked eye observation was correctly ruled out through microscopic observation. Two surfaces (S4F4 and S7F2) were correctly identified as unused through naked eye observation only to later have use-areas incorrectly identified through microscopic observation.

Tool	**Blind**		**Actual**
	Unaided Observation	**Microscopic Observation**	
S1F1	Used	Used	Used
S1F2	Used	Used	Not used
S1F3	Used	Not used	Not used
S2F1	Not used	Used	Used
S2F2	Used	Used	Used
S4F1	Not used	Not used	Used
S4F2	Used	Used	Not used
S4F3	Not used	Not used	Not used
S4F4	Not used	Used	Not used
S5F1	Not used	Not used	Used
S5F2	Used	Used	Not used
S5F3	Not used	Not used	Not used
S5F4	Not used	Not used	Not used
S61F1	Used	Used	Not used
S7F1	Used	Used	Not used
S7F2	Not used	Used	Not used

Table B.1: Results of the blind test for recognition of use areas.

The majority of the incorrect identifications were of unused surfaces that were identified as having been used. In the case of S6F1, this may be attributable to the extensive environmental polish that was documented to cover the entire surface of the tool. Other instances of mistaken identification of use may be attributable to a combination of environmental wear and grip polish given that the most common incorrectly identified task was abrasion of an oily or non-oily substance such as hide or meat.

Tool	Blind		Actual	
	Motion	**Processed Material**	**Motion**	**Processed Material**
S1F1	Indet	Indet	Striking	Bone
S1F2	Abrasion	Oily	Unused	
S1F3	Unused		Unused	
S2F1	Grip*	Oily	Abrasion	Dried Bone**
S2F2	Abrasion	Oily	Striking	Acorn
S4F1	Unused		Striking	Bone
S4F2	Percussion	Non-oily	Unused	
S4F3	Unused		Unused	
S4F4	Abrasion	Oily	Unused	
S5F1	Unused		Striking	Tendon
S5F2	Abrasion	Non-oily	Unused	
S5F3	Unused		Unused	
S5F4	Unused		Unused	
S61F1	Mixed	Non-oily	Unused	
S7F1	Abrasion	Oily	Unused	
S7F2	Abrasion	Non-oily	Unused	

Table B.2: Results of the blind test for identification of kinetic motion and processed material. Highlighted rows correspond to correct identifications.
**Considered a correct identification as this face was gripped during the acorn hulling experiment with S2F2.*
***Cancelled dried bone experiment.*

Of the tools that had been used, 60.00% (N=3) were correctly identified as such. Recognition of unused surfaces occurred at a similar rate of 54.55% (N=6). The most unexpected result of the blind test was that the bone comminution (S4F1) and tendon pounding (S5F1) tools were not recognized as having been used. Failure to recognize that the bone comminution tool had been used may be explained by the formation of highly conspicuous grip polish on two other faces of the tool (S4F2,4) obscuring which face had actually been used. Acorn hulling also went unrecognized in the blind test, but this result was not surprising given the paucity of use-wear reported in the experimental results.

Correct identification of the nature of use occurred just once as the wear on S2F1 was attributed to handling the tool during use. The bone breaking tool (S1F1) was recognized as having been used but no further identification of the motion of use or processed material was possible.

Consistency in Wear Trace Identification and Description

The descriptive framework established prior to the start of the blind test contains six different types of wear each associated with a set of descriptive parameters which are listed in table B.5. A total of six comparisons between the blind test and the experimental results were recorded for each tool and classified as *match*, *partial*, or *differ*. *Match* indicates that the same wear type was identified and described using the same terms or that the wear type in question was not identified in either the blind test or experimental results. *Partial* was applied to instances where the same wear type was identified by both researchers, but the descriptions differed. *Differ* indicates that a wear type identified by one researcher on a particular surface was not identified by the other. The rate of consistency was determined by counting the number of matches and partial matches out of the total number of comparisons. This allowed the consistency for each individual wear type to be compared and the consistency of wear trace identifications for each tool to be assessed individually.

The rate of consistency varied between the different wear types. Levelling, and micropolish had the highest consistency (87.50%) between the blind test and the experimental results while microfractures had the lowest consistency by far (18.75%).

The majority of disagreements (69.70%, N=23) consisted of wear trace identifications recorded in the blind test that were not recorded in the experimental results. Conversely, edge rounding was the most common wear type to be recorded in the experimental results but not the blind test (N=6). This constituted (18.18%) of the disagreements.

Tool	**Macroscopic observation**					**Microscopic observation**
	Levelling	**Pits**	**Microfractures**	**Edge rounding**	**Linear traces**	**Micropolish**
S1F1	Differ	Match	Match	Differ	Differ	Match
S1F2	Match	Match	Differ	Match	Differ	Match
S1F3	Match	Match	Differ	Differ	Differ	Match
S2F1	Match	Match	Differ	Match	Match	Match
S2F2	Match	Match	Differ	Match	Match	Match
S4F1	Match	Match	Differ	Differ	Match	Match
S4F2	Match	Differ	Differ	Differ	Match	Match
S4F3	Match	Differ	Differ	Differ	Match	Match
S4F4	Match	Differ	Differ	Differ	Differ	Match
S5F1	Differ	Differ	Partial	Match	Match	Partial
S5F2	Match	Match	Differ	Match	Match	Partial
S5F3	Match	Match	Differ	Match	Match	Differ
S5F4	Match	Match	Partial	Match	Match	Differ
S6F1	Match	Match	Differ	Match	Match	Match
S7F1	Match	Differ	Differ	Match	Match	Match
S7F2	Match	Differ	Differ	Match	Match	Match
R.C.*	87.50%	62.50%	18.75%	62.50%	75.00%	87.50%

*Table B.3: Comparison of wear trace identifications between the blind test and experimental results. *Rate of consistency (includes partial matches).*

This tendency for blind tester recognize certain wear types at a higher rate than the experimental results while others at a lower rate can most likely be attributed to their unfamiliarity with the natural appearance of the raw material and the pre-existing wear types described in section 4.1.1. The relatively higher rates of consistency for levelling, linear trace, and micropolish identifications may be due to the fact that these are more conspicuous types of wear whereas pits, microfractures, and edge rounding may be easier to confuse with the natural topography of the rock.

The rate of consistency varied between the used and unused tools. The highest rate occurred among the used tools (70.00%) while the rate for unused tools (63.64%) was slightly below the overall average (65.63%).

	Tool	Match	Partial	Differ	R.C.*
Used	S1F1	3		3	50.00%
	S2F1	5		1	83.33%
	S2F2	5		1	83.33%
	S4F1	4		2	66.67%
	S5F1	2	2	2	66.67%
	R.C. used				70.00%
Unused	S1F2	4		2	66.67%
	S1F3	3		3	50.00%
	S4F2	3		3	50.00%
	S4F3	3		3	50.00%
	S4F4	2		4	33.33%
	S5F2	4	1	1	83.33%
	S5F3	4		2	66.67%
	S5F4	4	1	1	83.33%
	S6F1	5		1	83.33%
	S7F1	4		2	66.67%
	S7F2	4		2	66.67%
	R.C. unused				63.64%
R.C. overall					65.63%

Table B.4: Rates of consistency for each tool.
**Rate of consistency (includes partial matches).*

Of the tools that were used, the rates of consistency are highest for S2F1 and S2F2. Both of these tools were correctly identified as used in the blind test and had correct or partially correct identifications of the gesture and processed material properties. This potentially indicates that the descriptive framework employed is most effective when applied to tools used to work oily materials with abrasion. However, it should also be noted that the majority of matching comparisons for these tools were agreements as to the absence of wear types which may be less difficult to determine than the presence and characteristics of wear traces.

Interestingly, the rates of consistency for S4F1 and S51 which were incorrectly identified as unused in the blind test are higher than that of S1F1 which was correctly identified as used. This may be due to the minimal development of use-wear reported during the bone breaking experiment as two of the disagreements were due to levelling and edge rounding being recorded in the experimental results but not the blind test.

Partial matches occurred a total of four times on three different faces of the same stone. Partial matches for microfracture descriptions occurred on S5F1 and S5F4, which was unused. A partial match of micropolish descriptions also occurred on S5F1 and on S5F2. Microfracture descriptions differed by how the distribution and depth were characterised while descriptions of micropolish differed by distribution and appearance.

Tool	Blind	Experimental
	Microfractures	
S5F1	Distribution: **covering** Density: connected Depth: **superficial**	Distribution: **concentrated** Density: connected Depth: **Wide and deep/** superficial and fine
S5F4	Distribution: **covering** Density: **connected** Depth: **superficial** and deep	Distribution: **loose** Density: **separated** Depth: **wide** and deep
	Micropolish	
S5F1	Distribution: **covering** Density: **close** Morphology: **flat** Texture: **smooth** Margins: **sharp** Vertical extension: **deep** Opacity: opaque Brightness: moderate Interpretations: none Associated wear: **striations**	Distribution: **concentrated** Density: **separated** Morphology: **sinuous** Texture: **rough** Margins: **diffuse** Vertical extension: **shallow** Opacity: opaque Brightness: moderate Interpretations: none Associated wear: **none**
S5F2	Distribution: **covering** Density: **close** Morphology: flat Texture: **smooth** Margins: diffuse Vertical extension: shallow Opacity: **transparent** Brightness: **dull** Interpretations: none Associated wear: **none**	Distribution: **concentrated** Density: **connected** Morphology: flat Texture: **fluid** Margins: diffuse Vertical extension: shallow Opacity: **translucent** Brightness: **moderate** Interpretations: none Associated wear: **levelling**

Table B.5: Summary of descriptions for all partial matches.

The differences in microfracture and micropolish descriptions between the blind test and experimental results may reflect a tendency on the part of the blind tester to interpret certain aspects of the natural topography of the rock and pre-existing wear as use-wear. This highlights again the influence of familiarity with the raw material and experimental assemblage or lack thereof as the blind tester did not have the opportunity to observe and document pre-existing wear and natural features of the surface that could be mistaken for use-wear.

An additional factor that may have influenced descriptions of the micropolish appearance specifically is the ambiguity of certain descriptive parameters. For example, two researchers might be more likely to agree on the presence or absence of associated wear traces than the brightness of micropolish as the distinction between dull and moderate is somewhat subjective. However, it should be noted that other differences in micropolish descriptions are between less ambiguous parameters (eg. margins or associated wear).

Summary

Determination of use and especially use parameters constitute the least successful aspects of the blind test. 43.75% of the tools were correctly identified as used or unused while the nature of use was discerned just once. The most success came from wear identifications and descriptions. The high rates of consistency between the blind test and experimental results for these portions of the blind test demonstrate the reliability of the descriptive framework employed and the replicability of the use-wear results for the experimental assemblage. However, the results also revealed some limitations of the design of the blind test itself.

Although Nicholas Stevenson was familiar with the descriptive framework and methods of observation, more efforts should have been taken to account for differences in experience with specific types of ground stone tools and processed materials between different researchers. Identification of the processed material properties may have been improved with an appropriate comparative basis such as example pictures or descriptions of use-wear patterns typical of each processed material and pictures of each unused surface.

Additionally, the robusticity of the protocols for this blind test would have been strengthened by the incorporation a double-blind element. This would have been achieved by having each participant perform a series of experimental tasks according to a set of predetermined task parameters such as the gesture, processed material, and duration of the experiments with two separate assemblages of experimental tools. These assemblages would then be swapped between participants before the examination of use-wear traces. This would have eliminated the expectation of the location and appearance of wear traces as a potential source of bias as neither researcher would know which of the tools had been used in each task.