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PhD-thesis

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Approaching Past and Changing Foodways Through Ground Stone

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Supervisor: Tobias Richter

Date: 31. January 2022

Name of department:	Department of Cross-Cultural and Regional Studies - Centre for the Study of Early Agricultural Societies
Author(s):	Patrick Nørskov Pedersen
Title and subtitle:	Approaching Past and Changing Foodways Through Ground Stone
Topic description:	This project aims to elucidate the use of ground stone tools, such as querns and mortars, in processing plant and animal matter for consumption and how these tools and practises changed during the Late Epipaleolithic and Early Neolithic, when human went from being mobile hunter-gatherers to sedentary agriculturalists.
Supervisor:	Tobias Richter
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☐ Paper 1: 16,840

☐ Paper 2: 26,686

☐ Paper 3: 7,856

☐ Paper 4: 16,636

☐ AGSTR-paper: 6,150

☐ Kappe/Synopsis: 14,303

Danish and English summaries not counted

Table of contents

The submitted version of PhD-thesis you are reading is divided in to three parts:
The kappe/synopsis (A.), the five PhD-papers themselves (B.) and the Appendices: Ia, Ib, II, III (C.).
Note that each paper has its own page numbers, and the same goes for the synopsis and the appendices, thus they do not follow an overall sequence of page numbers.

Overview of papers submitted as the thesis

AGSTR-paper

Title: *The Ground stone Assemblages of Shubayqa 1 and 6, Eastern Jordan - Technological choices, Gestures and Processing Strategies of Late Hunter-Gatherers in the Qa’ Shubayqa*

Author: Patrick Nørskov Pedersen (sole author).
Published: December, 2021.
In: Proceedings of the 3rd Meeting of the Association of Ground Stone Tools Research - Ground Stone Tools and Past Foodways. (editors Patrick Nørskov Pedersen, Anne Jörgensen-Lindahl, Mikkel Sørrensen and Tobias Richter). Archaeopress - Access Archaeology. ISBN 9781789694796

Paper 1:

Title: *Of Muscle and Stone: Ground Stone Tools and Food Processing Technology - Bodies of knowledge*

Author: Patrick Nørskov Pedersen (sole author).
Unpublished

Paper 2:

Title: *Cast in Stone: Tools from movements, movements from tools - Approaching ever changing ground stone*

Author: Patrick Nørskov Pedersen (sole author).
Unpublished

Paper 3:

Title: *The chaîne opératoire of club-rush tuber exploitation (Bolboschoenus glaucus), disentangling Early Natufian root-food gathering and processing activities in Southwest Asia*

Author(s): Amaia Arranz-Otaegui, Patrick Nørskov Pedersen, Ann Frijda Schmidt, Anne Jörgensen-Lindahl, Joe Roe, Johanne Villemoes, George Alexis Pantos, Kathryn Killackey
(as co-author).
Submitted: January 2022.
Journal of Archaeological Science (JAS Rep), expected out in 2022

Paper 4:

Title: *From Stone to Food: Foodways and processing during the Natufian and Early Neolithic of Eastern Jordan - A Ground stone perspective*

Author(s): Patrick Nørskov Pedersen, Monica Nicolaides Ramsey, Amaia Arranz-Otaegui, Tobias Richter
(as main-author).
Unpublished

Dansk resume: Approaching Past and Changing Foodways Through Ground Stone
- En artikelbaseret Ph.d. ved Københavns Universitet

Menneskets diæt, bearbejdning og tilberedelse af mad gennemgår grundlæggende forandringer som resultat af agerbrugets fremkomst i det sydvestlige Asien for cirka 15.000 til 8500 år siden. Denne afhandling undersøger, hvilken rolle bjergartsredskaber spiller for forandringer i madproduktion og madkultur i denne periode. Dette undersøges gennem analyse af bjergsartsredskaber fra de to bopladser Shubayqa 1 og 6 i det østlige Jordan, der er dateret til den epipalæolitiske natufiske periode og den tidlige præ-keramiske neolitiske periode (*Pre-Pottery Neolithic A/* PPNA). Jeg argumenterer for, at redskabernes morfologi sammen med slidsporsanalyse kan bruges til at genkende eksistensen af forskellige strategier for bearbejdning af mad (*food processing strategies*). Både morfologi og slidspor er et resultat af de kropslige bevægelser (*gestures*), mennesker anvender, når de bruger (sten)redskaber. Bjergsartsredskabers morfologi er således ikke kun et resultat af deres udformning, men også af deres brug – de ændrer konstant, men langsomt, form gennem vedvarende brug. Dette gælder også de mikroskopiske slidspor, der findes på redskabernes overflade, som ikke kun er et resultat af det materiale, de bearbejder, men også i høj grad et resultat af de bevægelser, der bliver anvendt i forbindelse med arbejdet. Der eksisterer derfor et dialektisk forhold mellem krop (bevægelser) og redskaber (materie). Repetitivt arbejde manifesterer sig således materielt både i morfologi og i mikroskopiske slidspor. Redskabernefortæller os noget om, hvad der blev bearbejdet, og hvordan. Derudover er det vigtigt at forstå, at bevægelser og redskaber ikke eksisterer i et vakuum, men er materielle og sociale. Kun ved at overveje de sociale, materielle *og* kropslige aspekter af redskabsbrug i forbindelse med madproduktion, får vi et mere holistisk blik for, hvordan madkulturen ændrer sig i denne afgørende overgangsperiode. På baggrund af dette genkendes en række bearbejdnings-strategier ved de to bopladser Shubayqa 1 og 6. Hvordan disse strategier ændrer sig over tid, undersøger jeg i afhandlinges fem artikler fra forskellige perspektiver. Med min tilgang til redskabsanalyse og ved hjælp af konvensionel slidssporsanalyse (samt mikrobotaniske prøver og arkæologiske experimenter) tydeliggør jeg interessante forandringer, men også en høj grad af kontinuitet, på Shubayqa-bopladserne: Min research finder frem til, at selvom redskaberne og strategierne for bearbejdning af mad ændrer sig over tid, er der en vis kontinuitet i brugen af råvarer. Det gælder for eksempel i seneste epipalæolitiske *Late-Natufian*-periode og tidligste neolitiske *Early-PPNA*-periode, at mange af de samme planter og råvarer bearbejdes. Dog ændrer redskaberne samtidig form og bevægelser og bearbejdningsstrategier går fra at være cirkulære til lineære.

I det tidlige neolitikum ses også en (forventet) stigning i udnyttelsen af korn (formentlig vild enkorn eller lignende), men gennem alle perioderne indikerer slidsporerne at der er en bred vifte af ressourcer, der bliver brugt, her er en af de vigtigste rodknolde fra planten *Bolboschoenus glaucus*, sammen med bælgfrugter, frø, og animalske ressourcer. Denne forskning viser således at madkulturen i periodener mere kompleks end som så, både i den natufiske periode og i det tidlige neolitikum. Dette tydeliggør, at min anvendte metode er brugbar og bidrager til et holistik perspektiv. Analysen viser også vigtigheden af at undersøge brugen af bjergartsredskaber i fortiden, og hvordan de kan styrke vores viden om madkulturens forandringer i en vigtig periode af menneskehedens historie.

English abstract: Approaching Past and Changing Foodways Through Ground Stone
- An article-based PhD at the University of Copenhagen

Human diet, food procurement and processing underwent fundamental changes as agriculture slowly emerged in Southwest Asia during the Late Epipalaeolithic and Neolithic c. 15,000 – 8,500 years ago. This thesis examines the role ground stone tools played in the foodways of people during this transformative period. Looking at the "food processing" ground stone tools from two sites located in eastern Jordan, Shubayqa 1 and 6, dated to the Natufian and Early Neolithic (PPNA) 14,800-10,600 cal. BP. It emphasizes the importance of a holistic approach to ground stone tools, one that considers bodies and movements. Food processing ground stone are tools operated by individual bodies using movements, or *gestures*, to alter material properties of foodstuff. Not only are they shaped by manufacture, but also through continuous use and the repetitive gestures this labour requires are expressed materially as morphology. Importantly technology is also both social and material, so tools and bodies are part of larger sociotechnical systems where ideas, people and tools all interact and influence each other. Tool morphology is thus a place where we may see technological practices of society and individual bodies.

The thesis uses this background to highlight that there also exists interconnected relationships between tool morphology and the macro/microscopic surface wear of the ground stone, both in turn affected by continuous use and wear maintenance (the progression of wear). These tools are thus objectified bodily practices. Conducting microscopic use-wear analysis may therefore not only tells us about what was processed but how. By considering the gestures behind food processing, I underline, that location and type of specific use-wear traces are a result of repetitive ways of use, not just of intermediate contact materials. We see tool and body influence each other dialectically in tool-body relationships. Using this approach, I group the large and diverse food processing ground stone assemblages from Shubayqa 1 and 6 into categories of *"processing strategies"*, to illuminate how different tools where used within food processing. I then examine how these processing strategies change over time. This is done in conjunction with conventional functional analysis, applying low-power microscopic use-wear, residue analysis and food experiments, to elucidate the past foodways at the sites from a ground stone perspective. Going from muscle to stone: material expression of changing gestures and practises, the traces of changing foodways "cast in stone".

My research thus both outlines a general approach to ground stone and offers several interpretations of the changes we see the Shubayqa sites. It finds that both processing strategies and contact materials change over time, however the tools appear to change somewhat independently of the contact material. The shift between the Late Natufian and Early PPNA for example, show a change in the tools used: gestures and consequently processing strategies, evidently change from circular to more linear in this period, while the use-wear suggest continuity in the contact materials.

By the Neolithic there seem to be an increase in cereal exploitation, however in all the analysed phases there great variety of raw materials. Tubers processing appears common as well as legume and seed processing, in addition to meat and animal products. It appears; as if the changes we observe at Shubayqa are a combination of intensification is certain food resources *and* ways of processing them. The thesis ultimately highlights the complexity of past foodways, technological practices and resource exploitation, and the shows the usefulness of the chosen approach. The study contributes to knowledge about these changing foodways around a crucial period in Southwest Asia, the transition from foraging to incipient farming.

A.

Kappe/Synopsis for the PhD:

“Approaching Past and Changing Foodways Through Ground Stone“

By

Patrick Nørskov Pedersen

University of Copenhagen, Department of Cross-Cultural and Regional Studies,
Centre for the Study of Early Agricultural Societies

Approaching Past and Changing Foodways Through Ground Stone

- An article-based PhD

by Patrick Nørskov Pedersen, University of Copenhagen,

Submitted 31. January 2022

1. Introduction

1.1. Structure and contents of the thesis

This thesis was written as part of the larger research project **"***Changing Foodways in Prehistoric Southwest Asia: Reconstructing food procurement, processing and cooking during the Epipalaeolithic-Neolithic transition"*, a project led by Dr. T. Richter.
This project explores changing foodways in Southwest Asia during the Epipalaeolithic-Neolithic between c. 15,000 – 8,500 years ago.
This period saw some of the most fundamental changes to diet, food procurement and processing in human history: the transition from foraging to agriculture. The project aims to disentangle the relationship between food resources and people and illuminate why changes to past foodways occurred. It sets out to reconstruct a *châine opératoire* of foodways from acquisition and processing to cooking and discard. This is done to better understand these changes to diets in Southwest Asia during the Late Pleistocene and Early Holocene.
My part of the research looks specifically at food processing. It focuses on the role played by ground stone tools in the processing of plant and animal matter. These tools would have been used for numerous tasks like crushing, abrading, pounding and grinding a wide range of materials, and importantly for this thesis, the pulverising foodstuffs.
In this thesis, I examine these tools to understand their role in food processing and how they change over time from a range of different perspectives. The tools I analyse come from the two sites Shubayqa 1 and 6 located in the black desert of Eastern Jordan. These two sites are dated to the aforementioned period the Late Epipalaeolithic, Shubayqa 1, and the Early Neolithic, Shubayqa 6, and were occupied between *c.* 14,800 – 10,600 cal. BP.
By applying an analytic approach that recognises the interplay between movements, tool morphology and macro- and microscopic use-wear, along with conventional functional analysis, including also experimental studies, I attempt to illuminate what this tool class can tell us about changing the foodways during the Epipaleolithic-Neolithic transition.

This thesis is an article-series and consists of five papers. Four of which I am the main author, including one with co-authors, and one paper as a co-author myself. The thesis bears the overall title: *"Approaching Past and Changing Foodways Through Ground Stone"*.

Each article covers a different topic and perspective related to ground stone tools and past foodways and I present their themes, observations and findings in summary below.

Firstly, I will briefly lay out the structure of the thesis and present the individual papers, and the order in which they should be read. I also note the main topics, other authors and what supplementary material is relevant to each of the papers.
For the purpose of this synopsis/kappe each of the papers are numbered, or have an abbreviated title. This is for the sake of brevity and to avoid confusion when addressing them throughout this introduction. The four main papers are numbered Paper 1, 2, 3 and 4. In addition to this, is the so-called AGSTR-paper, which is based partly on work done for my unpublished MA-thesis (Pedersen 2017), but with significant modifications and in a considerably re-worked format. This AGSTR-paper is already published and acts as an additional "background article" for the rest of the thesis, as many observations initially made in this paper also inform the thesis. It should preferably be read before Paper 1, as Paper 1 extrapolates the theory behind the "processing strategies"-approach found in there and throughout the other papers as well. Paper 2 uses the same basic method as the AGSTR-paper but elaborates and advances the approach while also providing a full overview of each and explanation of each of the suggested "processing strategies".

The AGSTR-paper importantly contains an overview of the tools analysed in Paper 2 and Paper 4. The data from the AGSTR-paper is then also used in parts of Paper 4, mainly for comparisons and assemblage overview. The more detailed and thorough exploration of the Shubayqa ground stone tools and their relationship to foodways found in the thesis is thus aided by the overview found in the AGSTR-paper.

The rest of the papers, Paper 1-4, contain the bulk of the data and work done for the thesis, including theoretical and methodological background (Paper 1 and 2), the analyses, experiments, discussions and conclusions (see Paper 2, 3 and 4).
Within the text, i.e. within the individual papers, I generally refer to the other PhD-papers as "*forthcoming",* this is the case for Paper 1, 2 and 4, while Paper 3 is referred to as "*submitted"*.
Paper 1 provides the basic definitions of terms, theory and concepts used throughout the articles. These include concepts and terms like: foodways, food production, food processing ground stone tools, *gestures* and the body in tool use, as well as theory on sociotechnical systems and *technology*, labour processes and the division of labour within food processing.
Paper 2 contains a detailed overview and explanation of the "processing strategies"-approach, originally proposed in the AGSTR-paper, and a thorough elaboration and expansion of this approach. It adds the qualitative low-power microscopic use-wear of a subsample of the Shubayqa 1 and 6 processing ground stone tools, and includes considerations of wear management, changes to tool morphology to substantiate the use of the "processing strategies" approach. Thus it modifies and expands on the methodological background of the approach used in the thesis.
Paper 3 presents experiments we conducted in Jordan in 2019. These experiments included reproducing Natufian style food products and using ground stone replicas, made in Jordan

from local basalt by this author, to process plants. The focus of these experiments was reconstructing a *chaîne opératoire* of tuber processing during the Early Natufian. These tuber being the underground storage organs (rhizome tubers) of *Bolboschoenus glaucus* (club-rush), a semi-aquatic plant species of the Cyperaceae family found frequently in the Early Natufian archaeobotanical assemblage of Shubayqa 1.
Paper 4, the final paper, presents the results from the low-power microscopic use-wear analysis of 64 ground stone tools from Early and Late Natufian occupation at Shubayqa 1 and Early to Late PPNA occupation at Shubayqa 6. The same subsample was also analysed in Paper 2. This functional analysis is aimed at finding the contact material (i.e. what was processed) and also includes residue analysis of samples taken from the ground stone tools.[1] It combines these results with the processing strategies-approach outlined in the previous papers (Paper 1, 2 and the AGSTR-Paper) to examine the relationship between strategy and processed materials, as well as changes over time.

In overview, the five papers included in the thesis are:

AGSTR Paper
Title: The Groundstone Assemblages of Shubayqa 1 and 6, Eastern Jordan - Technological choices, Gestures and Processing Strategies of Late Hunter-Gatherers in the Qa' Shubayqa.
In: *Proceedings of the 3rd Meeting of the Association of Ground Stone Tools Research - Ground Stone Tools and Past Foodways*. (edited by Patrick Nørskov Pedersen, Anne Jörgensen-Lindahl, Mikkel Sørrensen and Tobias Richter). Article based on parts of my unpublished Master's-dissertation (Pedersen 2017).
Author(s): P. N. Pedersen
Topics: Assemblage overview and changes to processing strategies over time. Initial application of the processing strategies approach.
Publication status: published, December 2021, Archaeopress - Access Archaeology.
ISBN 9781789694796
Link:
https://www.archaeopress.com/ArchaeopressShop/Public/displayProductDetail.asp?id=%7b19F844D2-35F7-44AB-B05F-025A06D14E52%7d

Paper 1
Title: Of Muscle and Stone: Ground Stone Tools and Food Processing Technology - Bodies of knowledge.
Author(s): P. N. Pedersen
Topics: Introduction to food processing technology and strategies, gestures and general theory
Publication status: unpublished

[1] Unfortunately this analysis was not completed in time

Paper 2
Title: Cast in Stone: Tools from movements, movements from tools - Approaching Past and Changing Ground Stone.
Author(s): P. N. Pedersen
Topics: Detailed methodological overview and elaboration of the "*processing strategies"*-approach, including qualitative low-power use-wear analysis
Publication status: unpublished

Relevant supplementary material:

Appendix Ia: Ground stone sampling and use-wear protocol
Appendix Ib: Raw material notes for Ground stone use wear
Appendix II: Processing strategies A1.-A3. + B.
Appendix III: Experiments conducted 2019

Paper 3
Title: The *chaîne opératoire* for club-rush (Bolboschoenus glaucus) tuber gathering and processing, an interdisciplinary approach.
Authors: Amaia Arranz-Otaegui, Patrick Nørskov Pedersen, Ann Frijda Schmidt, Anne Jörgensen-Lindahl, Joe Roe, Johanne Villemoes, George Alexis Pantos, Kathryn Killackey
Topic: Experimental archaeology, reconstructing Early Natufian foodways, the use of tubers as a food resource and *chaîne opératoire* of plant foods.
Publication status: submitted, Journal of Archaeological Science (JAS Rep), expected out in 2022

Relevant supplementary material:

Supplementary material already in the paper (after the references).
But see also the thesis Appendix III: Experiments conducted 2019

Paper 4
Title: From Stone to Food: Foodways and processing during the Natufian and Early Neolithic of Eastern Jordan - A Ground stone perspective
Author(s): Patrick Nørskov Pedersen, Monica Nicolaides Ramsey, Amaia Arranz-Otaegui, Tobias Richter
Topics: GST use-wear (and residue) results, processing strategies and function, past and changing foodways
Publication status: unpublished

Relevant supplementary material:

Supplementary tables ST1-5 in the paper itself
and see also
Appendix Ia: Ground stone sampling and use-wear protocol
Appendix Ib: Raw material notes for Ground stone use-wear
Appendix II: Processing strategies A1.-A3. + B.

1.2. A brief background: The Epipalaeolithic and Neolithic of Southwest Asia - the "Changing Foodways" and the changing ground stone of Shubayqa

Firstly, as mentioned, what this thesis contributes to broadly is ground stone technological developments in Southwest Asia (SWA) during the Late Epipalaeolithic and the Early Neolithic, or Pre-Pottery Neolithic as it is also known. SWA is a vast geographical region that stretches from Iran in the East to Turkey in the Northwest, and the Arabian peninsula in the Southwest. The SWA region encompasses a vast and diverse area that includes mountain ranges (like the Zagros and Taurus, Lebanon etc.), coast, alluvial plains forests, steppes and deserts. The region is even more enormous if also counting North Africa, i.e. modern Egypt, Libya, Tunisia, Algeria and Morocco and West Sahara, the two regions together sometimes termed SWANA. I humbly mainly focus on a "smaller" part of this, the Southern Levant, broadly speaking Jordan, Palestine, Israel, Southern Lebanon and Syria. The specific period that I deal with in this thesis is, as mentioned, the Late Epipalaeolithic (Natufian) to the Early Pre-Pottery Neolithic (PPN) between roughly 15,000 to 10,000 years ago. As mentioned, the data included in this thesis comes from the two sites in the Eastern *badia* of Jordan, the black desert, or *harra.* In this current research I focus more or less exclusively on the "food processing" ground stone of the sites. The tools come from the Early and Late Natufian phases at Shubayqa 1 and the Pre-Pottery Neolithic A (EPPNA and LPPNA) phases at Shubayqa 6, encompassing both Early PPNA to Late PPNA phases. The Shubayqa 6 tool assemblage also includes material from a transitional Late Natufian/EPPNA phase and a Late PPNA/Early PPNB phase which is included in the analyses as part of the EPPNA and LPPNA assemblages respectively. Shubayqa 1 also includes a Final Natufian phase (Richter et al. 2017), which is not included in the analysis. This ground stone assemblage was small and highly fragmentary. Further details on the provenance of the tools, including detailed definitions, typology, categorisation of processing strategies and description of the sites, their phasing and setting is found in the papers themselves (e.g. Paper 2 and 4).
I therefore now move on to the more general themes of the thesis.

Both the archaeological tradition and chronology of the SWA region is long and complex, but it is seen as one of the earliest and normatively "important" centres of domestication, and consequently agriculture. This region's importance is perhaps also a result of the "success" of the domesticated plants and animals that come from here and their subsequent spread throughout Western Eurasia. This includes the domestication of the so-called "founder crops" local to the greater region. These SWA "founder crops" are traditionally understood as: emmer and einkorn wheat, barley, lentil, bitter vetch, chickpea and pea (Arranz-Otaegui et al. 2018b; Weiss and Zohary 2011; Willcox et al. 2008; Willcox 2012). Add to this the animals that were domesticated throughout SWA, note many beyond the Levant, e.g. sheep, goat and pig (M. Rosenberg et al. 1998; Riel-Salvatore et al. 2021; Daly et al. 2021; Munro et al. 2018).
All of these resources were and are important without a doubt.

However, other wild plants like leaves, herbs, barks, nuts, oily seeds, grasses, tubers, rhizomes and roots (and indeed other materials), which are considered less frequently, would also have held huge importance (Arranz-Otaegui et al. 2016; Arranz-Otaegui et al. 2018a, 2018b; Benz et al. 2017; Colledge and Conolly 2010; Willcox et al. 2008; Wright 1994), along with wild animals hunted, trapped, killed and consumed (Munro 2003, 2009; Rosen and Rivera-Collazo 2012; Yeomans and Richter 2020). The presence of a 'Neolithic package' (*sensu* Childe 2003), in the region of SWA has over the years resulted in research that prioritised finding the origin of that package: i.e. when and where it first appeared (Hodder 2018).
This current study here, tries to nuance this picture, as well as, adding to it. While intending to explore and examine the changes (and continuities) present in the record of Late Epipaleolithic and Early Neolithic, the "transition" and the changes to foodways this period no doubt entailed, it attempts to steer away from grand narratives of founder crops and Neolithic packages. Though the idea of "a package" (Allaby et al. 2021; Weide 2021) has largely been abandoned a result of this thinking, I would argue there still exist an overemphasis on the importance of certain resources, in particular cereals and other founder crops, often at the expense of other plants (or animal) resources outside of this "founder package"(see also Arranz-Otaegui et al. 2018a, 2018b; D. Rosenberg 2008; Willcox et al. 2008; Wollstonecroft et al. 2008, 2011).
This is also to an extent reflected in ground stone tool (GST) research and GST use-wear studies.

Ground stone tools appear in earnest in SWA during the Upper Palaeolithic and consist mainly of grinding tools, handstones and querns (Kraybill 1977; Wright 1991). They become more common in the Epipaleolithic and explode in number and diversity by the Late Epipaleolithic (Natufian). In particular mortars and pestles but also grinding tools (D. Rosenberg 2008; D. Rosenberg et al. 2012; Wright 1994; Dubreuil 2004, 2008).
Much research has focused on these Natufian assemblages, along with a handful of studies on Early Neolithic material and the Levant has the seen most extensively investigated assemblages (e.g. Wright 1991, 1993, 1994; Dubreuil 2004; Pedersen et al. 2016; D. Rosenberg et al. 2012; Rowan and Ebeling 2016). Much less is known about Mesopotamian and Iranian assemblages (but see (Solecki 1969; Conard and Zeidi 2013).

The intensification of ground stone tool use in the Natufian and Early Neolithic presumably mirrors an intensification in food processing, especially pulverising through grinding and pounding, compared to previous periods. This is something that is not in any great doubt, however as mentioned, it is often a priori assumed to be related to cereal or founder crop processing. This is despite the fact that, though cereals are known from several Natufian sites, they are often in relatively low quantities (Arranz-Otaegui 2018; Wright 1994). The same goes for many of the earliest Neolithic sites and not until the PPNB do we really see a significant and dramatic spike in the presence (and thus exploitation) of "founder crops" (Arranz-Otaegui et al. 2018), but see e.g. Jerf el-Ahmar, Tell Abr' etc. (Willcox 2012).

Though we may quite surely recognise adaptations to accommodate foodways, a projection

of the importance of certain crops/resources back in time, to before the Neolithic and even on the earliest parts of the Neolithic in SWA (e.g. the PPNA) where we can not be sure of whether a cereal-based diet had already been established, is dubious.
This is to an extent a teleological issue, aiming to locate the founder crop based economies in diverse and complex foodways of pre-agricultural past. A projection of "founder crop"-primacy backwards, so that these plants become the end all, be all, of plant exploitation in the Early Neolithic or even the Epipalaeolithic.
No doubt "Neolithization" in SWA was a long and drawn out process, taking at least 3000 years (Allaby et al. 2021; Graeber and Wengrow 2021; Hodder 2018; Weide 2021), traces of which may stretch all the way back into the Upper Palaeolithic (Hodder 2018) and not really a swift revolution, as Childe once suggested (Childe 2003). However, interpreting past adaptations and foodways from their conclusion and end-point should be avoided (Finlayson 2013). It is no wonder then, that this also influences the image of ground stone tools and their relationship to these crops. A "marriage" of cereals and GST, as is examined in the course of this thesis, should be approached carefully. We need to divorce this relationship, in order to look at it with fresh eyes, and then we may find that the assumption about an association between GST and certain ressources to be true, but it should be approached open-mindedly and critically, not teleologically.

Certain adaptations that appear prior to Neolithization may or may not reflect changes in diet and there is no guarantee that an adaptation will "stick" and develop into a new economic form ("Neolithic" etc.). However, changes and adaptations to tools and technology (and techniques) still reflect changing foodways as they reflect changes to how food was procured and processed. If we take ground stone as an example, this is after all the material culture explored in the thesis, a change from one form of grinding to another, or to pounding, *is a change*. A change of processing strategies and of production and labour processes. T
his does however, not necessarily reflect a change in the resources being procured for processing. GST appearing does not necessarily spell the rise of cereals.
Rather it may reflect changes to the desired end-products or changes to how labour was organised and performed. We should then perhaps not see the appearance of GST in SWA by the Upper Palaeolithic as part of a starting unavoidable process and entanglement that eventually led to the advent of agriculture (cf. Hodder 2018).
But, rather see it as a new adaptation, a new element of past foodways that enabled the processing of certain things and the production of certain end-products (e.g. meal, flour, porridge, gruel, sauces, tenderised meat, mineral powder etc.) that could and would eventually be an important part of "Neolithic" and cereal-based economies (e.g. see Alonso 2019).
I return to much of this in the papers below but first, let me establish the overall basic approach this thesis takes to ground stone tools.

1.3. Approaching our topic and overall theme - Ground stone tools and food processing strategies

This thesis presents a way to examine specific types of food processing tools, and activity, and more generally how to approach *ground stone tools* (GST) used in food processing. It looks at their role in food processing as a specific task, i.e. post-procurement and pre-cooking food processing, within a larger social production that would have included multiple interconnected tasks, objectives and people. It sees food processing with ground stone tools, like querns, mortars and pestles, not solely as tools with repetitive, menial sequences of necessary operations, but also as socially conditioned actions, *gestures*. These gestures were performed in particular ways, normative ways of use, based on existing knowledge, traditions within society, *habitus* if we follow Bordieu (Bourdieu 1977): 72-96). Actions performed by individuals in order to achieve desirable change in the properties of foodstuff and raw material. Their repetitiveness is exactly where we may extrapolate tasks and products, because such gestures are "absorbed" in and through the tools, materially expressed as morphology and as specific kinds of wear, i.e. use-wear (as well as being deposited as microremains or residues).

These tools thus become an important proxy for specific types of food processing strategies and the production of particular kinds of foods. But without assuming, *a priori*, that it was specific resources that were processed. The aim here is thus to say something about *a* part of *a* process. It is important however, to recognise this is only part of very complex processes and it necessarily links to other processes and thus other studies by other specialists as noted by K. Twiss (2012). Hence the thesis should not be assumed to be "complete" or whole, but rather represents one line of evidence, a focal point, and the analysis of this specific line should be complementary to a range of other different datasets that may also be considered in the future through other kinds of analysis. For example, consulting with archaeobotanists working with macrobotanical material and food remains reveal even more comprehensively what end-products were produced using these tools. Thus I refer, when possible, to the work of my colleagues who specialise in these other lines of evidence, this is mainly the case in Paper 4 (and in part Paper 3), drawing on archaeobotanical and also some zooarchaeological data from the Shubayqa sites.

Embedded in the suggested approach to analysing processing ground stone tools, is a clear recognition of the importance and value of tying (qualitative) macro-, microscopic use-wear-approaches and morphological studies together, to understand how tools were used and on what. The thesis therefore employs a combination of morphological considerations, with low-power use-wear analyses, in an attempt to establish both *how* processing happened, *what* was processed and if/when changes to foodways occured. The reasons for choosing an approach based on movements/gestures, "processing strategies" and low-power use-wear analysis is extrapolated below and in more detail in Paper(s) 2 and 4. This analysis, along with the analysis of microbontaical residues from tools, is used to tease out the traces of the raw material input. The data extracted through use-wear analysis and combined with sampling residues may also tell us a lot about the finished products or output for consumption (Ball et al. 2016; Dubreuil and Nadel 2015; Dubreuil et al. 2015; Fullagar et al. 2015; Lucarini and Radini 2019; Ma et al. 2019; Owen et al. 2019; Portillo et al. 2017; Terradas et al. 2013). The microbotanical residue aspect was planned to be included in Paper 4. These results should substantiate the results of the microscopic use-wear analysis seen in Paper 4, but unfortunately the results from the residues were not completed in time for the submission of this thesis. I rely therefore mainly on use-wear along with processing strategies-approach as means for analysis.

1.4 Current state of GST microscopic use-wear studies and my contribution

A review of the literature and state of use-wear studies is also provided in Papers 2 and 4, but a few comments on how my approach contributes and fits into this field is pertinent.

Ground stone use-wear uses a range of methods, both qualitative and quantitative (including GIS and 3D), to assess how surfaces are altered through use and by contact material. It has by now shown that you may distinguish between relatively broad categories of processing, like grinding from pounding, and between different "contact-materials": e.g. hard seeds, grains (like cereals) from legumes, and these from softer, starchier or oily materials like nuts, or pliable wood. These may then be distinguished minerals, bone or stone and these then from other animal matter like meat, skins and hides (e.g. Adams 2014; Dubreuil 2004; Cristiani and Zupancich 2021; Hamon 2008; Martinez et al. 2013).

Getting much closer to specific contact material, e.g. cereals at taxa level, appears beyond the reach of use-wear alone, no matter how advanced the microscopy is that is applied (e.g. (Li et al. 2020). It is important to note that generally use-wear traces are ambiguous and interpretations of wear are naturally affected by human error and subjective differences in observations (Hamon 2008; Hayes et al. 2017).

This includes both qualitative and quantitative approaches, and the functional interpretations that may be squeezed from such data. These limitations are however, not entirely detrimental, rather they delineate the range of processing activities that it is possible to recognise quite well.

I chose to focus on qualitative low-power use-war analysis, using the well-established protocols for low-power use-wear (see in Adams 1989; 1993a; Adams et al. 2009; Dubreuil et al. 2015) to explore the different contact materials involved with the Shubayqa GST material in Paper 4 (and Paper 2). This works quite well, I believe, with the processing strategies-approach applied throughout, as it allows me to establish a baseline for future investigations. It also allows a basic functional interpretation, using the indicators of differing wear traces, i.e. "characteristic wear", surveyed from a range of studies of basalt ground stone from the SWA region and beyond (see Paper 4 and the supplementary materials there). Beyond just contact material, use-wear may also be used to substantiate the recognition of present processing strategies, their related wear and how wear forms and changes through use (see Paper 2).

Few would argue for using any one use-wear technique alone. But unfortunately, it seems that even fewer argue for a focus on the movements and bodies involved in processing and which would have the prime mover in any tool technology supplied with human power alone. This is where I in particular aim to contribute.

Often focus within GST wear analysis has been mainly on recognizing contact material (e.g. (Liu et al. 2010; Revedin et al. 2014) and somewhat neglects considerations of *how* tools were used, e.g. looking at gestures etc. The ways tools are used (*ways of use*), influences the formation of surfaces and their wear, while these tools also dialectically and continually influence how they may be used. For example, as a lower grinding is used repeatedly in the same way the active surface of it will change, e.g. become deeper, more narrow and/or more concave (e.g. Adams 1993a, 1993b; Stroulia et al. 2017; Delgado-Raack and Risch 2009) see also Paper 1 and 2). Similarly at a macro/microscopic-level, a surface takes on the wear and traces of the gestures, the corresponding (upper/lower) tools and of the contact material. At some point the surface will also "wear-out", meaning it can no longer be used effectively (from a loss of abrasiveness) and will need a re-dressing/re-pecking of the surface to be functional again (Adams 2014; Nixon-Darcus and D'Andrea 2017; Robitaille 2016). This then changes, and erases, the previous use-wear. This means that tool surfaces and consequently use-wear traces are constantly influenced by factors that function *in addition* to the material properties of the contact material itself, *i.e.* factors like gestures, tool compatibility, desired end-product, that all part of the food processing chain (see Paper 1 on this). Thus, focusing solely on how contact material must have affected the stone (surface) rather than on how was processing achieved (what way of grinding or pounding); and how might the two stones in a food processing tool pair have affected each other, leaves out important parts of the story. This is why it is important to consider gestures and view tools as part of larger processing strategies. These things I address in Paper 1. What I then elaborate in Paper 2 is how to recognise and delineate these strategies through morphology (also done in AGSTR Paper) and by using low-power use-wear analysis. In Paper 4 these considerations are combined with more traditional functional use-wear analysis of the Shubayqa ground stone.

Now, I am not the first to suggest that gestures, actions and movement are important in GST research (e.g. (J. L. Adams 1993b; de Beaune 1989; de Beaune 2004; Dubreuil 2008; Dubreuil and Plisson 2010; Kadowaki 2014). They very often included in experiment, but how kinetics and movements influence GST use-wear and surfaces has been somewhat lacking (noted in (Dubreuil et al. 2015) and kinetic factors are not always considered in SWA ground stone studies (but see, e.g. (Dietrich et al. 2019; Dubreuil 2008; Dubreuil and Plisson 2010; Dubreuil and Nadel 2015; Kadowaki 2014; Nierle 2008).

Generally within GST use-wear studies there appears to be more interest in, and use of, high-power types of microscopes and microscopy, 3D imagery, and advanced qualitative and quantitative approaches (Adams et al. 2009; Adams 2014; Adams et al. 2015; Delgado-Raack and Risch 2009, 2016; Dubreuil et al. 2015; Dubreuil and Grosman 2013; Dubreuil and Plisson 2010; Revedin et al. 2018), often in combination (Bofill 2012; Caricola et al. 2018; Cristiani and Zupancich 2021; Dietrich and Haibt 2020; Zupancich and Cristiani 2020; Zupancich et al. 2019; Chondrou et al. 2021; Martinez et al. 2013; Benito‐Calvo et al. 2018). This relatively recent trend has perhaps blurred or clouded the importance of understanding tools as more social technologies, parts of sociotechnical systems, and not seeing how GST use-wear is also influenced by a range of social factors, that affect ways of use, and thus tool morphology and wear traces (but see Delgado-Raack and Risch 2009, 2016). Appealing as new methods and techniques are, as new tools to illuminate use, they are not a “shortcut” to grasping socio-technical or subsistence behaviours. The analysis and results are still filtered through human actions and interpretations, a Baradian process (see (Tsoraki et al. 2020). For example, as noted by (Zupancich and Cristiani 2020), quantitative methods which are increasingly popular, fall short when assessing gestures used, thus losing sight of the motive forces that enable the use of the tool. In addition raw material properties highly influence the quantitative results (Chondrou et al. 2021). Concurrently qualitative studies often are mired by issues of reproducibility (Hayes et al. 2017) and some types of use and related use-wear may be more pronounced and leave clear traces (e.g. cereal processing) observable both qualitatively and quantitatively, while other contact materials may only be recognised through residues and (microbotanical) sampling (Fullagar et al. 2016; Hamon et al. 2021; Hayes et al. 2021; Liu et al. 2014; Santiago-Marrero et al. 2021).

As mentioned, the focus on “founder crops” also affects the way GST are perceived and interpreted, and this also includes GST use-wear studies. A brief survey of use-wear studies from 2001-2021 (of 18 studies)[2] show that most use-wear studies have tended to focus on these plants normatively associated with the Neolithic transition in SWA (and North Africa). “Founder crops” are the contact materials most often mentioned. 78% (*n= 14*) of the studies consider cereals or other founder crops[3]. A resource commonly found in the macrobotanical assemblages of the Natufian and Neolithic of SWA is tubers (Arranz-Otaegui et al. 2018b). This resource is however almost never mentioned or explored, either in experimental programs or interpretations, in GST use-wear studies. Only one paper from a SWA assemblage mentions e.g. tubers/USO’s and even in this study the evidence comes from microbotanical residues and not from GST use-wear itself (see (Santiago-Marrero et al. 2021). Ten studies also mention nuts, fruits, other seeds and wild grasses, and four mention meat but the focus quite clearly falls on ”founder crops”, and cereals in particular. It is often thus the assumption, *a priori, that* it was cereals or other kinds of “founder crops” that these tools processed at least by the Early Neolithic (Dietrich and Haibt 2020; Martinez et al. 2013; McCorriston and Hole 1991; Portillo et al. 2013). As mentioned, this is likely because they are the resources that we scholars most commonly associate with Neolithization, domestication and early farming (Boyd 2002).

Now this is not to say these previous studies are not all very important, quite the contrary. They have helped greatly to establish a baseline from which to conduct use-wear on SWA assemblages. This simply means that both archaeological interpretations, in research design and in development of experimental programs, often focus on these “founder”

[2] These 18 studies are: (Bofill 2012; Bofill and Taha 2013; Dietrich et al. 2019, 2020; Dietrich and Haibt 2020; Laure Dubreuil 2001, 2004, 2008; Laure Dubreuil and Grosman 2009; L. Dubreuil and Grosman 2013; Laure Dubreuil and Nadel 2015; Laure Dubreuil and Plisson 2010; Liu et al. 2018; Lucarini et al. 2016; Lucarini and Radini 2019; Martinez et al. 2013; M. Portillo et al. 2013; Santiago-Marrero et al. 2021; Terradas et al. 2013)

[3]A mention here refers to if a contact material has been considered either in the experiments, through archaeological evidence, including both use-wear as well as botanical residue evidence. So not the times it is mentioned in a text but whether it is considered in the text. So if one or several founder crops is processed in some experiments it counts as only 1 mention of founder crops, if hide-working is identified or tried, it counts as 1 mention of hide and skin processing within that text and so on.

activities. It is rather a caution and call to expand experiments and interpretations of contact materials and an issue I explore in my thesis.

As mentioned, one should also keep in mind that wear traces and interpretations of use-wear, no matter the scale, method and approach is not clear-cut evidence of activities, rather they simply may indicate an activity. This is not the full sum of activities nor is the interpreted use-wear the "true" use (Marreiros et al. 2020). It hints at possibilities but does not "prove" them . This is not to discredit GST use-wear analysis, after all it is a method of analysis and interpretation used in this thesis, rather it is to caution. To highlight that both the use of advanced methods of qualitative and quantitative, as well as simpler lower-power approaches have their limitations and should stand on their own. In the future it will be useful to combine my results with 3D, GIS and photogrammic approaches and with experimental food processing to further flesh out morphological changes to tools from wear along with the resulting use-wear.

1.5. Main questions and issues tackled by the thesis

It is the intention of this thesis to highlight that food processing ground stone tools are technologies consisting of corresponding artefacts working together to change material properties/textures of food-products, and they are operated by the gestures of human agents (and their) agency. They are embedded within sociotechnical traditions and practises, with associated ideas, intentions and traditions that are trapped materially in stone. It aims to refocus the sometimes lacking conceptual understanding of these tools and the social conditions and milleus that they work in and what specific processing methods they represent, and not just what they are used to process. By (re-)introducing the body and movements (gestures) from the perspective of the stone tool, I here try to recalibrate the gaze and by fixating on these idealised examples of use and wear, these ways of processing, creating larger categories of "*processing strategies*". This is a view of movement and bodies, from the perspective of the tools, the object, the material.
What it also explores is whether these broad categories correspond with broad categories of processed material, be they tubers, nuts, cereals, meats etc. Or whether they rather illustrate *how* things are processed. Ways of use, not tied to very specific materials and functions, but to processing tasks/steps. By applying the approach advocated for in the papers and considering both use and contact materials more broadly, we may elucidate the different ways of processing present at a site. These *ways of use* come to represent specific parts of the *foodways* of people in the past. How they interacted with food prior to consumption. Using the tool to elucidate movements, bodies and the intentions of agents.

In conjunction with emphasising the importance of gestures and strategies and their effect on tools, this thesis does not shy away from contributing to the understanding of what was processed using these tools, i.e. contact material. It will however aim to expand our interpretations somewhat. As mentioned this is done by conducting classic functional analysis, but it is also attempting to show that the use and function of these strategies was not uniform, and at times were quite diverse. This is an issue that was just illustrated by looking at the literature on ground stone tool use-wear and contact materials. This consequential “founder crop” -rimacy comes at the expense of considering other materials (but see Dubreuil 2004). The work wishes to nuance this view.

Selection of data

The thesis in its selection of empirical data, its focus and approach and its interpretations, attempts to close several knowledge gaps. Firstly, it tries to argue for the recognition of broad “processing strategies” within GST used in food preparation. This recognition and categorisation of strategies should be based on gestures, tools morphology, considering the progression of wear through use and the macro/microscopic traces of gestures. This is based on empirical data, from the two Shubayqa sites, spanning the Early Natufian to the Early and Late PPNA (to Early PPNB) and the strategies are illustrated using the materials from those sites.

Furthermore this data is also selected because it covers a transitional period, the Late Epipaleolithic to Early Neolithic. The assemblages used in the thesis and the subsample subjected to use-wear analysis thus also spans a quite long period, within the same area, something most use-wear studies of SWA assemblages do not. Often GST use-wear studies deal with either with Late Epipaleolithic (Natufian) assemblages (e.g. Dubreuil 2004; Dubreuil and Grosman 2013; Terradas et al. 2013) or Early Neolithic ones (e.g. Bofill and Taha 2013; Dietrich et al. 2019; Dietrich and Haibt 2020; Martinez et al. 2013). Rarely is material both periods analysed (but see (Dubreuil 2008). The data presented here thus helps bridge this gap and look at technological trends and changing foodways over a longer time period.

Finally, this data was also selected as it has the potential to expand our understanding of processed contact materials. Since tubers are such an abundant resource at Shubayqa 1 (see (Arranz-Otaegui et al. 2018a, 2018b) and Paper 3 and 4 below), we would expect at least some chance of seeing the traces of tuber processing in the ground stone assemblage. This is addressed in this thesis in Papers 3 and 4 in particular. The results from the experiments in Paper 3 are thus an important addition as they aid in recognising other contact materials than are conventionally considered within SWA GST use-wear.

So the thesis touches on both *what* and *how* foodstuff was processed. It is underlined that the way people treated certain foodstuffs after procurement is an equally important part of past foodways as what resources were processed (Hastorf 2017; Twiss 2012, 2019).Though we may not be able to extract specific recipes, we may reveal how processing occurs, and on what material and follow these changes over time, thus illuminating changing foodways. By looking at food processing ground stone tools, from a specific point in time, the Late Epipaleolithic to Early Pre-Pottery Neolithic, and in a specific setting i.e. the Qa’ Shuabayqa of Eastern Jordan, we may find information that is crucial for our understanding of food technology and society and developments during a transformative period of human history.

2. Summary of papers

2.1. AGSTR-paper, title: The Groundstone Assemblages of Shubayqa 1 and 6, Eastern Jordan - Technological choices, Gestures and Processing Strategies of Late Hunter-Gatherers in the Qa' Shubayqa.

As sole author, published in AGSTR 2019 conference proceedings by Archaeopress.

Main purpose: *Overview of assemblages and sites included in the PhD-thesis, focusing on food processing strategies present at the sites and changes to these over time.*

This paper was published as part of the conference proceedings of the 3rd AGSTR meeting, held in 2019. The paper was based in part on work I did for my unpublished MA-dissertation (Pedersen 2017). It synthesises that larger dissertation, while including extra data (and excluding other general data) and reworking the narrative and focus. It was rewritten to present a more concise and clear point and edited to fit the format of the publication. This paper acts as a background article to the rest of the article-series. It was in this work (i.e. the MA-dissertation), I first developed and applied the "processing strategies"-approach. Then called "pulverizing-strategies", this initial study showed the approach's usefulness and it was therefore updated for my presentation at the AGSTAR-conference. The paper was subsequently peer-viewed and edited in the course of the production of the proceedings and is now published (as of December, 2021) as a book by Archaeopress, part of their Access Archaeology series. This publication also gathered most of the other contributions from the AGSTR 2019 conference and work as editor of the publication was also undertaken by me as part of the work contribution for my PhD-program. I provide here an amended and expanded abstract of the published article to serve as the summary for this paper.

In this paper I explored local scale technological changes in ground stone technology from the Early and Late Natufian to the Pre-Pottery Neolithic by looking at two ground stone assemblages from the two Levantine prehistoric sites: Shubayqa 1 and 6.
These sites are located in the harra desert of eastern Jordan and the material presented here comes from phases dated to the Early and Late Natufian and the Pre-Pottery Neolithic (PPNA to early PPNB) respectively (c. 14,600–10,500 cal. BP). With a focus on tools used in processing, or crushing tasks, I here concentrated on a specific element of ground stone technology: i.e. how gestures (or technological actions), influenced, and were influenced by tool morphology; and how this can be seen as an expression of technological choices, aimed towards different processing strategies, taking place within a larger sociotechnical system where such actions were conditioned. Using the ground stone assemblages of the Shubayqa sites, this paper surveyed the distinct technological developments that took place during a period where significant societal changes occurred. Most importantly perhaps was dietary and social changes in the wake of the transition from mobile hunter-gatherers towards more sedentary, agricultural ways of life. Thus, this data provided an insight into how food processing strategies changed, at a local scale, at the end of the Epipaleolithic and the

beginning of the Neolithic and refined the "standard-view" of technological developments. The paper used the scheme of food processing strategies based on gestures (elaborated in Paper 2) and their dialectic relationship with tools and wear. I illuminated how technological choices changed and I suggested that most of the changes I observed were the results of local modifications and adaptations based on past knowledge and traditions within a sociotechnical system. This knowledge was applied by individual agents by choosing specific actions to meet challenges and process food in ways they found satisfactory. The analysis showed that it was possible to refine the "*standard view"* of ground stone technological development by using these processing strategies showing that technological developments are less linear and singular than often assumed. The diversity of strategies was also shown to change over time. The period with the most diversity at Shubayqa was the Late Natufian, possibly due to a changing local environment. Over time there was an increase in the size of active surfaces and a focus on confined grinding strategies, in the Late Natufian circular grinding (RGP-strategy) and in the EPPNA back-and-forth grinding (CRG-strategy). This reflects conscious choices, I argue, people using existing technology and knowledge to either: increase the amount of edible end-product, stretch or intensify the use of resources, shorten work time, efforts towards producing specific end-products, or possibly all of the above.

2.2. Paper 1, title: Of Muscle and Stone: Ground Stone Tools and Food Processing Technology - Bodies of knowledge.

As sole author. Unpublished.

Main purpose: *Defining food processing, ground stone used in food preparation, the role of gestures, socio-technical systems and (re-)Introducing the body from the perspective of the tool*

This paper outlines the key concepts of the article-series/thesis and the theoretical approach. It attempts to stay general, while also drawing on the specific knowledge accumulated from my work on SWA assemblages. Rather than going into details with the tools, and specific periods that the rest of the thesis deals with, it presents the broad concepts crucial to the methodological approach outlined in Paper 2. These concepts are also applied in the AGSTR-Paper, Paper 2 and in the final paper, Paper 4, to elucidate the changing foodways of the people inhabiting the Shubayqa sites.

Most importantly these concepts include: "pre-consumption preparation" and food processing, sociotechnical systems and *technology,* techniques and gestures (a crucial part of labour processes). Below I provide a brief overview of these concepts as they are outlined, defined and used in Paper 1, and also in the rest of the article-series.

Firstly, in Paper 1, I wish to define what I mean by food processing broadly, and more specifically non-mechanical food processing using hand-made (stone) tools.

Here, I borrow the definition by Crittenden and Schnorr: *"the purposeful external modification of a resource to change its physical or chemical attributes in preparation for consumption"* (Crittenden and Schnorr 2017): 91). This is naturally a broad definition and can refer to a number of different tasks and processes, therefore I further specify the exact process that would involve the GST I examine. This I find within the work of K. Twiss. GST, it is argued, are part of pre-consumption preparation (Twiss 2012). GST aid in post-procurement and pre-consumption processing activities, rendering food cookable, edible or storable. This labour is not only interesting in of itself, but also because of the other tasks it implies. A number of different (before *and* after) processes are linked and entangled, e.g. harvesting, cleaning, threshing, winnowing, peeling, drying, sorting, roasting, booking etc. (see also in Hodder 2018).

As it is non-mechanical this processing is done by people, enabled by their tools and operated by their bodies and gestures. The main force of change is the *subjective* body and gestures and the *objective* tools and their material properties. Such, processing may or may not involve some thermal/chemical processing e.g. roasting or soaking as part of the processing, but the main mode of change is through the kinetic energy supplied by the body (see examples in (Alonso 2019; Ertug 2002; Schroth 1996; Searcy 2011; Shoemaker et al. 2017). The body in turn then receives its metabolic energy from the food produced. This is a labour process, with a raw material input, i.e. wild foods (plants and animals), transformed (processed) by bodies (human agents) and tools (GST) into changed "products" ready for further processing, cooking, storing or consumption, and so the labour process continues and repeats. This labour process is driven by human "gestures" and is inherently a social process which leads us to the next core concepts:

This food processing, i.e. this labour process happens within the *technology* of a society. Technology is broadly defined in this work as: *"...a mode of production, as the totality of instruments [..and..] a mode of organization and perpetuating (or changing) social relationships, a manifestation of prevalent thought and behavior patterns…"*(Marcuse 1941: 139). This definition is akin to the sociotechnical systems concept proposed by Pfaffenberger (Pfaffenberger 1992), that is also applied here. Within this framework technology, including the production and use of tools, is influenced by social aspects and elements and part of a larger social complex. It is within these (socio-) technical systems, this *technology* (*sensu* (Marcuse 1941), that tools and gestures are applied to transform material, to process foodstuff. Technology is thus a totality of labour and techniques, communication and the social coordination of labour, including norms and ideas of tool use and tasks, condition gestures and tools.

Gestures, following (Leroi-Gourhan 1993), are established as the bodily movements and actions that make tools and make tools function. These gestures are a result of social knowledge, practises and traditions, personal experiences, and learning. All "non-mechanical" tools will require gestures or *techniques* to function, though techniques do not necessarily require tools (Ingold 2002). Following the line espoused above one cannot detach a tool from the gestures that make them functional (see also Lemonnier 1992: 50), nor from the sociotechnical system exist in.

The tools are thus results of labour, they absorb labour and also facilitate labour, through the animate power of the human body (see (Malm 2016): 13, on animate power). They only really "become" tools when used with the techniques of a subject (Ingold 2002). Tools and related gestures, are thus both the result of sociotechnical traditions of a society and in turn influences that society's traditions and mode of production (Pfaffenberger (1992)

When it is possible for us to at least try to unpack the social reality behind techniques and tools (in this case GST) it is because of the reciprocal and dialectical relationship that exists between gestures involved in the operation/use of artefacts and the subsequent morphology of the used tool (and surfaces). Just like there exists a dialectical relationship between gesture and language (Mcneill 2006) there exists one between gestures (bodies) and tools (objects).

It has long been established that continuous use alters the physical appearance of the artefacts and in this also the case with ground stone tools, at both a overall morphological, macroscopic level observable with the naked eye (Adams 1993a, 1993b, 1999; Delgado-Raack and Risch 2009, 2016; Dubreuil 2001; Kadowaki 2014; Nierle 2008) and at a microscopic level (Adams 2002; Adams et al. 2009; Dubreuil 2004; Dubreuil and Plisson 2010; Dubreuil and Savage 2014; Marreiros et al. 2015). Gestures, *i.e.* labour, are thus expressed in the instruments used, as well as in processed material.

Use-wear and wear management therefore equals the *remains of labour, gestures and social processes*. This makes ground stone tools highly suited for studies of differentiating technical gestures and consequently social behaviour. This is why I, in the subsequent papers, e.g. in Paper 2 and 4 in particular, argue for combining an approach that uses both typology and morphology, along with qualitative use-wear to establish broad categories of processing strategies. These strategies are then in turn based on gestures as these gestures are expressed in morphology and wear; and in turn inform about the sociotechnical traditions of people, society.

To summarise these central concepts: food processing (labour) needs gestures to be performed; these are socially conditioned and follow the norms of the sociotechnical system. This is then expressed materially in the tools; a material expression of these dialectic relationships between tools, bodily gestures, social relationships, raw material, societal norms *etc* that which we attempt to disentangle, observe and analyse.

I then by the end of this paper turn to the role of the body and argue for a (re-)introduction of the body, but from the perspective of the tool. Importantly these tools are still "subject-centred", meaning they are operated by individuals' bodies, techniques and gestures (Ingold 2002). Bodies and gestures shape tools and surfaces, and tools and gestures affect the body, quite literally. Often this may be explored through osteology. In SWA, studies have examined the relationship between GST and bodies through this bioarchaeological lens. Such studies have examined skeletal stress markers, robusticity of muscle attachment sites or joint deterioration on human remains to see the results of food processing activities on the body (e.g. (Eshed et al. 2004; Molleson 1994, 2000). However, such studies rarely consider the tools or the perspective of the tool, and specific gestures involved in any great detail, and consequently I feel these interpretations fall short. Instead of considering the labour's effect on the body, we may turn this on its head, understand the gestures behind tool use, and then the effect on the body. This is at least a point to highlight for future research, to consider the tools' perspective on the body as well as the osteological evidence.

I also then touch on the question of whose bodies were involved. Here I find that, though often the case, there is a slight overemphasis on food processing and consequently gathering, as exclusively female labour. I caution that we project a certain (sexual) divisions of labour unto the past uncritically. Furthermore, I also challenge other common misconceptions, that tool surface shape is somewhat unintentional. As the approach and the concepts above outline, wear in the form of surface use-wear traces and morphology is not simply the unintentional results of use, but the intentional use of specific gestures and tools (Adams 1993a). Concurrently, both pre-use shaping, i.e. making the stone tool and shaping *through use* is entirely intentional.[4]

Finally, I return to and highlight the importance of food processing for pre-mechanical and pre-agricultural societies. Pre-consumption processing tasks are time-consuming tasks. Making plant and animal matter edible, cookable or storable requires intimate knowledge of the tools and raw material involved and how to coordinate labour and communicate requirements of specific tasks. Pre-consumption processing thus sets a whole sociotechnical system in motion.
Ground stone tools offer a way to see the actions of human bodies and the effect of their gestures on tools, as material expression of sociotechnical systems and human agents. Changes to these systems and gestures, thus reflects changes to foodways, adaptations and innovations to food processing.

2.3. Paper 2, title: Cast in Stone: Tools from movements, movements from tools - Approaching ever changing ground stone.

As sole author.

Topic: *Tool morphology as the material expressions of gestures, bodies and labour. On finding processing strategies from tool surfaces, progressive wear and use*

As I established in Paper 1 tools are the material results of labour and techniques. Gestures are thus expressions of a labour process and they are absorbed and objectified both as the end-product; e.g. food, but these movements are also absorbed and objectified in the instruments of labour, the tools.
The traces of these gestures are trapped and materially expressed in tools as morphology and microscopic use-wear traces, left for us to examine. Thus, at the basis assumption of this paper follows what was established in the previous ones, I reiterate: *ground stone tools are*

[4] Note that parts of the section on the gender aspects of ground stone tools presented in Paper 1 was originally devised during an MA-course and exam in 2015. This work is unpublished but nonetheless a few observations and points made there also feature in that section.

repositories of social labour processes and individuals' actions and choices, embedded within sociotechnical systems with norms, practises and traditions.

In this paper (Paper 2), I aim to detail further and expand on the reasoning behind the so-called "processing strategies" (also seen in AGSTR-paper).
It uses tool morphology and typology (specifically Wright's 1992), along with macroscopic and microscopic wear on tools resulting from use to argue for the existence of certain processing strategies.

In the past kinetics and movements, i.e. gestures, have often been mentioned but rarely explored in detail in use-wear studies. This paper creates a synthesis of the concepts espoused above and low-power use-wear, along with an understanding of the progressive nature of wear and how different stages of wear affect both the overall morphology of the tool and the active tool surface(s) and their macro/microscopic wear.
This is thus an attempt to synthesise different levels of observation and analysis into a coherent understanding of *ways of use,* i.e. tools and processing strategies express ways to process material and to manage tool wear; and not (necessarily) the processing of specific materials (e.g. cereals). Rather they represent overall strategies of reduction, of changing material properties of food and other matter.

The physical properties of the artefact, either through design and/or continuous use, confine, limit, guide or control the actions/gestures it is possible to perform effectively on/with that artefact. Again this is done with the intent of changing the properties of matter in desirable ways, by performing socially conditioned gestures, in ways deemed correct. In addition to the importance of gestures, the approach is inspired by the "tool pairs" and "wear-management" concepts seen in Adams (e.g. Adams 1993b, 2002). These aspects all influence the compatibility of the tools and ensure that use may continue uninhibited.

As was also the case with Paper 1, this work attempts to be relatively "general". It aims at outlining a general approach to GST and processing strategies that may be used for other assemblages, not just in SWANA, but elsewhere as well. I thus believe it has future potential. If, for example, it is applied to other SWA GST assemblages, it may reveal more detailed information about the practises of (food) processing and how they changed more broadly in the region, during the Late Pleistocene and Early Holocene. I include such a short, and admittedly incomplete, comparison in the thesis in Paper 4, to illustrate this possibility.

The work in Paper 2 (and beyond), is based on the GST assemblages of Shubayqa 1 and 6 that were also analysed in the AGSTR-paper, while also using a subsample of 64 tools that is then subject to low-power use-wear analysis. The tool, as mentioned, dates to the Early and Late Natufian at Shubayqa 1 and the Pre-Pottery Neolithic EPPNA to LPPNA, from Shubayqa 6, spanning c. 14,800–10,600 cal. BP. Again, the exact dating and phasing of the site is not all that important for the paper here, and this is more part of the discussion in Paper 4 (and also the AGSTR-paper).

The paper argues that there are four main ground stone "food processing strategies" present at the two Shubayqa sites. Three *diffuse resting percussion* i.e. grinding strategies and one *diffuse thrusting percussion*, i.e. pounding strategy (see also (Leroi-Gourhan 1993; de Beaune 2004). These are: A1. Confined Reciprocal Grinding (CRG), using an ovate-type handstone moved in a back-and-forth gesture on a basin-type grinding slab. A2. Open Reciprocal Grinding (ORG), using a loaf-type handstone moved in a back-and-forth gesture on a block- or saddle-type grinding slab. A3. Rotary Grinding with some pounding (RGP) using a discoidal-type handstone moved in a circular/rotary gesture on a basin- or block-type grinding quern. B. Confined Pounding with some rotary grinding (CPR), using a pestle moved in an up-and-down and circular/rotary gesture against the (interior) bottom and sides of a mortar. These were initially defined as part of my MA-dissertation and AGSTR-paper, but in Paper 2, I outline how wear, wear management, i.e. stages of wear and macroscopic and microscopic traces substantiate and delineate the different strategies.

As mentioned above the macro/microscopic traces are observed through qualitative low-power use-wear analysis using the protocols suggested in (Adams et al. 2009; Dubreuil et al. 2015). An overview of this use-wear and residue sampling protocol is detailed in Appendix Ia and Ib.

For each strategy I go through the Shubayqa archaeological data, i.e. sizes, planar, longitudinal and transversal shape along with observations of how morphology and shape changes through use/wear. Over time tools from the respective strategies go through different "stages of wear" and so too does the macro/microscopic wear. I present these stages of wear in schematic idealised illustrations of tool shapes and their wear along with archaeoæogical examples. The archaeological examples are then used to highlight the microscopic correlates of the different strategies. These idealised stages of wear, and schematic overview of changes to tools through their use (use-life) seen in the figures, then illustrate the usefulness of considering tools of variable sizes and shapes as part of broad "processing strategies". Importantly these strategies that coexist, supplement each other and sometimes overlap. In Appendix II each of the strategies described in the paper is described in even further detail.

As noted, the proposed wear stages also includes a macro/microscopic perspective, gathered from the low-power use-wear analysis. This perspective focuses on the location of wear traces and their interpreted directionality (or patterning). This is slightly in contrast to Paper 4, where focus is on the interpretation of the traces as indicative of certain contact materials. These patterned traces reflect the strategies the analysed tools would have been used in. Importantly, just like the stages of wear suggested to affect the overall morphology of the tool, these macro/microscopic traces also go through different stages, from "beginning", to being "pronounced" to then be "worn-out". These traces, it is argued, appear and disappear through use, and thus along with the overall "stages of wear" allow for an assessment of both the strategy and use. The stages of wear and directionality also affect how "clear" or characteristic wear traces will. As seen in Paper 4, if a tool has a pronounced wear pattern, this wear may inform both about the contact material, more so than a "worn-out" piece (see also (Adams 2014).

Of course these are qualitative observations and idealised suggestions of the progression of wear based on a limited sample, and are not going to be exactly what one faces in reality as a ground stone analyst and specialist. But they provide suggestions as to why some tools look the way they do, what tools should be grouped together (as a "processing strategy") and suggest why they should be grouped as such, and what these general broad categories then help us examine (again see also details in Appendix II).

This then provides a basis for the analysis of contact materials as is seen in Paper 4, one that also considers the tools as representative of *ways of processing* raw material. Expressions of labour processes, absorbed and objectified in the tools, as well as absorbed and objectified in the contact material and the end-product; *e.g.* food for consumption. Thus they represent changing foodways not just in the contact material, the food being processed, but the ways of processing it. As established in Paper 1, these strategies and this wear are of course entangled with bodies of agents and wider technological practises and labour processes. All of this happens within a society that also influences the labour, the gestures, the processed material and the tools.

2.4. Paper 3, title: The chaîne opératoire for club-rush (Bolboschoenus glaucus) tuber gathering and processing, an interdisciplinary approach.

As a co-author. All authors are: Amaia Arranz-Otaegui, Patrick Nørskov Pedersen, Ann Frijda Schmidt, Anne Jörgensen-Lindahl, Joe Roe, Johanne Villemoes, George Alexis Pantos, Kathryn Killackey. Submitted (JAS), but not published.

Main purpose: *An experimental study and attempt at reconstructing the use of club-rush tubers (Bolboschoenus glaucus) as a food resource during the Early Natufian.*

This paper was initially presented by me at the 26th Annual Meeting of the European Association of Archaeologists (EAA) 26.-30. August 2020, held online because of the COVID-19 pandemic.

It presents experimental archaeological and archaeobotanical research conducted over several years (field-seasons) in the *harra* desert of Eastern Jordan by various members of the Shubayqa Archaeological Project team, including myself. The experiments were led by Archaeo- and Ethnobotanical specialist A. Arranz-Otaegui, who is also the main author on this paper. Arranz-Otaegui designed the majority of the experiments, especially those related to procurement and initial processing of the *Bolboschoenus glaucus* (club-rush) tubers. The tubers were harvested" over several seasons, during winter, spring and summer and autumn, and all were collected from the shores of Lake Burqu some 50 km east of the Qa' Shubayqa. My part of the experiments initially consisted of assisting Arranz-Otaegui and later, during our last field-season in the spring and early summer 2019, producing and using experimental replicas of Natufian basalt ground stone tools.

The purpose of the study was to expand on the current literature of *chaîne opératoire* reconstructions for plant exploitation within archaeobotany as previous studies have often focused on "founder crops" like cereals. Our study on the other hand provides new insights into the use of another wild plant resource: *Bolboschoenus glaucus* (club-rush), a plant that produces edible rhizome-tubers. Interestingly, this is one of the most common taxa found in the archaeobotanical assemblages of Natufian and Neolithic sites in Southwest Asia (Arranz-Otaegui et al. 2018a; 2018b; Wollstonecroft et al. 2008). The archaeobotanical assemblage of Early Natufian Shubayqa 1 is no exception with over 50,000 tubers and tuber fragments being retrieved from to fire-installations (hearths). This suggests that people were exploiting this resource, in one way or another, continually going back to c. 14,600 years ago.

In the experiments the tubers were processed in a number of ways including drying, roasting, as well as pounding and grinding (with GST). Tuber "flour" was also produced, along with cereal flour, and made into bread-like food products (this part of the experiments however, did not make it into this specific study, nor the dissertation, and will only be published at a later point). The study thus attempted to establish how these plants were procured and processed, using an interdisciplinary approach, combining experimental archaeobotany and analyses of experimental ground and chipped stone tools. Based on our experiments the overall conclusions of the study were:

1. The best season for club-rush rhizome-tuber collection in the *harra* was spring-summer time

2. That the best method to harvest the plant was uprooting

3. That the most efficient approaches to obtain perfectly peeled and clean rhizome-tubers could have entailed activities like drying, roasting and gentle grinding using ground stone tools.

We note that many different ways of processing tubers likely coexisted. For example, several of the archaeological tubers went into the hearths fully processed and thus our study may in the future also allow us to suggest what different processing modes were present, and not, in the archaeological assemblage(s). The study produced crucial reference materials that going forward, may be used as a basis to classify the state of the archaeological rhizome tuber assemblage recovered from Shubayqa and beyond. It allows us to start and try to disentangle some of the activities related to the procurement and processing of this particular root food. As alluded to in Paper 1, these were complex and entangled tasks, that communities were engaged in, and would have required several steps and the coordination of a significant amount of labour and people.

This study thus, also provided a baseline for tuber/USO use-wear on ground stone tools. Presenting notes on characteristic traces of tuber processing from both grinding and pounding (see also Appendix III). Tubers are still a material rarely explored (or recognised) within GST use-wear studies (but see Hayes et al. 2021; Liu et al. 2014). The results of a low-power use-wear analysis based on the experimental processing of tubers (and cereals) in this paper appears in Paper 2 and 4. All six experimentally produced basalt tools were subject to this use-wear analysis. Though this analysis does not appear in this paper (Paper 3), some of the results and interpretations can be found in Paper 2 and 4. In Paper 2 focus was mainly on body positions and the location and directionality of use-wear traces on the experimental tools. Paper 4 uses the use-wear results for interpretation of archaeological traces, to find wear indicative of tuber processing on the archaeological tools from Shubayqa 1 and 6.

My contribution(s) also focused mainly on the ground stone tool parts of the study. This included selecting tool types to be replicated, choosing the right (basalt) raw material, and producing and using the basalt replicas. In addition, I aided in planning and carrying out most of the experiments, including recording data and acquiring materials for experiments. Participated in the execution of the gathering, processing and cooking experiments conducted in Jordan in 2019, in close collaboration with the main author A. Arranz-Otaegui. Including but not limited to, collecting tubers at Lake Burqu, building fire-installations, in addition to making and using the ground stone tools in the tuber processing and sampling tools for microbotanical residues.[5] The low-power use-wear analysis of the experimental basalt tools (and residue analysis) did not make it into the paper, but the results are presented in the other papers: Paper 2 and 4 (and Appendix III).

Specific sections authored by me are: 2.2.1. and 2.2.4. in the main text. While I also participated in the execution of the experiments in sections 3.1. and the associated experiments. Sections 3.2.2.1. and 3.2.2.2. were authored together with main author A. Arranz-Otaegui. I made and arranged figures no. 2, 4, 7, 9 and 10. Generally, I also edited and commented on all previous versions of the paper. In addition to this, I authored sections 2.1 and 2.3. and co-authored section 3. in the supplementary materials.

2.5. Paper 4, title: From Stone to Food: Foodways and processing during the Natufian and Early Neolithic of Eastern Jordan - A Ground stone perspective

As main author, all Author(s): Patrick Nørskov Pedersen, Monica Nicolaides Ramsey, Amaia Arranz-Otaegui, Tobias Richter. Unpublished.

A Contribution to understanding changes over time

The work here (and in Paper 2 and 3 as well), is based on tools on the knowledge gap explained above. Most use-wear studies of SWA assemblages do not consider gestures (in detail at least) and often focus on a limited number of contact materials. Furthermore, scholars often deal with either assemblages from the Late Epipaleolithic period, i.e. the Natufian (Dubreuil 2004; Dubreuil and Grosman 2013; Terradas et al. 2013) or the Early Neolithic (Bofill and Taha 2013; Dietrich et al. 2019; Dietrich and Haibt 2020; Martinez et al. 2013). Few look at both these two broad periods together and provide data that encompass this transition. Though some studies do this for the earlier parts of these periods, e.g. the Natufian (Dubreuil 2004; Dubreuil and Plisson 2010) or the later Neolithic (e.g. Portillo et al. 2013), this unfortunately ends up excluding observations of trends over longer time periods; and crucially the transition from the Natufian to Neolithic (but see (Laure Dubreuil 2008).

[5] These residue samples from the experimental work are not included in the PhD-thesis but will be published at a later stage

Our study in including tools from the Early to Late Natufian and going into the Early Neolithic, i.e. Early and Late Pre-Pottery Neolithic A periods suggest interesting developments in the use of gestures and tools (i.e. *processing strategies),* that seem to reflect changes in how things are processed, and not necessarily what is processed. We thus elucidate both change and continuity over time. This study uses the previously established framework gesture/movements approach to GST (seen in Paper 1 and 2 and AGSTR-paper) with more "traditional" functional analysis (including tuber use-wear data collected in conjunction with Paper 3), and residue analysis[6] to delve into the specific changes that we see at the sites Shubayqa 1 and 6 in aforementioned periods.

The low-power use-wear results indicate the main activity we can associate with these tools with, both in the Early Natufian, Late Natufian, EPPNA and LPPNA is producing (processing) plant foods. Wild cereals/seeds appear to be the plants most commonly processed, but with tubers/USO's close behind. Only in the LPPNA do cereals truly begin to dominate. Processing of these tubers (presumably *Bolboschoenus glaucus*, i.e. club-rush) USO's in the Early and Late Natufian is achieved through pounding and rotary grinding (CPR and RGP strategies respectively) and by the EPPNA, pounding and reciprocal grinding (CPR and CRG strategies respectively).

Confined reciprocal grinding (CRG) that is the most common processing strategy in the EPPNA and LPPNA, appears to be associated with cereal processing but there is generally great variety and diversity in the use of all the processing tools. Other important resources seem to include meat, oily seeds (possibly wild poppy seeds), legumes (of unknown species), as well as pigment/mineral crushing and hide processing.

It appears that the main way that foodways are changing is the *how* and not the *what*. There is for example great continuity in the contact materials (from the use-wear at least) between the Late Natufian (Shubayqa 1) to the EPPNA (SHubayqa 6). These two phases also have the same novel "trend", placing processing tools in the floor of structures (e.g. Structure 2 at Shubayqa 1 and Space 4 at Shubayqa 6). Some kind of incorporated (internal?) processing installations. However, this transition between the Late Natufian (Shubayqa 1) to the EPPNA (Shubayqa 6), is where we see a clear shift from a mix of circular grinding (RGP-strategy) and open reciprocal grinding (ORG-strategy) to confined reciprocal grinding (CRG). It may be a "convergence" of the two strategies from the Late Natufian, i.e. circular confined grinding (RGP-strategy) and open reciprocal grinding (ORG-strategy), into a single "confined reciprocal grinding", i.e. CRG, strategy. Note however, that none of these strategies disappear entirely.

How things are processed thus seem to change, from circular to linear movements, bodies adapting and changing and tools also, but still processing similar things (similar contact materials). This at least, is the impression we get from the low-power use-wear. Use-wear results are as noted however somewhat ambiguous (Hamon and Plisson 2008; Hayes et al. 2017) and we will need residue analysis to further substantiate the results.

[6] Note this residue analysis was unfortunately not completed in time by the collaborator.

Unfortunately the residue analysis was not completed in time before the submission of this thesis so results from the botanical microremains are pending.

Instead the paper provides a comparison with other sites in the region belonging to roughly the same time periods as we examine here. Using the data collected on the Shubayqa 1 and 6 food processing strategies, that was presented in the AGSTR-paper, we compare the results to the other SWA sites, deduced from their published ground stone assemblages. Using my specific processing strategies we see a great variety in sites from the same periods and also some similarities. We contend there are certain trends, i.e. increasingly grinding processing strategies, and in particular linear grinding (gestures) but there are exceptions (e.g. Wadi Jilat 7, Beidha, Skharat Msiad) and multiple strategies co-exist and presumably complement each other. As noted back in the first paper, Paper 1, this is expected. The food processing is not one singular labour process, plant and animal processing would have included numerous steps post-procurement, pre-consumption processing. The gathered resources, be they plant or animal would have to be treated in numerous ways to ensure they could be cooked, consumed or stored, requiring coordination of labour, of multiple people and tools and tasks.

The changing foodways of Shubayqa then seem to show a preference for certain resources, i.e. plants and in particular cereals, tubers and oily seeds/legumes, that appear to continue and intensified over time. While at the same time the mode of processing changed more than the resources themselves. This is the perspective that we are offered from the ground stone at least. In the future this data will be compared with data from the chipped stone assemblages, archaeological fauna and flora, as well as the pending residue analysis.

The study in Paper 4 was carried out on the initiative of me, the PhD-student, with assistance and guidance from my supervisor T. Richter as well as input from the co-authors A. Arranz-Otaegui and M. N. Ramsey. I authored the introduction (section 1.), ground stone background (2.1.2.) and analysis (2.2.), including low-power use-wear analysis (see Section 3.). The results section (3.) along with the comparisons, discussion and conclusions (sections 4. and 5.) were also authored by me in close consultation with T. Richter. T. Richter also aided in the editing of the overall text and he authored the section on the Shubayqa sites, their setting and dating, i.e. section 2.1.
The archaeobotanical section (2.1.1.) was authored by A. Arranz-Otaegui and edited by me. The residue analysis part of paper was intended to be authored by M.N. Ramsey, but this analysis is currently incomplete, and not included in this draft. The brief section (3.2.1.1.) on the residue sampling method for the ground stone tools was authored by me based on a protocol provided by M.N. Ramsey.

3. Overall conclusions of the thesis

I have tried to provide the conclusions of the thesis throughout this synopsis as we were going over the main themes, questions and issues in each of the individual papers. I will therefore simply summarise the already covered points and provide a more overall conclusion of the research undertaken during the last three years.

I established what is meant when talking about (non-mechanical) food processing and the crucial role GST play, specifically in pre-consumption preparation. These tools, primarily grinding and pounding tool pairs, are used to crush, abrade, grind and pulverise matter. They change the material properties of the processed intermediate material and in the case of food to make it more consumable, palatable, mixable or storable etc. I outlined the concept of gestures and their importance in recognising processing strategy. Food processing ground stone should be seen as parts of larger sociotechnical systems and *technology* that encompass both the tools, the body and gestures, coordination of labour, and ideas and knowledge of how and why to use GST in processing. This is a labour process, using gestures and tools to transform matter, i.e. "*processing strategies"*, and these labour processes would have been complex and diverse.

This study situates technology in the body: the body makes and moves the tool. We may thus "recognise" the body *in* the tool, its morphology and wear traces. It was established that we may view the body from the perspective of the tool and the tool from the perspective of the body (i.e. through gestures). The body of whom exactly, it may be difficult to assess, even through osteology or bioarchaeology, but the importance of the body as the main "motor" of change and transformation remains. The clarification of concepts and the theoretical considerations found in Paper 1, outlined the background for the gesture-based *"processing-strategies"*-approach used in the AGSTR-paper, Paper 2 and 4. In the AGSTR-paper, I showed an example of how to recognise gestures, and consequently "processing strategies" and how to apply this approach to an assemblage, using mainly tool typology and morphology. The approach's usefulness in elucidating changes to processing technology at Shubayqa 1 and 6, led to further investigations in the other PhD-papers. These papers built on the initial observations of the AGSTR-paper and included novel use-wear and wear management perspectives, both as ways to elaborate the definition of strategies and finding contact materials (as seen in Paper 2 and 4).

It has shown the worth of combining and incorporating qualitative low-power use-wear analysis in the processing-strategies approach and the importance of considering how wear progresses and is managed and consequently how tool morphology is affected by use, including at a macro/microscopic level. By considering these elements we can better recognise, or more holistically understand, the (food) processing strategies present at a site and how they change over time.

This is also true for the use-wear, it was argued, that forms both as a result of contact material, but also from tool compatibility (tools pairs), of repetitive gestures and continual management of the resulting wear. It was established that tools go through several cyclical, repetitive stages of wear that affect their overall morphology (tool and surface shape) and the macro/microscopic morphology (surface shape and wear traces). At the same time it argues these micro/macro traces also go through stages of wear, i.e. beginning or pronounced etc., that affect both the patterning of traces, their directionality and how recognisable or characteristic wear traces will be (see Paper 4). This argument is also alluded to in Paper 4, when dealing with the basis of the interpretation(s) of the low-power user-wear analysis. Whether wear can be interpreted or not, whether it will be characteristic or unclear. All of this was based on qualitative observations of the Shubayqa ground stone, and also included idealised or schematic illustrations of the (progressive) wear stages. All in all, Paper 2 shows the importance of considering these different elements both when "finding" processing strategies at a site and in interpreting use-wear, along with the interplay between wear, the strategies, the contact material and the surrounding sociotechnical system. This gestural approach thus, as was argued in Paper 1, aids in illuminating the bodies and people that make up societies and their tools and practises (strategies), including ideas about how to process matter and how these ideas and practises change over time.

In Paper 3, we recognised the issues that arise when focusing mainly, or solely on, founder crops both within experimental archaeobotany and stone tool studies. It established a baseline to recognise tuber processing based on the experiments conducted and on the evidence of large amounts of club rush tuber at Shubayqa 1. This study also helped this author understand better both the production and use of GST (in more detail) in addition to also getting an appreciation of the complex tasks of procuring foodstuff. The study also included a low-power use-wear of the experimental tools, that aided in recognising wear traces related to tuber pounding and grinding, and thus helps the interpretation of wear present in the archaeological GST assemblages from Shubayqa 1 and 6. This data was then used the inpertretations of wear found in Paper 4. The data I collected here can also be used for further future research into the traces of tuber processing within GST use-wear, this in addition to the overall study's contribution to experimental archaeobotany.

In Paper 4, the processing-strategies approach established above was applied along with "conventional" qualitative low-power use-wear analysis. Our results indicate that the main activity we can associate with food processing GST at Shubayqa 1 and 6 is the processing of plant foods and this is true for all phases (from the Early Natufian, Late Natufian, to the EPPNA and LPPNA). Wild cereals/seeds seem to be the most commonly processed plant, but tubers/USO's are also very prevalent along with legumes, oily seeds and animal products. Only by the LPPNA do cereals begin to dominate in earnest. The use-wear indicates that processing of tubers (probably *Bolboschoenus glaucus*, i.e. club-rush) was achieved through pounding and rotary grinding (CPR and RGP strategies respectively) in the Early and Late Natufian and by the EPPNA by pounding and reciprocal grinding (CPR and CRG strategies respectively). This corroborates somewhat our experiments from Paper 3, which also suggested that pounding and rotary grinding (CPR and RGP strategies) worked quite well as means to both "peel" or pulverise roasted tubers. Generally, by the EPPNA we see the confined reciprocal grinding (CRG) strategy begin to be the most common processing strategy. This appears to coincide, in part, with cereal processing and the CRG strategy appears to process slightly less diverse materials, but there is generally great variety and diversity in the use of all the processing tools (and in all phases as well). Other important resources seem to include meat, and from the Late Natufian on, oily seeds (possibly wild poppy seeds) or legumes (of an unknown type), as well as non-food activities such as pigment/mineral pulverising and hide processing.

It appears that the main way that foodways are changing is the *how* and not the *what*. There is quite a bit of continuity in the contact materials (deduced from the use-wear at least) between the Late Natufian at Shubayqa 1 to the EPPNA at Shubayqa 6. But there is also marked change in the tools and gestures used. Going from circular grinding (RGP-strategy) and open reciprocal grinding (ORG-strategy) to confined reciprocal grinding (CRG). It was suggested that we may see here a "convergence" of two prevalent strategies from Late Natufian, i.e. circular confined grinding (RGP-strategy) and open reciprocal grinding (ORG-strategy), into a single confined reciprocal grinding (CRG) strategy by the EPPNA. Still coexisting however, with other strategies.
In our discussion there we also add a brief comparison to other sites in the region from the same periods, so that we may see broad trends and development in ground stone tools in SWA. The general trends we observe includes, increasingly grinding from the Natufian and into the PPNA/PPNB, and in particular linear grinding (gestures) become prevalent and by the PPNB is the main mode of processing, with exceptions These trends are also previously noted by Wright (1994) and our brief comparison seems to corroborate this. However as just noted with Shubayqa 6, multiple strategies coexist and presumably complement each other at the sites.

We highlight how this underscores the theme thesis and validates the usefulness of the suggested approach, theory and methodology applied in the thesis:

That we may see adaptations and changes of movements of the body of the gesture and tool, to process things in specific ways, i.e. changing ways of processing within foodways, rather than necessarily changing the raw martial input. Over time however, a concentration or intensification of cereal processing slowly starts to appear. More research into the later periods (LPPNA/EPPNB) at Shubayqa 6, and beyond, is needed. In the future this data will need to be compared with data from the ongoing studies of other material from the Shubayqa sites, as well as the pending residue analysis. Future studies from our team and project will elaborate this story, by expanding on the archaeobotanical, zooarchaeological and chipped stone perspectives from the Shubayqa material. The conclusions here are thus only preliminary observations of the changing foodways that obviously were both complex and variable. What I provide is naturally only a snapshot of the changes, merely one perspective interpreted from ground stone tools.

Generally, spanning the entire period from the Natufian to PPNA, this study observes interesting continuities, adaptations and shifts in the past foodways of the Qa' Shubayqa inhabitants, as well as attempting to establish a (somewhat) novel way to approach GST and foodways through a combination of qualitative morphological and use-wear perspectives. My approach suggest that changing foodways of Shubayqa seems to show a preference for plant resources, something that continued and intensified, and where the mode of processing changed while there was considerable continuity in contact materials.

Overall the thesis shows that food processing and GST involved in these activities are not singular straight forward labour processes, where specific plants and animal processing happens. Rather these are complex processes, people applying diverse, broad strategies to transform food resources, that would have included numerous steps post-procurement, pre-consumption processing and preparation. The gathered resources, be they plant or animal would have to be treated in numerous ways, with different tools, to ensure they could be cooked, consumed or stored. A coordination of labour and of multiple people, tools and tasks. Over time, changes may have reflected an increasing reliance on cereal foods, but again these would have been part of complex food systems, complex uses of the body, gestures and tools.

I therefore return, lastly to the body again. It is bodies that are changing their relationship to tools, we see this through the changing morphology of the tools, adaptations of movements and human agency expressed in the material. I hope this thesis will show the usefulness of using the tool to explore the role of the body and vice-versa and that by considering ground stone tools as parts of larger food processing strategies, foodways and sociotechnical systems we may understand the past developments within food preparation a tiny bit better.

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B.

Papers submitted as the PhD:

“Approaching Past and Changing Foodways Through Ground Stone“

By

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2. The Groundstone Assemblages of Shubayqa 1 and 6, Eastern Jordan - Technological choices, Gestures and Processing Strategies of Late Hunter-Gatherers in the Qa’ Shubayqa

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Introduction

Since the early 2000s, there has been an increasing interest in groundstone tools and technology in prehistoric archaeology of Southwest Asia (henceforth SWA). Publications have addressed varied topics related to the use of groundstone tools from food production and their relationship with pre and early agricultural societies (e.g. Dubreuil 2004; Dubreuil and Plisson 2010; Dubreuil and Nadel 2015; Hayden *et al.* 2016; Hodder 2018; Rosenberg 2008; Rosenberg and Gopher 2010; Wright 2000, 2014), their social significance; exploring their role in burials (Dubreuil and Grosman 2009; Dubreuil *et al.* 2019; Liu *et al.* 2018; Richter *et al.* 2019; Rosenberg and Nadel 2014), social inequality (Wright 2014; Molleson 1994) and using a range of methods like microscopic use-wear (e.g. Dubreuil 2004; Dubreuil and Grosman 2013; Dubreuil and Plisson 2010) and residues (e.g. Liu *et al.* 2018; Terradas *et al.* 2013). However, I believe further issues remain: the view of how this technology develops is tied to a linear *standard view* of technological development and tool use, in for example food processing, is not always fully recognized as representations of technological choices and consciously selected *processing strategies* by individuals and communities. These issues, I tentatively address here. The focus in this paper is on the influence of movements, or *gestures,* on tool morphology and tools as representations of processing strategies; a material reflection of choices that change over time. Using the groundstone tool assemblages of two prehistoric sites located eastern Jordan: Shubayqa 1 and 6, dated to the late Epipaleolithic-early Neolithic respectively and concentrating on groundstone tools used in food processing tasks, I elucidate local scale changes in technological practices and consequently processing strategies during the Natufian and Pre-Pottery Neolithic of SWA by introducing a way of analysing assemblages based on the interplay between movements, gestures and tool morphology.

The Natufian and the early Neolithic of Southwest Asia

The Natufian period is part of the late Levantine Epipalaeolithic and lasts approximately 3500 years from around 15,000 to 11,500 cal. BP (Grosman 2013; Richter *et al.* 2017; Weinstein-Evron *et al.* 2012). The period is divided into the early Natufian (*c.* 15.000-13.600 cal. BP) and the late Natufian (13.100-11.500 cal. BP) (Grosman 2013). Climaticly it coincides with the Bølling-Allerød interstadial and resulting wet and warm climatic conditions *c.* 14.700-12.900 cal. BP (Blockley and Pinhasi 2011; Jones *et al.* 2019; Rosen and Rivera-Collazo 2012). In the late Natufian, sites seem to become smaller and more dispersed indicating less sedentism in this period (Belfer-Cohen 1991; Grosman 2013). This shift in the late Natufian has often been seen as a response to environmental stress climatic changes caused during the Younger Dryas *c.* 12.900-11.700 cal. BP (Goring-Morris and Belfer-Cohen 1997). This event supposedly caused colder, drier weather and featured increased seasonal variability (Blockley and Pinhasi 2011; Goring-Morris and Belfer-Cohen 1997; Moore and Hillman 1992; Stutz *et al.* 2009). However, mounting evidence seems to suggest that climatic impact of this event was less severe, or perhaps at least more locally variable, than previously thought (Grosman 2013; Richter *et al.* 2017; Rosen and Rivera-Collazo 2012;

Yeomans *et al.* 2017; Yeomans 2018). Subsistence during the Natufian was based on hunting principally gazelle, but also smaller game especially in the late period, and gathering of wild plants (Arranz-Otaegui *et al.* 2018; Munro 2004; Olszewski 2004; Rosen and Rivera-Collazo 2012; Stutz *et al.* 2009; Willcox 2012; Yeomans *et al.* 2017). Plant resources seems an important component of a varied diet (Arranz-Otaegui *et al.* 2018; Rosen and Rivera-Collazo 2012; Willcox 2012). The early Neolithic of SWA, the so-called 'Pre-Pottery Neolithic' is characterized by several Neolithic features such as, increased sedentism, population density, cultivation and incipient domestication of plants and animals but without ceramics (Bar-Yosef *et al.* 1991; Bar-Yosef and Belfer-Cohen 1989; Finlayson 2009; Kuijt 2002, 2011; Kuijt and Goring-Morris 2002). The PPNA is the earliest phase this period featuring most of the above characteristics but with no definite evidence for the domestication of plants and animals (Asouti and Fuller 2013; Horwitz *et al.* 1999; Kuijt and Goring-Morris 2002; Mason and Nesbitt 2009; Willcox 2012; Willcox *et al.* 2008; Willcox and Stordeur 2012). In this paper the period will mostly referred to as the Early Pre-Pottery Neolithic (Henceforth EPPN), encompasing both the PPNA, but also parts of the late PPNA and subsequent early PPNB and for our purposes dates to *c.* 11,600-10,600 Cal. BP (see below). EPPN subsistence also relied on hunting and increasingly plant resources, climatic conditions improved in this period with wetter, warmer conditions in comparison with the end of the Natufian (Rosen and Rivera-Collazo 2012; Willcox 2012).

Food Processing Groundstone Technology

The tools I examine in this paper are groundstone tool pairs used to significantly reduce the particle size of an intermediate edible matter between two stones through abrasion, crushing or a combination of both (Adams 2002). I use the generic term: food processing or processing tools here. These groundstone tools consist of an upper mobile and lower stationary tool and may be further subdivided into two subgroups: grinding tool pairs, handstones and grinding slabs or querns (Wright 1992a), and pounding tool pairs, pestles and mortars (Wright 1992a).

Epipaleolithic-Neolithic Food Processing Groundstone in SWA in the standard view

To contextualize the Shubayqa groundstone assemblages within more general technological trends during the period covered I establish the standard view of the emergence of food processing groundstone in SWA. Groundstone tools first appear in the Upper Palaeolithic and during the subsequent Epipaleolithic vessel-style mortars and pestles appear (de Beaune 2004; Dubreuil and Nadel 2015; Kraybill 1977; Wright 1991). These types become even more common during the late Epipaleolithic Natufian, where groundstone tools in general are more widespread and numerous (Kraybill 1977; Wright 1991, 1992b, 1994). In this period both pounding and grinding tools become major tool groups within the inventory of Natufian foragers, but pounding tool pairs are most abundant (Dubreuil 2004; Dubreuil and Plisson 2010; Kraybill 1977; Wright 1991). In the late Natufian, vessel-mortars were superseded by boulder and bedrock mortars (Rosenberg and Nadel 2011, 2014; Power *et al.* 2014; Terradas *et al.* 2013). Pounding tools evidently give way to grinding tools over time (see Dubreuil 2004; Wright 1994) and by the EPPN, grinding tools are the most common, this seen as a result of increasing reliance on cereals grains (Wright 1994), while pounding tools continue to be found less frequently. This trend continues into the later Neolithic (Wright 1992b, 1993).

What was presented above, follows a somewhat linear and direct path of technological development from elaborate pounding tools in the late Epipalaeolithic to grinding tools in the EPPN. This is an example of what Pfaffenberger (1992) criticized as being a *standard view of technology*, i.e. a history of technological development that is linear and singular with the development of inevitably 'correct'/'commonsense' technologies. What will be argued here, is that by applying a different approach to these technological developments, one based on the relationship between movements (or *gestures*), tool pairs and wear, we may refine this linear and singular standard view.

The setting and the sites

The sites are located in the *harra* desert of eastern Jordan. The *harra* is a basalt desert spreading from Syria and the Jebel Druze to the north across the *badya* region of eastern Jordan continuing into the Arabian peninsula to the south (Betts 1998). This basalt desert is the result of volcanic activity in the late Tertiary to Quaternary, from approximately 8.9 to 0.1 mya (Allison *et al.* 2000). It is defined by Saharo-Arabian type steppe vegetation and currently receives less than 200 mm of mean annual rainfall (Zohary 1973). The Shubayqa sites are located in the *Qa'* Shubayqa (see Fig. 1), a twelve square-kilometre large mudflat basin (Richter *et al.* 2012; Richter 2014; Richter *et al.* 2016).

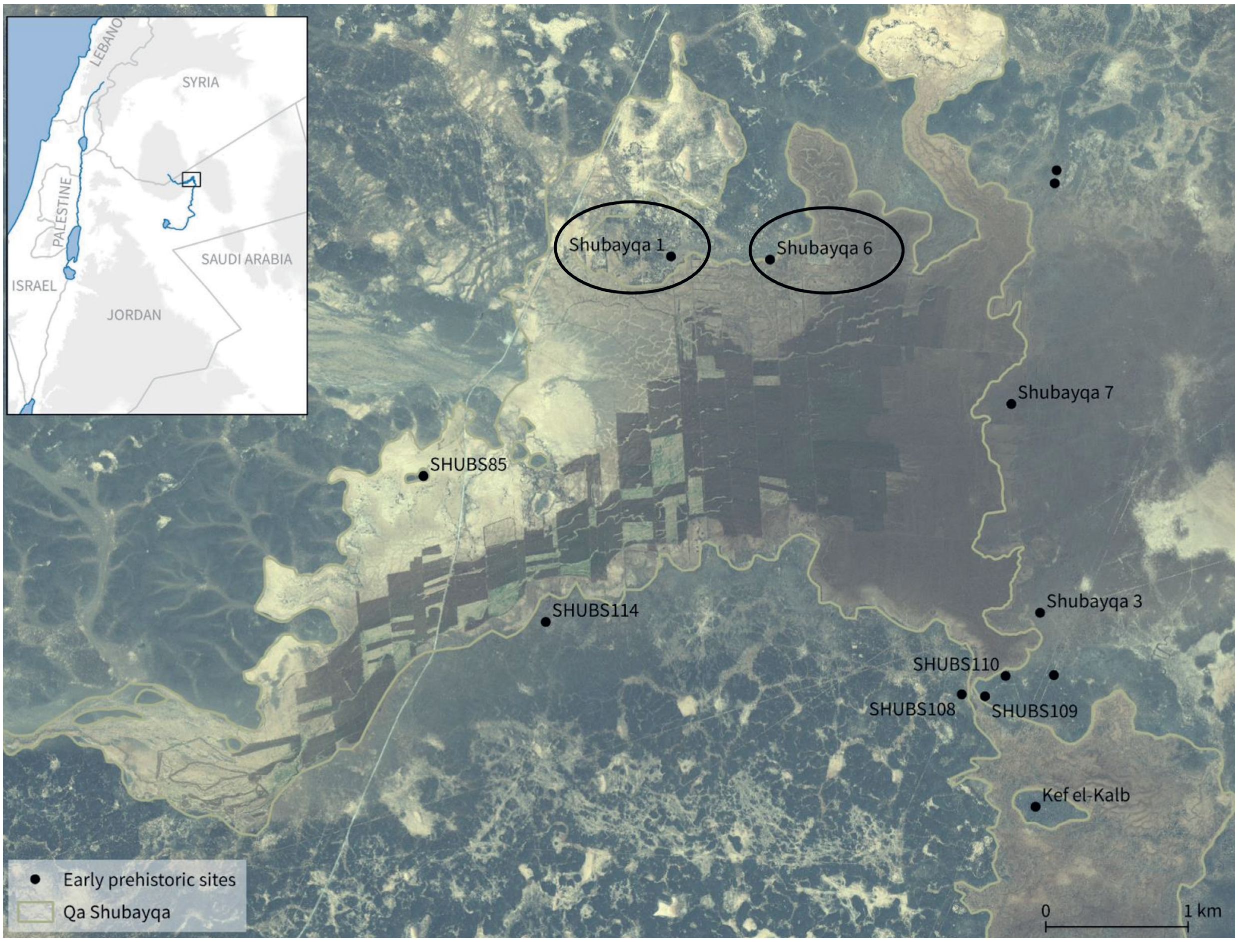


Figure 1: Shubayqa 1 and 6 location.

Shubayqa 1

Is located on a two to three meter mound, on the northern edge of the *Qa'* near the abandoned Islamic period village of Khirbet Shubayqa (Richter *et al.* 2012, 2014, 2017; Richter 2017). Alison Betts first discovered Shubayqa 1 during survey in 1993 (Richter *et al.* 2012). Between 2012-2015 the site was excavated by a team from University of Copenhagen.

Table 1: Shubayqa 1 dating, for detailed overview see (Richter *et al.* 2017).

Phase	Period	Date range cal. BP at 68% probability
1	Final Natufian	~12.083-11.807
2-3	Late Natufian	~13.300-13.100
4-7	Early Natufian	~14.400-14.100

Initial occupation of the site is dated to the early Natufian (Table 1: Phases 4-7) and relates to the construction and use of Structure 1, a large roughly oval-shaped stone built structure of upright basalt boulders with a flagstone floor and a central hearth (Richter *et al.* 2017) (Fig. 2). The hearth held substantial amounts of charred plants, especially club-rush tubers, faunal remains and lithics (Richter *et al.* 2017; Yeomans *et al.* 2017). Food remains were also retrieved including fragments of flatbread (Arranz-Otaegui *et al.* 2018). Another paved area featuring a hearth (Phase 5), included the remains of at least nine individuals (perinates, infants and adults) interred beneath the paving (Richter *et al.* 2019). Late Natufian occupation at Shubayqa begins with the construction and use of Structure 2 (Phase 3). This structure is also stone-build with a flagstone floor and a hearth (Fig. 2), but significantly less well-preserved. Also features several burials beneath the pavement (Richter *et al.* 2019).

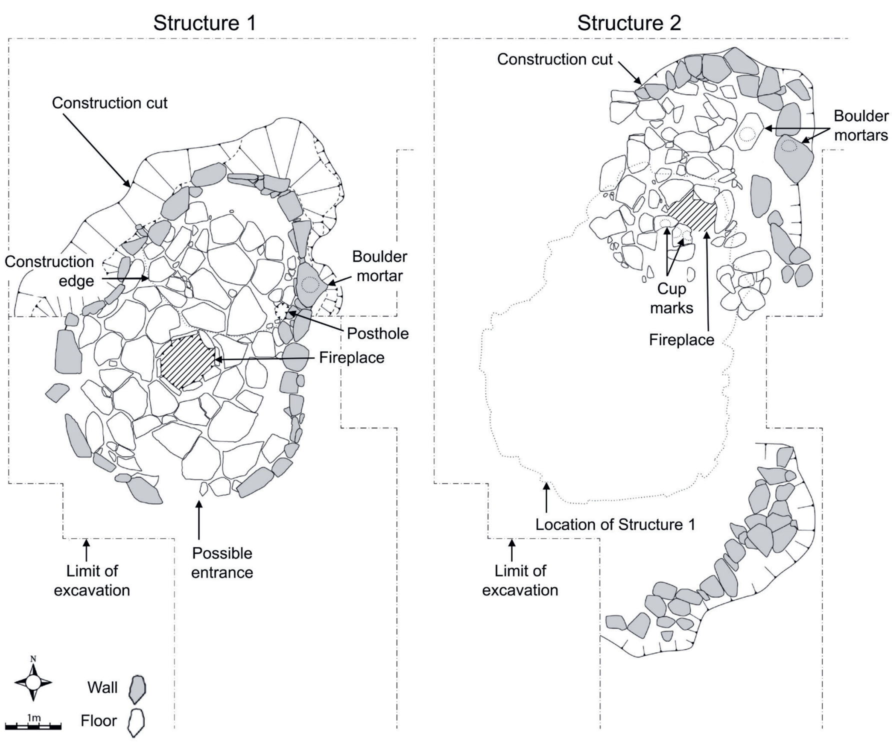


Figure 2: Shubayqa 1.

Shubayqa 6

Two to three meter high mound, located some 700 m east of Shubayqa 1, discovered in 2012. Excavations started in 2014 (Richter *et al.* 2016) and are ongoing. The site consists of a Neolithic settlement with several circular to sub-circular dry-stone buildings two to six meters across (see Fig. 3) (Richter *et al.* 2016). The exact stratigraphic relationships and phasing of the site is still being examined, so for the purpose of this study, it is tentatively divided into two occupational phases (see Table 2).

Table 2: Shubayqa 6 Dating (based on (Yeomans *et al.* 2019).

Space (Phase)	Period	Date range cal. BP at 68% probability
Space 4 (upper infill) + Space 3	LPPNA-EPPNB	~10,729-10,588 (Poz-76085)
Space 4 (lower infill)	PPNA	~ 11,595-11,267 (RTD-9342)

The first phase is contemporary with PPNA (Richter *et al.* 2016). The second phase encompasses late PPNA to early PPNB. Collectively these two phases are referred to as 'EPPN'. The archaeobotanical material from Shubayqa 6 is currently being examined. However, the archaeobotanical evidence from Shubayqa 1 would substantiate that tubers, alongside wild cereals, must have been important resources. Evidence suggests that dogs were present at EPPN Shubayqa 6 (Yeomans *et al.* 2019).

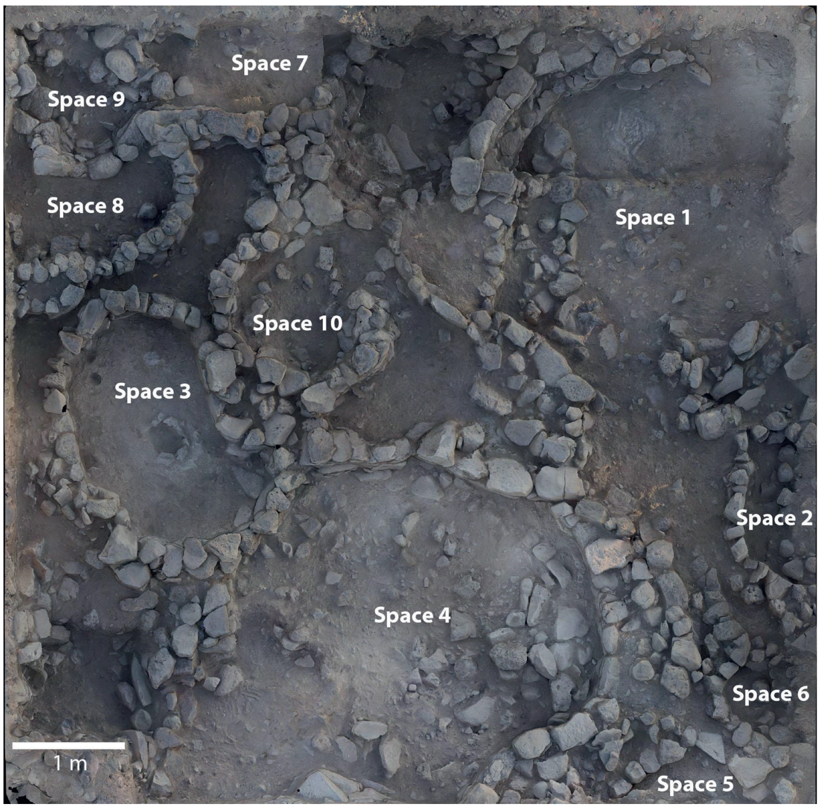


Figure 3: Shubayqa 6.

The Shubayqa 1 and 6 groundstone assemblages

Raw material

Located in a basalt desert, the assemblage consists almost exclusively of basalt implements. Chemically the basalt is defined as mafic alkali to sub-alkali basalt (Al-Malabah *et al.* 2002; Ibrahim and Al-Malabeh 2006; Krienitz *et al.* 2007; Shaw *et al.* 2003). It often features vesicles and generally has a fine to medium grained porphyritic texture, holocrystalline with phenocrysts primirally of olivine, plagioclase and clinopyroxene (Al-Malabah *et al.* 2002; Odat 2015; Shaw *et al.* 2003).

Assemblages

Table 3 provides an overview of the assemblage. Classifications and definitions generally follow Wright (1992a).

Table 3: Assemblage overview.

Tool type	Early Natufian	Late Natufian	PPNA	LPPNA-EPPNB	Total
Axe/adze	3	-	1	1	**5**
Cupmark	3	2	1	1	**7**
Groovedstone	3	2	1	1	**7**
Hammerstone	2	1	2	3	**8**
Handstone	149	346	62	36	**593**
Slab/Quern	13	34	19	15	**81**
Mortar	29	11	5	2	**47**
Pestle	40	28	11	10	**89**
Polisher	2	5	-	-	**7**
Pounder	5	2	3	1	**11**
Vessel	4	12	-	3	**19**
Multiple tool	14	27	3	4	**48**
Varia	2	3	1	1	**7**
Debitage	39	-	8	9	**56**
Unidentified	81	63	13	25	**182**
Total	**388**	**535**	**129**	**112**	**1164**

The Shubayqa Groundstone

The Shubayqa assemblages conform, from a typological standpoint, with other levantine assemblages and seem to follow developments elsewhere; thus, on the surface, it more or less confirms the *standard view* of technological development. E.g. vessel-mortars are the most common in the early Natufian phase at Shubayqa 1 making up 70% (see example Fig. 4.1), then boulder mortars (Fig. 4.3) become prominent in the late Natufian phase making up 45% of mortars, similar to trends elsewhere in SWA (e.g. Edwards and Webb 2013; Rosenberg *et al.* 2012; Rosenberg and Nadel 2014; Wright 1991). Both early and late Natufian also feature grinding tools (see Fig. 4.2 + 4.4). The proliferation of basin type grinding slabs and ovate handstones (see Fig. 4.5-6) at Shubayqa 6, also conforms to what is observed at other EPPN sites (e.g. Harpelund 2011; Kadowaki 2014; Nierle 2008; Rosenberg and Gopher 2010; Wright 1992b, 1993).

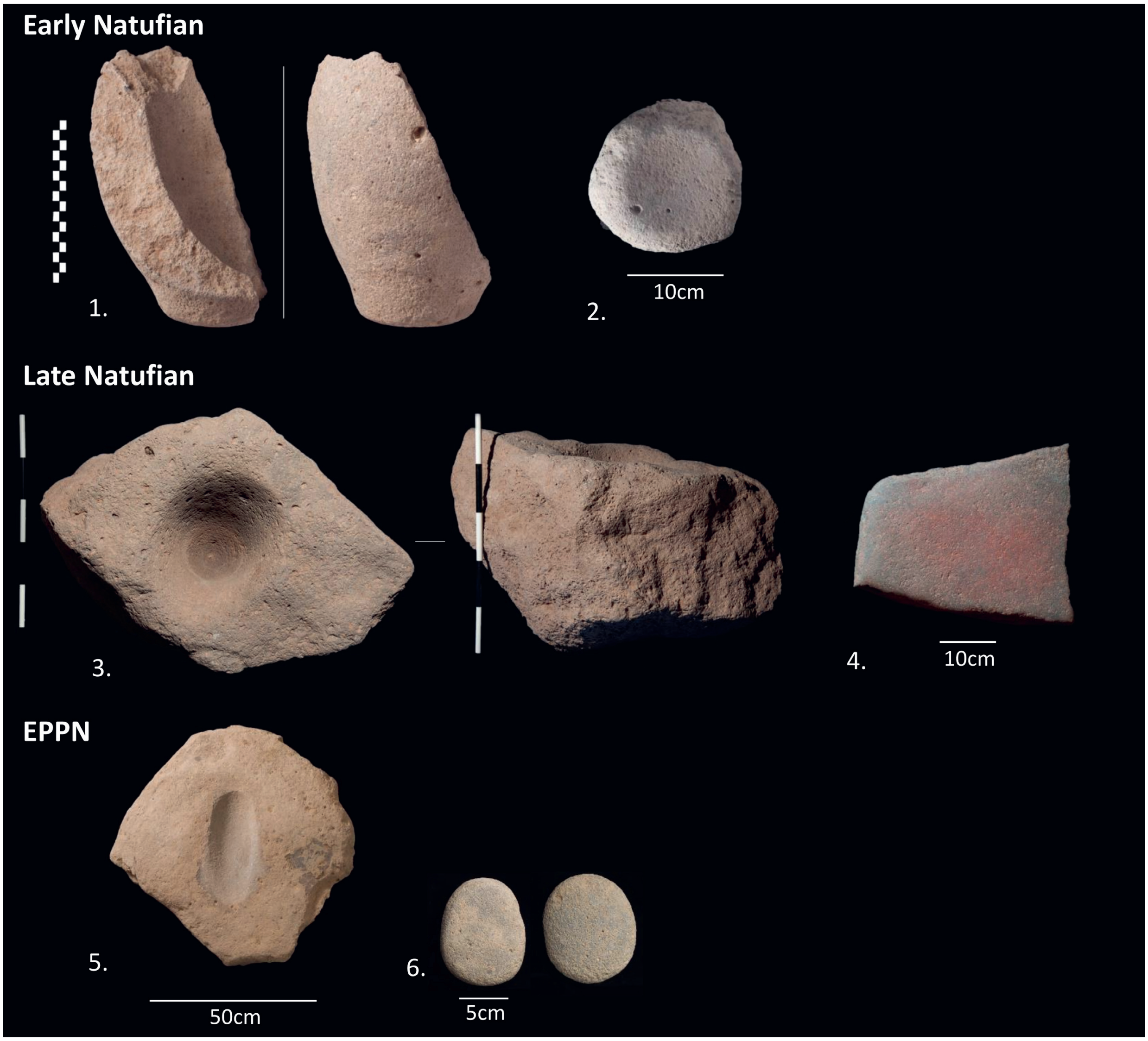


Figure 4: Selected examples from the Shubayqa assemblages, early and late Natufian from Shubayqa 1 and EPPN from Shubayqa 6 (photos by Alexis Pantos).

Towards a socio-technical approach to groundstone, technological choices and food processing strategies

The *food processing strategies* categories applied here are a synthesis of operational movements (*gestures*) and the use and wear expressed materially in archaeological tools. A more detailed presentation of the approach than given here is underway (see Pedersen *forthcoming*). The use of the term technology and *gestures* further rely on additional concepts, most importantly: the sociotechnical system and technological choice. The sociotechnical systems approach sees technology, not only as relating to making and using objects, but also involving the social relations and dynamics engaged in technological activities and actions (Pfaffenberger 1992, 513). Further these actions imply agency; the agency of individuals and groups of individuals engaged in solving technical problems (Dobres and Hoffman 1994). Technological change, as I examine here, happens within such a system through external borrowing or internal innovation, or the result of external stresses that may cause mutations of the system (Leroi-Gourhan 1993). Changes within a system further entail social aspects that may promote or impede the adaptation of certain techniques (Pfaffenberger 1992). Technological choice is the choice of an individual or individuals, to do specific things during the performance technical actions, whether this is overtly conscious action or not (see Lemonnier 1992). Choices are ultimately what changes the system. Technological choices also require the performance of specific bodily actions, i.e. *gestures,* often in conjunction with artefacts. The term *gesture* coined by André Leroi-Gourhan (1993) are the bodily movements with which humans interact with the material world and are necessary in operating tools, making them technically effective. Thus, gestures are specific technological choices, influencing and influenced by the system, i.e. the technological traditions and norms within the community (Hegmon 1998; Leroi-Gourhan 1993; Mauss 1979) and by using particular gestures instead of others, people interact with tools through gestures according to, and modifying, traditional ways of overcoming problems (Dobres and Hoffman 1994; Wobst 2000). Tools are then the '*objectified result of techniques*' (Dietler and Herbich 1998, 235) and gestures (as technological choices) are 'trapped' materially in the tool through use and observable to us in tool shape and surface morphology.

Food processing strategies

Based on the synthesis of these elements: gestures, use and wear progression and resulting tool shape and surface morphology, I have devised the scheme below for the Shubayqa groundstone. Gestures are identified from my own observations of the morphology of the tools in the assemblages, along with some exploratory experimentation in making and using these tools (articles are forthcoming) and from published ethnographic observations (Ertug 2002; L. A. Nixon-Darcus 2014; L. Nixon-Darcus and D'Andrea 2017; Hamon and Le Gall 2013; Robitaille 2016; Searcy 2011; Schroth 1996). In addition I draw on work by others, whom have applied similar schemes for analysis in SWANA: Kadowaki (2014), Nierle (2008), Banks (1982) and Dubreuil (2001; Dubreuil and Plisson 2010), as well as in the Aegean (Stroulia *et al.* 2017) and from Iberia (Delgado-Raack and Risch 2009, 2016) (Delgado-Raack and Risch 2009, 2016). The gestures involved in operating food processing tool pairs follow Leroi-Gourhan's (1993) terminology as presented by Sophie de Beaune: *diffuse resting percussion*, i.e. grinding and *diffuse thrusting percussion*, i.e. pounding (de Beaune 2004). In my scheme I propose three processing strategies that are types of grinding and one pounding. These are, respectively: Confined Reciprocal Grinding (CRG), Open Reciprocal Grinding (ORG), Rotary Grinding (RGP) and Confined Pounding (CPR). See Figure 5-6 and Table 4 for illustrations, archaeological examples, detailed description, explanations of tool pairings and overview of strategies. I henceforth stick to the abbreviations CRG, ORG, RGP and CPR for the strategies.

Table 4: Strategies: Action, gestures and resulting tool shape and surface morphology based on observations of the Shubayqa material.

Strategy	Primary function	Overall movement	Gesture Description	Upper tool	Lower tool	Upper surface shape	Lower surface shape
Confined Reciprocal Grinding (CRG)	Diffuse resting percussion Grinding, abrading	Linear, Reciprocal. Movements within a depression, which constricts movements	Performed with one or two hands, pressure exerted from the shoulder(s)	Ovate handstone	Basin or trough blab	Planar: Oval/ovate/ rectilinear Transverse: Flat (>) to convex Longitudal: Flat (>) to convex	Planar: Elongated/ elliptical Transverse: Concave Longitudal: Concave or sloped
Open Reciprocal Grinding (ORG)	Diffuse resting percussion Grinding, abrading	Linear, Reciprocal. Movements on open surface. Movements relatively free across the surface of the lower	Action primarily performed using two hands. Pressure exerted from the shoulders, most of this created proximally; closest to the operator	Loaf handstone	Flat block slab or baddle slab	Planar: Elongated rectilinear Transverse: Flat Longitudal: Flat (>) to concave	Planar: Elongated rectilinear Transverse: Flat (>) to convex Longitudal: Flat (>) to concave

Table 4 continued: Strategies: Action, gestures and resulting tool shape and surface morphology based on observations of the Shubayqa material.

Strategy	Primary function	Overall movement	Gesture Description	Upper tool	Lower tool	Upper surface shape	Lower surface shape
Rotary Grinding (with some pounding) (RGP)	Diffuse resting percussion Grinding, abrading	Rotating or circular. Movements within a depression, but the upper stone is moved freely within	Action primarily performed using one hand. Pressure exerted by the arm, with less and less pressure the farther it moves from the operator.	Discoidal Handstone	Basin quern, Block quern, Boulder quern	Planar: Circular or oval Transverse: Convex (>) to flat Longitudal: Convex (>) to flat	Planar: Circular or oval Transverse: Concave (>) to shallow Longitudal: Concave (>) to shallow
Confined Pounding (with some rotary grinding) (CPR)	Diffuse thrusting percussion Pounding, crushing	Downward stroke or thrust. Movements within a depression, the upper stone is moved somewhat freely up and down. The base and sides of the hole allows for some grinding by twisting the upper stone within lower	Action, performed with one hand or two, force exerted using both elbow(s) and shoulder(s)	Pestle	Mortar	Overall: Cylindrical or conical Profile: Circular, sub-circular, oval, square, rectangular Terminus transverse: Convex (>), flat or concave	Planar: Circular, sub-circular, oval Transverse: Concave or conical

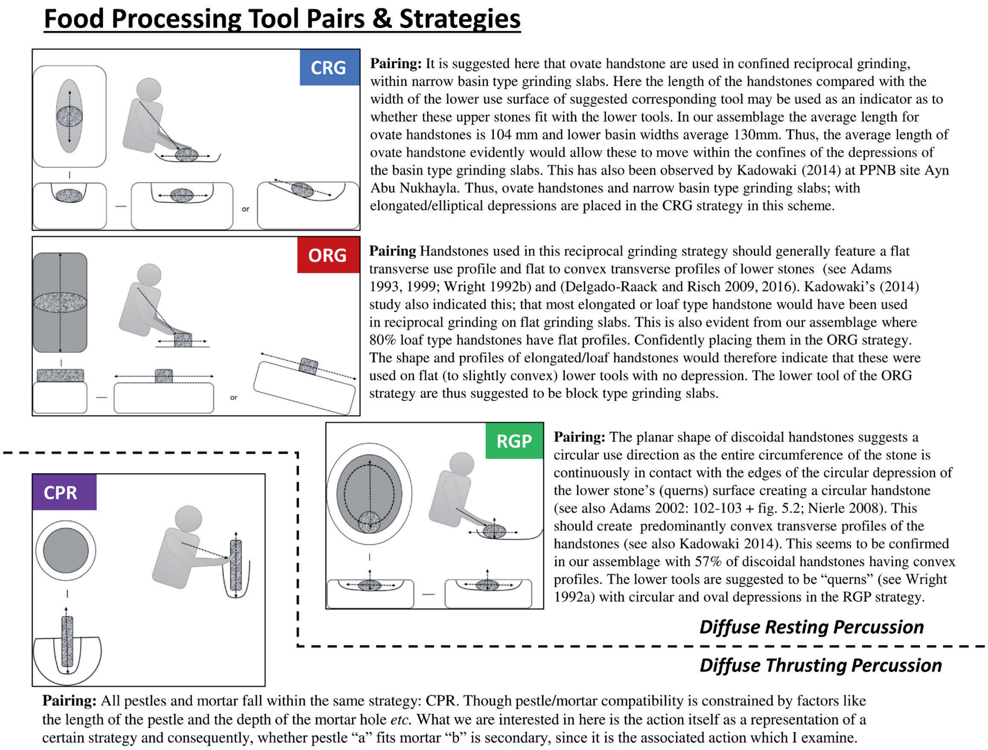


Figure 5: Food processing strategies.

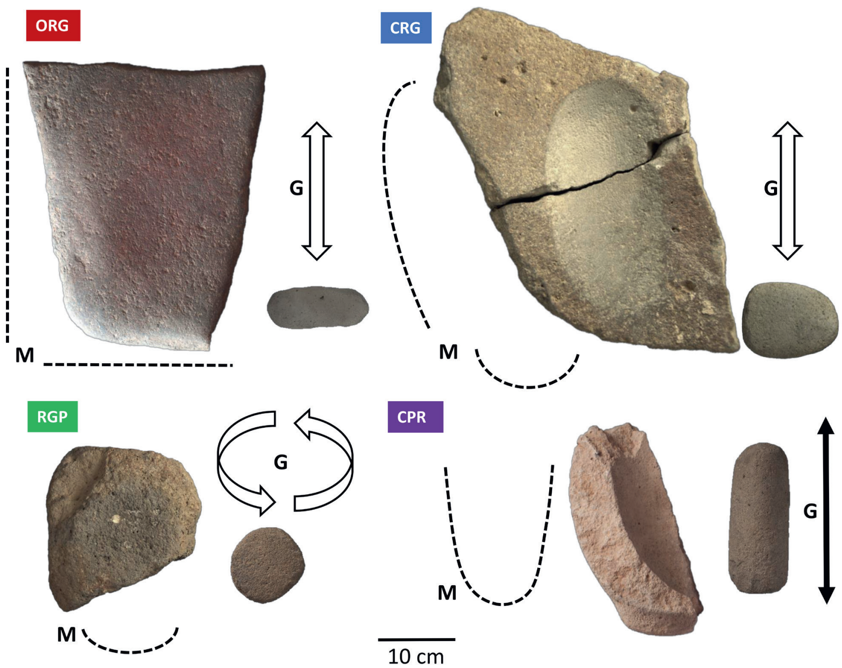
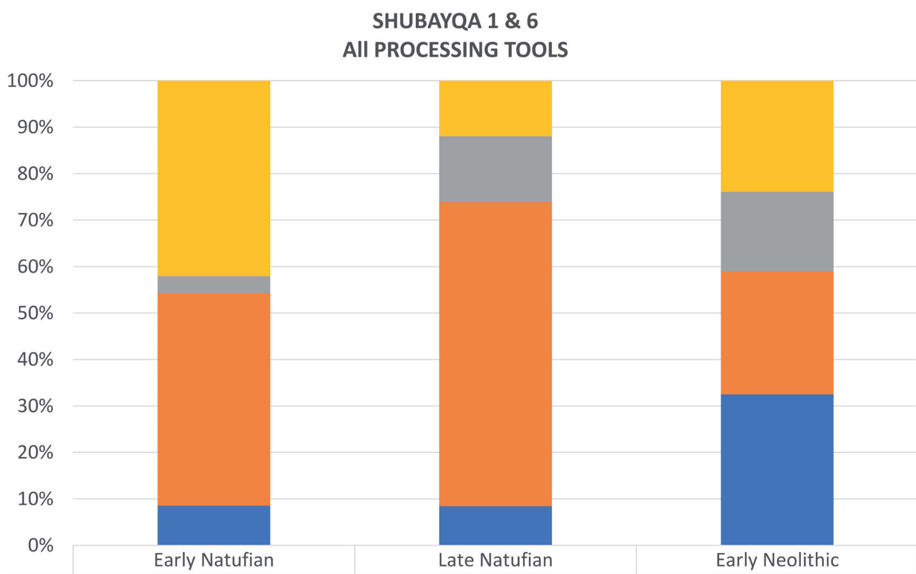


Figure 6: Archaeological examples of the different tool pairs and strategies from the Shubayqa assemblages with the transversal and longitudinal morphology of the used surfaces: M along with the related gestures: G.

Analysis

Initially, all implements count for one example (or expression) of a strategy. Meaning even small fragments count representative of a strategy.

Looking at all tools (including fragments) of processing strategies, divided into three larger periods, it appears that in early Natufian there are two main strategies (see Fig. 7). The first strategy, accounting for 42% of tools is pounding in mortars, or CPR. As was also explained above this is a strategy that has been observed at many early Natufian sites, and in the mediterranean zone this appears to be the most common processing strategy (Wright 1991, 1994). However, the most common strategy at early Natufian Shubayqa 1, seems to be reciprocal grinding on open slabs, ORG, accounting for 46% of the tools. This is an interesting contrast to the evidence just cited. In the late Natufian there seems to be a concentration on a single strategy, the aforementioned ORG strategy (see Fig. 4.4), which mirrors observations at late Natufian Abu Hureyra (Moore 2000). There is also an increased involvement of the confined rotary grinding, RGP. The pounding strategy (CPR) comes back at 24% in the EPPN and at 27% ORG, continues to be common. However, a previously less used strategy increases explosively in the EPPN, confined reciprocal grinding, CRG at 32%.

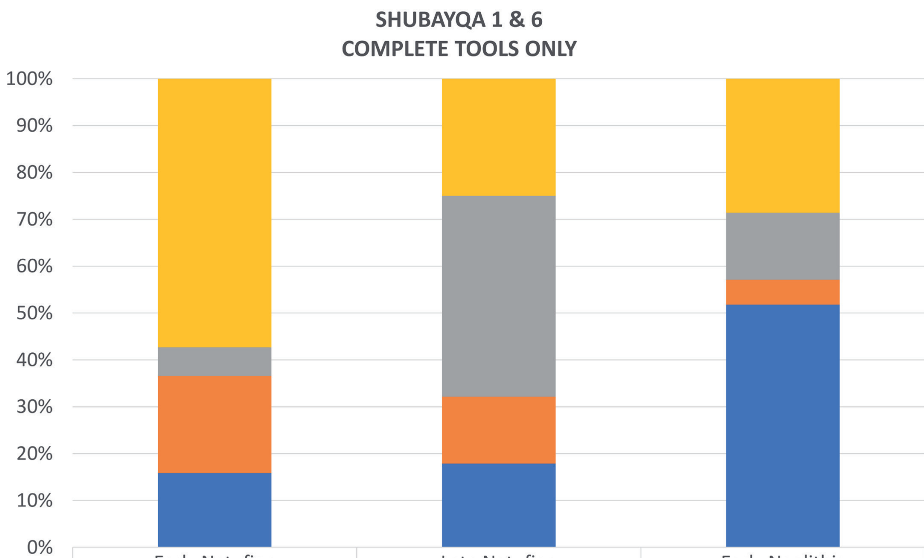


	Early Natufian	Late Natufian	Early Neolithic
CPR	69	27	28
RGP	6	32	20
ORG	75	148	31
CRG	14	19	38

Figure 7: Strategies with all tools.

An issue with the numbers above are however, the numerous small fragments of upper implements, especially handstone. These somewhat skew the numbers towards certain strategies. Often upper stones will be more numerous in analysed assemblages, as they expire faster (Delgado-Raack and Risch 2009) and, in my experience, are more easily identified than smaller fragments of larger lower tools. Especially common are fragments of elongated handstone, smaller one-handed loaf types that are associated with open reciprocal grinding (ORG). Whether these were exclusively used in this strategy is also contentious since some of them have evidence they might also have been used in pounding (see Pedersen *et al.* 2016). So to eliminate their skewing effect on the data, I opted to do a second analysis, using only complete tools. Of course, taphonomic factors and presence of intentional and unintentional breakage, plays a role here (Adams 2008; Dubreuil *et al.* 2019; Rosenberg *et al.* 2012), but this allowed me to more securely pair tools with individual processing strategies.

Little changes in the early Natufian (Fig. 8). However, it clearly shows that the most widespread strategy is pounding here confirming the standard view of early Natufian groundstone. Though at 40% grinding strategies seem more important here than what is usually assumed (e.g. (Wright 1991, 1994). In the late Natufian there is a marked increase in circular grinding, the RGP strategy. Multiple complete querns and discoidal handstones are present in that period (Fig. 8). Before a high number of small handstones fragments of the ORG strategy overshadowed this, we now observe that circular grinding is prominent in this period. At the same time pounding is proportionally more important than what the other graph showed, but is still less than in the early Natufian. In the EPPN, pounding strategy remains more or less the same (Fig. 7 + 8), but the most common strategy for processing is by far the CRG confined grinding strategy. There seem to be some similarities between proportions of the different strategies in relation to one another between certain phases; e.g. pounding drops after early Natufian and in the proceeding periods. Something that confirms previous studies and the standard view (Dubreuil and Plisson 2010; Wright 1992b, 1994). But, it is interesting that confined grinding in general becomes more common. First with a confined circular grinding RGP, which is then replaced with a confined reciprocal strategy CRG. Though CRG, along with the ORG strategy, appears to be the most common by the EPPN elsewhere in SWA (e.g. Harpelund 2011; Kadowaki 2014; Wright 1992b). This analysis reveals that technological choices and sociotechnical systems are geared towards more than simply more grinding and less pounding over time as has perhaps been the general assumption (e.g. de Beaune 2004; Dubreuil 2004; Dubreuil and Plisson 2010; Wright 1991, 1994). Perhaps not unrecognised by others, but perhaps underrepresented in the standard view. I.e. there is an expression in specific ways of grinding: from circular to linear gestures, choices by individuals materially expressed in the CRG strategy eclipsing the RGP, at least at the Shubayqa sites.



	Early Natufian	Late Natufian	Early Neolithic
CPR	47	14	16
RGP	5	24	8
ORG	17	8	3
CRG	13	10	29

Figure 8: Strategies with only complete tools.

Diversity

Technological choices by individuals and preferences for certain strategies within a sociotechnical system may also be expressed in the diversity of strategies within these periods. Here, I briefly examine different coexisting processing strategies and if they increase or decrease over time at the Shubayqa sites. If fewer strategies become dominant over time, meaning less diversity, it may suggest a specialization in processing, or a concentration of labour around specific tasks (Risch 2008). I here applied a Simpsons Diversity Index, which is usually used to examine the diversity of species at a specific location. Here, I apply it to the strategies at Shuabyqa, divided into three large periods. The Index follows the statistic formula: $D = (n / N)^2$. D equals the diversity of strategies in a value between 0 and 1, with 0 representing infinite diversity and 1 being no diversity.

First including all tools (Table 5), the period with most diversity seems to be the early Neolithic, followed by the early Natufian and the late Natufian the least. However, these are heavily influenced by the presence of fragments and again I have opted to put in a table where only complete tools feature.

Table 5: Diversity of strategies when including all tools, i.e. fragments etc.

			ALL TOOLS
Diversity	Early Natufian	Late Natufian	Early Neolithic
D =	0.39	0.47	0.26

Using the complete tools reverses the story (Table 6). While the early Natufian stays the same, with its reliance on the pounding strategy, the late Natufian and early Neolithic switch places, the most diverse being the late Natufian. It has been argued that in the late Natufian, we may observe a steady decline in the diversity of grinding implements and an increase in the frequency of grinding implements (e.g. Dubreuil 2004). This does not fit the data in our second table. That the late Natufian is actually the most diverse appears contrary to the standard view of a concentration of labour and tasks in that period (see Dubreuil 2004; Dubreuil and Plisson 2010; Wright 1991).

Table 6: Diversity of strategies when including only complete tools.

			COMPLETE TOOLS ONLY
Diversity	Early Natufian	Late Natufian	Early Neolithic
D =	0.39	0.29	0.36

Tools and surface size

Another change occurring is the change in size of used surfaces of upper and lower tools. Examining grinding tools only using the approximate surfaces in contact with the intermediate material with length and width as the variables.

Starting with the lower tools, early Natufian have the smallest average size, late Natufian the largest (most of them RGP), closely followed by the Neolithic lower tools (see Fig. 9). Again, as with the increased diversity of strategies in the late Natufian, there is great variety in the sizes for faces from this period. So diversity in strategies is also mirrored in a diversity of tool sizes it seems. The early Neolithic slabs are, barring one that clusters with the late Natufian ones, generally long and narrow depressions. This fits with the confined grinding strategy (CRG) that people of the period seem to have preferred.

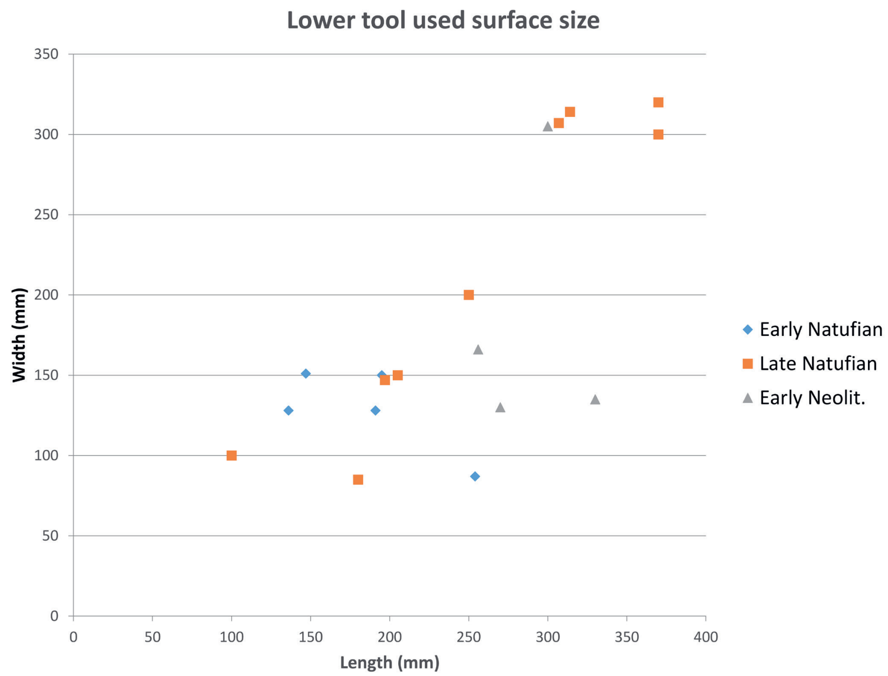
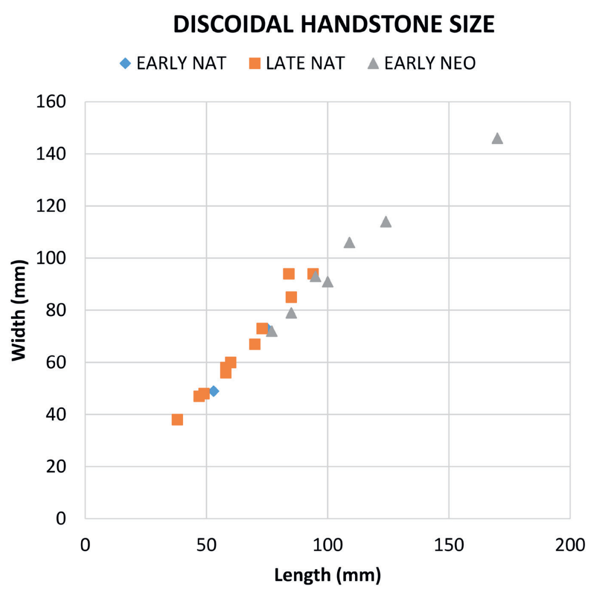


Figure 9: Lower tool active surface size.



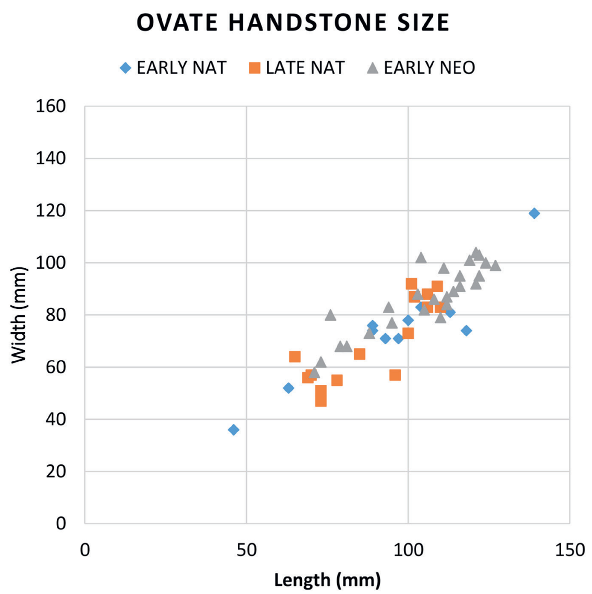


Figure 10: Handstone size.

It was only possible to compare sizes of the two most common handstone types: discoidal and ovate. Discoidal handstones from the Neolithic are generally larger than the Natufian examples (Fig. 10). There is again a great deal of variety in the sizes in the late Natufian, also for this handstone type. Ovate handstones have a less clear pattern. The early Natufian features both the smallest and the largest of this type. However, Neolithic examples generally cluster as the largest. It would appear that there is a general increase in handstone size of this type from the Natufian into early Neolithic. It has been noted that grinding tools in general seem to become larger in SWA from the Neolithic and onwards (Wright 1992b, 1993) and here in relation to handstone size our assemblage seems to confirm the standard view.

Discussion

The analysis shows that changes do not always happen in a linear or singular fashion, echoing Pfaffenberger (1992). Rather, multiple strategies of processing supplement each other, converge and diverge. Pounding (CPR) for example, seems to recede during the late Natufian, but increases by the Neolithic and confined grinding (CRG), suddenly increases drastically in the Neolithic, after being a marginal strategy in the Natufian (see Fig. 8). It may have been a modification of the previously prevalent RGP strategy; individuals consciously changing their gestures from circular to linear, from RGP to CRG. Furthermore, at late Natufian Shubayqa 1 we see a high diversity, contrary to the standard view (e.g. Dubreuil 2004). Perhaps this was a period with increased experimentation with the available resources? This may be attributed to local environmental factors, as well as social factors. In this period we see changes in the wetland resources of the *Qa'* Shubayqa area. Evidence from water fowl suggests that in the late Natufian, there was a less staple water resource in *Qa*' (Yeomans *et al.* 2017). Perhaps there was an incentive for people to explore, exploit and experiment with more diverse resources and techniques, which is then mirrored materially in the diversity of processing strategies at the site. The increase (and diversity) of sizes of lower surfaces in late Natufian (Fig. 9) may thus reflect intensive (or extensive) use of a wide range of resources, or perhaps a focus on exploiting specific resources in the face of a diminishing wetland (Yeomans *et al.* 2017). Thus, the local climatic conditions during the late Natufian may have been an external factor affecting the socio-technical system of the Shubayqa community, causing an internal adaptation; increasing the need to exploit different resources and thus diversifying strategies and enlarging tools, already present in the early Natufian. Hence, drawing on existing knowledge to increase end-product, through increased size of used surfaces of lower tools (see Fig. 9) as larger tools are also generally more 'productive' (Adams 1999; Buonasera 2015; Mauldin 1993), then combined with a diversification of strategies (see Table 6). By the EPPN people then opted to switch to narrow elongated lower surfaces, as this was deemed more useful in their eyes. These technological choices could thus be related to the amount of edible matter. Using larger surfaces and confined grinding strategies (RGP and CRG), and increasingly reciprocal confined grinding over time, from the Natufian into the EPPN, along with an increase in handstone sizes (Fig. 10) could be a way of maximising end-product. Jenny Adams (Adams 1999) has observed something similar happening in prehistoric Southwest USA. An issue with 'maximising' and 'effectiveness'' is however that it assumes that technological choices and strategies will be directed towards effectiveness and maximising this (Pfaffenberger 1988, 1992). Conversely, people having intimate knowledge of their environment and resources (Lemonnier 1992) acting as conscious agents (Wobst 2000) could have chosen certain strategies, potentially to maximise end-product. This does not necessarily entail that they become more 'effective' per se, but rather that they are deemed effective in the eyes of users and have a *'functionally satisfactory form'* (Leroi-Gourhan 1993, 301). I.e. choices are the result of agents interacting with and adapting to their physical reality (Wobst 2000) drawing on knowledge and traditions within their socio-technical system.

Work by Jenny Adams (1993, 1999) using experimental and ethnographic data, has suggested that adaptations towards reciprocal grinding strategies is also more 'efficient' in being less labour intensive, less straining on the body. This may be one of the reasons why reciprocal confined grinding CRG ends up dominating the EPPN (Fig. 8). Concurrently, linear grinding might also have been advantageous in terms of less complex movements. Fred Plog ((Plog 1974, 61) argues that: *'...simple repetitive acts are [generally] more productive than complex ones...'*. The preference for the linear confined grinding in the EPPN may have been to simplify gestures, i.e. a simplification of work (Risch 2008): It was seen as less straining and more 'effective' in people's eyes. This would, potentially, also allow for the production of more end-product or, less time and effort spent to produce the same amount of product (Adams 1993). Diversity drops in the Neolithic perhaps as there is a concentration on certain resources and tasks, the tool surfaces stay large and confined, but elongated. Again, I reiterate that these choices stem from the behavior of individuals within the sociotechnical system, perhaps affected by outside factors like the environment and available resources, or internal innovations: adjusting gestures. These adaptations and modifications were deemed useful and adopted in technological tradition (Dobres 2010; Dobres and Hoffman 1994; Hegmon 1998; Leroi-Gourhan 1993; Mauss 1979; Pfaffenberger 1988, 1992). Desired end-product could also have warranted adaptations. At early Natufian Shubayqa 1 we have evidence of bread-making (Arranz-Otaegui *et al.* 2018), which in turn implies flour production, and it seems a composite flour made of club-rush tubers and wild cereals was used to produce flatbread (Arranz-Otaegui *et al.* 2018). Tubers have been found in large quantities in the hearths of Shubayqa 1 and substantial ethnographic evidence exists of the consumption of such tubers (Fowler 1990; Hillman *et al.* 1989; Rivera *et al.* 2012). Though pulverizing is not a prerequisite of consumption, it has some advantages (Wollstonecroft *et al.* 2008, 2011) and it might have been deemed desirable to grind them into flour. It may be that some strategies at Shubayqa were aimed at recipes where tuber (and cereal) flour was the desired end-product. If the wetland of the *Qa'*, where these types of tubers would have grown, diminished by the late Natufian, the intensification of confined grinding strategies (i.e. RGP) may have been a way to 'stretch' ressources and/or increase the component of wild cereals, a resource that might have become the more important by the early Holocene.

Conclusions

This paper presented a way of examining changes in groundstone technology from the early Natufian to early Neolithic at a local scale by analyzing material from the Shubayqa 1 and 6. It has examined changes in sociotechnical systems by focusing on technological choices expressed in the form of gestures involved in operating groundstone tools. Using a scheme of food processing strategies based on gestures and their dialectic relationship with tools and wear, I have attempted to illuminate how technology and technological choices changed. I suggest most of the changes we observe are the results of modifications and adaptations based on past knowledge and traditions within a sociotechnical system applied by individual agents choosing specific actions, in our case gestures and tools, to meet challenges and process food in ways they found satisfactory. To conclude:

1. The analysis showed that it was possible to refine the *standard view* of groundstone technological development by using the scheme of *processing strategies* and looking at local scale developments, showing developments are less linear and singular than often assumed

2. The diversity of strategies can change over time. The period with the most diversity is the late Natufian, possibly due to a changing local environment

3. Increases in size of used surfaces and a focus on confined grinding strategies, late Natufian (RGP) and in the EPPN (CRG), reflect conscious choices, using existing technology and knowledge to: a. increase the amount of edible end-product b. stretch resources *c.* shorten work time or d. may also reflect efforts towards producing specific end-products (flour). Or all of the above

4. Concurrently changes may also be influenced by the effect it has on the body, perhaps related to stress and fatigue and/or preference for less complex movements and/or decreasing work-time

Further work on these initial observations about changes in technological practices is needed. The evidence presented here is now being paired with microscopic use-wear analysis and residue analyses. This will help us assess whether we can further substantiate any of the above observations. In addition, future experimental studies will also be required to further establish the relationship between gestures, tool morphology and use, stress, strain and labour time.

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Of Muscle and Stone: Ground Stone Tools and Food Processing Technology - Bodies of knowledge

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1. Introduction

1.1. Foodways and ground stone technology

In this paper I argue that understanding ground stone technology and the processing phase of ancient foodways, requires a firm grasp of the diverse elements that make up past foodways and ways of processing. Firstly, I argue for a specific conception of food processing, a labour process in which ground stone tools were heavily involved. Secondly, I highlight that gestures of human bodies are essential to make tools function. These gestures both produce tools and make them function, by providing the motive force behind the tools (at least in the case of food processing ground stone). Gestures are in turn influenced by the technology of that society: a sociotechnical system in which several other social material and immaterial elements influence the technological choices (e.g. gestures) of human agents (and their bodies). It presents thus, a general way of understanding technology with a specific focus on food processing and food processing ground stone tools and their relationship with people. This is a type of labour made up of gestures and tools (the instruments of labour) that inherently both affects, and is affected by, the sociotechnical system.
Lastly, I emphasise the relationship between the tools and the body itself. As these tools are the results and repositories of labour (see also Pedersen *forthcoming*), so too is the body. The body of the operators of these tools also bear the traces of use, which plainly exemplifies just how technology is a totality: of society, tools, people and their bodies.

1.2. Ground stone and the emergence of agriculture in SWA: ground stone as indicators of change

Though this current study outlines a general approach to ground stone technology and food processing, my research background and thus the underlying data were gathered from a specific context. I examine tools belonging to the Late Epipaleolithic (Natufian) and Early (Pre-Pottery) Neolithic periods of Southwest Asia. These periods hold great importance to understanding both the development of cultivation of certain plants, e.g. the so-called "founder crops", but also many other plants (Allaby et al. 2021; Arranz-Otaegui et al. 2018 a; Willcox et al. 2008; Willcox 2012), animal husbandry, and incipient agriculture. Concurrently these periods also witness a veritable explosion in the number, prevalence and diversity of ground stone tools (henceforth GST), many of which would have been involved in food processing. During the Late Epipalaeolithic and Early Neolithic in Southwest Asia (SWA) there are also several other processes taking place, notably emergence of more sedentary/residential sites, including stone built architecture, “monumental” buildings, storage facilities, an increase in the number of burials (and burial grounds), decoration of the dead, expressive and portable art etc. (Bar-Yosef and Belfer-Cohen 1989; Belfer-Cohen 1991; Belfer-Cohen and Goring-Morris 2020; Finlayson 2009; Finlayson et al. 2011; Grosman 2013; Kuijt and Goring-Morris 2002).

The tools I deal with in this paper, and going forward (see Pedersen 2021, *forthcoming*; Pedersen et al. *forthcoming*), are mostly ground stone tool pairs used in food processing, and the processing of meat and minerals. Through either abrasion or crushing, or a combination of both (Adams 2002: 1-2), these tools significantly reduce the particle size of the intermediate material between the surfaces of two stones. The operator uses their body to move the upper stone against the lower stone to change the material. Throughout this paper I generally refer to the tool by generic terms: food processing or processing tools.
These ground stone tools may be subdivided into two main groups: grinding tool pairs, consisting of handstones and grinding slabs or querns and pounding tool pairs, consisting of pestles and mortars (see Wright 1992a).

Ground stone tools have often played a key role in indicating the emergence of agriculture in Southwest Asia and elsewhere (e.g. Bolger 2010; Hayden et al. 2016; Hodder 2018; Mauldin 1993), and they are seen as a crucial part of the Neolithic “package” (see Brami 2019; Childe 2003; Hayden et al. 2016). However, there is also ample evidence for the use of ground stone tools - in small numbers - in Palaeolithic and Mesolithic contexts in Europe and elsewhere (Caricola et al. 2018; Revedin et al. 2010, 2014). Some of the earliest studies on food processing implements, within archaeology of Southwest Asia and North Africa (SWANA) dealt with Late Palaeolithic, Epipalaeolithic and Early Neolithic GST assemblages (Banks 1982; Kraybill 1977; Roubet 1989; Solecki 1969). Also the seminal work by Karen Wright in the early 1990s and thereafter focused mainly on this period (e.g. Wright 1991, 1993, 1994).

Space available here does not permit a thorough review of these periods, but a very brief summary will just highlight the context and setting that shapes my view of food processing ground stone (see more in Pedersen 2021; Pedersen et al. *forthcoming*).
The Natufian period is part of the Late Epipalaeolithic in the Levant and spans roughly 3500 years from around 15,000 to 11,600 cal. BP, including the Early Natufian (c. 15.000-13.600 cal. BP) and the Late Natufian (c. 14,000/13.600-11.600 cal. BP) (Barzilai et al. 2017; Grosman 2013; Richter et al. 2017; Weinstein-Evron et al. 2012). Subsistence during the Natufian was based on hunting of gazelle and also smaller game especially in the later periods, and extensive gathering of wild plants like cereals, legumes, grasses, nuts and tubers (Arranz-Otaegui et al. 2016; Arranz-Otaegui et al. 2018; Munro 2009; Stutz et al. 2009; Olszewski 2008; Rosen and Rivera-Collazo 2012; Willcox 2012; Yeomans et al. 2017).

Following the Natufian we see the emergence and spread of a so-called "Pre- Pottery Neolithic" (henceforth PPN) in the Levant, and my research focuses on the Early part of this period, *i.e.* the PPNA to very Early PPNB c. 11,600-10,600 Cal. BP (Belfer-Cohen and Goring-Morris 2010, 2020; Edwards 2016; Finlayson et al. 2011). It is characterised by several "Neolithic" features such as increasing sedentism, population growth, intensifying cultivation and incipient domestication of plants and animals, but without ceramics and still largely reliant on hunting and wild plants (Ofer Bar-Yosef and Belfer-Cohen 1989; Finlayson 2009, 2013; Kuijt and Goring-Morris 2002).

The development of GST leading up to and during these periods follows several trends. Some of the first "food processing" GST in the Levant are grinding tools dated to the Upper Palaeolithic (Dubreuil and Nadel 2015; Kraybill 1977; Roubet 1989; Wright 1991). During the subsequent Epipaleolithic in the Levant, vessel-type mortars and long pestles start to appear (Maher, Richter, and Stock 2012; Wright 1991). These types became even more common during the Late Epipaleolithic Natufian where also grinding tools (handstones, slabs and querns) and ground stone tools in general spike drastically in number (Wright 1991, 1992b, 1994). The pounding tool group, pestles and mortars that evidently dominates Early Natufian give way to grinding tools over time (see Dubreuil 2004; Wright 1994) and by the Early Pre-Pottery Neolithic, grinding tools are the most common (Wright 1993). This is seen as a result of increasing reliance on cereals grains (Wright 1994). This is at least the "standard view".

In Pedersen (2021), I argue that often the developments within GST technology and Natufian to early Neolithic (Pre-Pottery Neolithic) foodways influenced by this "standard view" as a linear and commonsensical progression, that is reduced to a tautology: GST's are seen as representative of the emergence of Neolithic economies and vice-versa (e.g. Hayden et al. 2016). Rather, ground stone tools have longer and more complex relationships to domestication, agriculture and the changing foodways of the transition into farming, than is sometimes perhaps recognised. For example, we now know that so does the production of bread, a food type often associated with the Neolithic, first appeared long before plant domestication and also predates plant cultivation (Arranz-Otaegui et al. 2018).

The pounding and grinding of plants and associated tools was most likely an important part of forager subsistence and technology long before the so-called "Neolithic revolution", at least the case within SWANA, where these ground stone tools predate agriculture (e.g. Dubreuil and Nadel 2015; Kraybill 1977; Wright 1991). Furthermore evidence for pre-domestication cultivation (and inferently plant processing) has also been observed in pre-agricultural societies, and possibly as far back as the Upper Palaeolithic in SWANA (Dubreuil and Nadel 2015; Hillman et al. 1989; Rosen and Rivera-Collazo 2012; Roubet 1989; Willcox and Stordeur 2012).

Often we may imagine the structure of labour, the habits and tasks associated with food processing ground stone in the preceding periods mirror those found in the Neolithic, just less intense: that changes to ground stone simply reflect the increased reliance and intensification of certain activities (e.g. Dietrich et al. 2019; Dietrich and Haibt 2020). For example that grinding tools are representative of cereal processing and more grinding tools means more cereal processing (Wright 1994). What we risk though is teleologically projecting the future importance of these certain activities and tasks onto a past (e.g. the Epipaleolithic) where these activities may have been different, had different goals and were structured differently, or at least had not the same qualitative (and not just quantitative) characteristics they would later have. This is simply to note that when we associate these processing tools with or as representative of, a Neolithic "package" or lifestyle we should attempt to avoid being too deterministic (cf. Hodder 2018). Rather we should attempt to unravel their complex history and entanglement with entire foodway systems and not simply focus on what it resulted in, in later periods.

I posit in Pedersen (2021), using the same basic approach also outlined here, that this standard view is incomplete. Only by considering gestures, bodies and the progressive nature of wear (see Pedersen *forthcoming*) may we see foodways, and ways of using tools in food processing, as much more complex than the standard view would confess.

That is why the approach I argue for here (and also Pedersen *forthcoming*; Pedersen et al. *forthcoming*) is a useful tool to understand the technological development within ground stone technology during the long, drawn-out transition from foraging to farming.

In any case this paper is meant rather as an espousement of a general approach to food processing tools, what principles that shape and affect these technologies. Therefore, though my general research is based on a specific period and setting, and aims at illuminating trends and developments happening there, I intend that this approach may have applications more broadly. This leads to the main topic, the activity these GST were (and are) engaged in.

1.3. Food processing

Food processing can be defined as: *"the purposeful external modification of a resource to change its physical or chemical attributes in preparation for consumption"*(Crittenden and Schnorr 2017: 91) and includes several diverse activities happening after food resources are obtained. Crittenden and Schnorr (2017) argue that "traditional" food processing achieves these modifications and alterations of resources by "non-mechanized" technology, in contrast to modern food processing which uses mechanised methods. Though this definition is rather broad, it serves the purpose here well. I will avoid using the term "traditional", applied by Crittenden and Schnorr, as this to me has certain unwanted connotations. Rather than "traditional", I define these tools as non-mechanised, subject-operated and -centred (see below), stone tools and technology. Meaning food processing ground stones that are moved by human power, by human bodies and their gestures (and underlying agency). As is argued below, the body and its gestures and the motives of the operator are what make these tools function: actions are situated in the body and have not been appropriated by a modern "machine" (Ingold 2002, 315–318).

Twiss (2012) has argued that food processing can be subdivided into *initial preparation*, which would include butchering and *pre-consumption preparation* including both processing like crushing or grinding, and cooking. Here, one could argue that GST are used in a *"pre-consumption"* processing step which would encompass: grinding, pounding *etc.* This step may happen both before or after an actual cooking-step (i.e. boiling, roasting, baking and frying). Pounding/grinding pre-consumption preparation affects palatability, nutritional value through bio- accessibility and availability and reduces the need for mastication among other things (Wollstonecroft et al. 2008; Wollstonecroft 2011; Zink and Lieberman 2016). Using heat or other "non-crushing" processes in cooking importantly also alters the physical properties of food, including taste/palatability and the nutritional value of food (Carmody et al. 2016; Hardy et al. 2015; Wollstonecroft et al. 2008).

There is however, a slight difference here between processing through crushing, abrading and pulverising and (thermal) "cooking", chemical or biological treatment of products (e.g. boiling, roasting, soaking, sprouting, pickling, fermenting etc.). These processes are different, but not separate from grinding/pounding activities. The main divergence being, that in grinding/pounding the body and tools are the main "motor" of change, and not heat (fire) or chemical/biological processes (e.g. weather or acidic solutions). For example, these kinds of cooking often render the meal *ready to eat* (or stored as edible product), whereas *crushing* processing as I term it here (see Table 1 below), mainly prepares an ingredient (or several), to be combined with other ingredients at a later point. Of course, food preparation can also involve no thermal treatment, when cutting, pounding and/or dressing suffices like salads, *köfte* (Ertug 2002)*,* tatar or *pemmican* (Bethke et al. 2018). This also includes many recipes where ground stone tools, like mortars and pestles (or grinding slabs and handstones) are used in pounding/grinding to prepare food for consumption, by tenderising meat (Ertug 2002) or crushing plants making sauces, *guacamole* or *chutneys* etc. (Hamon and Le Gall 2013).

Conversely, thermal cooking[1], generally uses other types of tools (spoons and ladles), containers (vessels and pans, griddle rocks), fire and water. Here, thermal treatment enacts the desired change, and thus takes place at special locations where thermal treatment can be facilitated (hearts, fire pits, ovens), something that is recognised in Hodder (2018 and Atalay and Hastorf 2006 therein). Grinding/pounding tasks may often take place away from these "thermal" locations (see Ertug 2002; Schroth 1996; Searcy 2011), and again using other types of tools and gestures (e.g. grinders/mortars) and with no thermal treatment during the actual operation of the GST (Ertug 2002; Fauvelle et al. 2012; Schroth 1996; Searcy 2011).

Furthermore, some ingredients are also cooked before being processed again. They may be roasted, boiled, parched, dried or soaked, as a prerequisite to subsequent crushing and pulverising, like the nixtamalization process for example (Arendt and Zannini 2013; see also

[1] I would generally include chemical or biological preservation, such as pickling, salting and drying as a subtype of this kind of *cooking*

Arranz-Otaegui et al. *submitted*). As shown by Alonso's (2019) in a recent survey of the non-mechanical cereal processing, these "pre-cooking" treatments can be extremely complex processes, and may involve several sorting, dehusking, soaking and roasting steps. However, many of such processes leave few(er) archaeological traces.

Consequently, though I may distinguish qualitative difference between thermal (and chemical and biological) treatment of the products in cooking and the act of pulverising and crushing, pounding and grinding, the process is not linear. Sometimes roasting or soaking may come before grinding or pounding, then the product is mixed with another and perhaps cooked again or stored. These are therefore complex processes and our distinction between them is merely a matter of analysing tools that may have been used in specific steps in a labour process. The exact relationship to the other steps in this process may be extremely complex to untangle and recognise. It may therefore suffice to say that these tools are used in post-procurement and pre-consumption processing, their main mode of transformation is the human body, its movements (*gestures,* see below) and kinetic force, the material properties of the upper and lower stone tool surfaces, both the petrographic properties and the ones created by humans, including tool shape, size and weight.

I also note that there is the step of presenting the food, e.g. its placements on plates etc. This has a huge significance that may often be overlooked (Hamilakis 1999, 2017; Twiss 2008; 2012). It also takes place within specific social contexts, perhaps involving different people than during earlier pre-consumption processing (Twiss 2012). What I would suggest then is a *chaine operatoire* of "non-mechanical" and "pre-agricultural" foodways with definitions of specific stages processing inspired by Crittenden and Schnorr (2017), Hodder (2018) and Twiss (2012) (see Table 1).

Production

1. Procurement (tools: weapons, digging sticks, sickles, nets, hooks etc. - [Locations: off-site, steppes, lakes, rivers, foothills etc.]
    i. Gathering
        - Includes plant tending
    ii. Hunting
    iii. Fishing
        - These also include animal trapping
2. Post-procurement
    a. Initial preparation (tools: bowls, sticks, mortars and pestles, grinding and abrading tools, flails, racks, sharp-edged tools, containers, hearths, sieves etc) - [Locations: off-site and on-site, initial steps may be done before return to camp]
        i. Drying
        ii. Soaking
        iii. Fermenting

iv. Butchering
v. Sorting
vi. Threshing/winnowing/dehusking

- *Storage (possibly)* (tools: containers, racks, holes) [Locations: mainly on-site, exterior or interior, in common or "private" areas]

b. Pre-consumption preparation

i. "Grinding/pounding" processing (tools: mortars and pestles, grinding stones and hand stones, pounders and anvils, graters, containers, sieves etc) - [Locations: mainly on-site, exterior or interior, in common or "private" areas]
  - Grinding
  - Peeling
  - Pounding
  - Grating
  - Mixing
  - Softening

- *Storage (possibly)* (tools: containers, racks, holes etc.) [Locations: mainly on-site, exterior or interior, in common or "private" areas]

ii. "Actual" cooking (tools: plates, ladles/spoons, hearths, ovens, bowls/vessels, mortars and pestles, sharp-edged tools etc.) - [Locations: mainly on-site, exterior or interior, in common or "private" areas, e.g. hearths where cooking may be facilitated]
  - Thermal/chemical alteration (roasting, boiling etc.)
  - Combining
  - Seasoning

c. Presentation

i. Arranging etc. (tools: plates, bowls, platters, leaves, containers, eating utensils?, skins/mats etc.) [Locations: mainly on-site, exterior or interior, in common or "private" areas]

Reproduction[2]

3. Consumption
   a. Daily meals
   b. "Special" meals
   c. Offerings
   d. Feasting
      i. Postprandial

Table 1: A suggested *chaine opératoire* of pre-agricultural foodways with an emphasis on the *pre-consumption processing* activities. It attempts at both being general and specific to Late

[2] Reproduction in the Marxian sense i.e. subsistence. Food people eat to stay alive and regenerate their labour power (Marx 1887: 120–121)

Pleistocene-Early Holocene Southwest Asia. (Table inspired by Atalay & Hastorf 2006 in Hodder 2018).

In the table above, food processing is imagined as a chain of operational sequences. It is important to note however, that this is not rigid nor should be understood as necessarily linear; changes and interventions in the steps may frequently occur. Further, it is by no means meant to be an exhaustive list. All the steps before 3. are related to the production side of foodways: i.e. 1. to 2. and their substeps, whereas 3. relates to the consumption and "reproduction" side of foodways. Unlike (Atalay & Hastorf 2006 in Hodder 2018) this table includes several points at which storage may be introduced and it also includes consumption as an activity, though this is related to reproduction and not production specifically. Reproduction (in the Marxian sense Marx 1887: 120–121) is the metabolic reproduction of the human body and human labour power (Risch 2008).

As is shown each step has tools and locations that are both specific to that activity or overlaps in more than one activity. This shows the complex web of entangled (see Hodder 2018) tasks and labour process that coalesce in food processing just as in most tasks. What is important is that we recognize the importance of each of these tasks and though we may not entirely be able to untangle the web, nonetheless attempt to discern some interesting points. Often an emphasis on procurement side of foodways have left the extremely important, labour intensive and crucial step of post-procurement treatment in the shadows (see Jarvenpa and Brumbach 2008; Leacock 1992). What I attempt is to show the importance not just of procurement but of processing, how it relates to humans' relationship with tools, their bodies and society as a whole and how these affect each other.

1.4. Foodways: beyond processing

Food production is not only about what foods are procured and how they are consumed, but also about all the steps in between. Food is much more than mere subsistence, the production of food - and its later consumption - is always social, and exists within socio-cultural contexts, where it may take on different meanings and roles (Hamilakis 1999; Hastorf 2017; Lemonnier 1993; Risch 2008; Twiss 2012).

Consequently food technologies, or *foodways* involve individuals, bodies, movements, senses, tools and activities socially organised, coordinated, connecting and guiding food production from initial procurement to subsequent processing, and also the final act of consumption; eating, drinking (Hamilakis 1999; Steel and Zinn 2016; Twiss 2012). It has been argued that: *"asking what we eat is therefore simultaneously asking how we eat"* (Crittenden and Schnorr 2017: 85). This statement also implicitly asks *what* we do to the things we eat and *how* we do it; alluding to the treatment of plants and animals once they were procured and before we eat them. For example, as illustrated humans may butcher, grind, season, knead, wash, cut, mix, bake, boil or grill plants and non-human animals before we consume them. In addition, this *how* also includes the manner in which this treatment is performed (social organisation and coordination) and with *what*: sticks, stones, knives, bowls, sickles, baskets, scrapers, mortars, querns *etc*.

An important factor to keep in mind is that the nutritional and social aspects of foodways can not be separated (Twiss 2012 and references therein). The culturally and socially specific ways we treat things and how we eat them has an enormous impact on the nutritional value of food (Crittenden and Schnorr 2017; Hamilakis 1999; Hastorf 2017; Steel and Zinn 2016; Twiss 2012 and references therein). Similarly production (here food processing specifically) and consumption can not be entirely separated. In the case with foragers at least, production, processing, food sharing and consumption mostly happens within the same small family/household group, in the case of "immediate" return societies at least (Layton 1986; Sahlins 1972; Solway 2006; Testart 1987; Testart et al. 1982; Woodburn 1982).The producers are thus also the consumers.

This mode of production is different from that of certain later periods (Marx 1965) and from our "modern" foodways. Hence, the approach suggested here is intent on showing how specific tools are used in processing and not only focusing on what they can produce. It includes considerations about the body (how it acts and is acted upon), but from the perspective of the tool (how it is operated and how use affects it) through gestures. The product, whatever it would have been, what is subsequently done with it *e.g.* cooking, how it may be prepared, consumed and thus return energy to the body once more is a topic to further investigate going forwards (see Arranz-Oategui et al. *submitted*; Pedersen *forthcoming*; Pedersen et al *forthcoming*). In section 2. I will turn to establish concepts of how the surrounding society, or sociotechnical system (see below) where these actions, artefacts and products exist, act and are consumed, influence and are influenced by this process. How society acts as a "conductor of activity" (Marx 1887: 128).

2. Gestures, Society, Labour and The Body[3]

"The body is [hu]man[kind]'s first and most natural instrument" (Mauss 1979: 104)[4]

2.1. Gestures

It is argued here that the study of technology and change, including food processing technology, is essentially a study of changing bodily movements: the movements, or *gestures,* applied in making and operating tools and the transformations of human-tool relationships is what is central (see also Hodder 2018). Gestures are then a proxy for human intentions, ideas,

[3] A much briefer version of the approach I elucidate here appears in my forthcoming publication (Pedersen 2021), and an earlier, much less developed version appeared in my unpublished MA-thesis (Pedersen 2017)
[4] Edited to remedy the androcentric language of Mauss. Though surely intended to reference "humans" and not men, the exclusion of women, trans and non-binary individuals from the the discourse of technology and tools (and often within stone tool studies), is real and prevalent, it is also something addressed further below in section 3.

bodily knowledge and action and ways of changing the "natural" world. Together with the resulting tools, bodily movements are part of a human-tool relationship: the body acts using tools to change a material in desired ways and in the process affects the tools. We may glean the "underlying" gestures by analysing tools (see in Pedersen *forthcoming*) and thus try to refine and untangle this human(body)-tool relationship, and see it change and attempt to explain these changes.

Andre Leroi-Gourhan developed the concept of *gestures*, in his seminal work Gesture and Speech (1993). Gestures are the movements that are performed in both making and using tools and these have great technological significance. To Leroi-Gourhan: *"the real significance of tools is in the gesture, which makes them technically effective"* (Leroi-Gourhan 1993: 237). In this text, he states that gestures are the way a body acts upon the world. This human way of acting upon the world is often done through the use of artefacts, in our case ground stone tools, an *"artifactual interference"* as Wobst (2000) puts it. Gestures are applied in making and using all tools (in pre-automated technology at least). They make them technological efficient, and they are therefore the (most) important element in the development and use of tools. Consequently, following this I argue technological change must be the expression of different forms of motion/gestures involved in making and operating tools (Leroi-Gourhan 1993: 251). Similarly, Shalins (1972: 79) noted that the most historically significant element of technology is the relationship between users, tools and labour, not necessarily the tool itself. However, the tool may be seen as the material expression of these relationships.

Importantly these gestures are not only internal, subjective, biological, motions, but are also influenced by external factors. Movements are biological but they are also learned, influenced by customs, practises, norms, habits and knowledge within a society, the way people move and what gestures they use, is to an extent *"imposed from without"* as asserted by Mauss (1979: 102). These external factors direct how actions should be performed, i.e. in ways that follow certain social norms and traditions as *"ordered, authorized, tested action"* (Mauss 1979: 102; see also Gosselain and Stark 1998). Imitation of authorised action, e.g. correct use of tools and gestures, is thus a result of internal psychological (cognitive), physical, biological (or bodily) aspects that follow external social elements (see also Dobres 2010; Pedersen 2017: 17). Consequently, as noted by Hodder (2018) actions are part of complex "*bio-socio-material entanglements"* or as Mauss (1979: 120) posits, essentially *"physio-psycho-sociological".* This I would argue is concurrent with the Leroi-Gourhan's statement above about gestures: the significance is situated in the tool as an expression of a human-tool relationship, in the gesture and the body, and cannot be easily separated from this. In addition, any technological behaviour is also political and symbolic (Pfaffenberger 1988). Tools are an extension of the human body and its capabilities (Leroi-Gourhan 1993), but also part of a *"tool-organism"* (Sahlins 1972: 80) emminating from the individual body and existing within a social setting, a mode of production, and at the same time operated through human action, by the individual user (and their agency). This establishes that gestures or technology does not exist separate from the world (see also Ingold 1997;

Pfaffenberger 1988). Gestures, like the body and the tool, are tied to a material reality within a social and cultural context, they are guided and constrained by the surrounding society (Dobres 2010; Mauss 1979: 102-120 ; Pfaffenberger 1992). This means that technological human (body)-tool relationships are also social in nature, not just one between the individual (body) and the tool, but also between individuals and society. The surroundings, both ecological and social, thus affect this relationship, and just as one cannot separate the ecological setting from tool use, technology cannot be disembedded from the social reality (Ingold 1997; Pfaffenberger 1992; Sillar and Tite 2000). Gestures are thus physically manifesting the actions of not only individuals, but of society's desire for change, through the production and use of specific gestures and tools and expressed materially in the tool(s).
In this case the specific gestures are involved in making/using food processing ground stone tools. Affected by the surrounding society and simultaneously affecting this society, in other words a *sociotechnical system*.

2.2. The Sociotechnical System

The concept of sociotechnical systems as proposed by Bryan Pfaffenberger (1992) aims to elucidate the social and cultural structures that create and are created by technological systems. In addition to Pfaffenberger, french anthropologist P. Lemonnier has also been influential and both have been instrumental in developing an anthropology of technology where the social and cultural aspects of technology are central (see Lemonnier 1986, 1992, 1993, 2012; Pfaffenberger 1988, 1992; see also Stark 1998; Ingold 2002).

Pfaffenberger (1992: 513) defines the concept as follows:

> *"[T]he sociotechnical system concept puts forward a universal conception of human technological activity, in which complex social structures, nonverbal activity systems, advanced linguistic communication, the ritual coordination of labor, advanced artifact manufacture, the linkage of phenomenally diverse social and nonsocial actors, and the social use of diverse artifacts are all recognized as parts of a single complex that is simultaneously adaptive and expressive."*

Within this framework technology, including the production and use of tools, is influenced by social aspects and elements and part of a larger social complex (Pfaffenberger 1988; Pfaffenberger 1992; Sillar and Tite 2000; Stark 1998). Technological systems are inherently *"social production[s]"* following Lemonnier (1992: 17). This emphasises that the study of a past technology not only tells about a specific product, object or tool and its production, but informs us about *"social relations"* and *"cultural values"* of societies (Sillar and Tite 2000), both modes of production as well the underlying ideas and norms. Technology is thus the expression of cultural practises and choices. Simultaneously as the anthropology of technology established itself, was the emphasis on the social and cultural characteristics of technology was not neglected by archaeologists, and interested in technological behaviour, innovation, change and agency and have produced considerable body of work from the early

1990s onwards, see for example Bryan Schiffer, Marcia Dobres and others (e.g Dobres 1995; Dobres 2010; Dobres and Hoffman 1994; Gosselain and Stark 1998; Hitchcock and Bartram 1998; Schiffer 2004, 2010; Schiffer et al. 2001; Sillar and Tite 2000; Sinclair and Schlanger 1990; Sinclair 2000; Skibo and Schiffer 2008).

Following these principles it becomes clear that all production (including food procurement and processing) within a society is situated within social relationships, organisation and the "*prevalent thought and behavior pattern"* of that society as noted by philosopher Herbert Marcuse (1941: 139). In fact, being part of a community is a "*natural* [human] *condition"* and prerequisite of most production and thus subjective existence and subsistence (production) is conditioned "*as much by relationships with other individuals"* as it is by relations with the earth from which resources are appropriated (Marx 1965: 90). As argued above, social elements, relations and dynamics, are always engaged in technological activities, but one should attempt to illuminate the role that both individual, subjective practitioners along with objective social structures play in the development of technology (Dobres 1995; Dobres and Hoffman 1994; Dobres and Robb 2005). Thus, material expressions of labour and techniques like artefacts, the objectified results of labour (Dietler and Herbich 1998) as well as the gestures applied in operating them and in production of products (that are also expressed materially) also elucidates the agency of people i.e. subjects, by physically manifesting their intentions, decisions and choices (Ingold 2002: 219-220; Sillar and Tite 2000; Sinclair 2000; Wobst 2000).

Furthermore, importantly, active social agents may select certain solutions and technologies, while abandoning or rejecting others, even if they appear more useful or worthwhile to an "outsider", and if the social aspects of technology are not considered such decisions may be difficult to comprehend (Lemonnier 1992; Pfaffenberger 1992). This entails that while the sociotechnical system both constrains, guides and determines correct actions, individual practitioners also influence this system in a dialectical relationship. So in addition to being a way of organising and performing technological actions and facilitating kinds of production, the system is also a venue where active social agents may select certain technological solutions, while abandoning or rejecting others, affecting the technological system as a whole (Pfaffenberger 1992). Marcuse (1941) argues there is a *dialectic of technology*, where tools and technical actions along with the overall modes of production are never neutral and engage and promote both; domination or liberation, scarcity or abundance (Marcuse 1941; Farr 2017); this also applies to change or continuity (Dobres 1995; Dobres and Hoffman 1994; Schiffer 2004), expansion or contraction of production (Sahlins 1972). Production is thus no more neutral than the agents engaged in its operation: the sociotechnical system and its boundaries; the proper tools, techniques and gestures are intimately entangled and intertwined with the agents, hence technology is an expression of human relationships as well as other "natural" material relationships (Marx 1965: 90).

2.3. *Technology, techniques* and *skill*

While on the subject of technology it is useful to briefly establish what I mean by technology. I favour a rather broad sense of the concept concurring with Herbert Marcuse in seeing technology as:

> *"[...] a mode of production, as the totality of instruments, devices and contrivances which characterize [...] at the same time a mode of organization and perpetuating (or changing) social relationships, a manifestation of prevalent thought and behavior patterns [...]"* (Marcuse 1941: 139).

A definition akin to the concept of the sociotechnical system (Pfaffenberger 1992), a system of *"related social behaviours and techniques"* (Pfaffenberger 1988: 241).
There are important distinctions, or rather subdivisions, within this quite broad definition. The subservient feature of technology is sometimes called *technics* (Marcuse 1941; 2013) and is usually defined as the*"technical apparatus"* (Marcuse 1941: 138) which may include tools or machines used within a *specific* mode of production, including knowledge, and ideas about their use (Marcuse 1941; Farr 2017). A similar definition is found in Pfaffenberger (1992: 497) and Lemonnier (1986, 1993) where *techniques* include tools, objects, raw materials, resources, along with knowledge, skills and operational sequences (these sequences would include *gestures*). In this way *techniques/technics* is part of *Technology,* as the way individuals (subjects) apply technology to *"[...] create man-made entities, by changing "natural" conditions [...]"* it is*"[...] the methodological negation of nature by human thought and action*" (Marcuse 2013: 45). *Technique/technics* is thus subjective, context-dependent, "practical knowledge" whereas *technology* is objective, context-independent and discursive, as Ingold (2002: 316-317) has pointed out.
However, it is also important to subdivide *techniques*. As Ingold (2002) argues, in contrast to Marcuse, using the term *skills* instead of *techniques/technics,* tools are not necessarily part of *techniques/technics/skills.* Some *techniques,* like dancing, do not need tools to be performed (Ingold 2002: 315). Therefore I mainly apply the term *gestures* because this, as I established above, specifically refers to movements that make tools or make tools function (i.e *sensu* Leroi-Gourhan 1993). Thus, following Ingold (2002) I also argue that though *gestures* are *techniques,* tools are not. Tools are rather the *"objectified result of techniques"* as Dietler and Herbicht (1998: 246) put it. This also follows Marx (1887: 129), who asserts that instruments of labour (*i.e.* tools) are the embodiment and objective representations, repositories and results of labour (Marx 1965: 86). Labour which is in turn forms of actions, with tools and gestures.

Tools as we deal with here thus come to *"symbolize a whole economic and social system"* (Childe 2003: 31). But again, it is important to note, just as we distinguished "non-mechanical", "non-automated" food processing we need also to distinguish the technology, and machines, of Marcuse and Marx, with the (prehistoric) ground stone tool (i.e. non-mechanical). The machine of the industrial age left little to no room for individual autonomy, the labourer often simply functioning as an attendant, Marcuse notes: *"[i]n manipulating the machine man learns that obedience to the directions is the only way to obtain desired results [g]etting along is identical with adjustment to the apparatus."*

(Marcuse 1941: 144). Something also noted about early industrial Britain by Malm (Malm 2016: 410-426).

Contrary, I would argue that ground stone processing tools, do to some extend leave more room for choices to be made by individuals or groups of individuals as they are still powered by individual practitioners and their movements; movements have yet to be completely "annexed"[5] by the machine. The object still operates through individual techniques/skills/gestures, with what may be called human *animate* power (Malm 2016: 37-41) and is thus, subjective, humanised and *"personal rather than mechanical"* (Ingold 2002: 314).

Meaning again that people for example engaged in processing as active, conscious, social agents (Dobres 2000; Dobres and Hoffman 1994; Pfaffenberger 1992), may change their ways of engaging with the object/artefact/tool. Hence, I put forth the case that it is rather objects that are appropriated by subjects (Marx 1965: 86) not the other way around. Though the subject and object interact dialectically.

Consequently, and to reiterate: gestures (*techniques*) are movements and the applied results of the personal (and social) knowledge (and identity) of the labourer(s), integral and inseparable in these non-mechanical processing practises. So, although the tool is the objectified result of gestures it is still subjective in its use, *i.e.* through techniques.

The externalisation of the subject from technical (skilled) practises and apparent separation of society (and social relations) from tools and technology does not happen until the age of machines and capitalist production (Ingold 2002; Marx 1965; Pfaffenberger 1988; Winner 1977)[6]. No matter how external to and separate from technology that the individual subject and society may appear today, technology is never just a simple matter of neutrally making and using tools. Because, as Marcuse (1941) argued, technology is never neutral (it is inherently ideological in fact). So the modern western view of technology, where human choices and intentions are mechanical and objectified may fit modern western and capitalist society (see Ingold 2002; Pfaffenberger 1988, 1992). However, uncritically viewing the past this way should be challenged. We should understand GST therefore instead as subject-centred and *humanised* (Ingold 2002: 317-319; see also Pfaffenberger 1988), *"personal"* and "*non-mechanical"* Ingold (2002: 314), moved by human gestures and force. A more holistic conception of technology, techniques, society and people is preferable. Such holistic approaches are found in the sociotechnical systems concept and generally in the recent anthropology of technology (e.g. Ingold 2002; Lemonnier 1992; Pfaffenberger 1988, 1992) which is also applied here.

An Old vs. New materialist approach

Actor Network Theory (ANT), New materialism and Posthumanism (see Latour 2007, 2012) have become increasingly popular within the humanities, social sciences and

[5] Though in Leroi-Gourhan's terminology milling stones are referred to as "hand-operated" machines (1993: 242):*"gesture became annexed by the hand-operated machine, the hand merely supplying its motor impulse by indirect mobility"* gestures are still the motor

[6] What Pfaffenberger (1988) calls "*technological somnambulism"*

archaeology within the last 5-10 years (e.g. Govier and Steel 2021; Tsoraki et al. 2020; Witmore 2014). These approaches in an "ontological turn" essentially gaze at objects, technology, society and people, by collapsing established distinctions like nature and society, social and natural, human and nonhuman agency, subject and object etc. Though interesting and useful in explaining certain phenomena, I apply here a "old materialist" or "critical materialist" approach (White 2013). Though beyond the scope of this paper to review and critique the entire body of work by scholars within these New materialist or Latourian approaches, I see two pertinent issues t. Both are part of the new materialist "ontological turn", one the affordance of agency to nonhuman actors, a Latourian object-fetischism, where I concur with (White 2013) and the second is the collapse of the nature and society dualism following a critique by Malm (2019). Other salient critiques have also emerged within archaeology e.g. (Hacıgüzeller 2021; Ribeiro 2016).
Important for these critiques and my own approach is the Marxist/Marxian perspective. I hold that the starting point for technology, society and human actions and agency is labour:

> *"Labour is, in the first place, a process in which both man and Nature participate, and in which [humans] of <u>[their]</u> <u>own accord starts, regulates, and controls the material reactions between himself and Nature"</u>* (Marx 1887: 127 emphasis mine).

Labour is thus a "formative activity", making something or making something happen (Sayers 2007). Now this is not to say that it is essentially "productive" but it is a human activity, that is intentional, socially organised and may often include the making and using of tools (Sayers 2007), but not all labour or techniques require tools as was noted by Ingold (2002: 315). However, it is human agency in action. This agency of humans is different from that of the nonhuman actors. Notably though human activity and agency in attempting to *"regulate"* and *"control"* of *"the material reactions between humans and nature"* (Marx 1887: 127), may not always be aware of the feedback loops and causal powers released by nature and nonhuman actors in return (Malm 2019). But it recognizes the initial point of this feedback with human (read social) activity.

The ontological hybridism of nature and society is thus problematic in that it obscures the relationship between the social and the natural. It is not that the two are not connected, but exactly because they are connected - but not the same - that they influence and affect each other. Both are part of a material world, interconnected and bonded, even "entangled" (Hodder 2011). However, only by attempting to "disentangle" and keep the natural and social analytically distinct, can we attempt to say something about human activity and how it affects and is affected by the natural (world) (Hornborg n.d.2014; Malm 2019). We may, as Malm points out, elucidate what: "[...] *aspects of the world that humans have constructed and those generated by forces and causal powers independent of them and examine how these have, at ever more complex levels, become braided."* (Malm 2019: 172).

To illustrate this point: a stone that is shaped into a specific form by humans is interesting as it represents human actions and intentions. Concurrently, a stone that has been shaped by natural processes may be equally interesting and may also be used by humans in the same way as the humanly shaped one. However, it is only imparted with intention and agency as it is picked up and used by an individual. It is only when it is filtered through human labour: shaping, using or picking it up, that we may say something about society. The "natural" stone is only "social" when going through this process, i.e. picked up by humans. But this is exactly why these categories and distinctions are useful and important (in analysis). I can analyse natural stones, naturally occuring in an archaeological context, to explain how nature may have affected society, but society may only affect nature by removing or rearranging those stones, e.g. turning them into a pile or into the wall of a hut or a tool.

Through labour, that formative activity (Sayers 2007; Marx 1887: 127), a stone moves from the natural to social, from nature to *humanised* and *historicised nature* following Pfaffenberger (1988) and (Malm 2019) respectively. Technology as I have just argued above is always social:

> *"To say that technology is humanised nature is to insist that it is a fundamentally social phenomenon: it is a social construction of the nature around us and within us, and once achieved, it expresses an embedded social vision"* (Pfaffenberger 1988): 244).

Meaning that technology, be it a hut or a tool or any other raw material filtered through human labour becomes part of a social process. However this does not mean that technology thus makes of independent of nature, on the contrary, as Malm puts it, talking about *historized* nature:

> *"The more profoundly humans have shaped nature over their history, the more intensely nature comes to affect their lives. The more the sphere of social relations has determined that of natural ones, the more the reverse [...]."* Malm 2019: 173

This mutual invasion of turf by the natural and social does not merit, in my view or in Malm's (2019), Hornborg (2014) or White's (2013) or other "old materialists", a collapse of the natural and social: Rather it emphasises this dialect!

Consequently, in analysing a hut or a tool, I am saying something about human actions, a social process embedded within a natural setting, but gaining something by separating the two. There are of course close ties, bodies, tools and products that may become entangled (Hodder 2018), but importantly that entanglement is one of human origin, nonhuman actors engage are an integral part of it and feedback from these affect human behaviour, but have human actors not the (potential) possibility of walking away? Nonhuman actors are severely limited in this. Objects for example may have consequences, buth they do not act (Hornborg 2014). There may be interesting minglings of human and nonhuman matter and "agency" (see (Govier and Steel 2021), a object may be treated as some subject and the other way around but these still are initiated by human agency, intention and actions of living entities (Hornborg 2014) and filtered through human interpretations (White 2013). Objects may be delegated agency, they can be symbols (or be imbued with magic power) afforded social agency, but will still be dependent on human perceptions (Hornborg 2014).

So further summarise, the totality of labour, *techniques* or *skills* (knowledge, ideas and actions, including gestures within specific modes of production), raw material, objects, tools along with knowledge, communication and larger social coordination of labour make up the sociotechnical system (Pfaffenberger 1992). In this sense the concept of sociotechnical systems mirrors *technology* as defined by Marcuse (1941): *i.e.* understood as a synthesis of humans, human social relationships, techniques, tools and raw materials. Labour is, as asserted by Marx (1887), the prerequisite of everything else, as also noted by Sahlins *"[f]or the greater part of human history, labor has been more significant than tools, the intelligent efforts of the producer more decisive than [...] simple equipment"* (Sahlins 1972: 81). Gestures as the bodily movements, skills and techniques performed *during the labour process* both make tools and make tools function, and are necessarily the starting point and of utmost importance as Leroi-Gourhan (1993: 237) also pointed out. They, tools and related gestures, are thus both the result of sociotechnical traditions of a society and in turn influences that society's traditions and mode of production as Pfaffenberger (1992), Lemonnier (Lemonnier 1992) and Dobres (2010) hint at (also see figure below). Technology thus consists of tools, techniques, gestures, both the performance and the learning of this labour (including the social coordination thereof) and also the ideas and perceptions surrounding; a synthesis, a wider system of activities, a sociotechnical system (Pfaffenberger 1992). When talking about a specific type of technology, like non-mechanical food processing (*e.g.* ground stone) technology, I am then talking about a range of tools used with specific *techniques, i.e.* gestures (and knowledge) by individuals (or groups of) subjects, within a sociotechnical system (the *technology* and specific modes of production of that society).

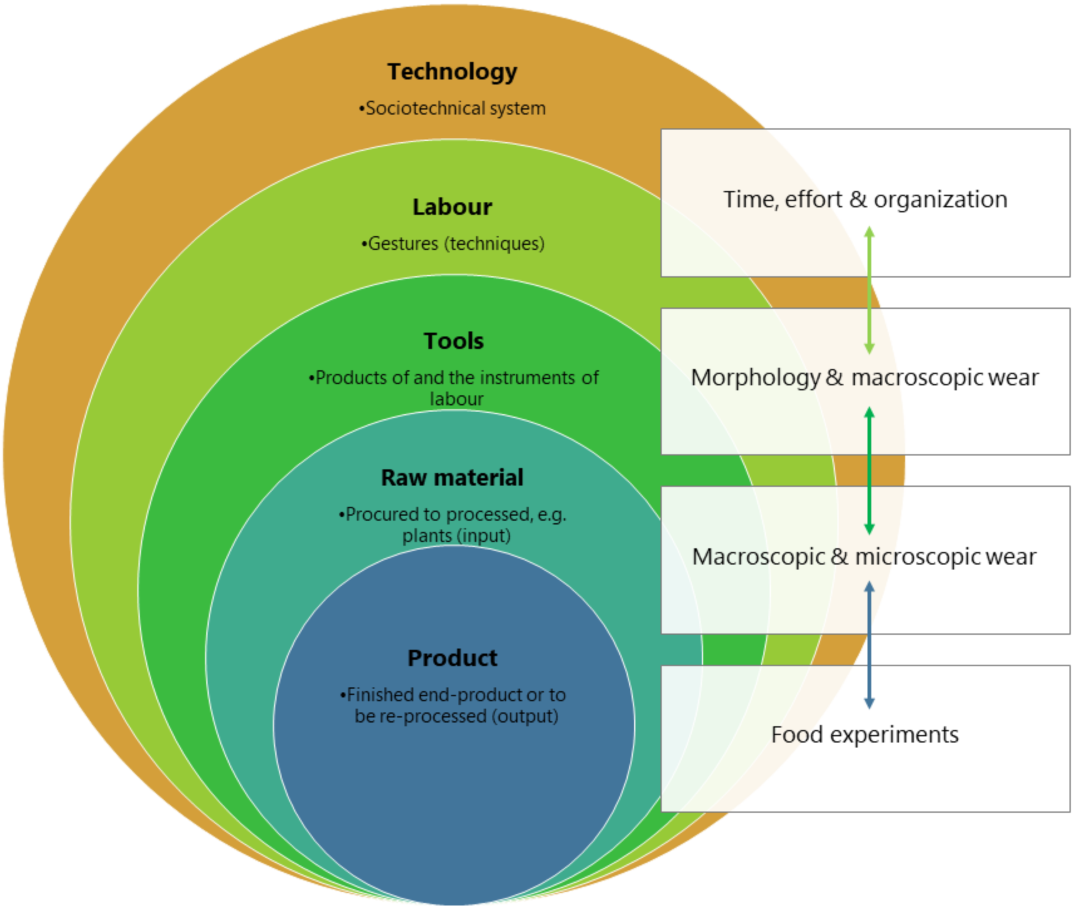

Figure 1. Terms applied and their synonyms (center) and how to examine them through ground stone tools (right).

2.4. Technological choices, learning and artefacts

Gestures also represent *technological choices* to occuring within the sociotechnical system. Technological choices, following (Lemonnier 1992) are the choices of an individual, or group of individuals, to do one thing (or nothing), during the performance of technical actions, whether with or without the use of tools. It is also the choice of using specific tools for tasks or the sequence in which those actions during a task is ordered (see in Lemonnier 1992, 1993). These choices of techniques and tools, in our case gestures and ground stone, are naturally part of the material reality, and consequently the larger sociotechnical system. They are influenced by cultural values of a society, as well as people's short- and long-term memory and social relations existing within that society (Lemonnier 1992, 1993; Pfaffenberger 1992), along with the mode of production as argued above. This echoes what was argued above, that human actions are affected by “social elements” (Hegmon 1998; Leroi-Gourhan 1993: 228–233; Mauss 1979: 102). These choices are based on knowledge that has previously been stored in long-term memory of an individual and/or group (see de Beaune 2004). That knowledge may be drawn on and applied to solve specific problems. This includes what is termed *practical knowledge* or *knowledgeable practice* by Ingold (2002: 315-317), *i.e.* the technical know-how of a group. Transfer of knowledge may then be done through, observation, experiential learning and language within or between sociotechnical systems (Pfaffenberger 1992; see also Lemonnier 1992), engaging both bodies and sensorial systems (Hamilakis 2017) artefacts and the phonological and visuospatial systems (Wynn and Coolidge 2009).

Learning is central to this transfer of technological know-how, skills and techniques. Learning within GST studies is poorly understood. Both using and making is often explored only from the perspective of the expert or craftsperson (e.g. Searcy 2011; Hayden and Nelson 1981). However ethnoarchaeological studies that do explore learning of food processing ground stone often note the presence of child-sized processing tools (for grinding see Shoemaker et al. 2017) and even the "practice" grinding of dirt on full-sized tools. These are examples of observation, imitation and experiential learning. This highlights an embodied *habitus* as noted by (Shoemaker et al. 2017; see also Dietler and Herbich 1998), the transfer of community skills, know-how and practises from generation to generation. As is also mentioned below, these tools have a very long use-life and are very durable meaning that these tools may have been literally intergenerational (see Hayden and Nelson 1981; Searcy 2011), and thus sites of intergenerational transfer of practical knowledge and learning.

Unfortunately with archaeological GST, the traces of production are erased or worn-out by use, or often not recognised in analysis. The learning process related to the making and using these tools is more difficult to elucidate than within, for example, chipped stone technology (e.g. Bamforth and Finlay 2008) or other stone technology (Rivero and Garate 2020). In addition, examples of such child-sized "trial" tools or traces of dirt grinding as observed ethnographically (e.g. Robitaille 2016; Shoemaker et al. 2017), is rarely found, or at least recognized archaeologically.

Importantly it is human agents that consciously or not (Lemonnier 1992) choose to interfere with their material world in these learned ways. In the case of ground stone processing tools, we may thus view them as artifactual and objectified expressions of intention. Intention to change the state of matter (raw material) in desired ways; manifestations of artefactual interference and dialogue between humans and matter (see also Sahlins 1972).

Consequently, changes in or to the sociotechnical system, the *technology* of society, *i.e.* innovations and novel approaches to problems and tasks, new tools or new ways of using them, are the cumulative and continued result of technological choices. Choices that are constantly taking place, both consciously and subconsciously (Lemonnier 1992). Past choices and solutions are drawn upon, new ones applied and then stored within the memory of the group, which in turn influence future choices (de Beaune 2004; Lemonnier 1992: 17–18). Choices, and the resulting maintenance and continuation *or* innovation and change, are not isolated but the result of long and complex processes, a constant dialogue between raw materials, people and bodies, learned skills, memories and tools. Both conscious and subconscious technological choices that lead to specific solutions. What we may attempt is to track these choices, to disentangle them and elucidate how and potentially why such and such changes occur.

2.5. Food processing and gestures as labour

I have established that food processing changes the appearance, taste, texture and nutritional value of food (Carmody et al. 2016; Hardy et al. 2015; Crittenden and Schnorr 2017) and is performed by conscious agents, subjects applying techniques and making technological choices, using their bodies through gestures in combination with tools to initiate desirable changes of raw material. We have also established what informs agents, their gestured choices and where they take place (*i.e.* within the sociotechnical system). But, returning to the body and the gestures, from our foray into choices and systems, what also needs to be established is that food processing is also a specific type of labour humans do: *"setting in motion arms and legs, head and hands, the natural forces of [their] body, in order to appropriate Nature's productions in a form adapted to [their] own wants"* (Marx 1887: 127).

Gestures are then the main component of this labour; together with tools (the instruments of labour), they are the means by which humans change or affect nature. Food production is thus facilitated through procuring material (the subject of labour) on which to subsist and changing this material (processing) requires only tools and the use of correct gestures. Labour is affected by the surrounding society. Just like *technology* as a whole (the sociotechnical system), labour as a *technique* is a social behaviour embedded within the social and relations of society (Pfaffenberger 1998). As Engels argued: *"[t]he hand is not only the organ of labour, it is also the product of labour"* (Engels 1883 [1998/2001]: 86) and the same can be said of movements (and tools for that matter). Accordingly, the gestures used in food processing, the technology (tools, bodies and know-how) and materials (nature) all interact dialectically. The movements performed with the body and tools will also affect the body dialectically corresponding to what Engels suggested; this is of course also true for ground stone use in the past (Molleson 1994; Sadvari et al. 2015) (see section 3. below). As Hodder (2018) also notes these are not only biological and material, but also social *"entanglements"*; tools and processing are also entangled in a larger web of social norms, meanings and activities. This follows what I argued above. Interaction between bodies, tools and raw materials is based on already existing knowledge, traditions, *habitus* as Bordieu (Bourdieu 1977: 72-96) would call it, but can also adapt to or change based on this knowledge as it is both subjective and intuitive (Ingold 2002) in the case of this non-mechanic or pre-agricultural labour (*i.e.* food processing). Just like tools and gestures themselves are entangled, what I have argued throughout is that specific gestural choices made in performing food processing labour are necessarily also intimately intertwined/entangled with society as a whole; in that they are made based on the accumulated knowledge of that society, governed by perceptions, traditions and norms within it (Bourdieu 1977: 72-96; Hegmon 1998; Jones 1998; Kuhn 2004; Lemonnier 1992; Mauss 1979; Pfaffenberger 1992; Sahlins 1972: 79-82).

In much the same way that gestures are both the result of and is itself *labour*, technological know-how is simultaneously based on past choices and traditions of society (Pfaffenberger 1992) and may create new ways of acting through adapting or changing choices during the labour process. Gestural choices are thus dialectically both rooted in the cumulative choices made in the past and choices continuously made during labour-processes, and its desired goals. These ways of acting thus both influence the maintenance, continuation and preservation of past ways, as well as the creation of new ways of acting; new knowledge, perceptions, traditions and norms.

So following what was established above, what can be presented here, is a generalised form/formula of the labour process of non-mechanical, pre-agricultural food production, as I imagine it during the Natufian-Early PPN period in SWA, inspired in part by the (dialectical) materialist approaches seen in Risch (2008) Malm (2016) and Marx (1965, 1887). Note in particular that grinding/pounding activities, as pre-consumption processing, would appear:

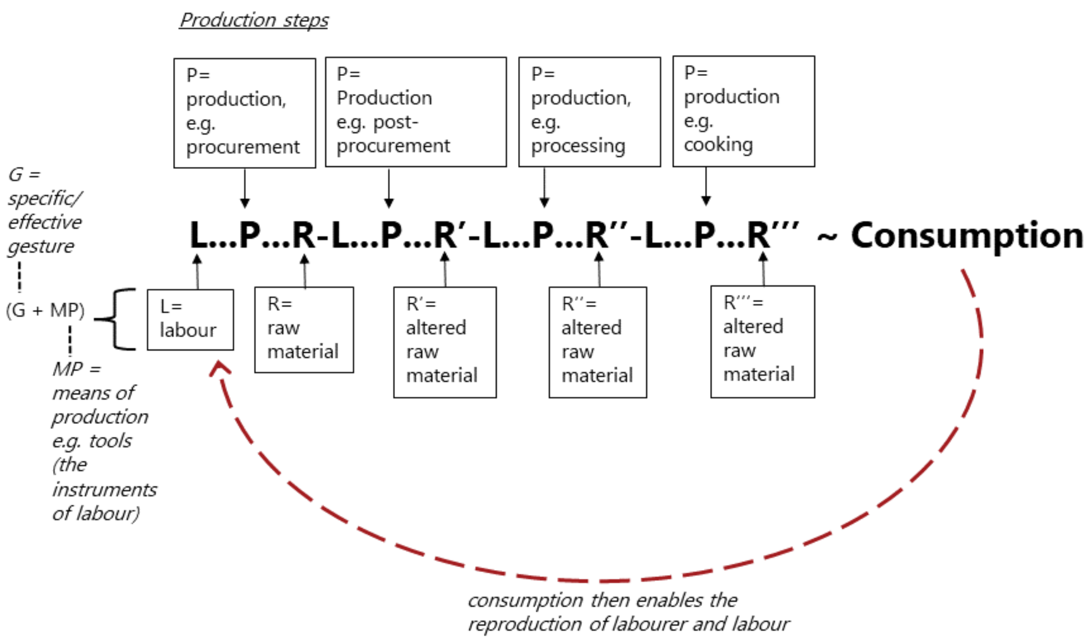

Figure 2. Labour process of non-mechanical, pre-agricultural food production: forager food processing. L equals labour, here in the forager society stripped of the commodified form (it has within Capitalism cf. Marx 1887), nakedly a coalescence of gestures (G)(actions and techniques) and the means of production (MP), i.e. tools (the instruments of labour). R equals raw material, initially unprocessed but filtered through labour nonetheless (e.g. procurement), here specifically foodstuffs

part of the foodway. P equals production, where L (G + MP) and R meet and transform R into an altered state R´ etc.

In contrast to the important and detailed overviews of such processing presented by ethnoarchaeological work like (Alonso 2019; Hamon and Le Gall 2013; Nixon-Darcus and D'Andrea 2017), that reaches a level of detail and observation of human activity that is beyond that of what can be obtained from archaeology, this general form, lays out the naked labour process (i.e. uncommodified cf. Marx 1887) as can be applied to the process more generically. One may, for example, add a second or third production step (P) for additional post-procurement and pre-consumption processing activities that would also occur and alter the state of the raw material (see Table 1). In any case, this general form allows the analyst an overview of where to add and intervene, and in any case observe the labour process in a form, in absence of more immediate detail.

3. The Body, the tool and the gesture

3.1. Body-Tool relationships: the bodies and labour of whom? On who is doing the labour[7]

Who were the people who would have been engaged in pre-consumption processing? Whose bodies would have operated the grinding and pounding ground stone tools? Ethnographic studies by and large suggest that these activities are primarily performed by the women within a society (e.g. Ertug 2002; Hamon and Le Gall 2013; Nixon-Darcus 2014; Schroth 1996; Shoemaker et al. 2017) see especially the recent survey by N. Alonso (Alonso 2019). Consequently this ethnographic record is usually what informs a majority of archaeological interpretations of these tools, related activities and thus their operators (e.g. (Bolger 2010; Molleson 1994). There are however, some issues that appear when associating tools and technology with any one specific group of peopleand these issues also affect how these activities are viewed and interpreted by archaeologists. This warrants further examination here below.

3.1.1. Some issues with sexual divisions of labour ("presentistism"): food processing as female labour

Firstly, when we *a priori* associate food processing ground stone tools with perceived "female" activities such as gathering and post-procurement food processing we tend to naturally differentiate these from "masculine" activities, normatively hunting, chipped stone tools and even technology more broadly (Conkey & Spector 1984; Cobb 2005; Gero & Conkey 1995). Specific types of hunting performed by women (or additional "othered"people

[7] A few parts of this review of the gender aspects of ground stone tool was originally devised during an MA-course and exam in 2015. This work is unpublished but nonetheless, some observations and points made there also appear in the following.

or identities), are often overlooked, diminished or ignored (e.g. (Lee and DeVore 1968), though quite a few examples of this exist (Dahlberg 1981; Jarvenpa and Brumbach 2008), for a recent archaeological example see (Haas et al. 2020). The same goes for male food procurement and processing or more generally all activities not directly related to the hunt and kill (Jarvenpa and Brumbach 2008). One could contend that this permanent element of forager studies, the i.e. sexual divisions of labour, may also have affected the image of ground stone tools and food processing. This has been argued by C. (Lidström Holmberg 1998); who noted that manual grinding (*i.e.* food processing) is *essentialized* and seen as inherently "female" (monotonous) labour. That food processing tools are "non-male" tools and that they, implicitly as female tools, are non-technological and non-intentional, as often "tools" and "technology" are intrinsically linked with ideas of maleness (Bolger 2006: 467; Gero & Conkey 1995). This is also reflected in studies of the Neolithic transition by people like J. Cauvin (Cauvin 2003: 25-33). Further it is viewed as menial, arduous and low status (Lidström Holmberg 1998). All this is primarily based on the idea of a "natural" sexual division of labor and also affects the way we perceive food processing technology and activities.

In most theories regarding the evolution of human societies including late foragers and early agriculturalists there appears, as a constant, the sexual division of labour (Hansen et al. 2015; Bolger 2010; Peterson 2002). Most notably is the "hunter-gatherer"/ "male-female" division. Though this hunter-gatherer dichotomy has been refined over the years the basic underlying issues of this sexual division thinking continue to arise. Initially, it underlines several questionable binaries: both gender binaries that assume the presence of only two gender identities, based on biological sex, something that could not and should not be assumed (e.g. Blackmore 2011, 2015; Cobb 2005; Dowson 2000; Voss 2000) and secondly that these gender identities correspond to biological sex, and that biological sex necessarily determined roles or tasks within societies (Conkey and Spector 1984; Hays-Gilpin 2000). In their seminal work Conkey and Spector (1984) argue that the idea of strict sexual divisions of labour as a cross-cultural constant in human history is a "presentist" view. Meaning that: *"the past is viewed with the intent of elucidating features that can be linked with the present"* (Conkey & Spector 1984: 5). This, they argue, causes two problems: one, research strategies will concentrate on continuities in human behaviour and two, it promotes the idea that some gender dynamics observed in modern contexts are "natural" (see also (Leacock 1992; Sutton 1993).

Furthermore, Conkey and Spector (1984) argue that such assumptions result in archaeologists, virtually regardless of what period they investigate, tacitly project these naturalised "built-in" gender structures onto past societies. What happens then is that researchers recurrently assume all hunting was done by males (with chipped stone tools) and all plant gathering and pre-consumption food processing (with ground stone tools) was done by women. This also guides how evidence is, especially when concerning tools and activities perceived as female (see Cauvin 2003; Eshed et al. 2004; Molleson 1994; Jones 1996; Peterson 1998; 2002), I return to this below. Though there may be a trend towards (normative) “men/males” mainly hunting and “women/females” mainly gathering and processing, divisions are not necessarily so clear cut, as many logistic and cooperative activities and their coordination, take place at the same time that all are intertwined and entangled (Jarvenpa and Brumbach 2008; Halperin 1980). In addition also excluding the possibility of non- or post-binary people, people with disabilities, children, elders and so on. The “presentist“ approaches were heavily critiqued in the 1980s as a part of a more general critiques that was put forward by feminist archaeologists like aforementioned Spector and Conkey (e.g. Conkey and Spector 1984), as well as Joan Gero (e.g. Gero & Conkey 1995) to name but a few. The field of gender archaeology is by now large, see e.g. (Bolger 2010; Nelson 2006; Peterson 2002; Sørensen 2000; Wadley 2018) and this knowledge has contributed greatly to our understanding of how we do archaeology and interpret our material. Furthermore, since the 2000s queer archeology (e.g. Blackmore 2011; Dowson 2000; Voss 2000) has also contributed to questioning the gender binary itself that underlies the dichotomous concept of sexual divisions of labour and many other aspects of our present projections on past to life. Again this also includes highlighting the need for considerations of other “others”, e.g. age, ableness, identity. It is beyond the scope to survey it all here but, I believe it would be a disservice to these fields of archaeology not to question and challenge a simplistic linear narrative, that would simply attribute all or most ground stone and all or most food processing labour in particular to a specific group, i.e. normatively women. This would also ignore the specific ways each society structures production, labour and technology. Something that I also asserted above following Pfaffenberger (1992): society and technology including production, labour, i.e. the use of bodies and tools, is not assembled and delegated in simple commensenseable ways that conform to our perceptions. Rather they conform to their own norms, which may challenge our normative imaginations.

So a concept of a sexual division of labour, useful as it may be in many contexts, needs to be challenged if we do not have the actual data to support it. Though considerable ethnographic evidence points to certain sexually based divisions in modern contexts, whether they actually exist to the same extent in the past is a crucial point to challenge.
The first conclusion here is then, that the issue is not whether labour was divided between gathering and hunting activities (if we can even use such simple divisions), but it was also divided into myriad of other activities of equal importance, like the processing of harvested plants and animals (Jarvenpa and Brumbach 2008). But what were these divisions based on? Skills, techniques or experience (see Hooper et al. 2015), were divisions permanent or based on season/ecology (see Halperin 1980)? Was this the case in all kinds of past forager economies, or specific ones? The issue thus, is rather that the processing of food, especially plant materials with the use of ground stone, is *a priori* assumed to be related to female activities (Conkey and Spector 1984; Lidstrom-Holmberg 1998) and it is assumed that the study of ground stone tools is *naturally* able to tell us about the sexual divisions of labour in societies, even all the way back, in to the late Epipalaeolithic and the Pre-Pottery Neolithic (e.g. Rowan & Ebeling 2008: 1). Now this is of course not to say that females do not appear to dominate in the post-procurement processing of plants (and animals) and in

gathering/procurement as noted by (Jarvenpa and Brumbach 2008). It is however, important to note when we base these divisions on evidence or assumptions (Waguespack 2005) and what our perception(s) of the activities related to *other* things, than hunting and killing are (Jarvenpa and Brumbach 2008).

3.1.2. Perceptions of making and using food processing ground stone tools: "intentional" or "non-/unintentional"

It is pertinent also to explore the interplay between manufacture and use of ground stone tools as this relates closely to the perception of these tools. Ground stone tools (GST), as we are concerned with here, can quite loosely be defined as tools manufactured mainly by pecking (impaction) and abrading, and primarily used in similar tasks i.e. pounding, grinding, abrading see (Adams 2002). The specific types that are most common and widespread in traditional food processing are grinding tools (slabs, querns and handstones: *manos* and *metates*) and pounding tools (mortars and pestles)[8] (Adams 2002; Alonso 2019; Ertug 2002; Schroth 1996; Searcy 2011; Shoemaker et al. 2017). These stone tools are however also produced through flaking, though sometimes ground stone tools are heavily contrasted to chipped stone (Rowan and Ebeling 2008). This may perhaps be traced back to normative insinuations that prehistoric technology and tool-making skills are *a priori* associated with males ((Lidström Holmberg 1998; see also Bolger 2006: 467; Gero & Conkey 1995) and food processing tools are thus seen as non-male (non-) technology (Lidström Holmberg 1998): these tools appear "non-technological" or "unintentional".

This is in particular regarding how their shape is affected by use, i.e. "unintentional", rather than shaped by use. This may have resulted in a lack of interest and subsequent research by scholars, at least according to (Lidström Holmberg 1998). This may have been the case within the archaeology of SWANA where few studies into Late Palaeolithic to Early Neolithic ground stone and food processing tools were conducted barring R. Solecki and Kraybill etc. (Solecki 1969; Kraybill 1977; Roubet 1989)) until the seminal work by K. Wright in the 1990s (Wright 1991, 1992a, 1992b, 1993, 1994). Though there has been a recent surge in ground stone tool studies in SWANA (and more globally) from the mid 2000s (Bofill and Taha 2013; Dubreuil 2004; Dubreuil and Plisson 2010; Dubreuil and Nadel 2015; Dubreuil and Grosman 2013; Kadowaki 2014; Lucarini et al. 2016; Martinez et al. 2013; Nierle 2008; Rosenberg 2008; Rosenberg and Gopher 2010; Rosenberg et al. 2021). However, recent work tends to focus on the contact materials, *i.e.* what was processed, rather necessarily how and by whom, though there is perhaps at least a tacit understanding that they relate to women and female activity (e.g. Dubreuil and Plisson 2010).

Shaping through use

[8] Although these may be made of wood, we here concern ourselves with stone tools.

It is pertinent to examine the presumed "unintentional" or "non-intentional": *shaping through use* noted by (Lidström Holmberg 1998) and how it is rarely given sufficient attention.
The view of surfaces and tools of ground stone being shaped by use and kinetics, i.e. the way the tool is used, is an element of GST analysis often recognised, but not always explicitly examined, and no clear framework for examining this process exists (Adams et al. 2009; Dubreuil et al. 2015), though some have attempted to establish one (Delgado-Raack and Risch 2016; Kadowaki 2014; Nierle 2008; Stroulia et al. 2017). Ground stone tools in particular it may be contented, are highly shaped by continual use (e.g. (Stroulia et al. 2017). In fact, they are often used for generations (Hayden and Nelson 1981; Searcy 2011), meaning that they are not only shaped by each individual person grinding or pounding, but also potentially by generations of people processing. Here, people are carrying on (or changing or adapting) the technological traditions (*e.g.* gestures) of their forebears.

The shape of used faces of a processing tool, expresses a material style, and as also argued above, materially trapped labour and intentions: the surface morphology results from different types of gestures and wear (see Pedersen *forthcoming*). These are expressions of individuals within the sociotechnical system, technology and intention in material form. Recognising this is central to the approach I argue for here. It helps us understand technology and food processing strategies as part of the sociotechnical system. For the sake of brevity I do not include a discussion and elaboration of the importance of wear and (microwear) traces to the study of gestures, as this is addressed thoroughly in the forthcoming paper (Pedersen *forthcoming*). I will note here however that this is an extremely important element in functional analysis and consequently the analysis of gestures (see Adams et al. 2009), including in understanding this labour and how it changes over time.

This shaping *through use* is thus inherently related to conscious (and subconscious) choices concerning management of wear. It requires intimate knowledge of the material properties of the tool, the material processed: how to maintain tool functionality (e.g. Adams 1993; 2002) while simultaneously ensuring satisfactory change of the material (food, plants, animals etc.), and this is based on technological traditions and technological know-how of a society (as argued above). It, I will hold, necessarily implies agency and intention.
Following Adams (e.g. Adams 1993, 2002), I carry on this argument further elsewhere see (Pedersen 2021; *forthcoming* and Pedersen et al. *forthcoming*): this labour, these gestures, are expressed in the shape and morphology of tools and on their used surfaces at both a macro- and microscopic level. Combining an analysis of a gesture-based analysis of food processing strategies with microscopic use-wear analysis (Adams et al. 2009; Delgado-Raack and Risch 2009; Dubreuil et al. 2015) and residue analysis (e.g. Lucarini and Radini 2019; Ma et al. 2019; Portillo et al. 2017; Zupancich et al. 2019) is a way of extrapolating additional information from these materially manifested, objectified results of techniques (see Pedersen *forthcoming*; Pedersen et al. *forthcoming*).

Shaping before use

Regarding *intentional shaping*, i.e. manufacture. There has been some growing interest in the production and manufacture of ground stone in prehistoric SWANA archaeology, both looking at reproduction of archaeological artefacts (Ahituv et al. 2019) (Arranz-Otaegui et al. *submitted*), prehistoric raw material sources, quarries (Ullman et al. 2021) and exchange (Rosenberg et al. 2021; Weinstein-Evron et al. 1999), though the study of manufacture continues to be a relatively minor aspect. Here we may again be posited: who is doing this manufacturing?

There appears no clear pattern from ethnographic records as to whether it is (normatively) women or men (or other genders), who mainly produce food processing ground stone tools. From a brief and admittedly incomplete glance of ethnoarchaeological litterature it appears that sometimes it is women who produce them (Haaland 1995; Lidström Holmberg 1998; Robitaille 2016) other times it is mainly men (Searcy 2011; Hayden and Nelson 1981; Nixon-Darcus and D'Andrea 2017), but overall there is significant variability (see (Shoemaker et al. 2017). Alonso (2019) however, contends that it is mostly, at least in the case of agricultural societies, done by male craftsmen (or specialists). I would argue based on the above, that there is no doubt that at least some women (o*r* genders beyond the binary, as well as children or elders) participated in manufacture (let us call it *normative intentional shaping*) of ground stone tools (again see. (Haaland 1995; Robitaille 2016; Shoemaker et al. 2017). However, one could note that the production of these tools was probably underrepresented in many earlier ethnographies (Kraybill 1977), missed by the *"anthropological gaze"* (Jarvenpa and Brumbach 2008) as a result of past prevailing androcentric ethnography, and consequently possibly neglected by much of archaeological interpretation (Conkey & Spector 1984). If we include here again our view of technology as socially constructed there may be elements in the sociotechnical system that promotes or impedes certain people from certain activities and these are again specific to each group and technology. Taboos regarding who may or may not participate in production or gain access to raw materials could regulate this, as observed among some groups by Shoemaker and colleagues (Shoemaker et al. 2017; Stout 2002).

To summarise: wear in the form of surface size and shape (morphology) is not simply the unintentional results of use, but very much intentional uses of gestures and tools (Adams 1993). Concurrently, both the intentional pre-use shaping, i.e. the manufacture of the stone tool (*normative intentional shaping)* and shaping *through use* is altogether intentional. Furthermore, both types of shaping interact, overlap and affect each other. Both are the artefactual and material expressions of intentions, repositories and resultants of labour, and in much the same way. The tacit "unintentional" or "non-intentional" attitude towards food processing GST should be vanquished from our discourse. This is to some extent aided by ethnoarchaeological studies (Adams 1999; Hamon and Le Gall 2013; Nixon-Darcus and D'Andrea 2017; Robitaille 2016). Though the shaping *before use* and *shaping through use* may be distinguished, one is no less intentional than the other and both interact.

3.2.1. The work: returning to labour

Lidstrom-Holmberg (1998: 127) argues that for long:*"grinding by hand was considered a hard and monotonous duty performed by uneducated poor people, women and slaves."* going back to at least the middle-ages in Europe. Similarly, Jennie Ebeling and Yorke Rowan (2004) also find support for this already in the biblical record (Ebeling & Rowan 2004: 109). That food processing as an arduous, hard, menial task is often echoed by archaeologists exploring the turn to (more?) plant-based agricultural subsistence economies. This appears, at least to some extent, among those studying economies that (seem) to be based on so-called "founder crops" (e.g. cereals) in SWANA, when they attempt to make sense of why people would submit themselves to such hard work (see Hayden et al. 2016), Hodder (2018) and Wright (1994). This goes all the way back to Lee and Devore (1968), and Sahlins (1972). Early ethnographies were often conducted by people (usually men) in privileged positions, i.e. academics unfamiliar with such work (Jarvenpa and Brumbach 2008). Unfortunately, I would argue this portrays food processing in a rather negative light. Not as a positive task providing much needed sustenance, but one to be endured. Perhaps somewhat implicitly another by-product of the *anthropological gaze* where procurement (especially of big game) is held in much higher regard than the subsequent processing of the resources or of plant foods more generally (Jarvenpa and Brumbach 2008; see also Halperin 1980). In this case, pre-consumption processing is considered a job to be reluctantly tolerated (e.g. Hayden et al. 2016; Hodder 2018; Wright 1994) as previously noted by Lidstrom-Holmberg (1998).
This is not to say that it is not hard work, nor that food processing and preservation are not time-consuming tasks; rather, *this is exactly the point!* Rendering plants and animals edible (as food) or storeable (as a non-perishable preserved product) is a tremendous task which also again requires intimate knowledge of the tools, materials involved, as well as the coordination allocation of labour to specific tasks. One that sets the whole sociotechnical system in motion. Just as the technological tradition is drawn upon in the act of using the correct tools and gestures, the correct coordination of labour etc. is done according to the technology of that specific society, in accordance with their mode of production (Pfaffenberger 1992; Marx 1887). As noted also by (Jarvenpa and Brumbach 2008), this is *the essential* and *invaluable* facet of processing: without the labour put into the tools, the application of the right gestures (in both making and using them) and the mobilisation of people, the procured animal carcasses and plants would rot before they were even consumed (or made ready for storage).

3.2.2. Food processing and GST effects on the body: physical tool-body relationships

If we hold that this labour, while being both vital and essential to subsistence, *is* hard, demanding; and entangled in the sociotechnical system, its norms and traditions about food processing, how does this affect the entangled bodies? (and again the bodies of whom?). Interestingly this again also influences the view of this kind of processing: the muscular and skeletal stress endured by bodies tautologically informs us of the arduous and menial nature of this task, as can be seen in the examples below.

The body firstly, is a physical entity of bones, muscles and organs etc. that has both an exterior surface and an interior. The exterior, and to an extent also interior, is perceived and interpreted socially by its contemporaries (Joyce 2005). For archaeologists, the body is often explored, as human remains, through physical anthropology and bioarchaeological methods or through analysis of material representations of the body and/or materials that would have adorned the body (Joyce 2005). These are, as most would argue, two approaches that may complement each other greatly. I would further hold that tools, just as much as dress or bones, become representations of the body and of tool-body relationships (or a human-tool entanglement as in Hodder 2018 and as the tool-organism of (Sahlins 1972). When examining tool use, as I do from the perspective of the tool, and primarily in the absence of actual remains of bodies and individuals to analyse, I find it extremely pertinent to include the body nonetheless. This is at the heart of the importance of gestures and tool use: that the body is the first tool (Mauss 1979: 102) and that it is the body that performs tasks with the tools and provides the motive power behind using the tool:*"[...] setting in motion arms and legs, head and hands, the natural forces of [their] body[...]"* (Marx 1887: 127). As established above this is especially true when the object still operates through individual techniques/skills/gestures, as our ancient food processing tools would have done. As Sahlins (1972: 80) noted: "*the tool thus delivers human energy and skill more than energy and skill of its own".* The tools are subjective, humanised and *"personal rather than mechanical"* as I, following Ingold (2002: 314), argued. That is not to say however that modern tools cannot be seen as representations of bodies, but simply to highlight that these subject-centred (Ingold 2002: 317-319), humanised tools are perhaps even more so.

Much research of the body in archaeology, and understandably so, focuses on how the body is and was perceived, the surface of the body, the dressed, decorated and performing body and often how this relates (or related) to identity (see Joyce 2005).
What I aim at here is centering the action of the body, the body as a site of action rather, and acting on material and consequently, dialectically on itself. The body is where one receives information about the world, through senses and from where we perceive the world and our physical presence in the world (Gallagher 2010; Hamilakis 1999; Merleau-Ponty 2002), as well as the way we act upon the world, through e.g. gestures (Leroi-Gourhan 1993). Just as dressing and behaving a certain way, labour is another form of repetitive performance: repeated actions by the body on material through tools. Not unlike Butler's (2002) view of how social meaning is constructed through repetitive action, so too is meaning constructed through technological actions, through repetitive labour, affected by and affecting both the tool, body and the sociotechnical system, as we argued above. This may also be referred to as Bourdieu's (Bourdieu 1977) embodied *habitus*, ingraining and shaping actions, habits and skills (see also Dietler and Herbich 1998).
The tools as repositories of gestures and labour have already been touched upon here briefly and are explored more fully in an upcoming publication (Pedersen *forthcoming*). Here at the end of this paper, I therefore wish to briefly touch on the other side of the coin: how labour and gestures get deposited in physical bodies.

Now, in the relative absence of bodies at the sites where I work, I rely on the work of others on the region and time period. At the sites that most of my own research deals with, the Late Epipaleolithic and Early PPN sites Shubayqa 1 and 6 only few burials and stray human bones have been retrieved (Richter et al. 2019). At Shubayqa 1, these are interestingly of perinatals and neonates, and there appears a connection between ground stone tools, ochre and burials (Richter et al. 2019) (see also Rosenberg and Nadel 2014) for similar observations). This may be another way tools come to represent bodies: through the association with burials, bodies acting bodies.

Returning to the physiological evidence of tool-body relationships there are only few publications that deal directly with this aspect from the time-period and region (e.g. Bolger 2010; Eshed et al. 2004; Molleson 1994; 2007; Molleson in Moore et al. 2000; Sadvari et al. 2015; Peterson 2002, 2016). Hodder's (2018) work on the entanglement of human and tool relationships also summarises some of this evidence, but focuses in particular on the dietary aspect of these relationships. Leaving for now for the sake of brevity and conciseness, that side of foodways: i.e. the consumption of food, and sticking to the preparation side of foodways, I give a summary of what the above mentioned evidence suggests.

What physical anthropologists and archaeologists in particular are able to observe in regards to actions/labour is muskolar-skeletal stress. The skeletal markers of that stress may be examined by looking at stress markers at muscle attachment sites (e.g. Eshed et al. 2004) and/or through joint degeneration (e.g. Molleson 1994), which can be caused by repetitive actions. In this way they provide a physiological, bioarchaeological perspective on gestures. The repetitive actions associated with food/material processing include kneeling or crouching while using ground stone tools, a common position (Alonso 2019; Sadvari et al. 2015; Robitaille 2016; Searcy 2011; Pedersen *forthcoming*), which in particular affects the knee, toe and back joints (Molleson 1994, 2000), as well as hips (Sadvari et al. 2015) and arms, e.g. the muscles of the upper limbs (Eshed et al. 2004). This happens when moving the upper stone against/towards the lower, in both grinding and pounding activities.
Eshed and colleagues (Eshed et al. 2004) studied muscle/ligament attachment sites on the clavicle, scapula, humerus, ulna and radius for stress lesions and robusticity, and scored these musculoskeletal stress markers (MSM). The higher the MSM score, the higher the stress that a person's muscles had endured during their life and work (Eshed et al. 2004).

Generally these stresses on joints and muscles, and consequently skeleton (their so-called MSM scores) were higher in the Neolithic than in the Natufian (Eshed et al. 2004), suggesting harder workloads, including presumably in food processing, during that period. This further suggests important nuances in the use of tools, activities and labour coordination and specialisation between the Neolithic and Epipalaeolithic (Bolger 2010; Eshed et al. 2004; Peterson 2002).
This evidence may be linked to increased and intensified processing activities (among other things) during early agriculture of the Neolithic compared with the foraging of the Epipalaeolithic: an increased entanglement of human-tool relationships during the Neolithic

transition as suggested in Hodder (2018). Though we should be careful assuming what tasks exactly were associated with these differences, food processing ground stone tools did increase in number in the Early Neolithic, but noting that this was a trend started in the Natufian (see (Wright 1991, 1992a, 1992b, 1993). Entanglement of production practises, tools and changing foodways, between these periods, thus included an entanglement with the body, expressed in bone as in stone, through repeated gestures (see also Pedersen *forthcoming*).

Furthermore, there may also be observed gender differences. Muscles attached at the elbow and in the forearms and the deltoideus attachment sites on female skeletons, seem to have seen more stress, and these may be related to repetitive grinding and pounding activities (Eshed et al. 2004; Molleson 1994). For some examples of these body positions, and body use, while food processing see Alonso 2019 (and also Pedersen *forthcoming*). Similar results were found by T. Molleson, in the analysis of the human remains from the Neolithic occupation at Abu Hureyra (1 and 2) in the Euphrates valley, Syria. The examination of joint degeneration there led them to suggest that women in particular, had spent much of their time/work in kneeling positions, presumably processing cereals on grinding implements (Molleson 2000: 310-316), though they seem to collapse evidence from both the Natufian and Neolithic phases at the sites (i.e. both Abu Hureyra 1 and 2). The affected joints included the big-toes (metatarsals), from hyperflexing the toe forward, the last dorsal vertebrae and the knee, suggested as a result of kneeling while performing reciprocal grinding (Molleson 1994). Correspondingly (Sadvari et al. 2015) argues that more frequent osteoarthritis in the hips and knees of females than males, as evidence of habitual, daily repetitive work i.e. grinding.

Conversely however, J. Peterson (2002) argued on the basis of a sample of 14 sites encompassing 158 skeletons from the Late Natufian to Early Bronze Age, that there was very little evidence for a sexual division of labour. In the Epipaleolithic Natufian, though males did generally show more asymmetrical skeletal stress than females which could potentially be related to hunting, e.g. a projectile delivering arm, there was considerable overlap between (biological) males and females according to (Peterson 2002). Her study even suggested dimorphism in stress markers between the genders became even less pronounced during the Early Neolithic (Peterson 2002): it seemed that both males and females had mainly used the same muscle groups throughout their lives and only in the Early Bronze Age did this seem to change. Sadvari and colleagues analysing material from Neolithic Catalhöyük, suggested some asymmetrical skeletal stress of upper limbs. This was interpreted as spear-throwing (hunting) activities being common among males (Sadvari et al. 2015).

Eshed (et al. 2004) found that the difference between muscular stress, between male and female, did not change significantly between the Natufian and Neolithic, i.e. differences in male and female stress patterns were present in both periods, but also stayed more or less the same.

We should, however once again be careful with assuming a division of labour based on sexual attributes, especially in the pre-agricultural Epipaleolithic and even the Early PPN.

Is there really evidence enough? Is there a difference between pounding and using a hoe, yes, but both engage upper limb muscles and forceful downward gestures, yet one is deemed male and one female, if we follow Eshed and colleagues (Eshed et al. 2004). Are some of these differences simply expected, and interpreted on the basis of assumptions about male/female roles? Further, even though such a division of labour might have been present at Neolithic Abu Hureyra, or at some of the other sites, we need not and should not project this unto the entire Neolithic or Epipalaeolithic. Differences may exist from site to site (Bolger 2010). Again, it is significant to note that the exclusion of certain genders from certain activities becomes a way of constructing both past masculinity, as well as past femininity. This places not just women but also men (and replicates this binary and dichotomy) in normative gender roles dominant in our own cultures or observed in contemporary ethnographic analogies (Nelson 2006). These assumptions: a binary opposition between male and female, hunting and gathering, killing and processing, chipped and ground stone tools, is not only inflexible and rigid but also potentially over-simplified and hides important nuances.

Interestingly, the three publications mentioned above (Eshed et al. 2004; Molleson 1994; Sadvari et al. 2015), argue for different body locations as evidence of grinding activities. Using each their own method: MSM scores (Eshed et al. 2004) or presence/absence of osteoarthritis (Molleson 1994; Sadvari et al. 2015), though dealing mainly with the same gestures, i.e. reciprocal grinding, these grinding activities is argued to be evidenced on several places of the body. (Eshed et al. 2004) sees musculoskeletal stress in the forearms and the deltoideus attachment sites, and though (Sadvari et al. 2015) also looks at upper limbs, the only statistically significant difference in osteoarthritis between male and female is in the hip (and a near statistical significance in the knees). Molleson (1994; 2000) mainly sees osteoarthritis on the big toes and last dorsal vertebrae, though also notes stress on deltoideus attachment sites like Eshed (et al. 2004). Thus, in each case somewhat different areas are affected, in addition to an overlap in the knees (compare Sadvari et al. 2015 and (Molleson 1994) and in the deltoideus areas (compare Eshed et al. 2004 and Molleson 1994). Each time the answer is clear: these stresses observed more frequently in females must be related to grinding practises (reciprocal grinding to be specific). Though these studies and this evidence might very well be correct, we run the risk of tautology: interpreting evidence of stress on the "female" body as evidence of "female" tasks. These methodological variables should make us cautious.

Here again we may note the crucial importance of the gesture. As the examples in (Alonso 2019; Ertug 2002 and also Pedersen *forthcoming*) show the diverse body positions and gestures applied would affect the body differently. Most of the studies mentioned here unfortunately consider only two main gestures or processing strategies: reciprocal grinding, and pounding (e.g. Molleson 2000; Eshed 2004). However, processing strategies and consequently gestures both in the Natufian and early PPN would have been much more diverse than that (see Pedersen 2021; Pedersen *forthcoming*). Even a brief glance at tool types from assemblages from Late Pleistocene-Early Holocene SWA would confirm this (Wright

1992a, 1992b), including also interesting variation between sites (e.g. Pedersen et al. 2016). Sadvari and colleagues (Sadvari et al. 2015) note for example, that the change in ground stone food processing tool technology, from two-handed reciprocal grinding on saddle slabs, to circular grinding on querns, was expressed in less osteoarthritis in the shoulders of inhabitants (statistically significant with a *p*-value of 0.02). This may exemplify the importance of also considering gestures when examining musculoskeletal stress. When this is not considered in detail, some nuance is sacrificed.
So, although physical anthropologists and bioarchaeologists consider the gesture explicitly, they do it primarily from the perspective of the body and do not also approach the gesture from the tool (i.e. only subject, not the object), important evidence is missed. The reverse is of course also true, considering only the object and not the subject of subject-centred (Ingold 2002: 317-319) technology and technical knowledge, is also erroneous.

To summarise, the processing of food acts also on the body: not only through consumption (see Boyd 2002; Hodder 2018) as sustenance and energy, but also through repetitive actions, motions (performance), leaving their traces on the physical body of the operator. We need to keep our perception of the body open, to invite several (disparate) lines of evidence into perceiving the body and not limit our understanding of the body to physical anthropology alone (Boyd 2002). We may also approach the body through the tool. Much like the tool, the body also becomes a repository of labour. If we return to Engels (1883 [1998/2001]: 86), the body (or hand), like the tool, is both the result of labour and the organ of labour. Many of the traces the body bears however, are internal: on muscles, joints and bones rather than external and on the surface of the body (unlike wear on the surface of a tool). These traces however, presumably also affected the surface of the body. Here we note that one should not necessarily distinguish harshly between internal and external body (Joyce 2005). Hence, both stone and bone are affected by the food processing practises and the changes they go through; both via diet but also through actions of, and on the body (see also (Boyd 2002). Here exist these entangled or dialectic relationships between people, foodstuff and tools and what is important is to recognise each of these as intertwined and connected and not separate. Gestures affect raw material, which turns raw material into tools, these tools then affect other raw materials by changing their physical properties, these are animated by gestures and along with the processed material, they in turn affect the tool surface and properties. The body and tools absorb the labour as wear, from the movements and the processed raw material.

In the body the results of gestures are not only deposited in muscular and joint stress on the skeletal remains, but also during the actual use by people through their senses. People would have experienced this labour, as they become tired, feel pain and fatigue in their muscles. Sights, sounds, taste and smells would also have been experienced. The whole sensory system involved as tasks were completed, an aspect not always appreciated in archaeology (Hamilakis 1999, 2017). Sometimes gestural choices may have been related to comfort and fatigue (Adams 1999): shifting hands, body position etc. and the work would also have included taking breaks, or going faster, stopping and talking with people, tending to other tasks in-between and so on.

In the ground stone, gestures are expressed as morphology of surfaces and the absorption may be quite literal, as processed raw material is deposited on and starts filling the interstices of the rock's surface (especially of porous and vesicular rocks see Adams 2014). This cycle continues until abandonment (Figure 3).

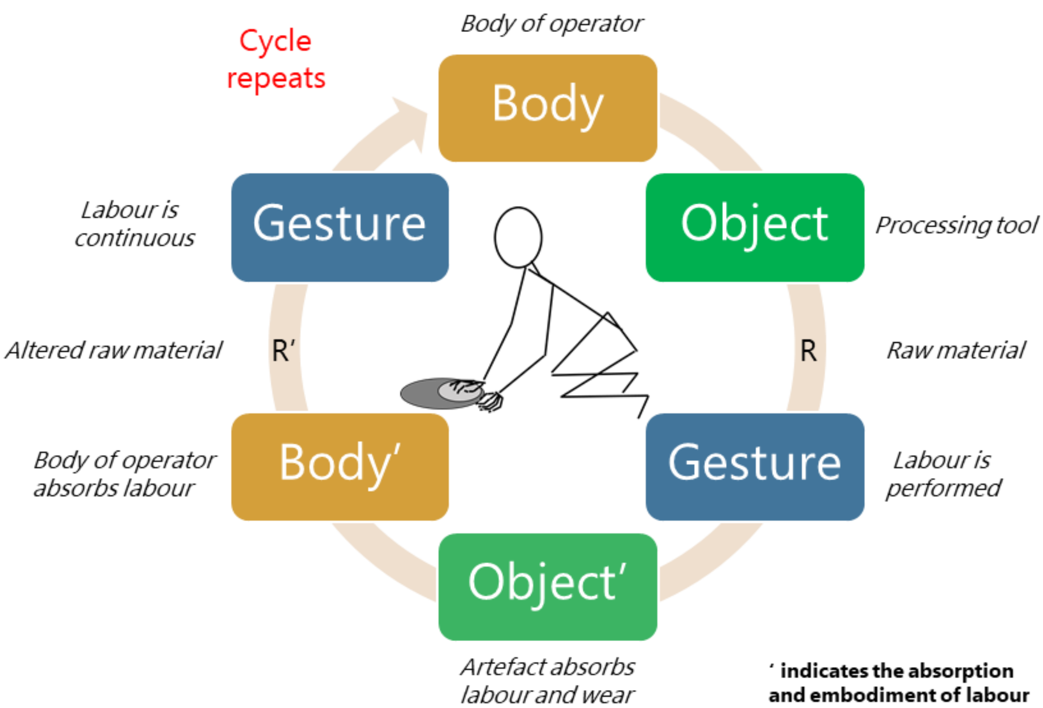

Figure 3. The tool-body relationship illustrated. It is a dynamic and continuous relationship. A constant entanglement where each element acts upon each other dialectically. A cycle that repeats until abandonment/discard.

4. Conclusions: The potential of gesture focused ground stone studies to (food) processing and foodway studies

I hope to have shown the importance of including the body and more specifically gestures as part of past food processing technology. How these, potentially as much as the tools themselves (and exactly through the tools), may inform us about past foodways. I have talked less about food than I intended and as the reader might have wished, and as such refrained from describing tools in great detail, but I deliberately placed emphasis on (stone) tools to focus on that material and the force(s) behind it somewhat generically. In upcoming research I immerse more deeply into the tools (Pedersen *forthcoming*) and into specific food processing (Arranz-Otaegui et al. *submitted*) aspects and aim to join it all together with use-wear and residue analysis to come closer to contact materials, food and foodways (Pedersen et al. *forthcoming*). What I have aimed at here has been a background of and for this.

I have talked less about the body, and bodies, from a physio-biological perspective, but have contended to stick to a more qualitative view of the body as the main creator and maker of tools and wear, not a specific body type or shape, but the body as a concept involving choices, intentions and motive forces (agency), that drive, shape and wear tools.

Concerning the “what, why and how” question of foodways alluded to in the beginning, I argued that *post-procurement, pre-consumption processing* was a specific kind of activity, or step, in the *chaîne opératoire* of food production. One with specific tools and gestures. Following this I established what exactly gestures are, in an archaeological/anthropological context, based on Leroi-Gourhan (1993), and why they are interesting and important to look at in relation to ground stone tools. How they are examples of specific techniques/skills (Ingold 2002), of technological choices (Lemonnier 1992; Sillar and Tite 2000) and technical knowledge operating within a sociotechnical system (Pfaffenberger 1992), a framework for understanding of technology and society (Marcuse 1941). I have highlighted how tools, bodily actions and labour both affect and are affected by the social, material factors. Entangled webs of tools, bodies and social norms (Hodder 2018; Mauss 1979; Pfaffenberger 1988). Gestures and their related tools are part of specific forms of labour, that changes the material natural world to satisfy human needs (e.g. Hornborg 2014; Malm 2019; Marx 1887) and these are also part of labour processes, specifically “non-mechanical” food processing.

All of this established that, not only are gestures and tools entangled, they are also integrally part of the surrounding society, but importantly gestures are bodily actions of individuals and their agency, that make tools and make tools function and they come from the body. So the body, as the “first” instrument/tool of humans (Mauss 1979), of the individual, both shapes and is shaped by tool use. Just as society both shapes and is shaped by humans, and tools both shape use and is shaped by use.

Following this I turned the gaze to the body. To establish what bodies are part of these body-tool relationships; who are the operators and labourers applying these gestures and tools? Without essentializing or defining any one particular group or body(-type) or individual, I think what is important is to (re-)introduce bodies, and to note that there are still interesting things to say about individual operators and bodies without pigeonholing them. These bodies would also differ in age, sex, gender, ableness and general physical appearance. How different bodies were affected by these tools is however, a difficult question to answer.

As acknowledged it is fairly evident that, ethnographically, activities such as gathering,plant food processing and ground stone tool use are most often related to women (e.g. Alonso 2019; Ertug 2002; Hamon and Le Gall 2013; Robitaille 2016; Nixon-Darcus and D’Andrea 2017;Nixon-Darcus 2014; Schroth 1996; Shoemake et al. 2017). For example, there is no evidence of any society where big-game killing (note not the hunt overall) is *exclusively* the task of women (as noted by Jarvenpa and Brumbach 2008 but see Haas et al. 2020) and there appears to be no societies where pre-consumption food processing, pounding and grinding especially, is *exclusively* a male task (e.g. Alonso 2019; Schroth 1996). However, we should also be careful of collapsing evidence from mobile forager and settled horti-/agricultural societies. Nevertheless, between these two (unlikely) extremes are a multiplicity of combinations of how to divide and coordinate labour. And again we must note the fluidity of the point at which one task ends and another begins, and recognize all the labour performed before and after harvesting plant or animal resources.

Continued research into this subject has revealed that there is plenty of ethnographic evidence for very adaptable and dynamic male-female (and presumably beyond this gender binary) work roles in forager societies in general (Jarvenpa and Brumbach 2008; Leacock 1992; Waguespack 2005). This variablitibily, adaptability and dynamism is something archaeological research may sometimes miss when uncritically, consciously or not, interpreting evidence in a presentist or unreflective way. It can be suggested that work and roles in past ("hunter-gatherer") forager societies were, at least to some extent, more interchangeable than we often imagine.

What is central is the significance of cooperative human behaviour: coordination, tactics, logistics and communication within and between groups of conscious agents. Notably, groups are often more effective in accomplishing numerous tasks, than individuals (Jarvenpa and Brumbach 2008) and within these groups the division of labour may be very complex and may differ according to environment, ecology and season (see Halperin 1980). This is also what I attempt to highlight here. Though it is not imagined that this is a particularly original claim: that tasks can before performed by either gender or that gender indentity or biological sex are not necessarily and constantly determining to what tasks, labour and technology one may be involved with.

What is illustrated here is indeed that when it comes to subsistence, the procurement and processing of this, it is pertinent that one acknowledges that different roles exist in forager societies with associated tools, techniques and products, performed in particular settings, but that these are entangled with other interconnected tasks. Further, what is equally important however is the realisation that these roles may be fulfilled by certain members of a society at certain times and not necessarily by a specific gender all of the time (see again Halperin 1980).

Lastly, I wish to underline that ground stone technology is situated in the body. Through the transfer of power from muscle to stone, these tools are used with the body as "prime-mover"; gestures supplying an human "animate power" (see Malm 2016: 37-41). Along with the material qualities of the tool - weight, texture and shape of the stone - it is human flesh and muscles that enact the desired change to the material processed. Tools are the material objectified results of bodily actions "cast in stone" and thus reflections of the norms and practises of that society. These stones therefore allow us to gleam at processes of processing and changing of foodways.

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Cast in Stone:
Tools from movements, movements from tools - Approaching ever changing ground stone

"That which in the labourer appeared as movement, now appears in the product as a fixed quality without motion" Marx (1887: 128)

1. Introduction

1.1. Perspectives on (food) processing

This paper will present a new approach to examine specific types of food processing tools and activity, and generally how to approach ground stone tools used in food processing differently. It aims to look at their involvement in food processing, not solely as a sequence of dull operations, but as socially conditioned actions: gestures, performed in specific ways, with the intent of changing the properties of matter in desirable ways (Adams 2002: 17; Dobres and Hoffman 1994; Hamilakis 1999; Leroi-Gourhan 1993; Sassaman 2000; Wobst 2000). Ground stone tools (henceforth GST) thus become an important proxy for food processing and production. The focus lies on how ground stone tools are used to process material (crush, grind, pulverise etc.) and in particular how this processing affects the morphology and wear of these tools. Thus, it deals with the "production" side of subsistence, looking at food processing, i.e. post-procurement, pre-consumption preparation (see Pedersen *forthcoming*), but more specifically from the perspective of the tool. Focusing on the wear of tools and their active surfaces, rather than the intermediate contact material they were processing. It establishes a way of distinguishing different strategies of processing food (termed *processing strategies*) and how to integrate the multiple levels and methods of analysis of GST with each other. What I suggest in this paper is an approach that centres movements and recognises the influence of bodily movements on the material. The wear and surface morphology of (food) processing GST are influenced not only by the material processed, raw material properties of the stone and manufacture, but also the techniques and gestures, the bodily movements applied while using the tools. These movements and how, why and when they are applied, are socially organised, coordinated, conditioned and embedded within a sociotechnical society and its traditions (Leroi-Gourhan 1993: 228–237; Mauss 1979: 102–120; Pfaffenberger 1992). Gestures along with the tools and bodies of agents are thus all part of labour processes which enables the changing of (raw) material (Pedersen *forthcoming*). This approach recognises gestures, and individual bodies as the "agents" of change and the tools of as reciprocals of that labour and intention: material expressions of technological choices and strategies. These materials in turn influence choices and strategies: labour in dialectic relationships with tools.

Thus, the approach aims to enable a more accurate, qualitative assessment of the *ways tools were used* and not just what they were used on/with. This relationship between movements, morphology and wear is often overlooked, perhaps recognised but not explored in detail and currently no framework exists that explores this (Adams et al. 2009). I therefore argue here that by better comprehending these *ways of use*, these *processing strategies* we may refine our understanding of the chronological changes ground stone technology goes through over time, potentially enhancing chronological importance of GST in dating and contextualising sites/areas/activities. We may better observe inter- and intra-site variations, change and innovation, as I have noted elsewhere (see Pedersen 2021; Pedersen et al. *forthcoming*). Hopefully, the presented approach can also lead to refining the understanding of macro- and microscopic wear, tool shape and surface formation by establishing a movement/body/tool framework. It helps explain the typological variations we see at sites in SWA (e.g. Wright 1991, 1992a, 1992b, 1993), (and potentially elsewhere) as the result of choices, of progressive wear, macro/microscopic traces of actions and of the management of wear. The framework is presented here as idealised shapes, qualitative tracking the progressions of wear and the movements that both create, change and/or maintain certain morphologies and wear, so-called *strategies*. Thes*e processing strategies* are based on naked-eye and low-power microscopic observations of tools from two Late Epipalaeolithic to Early Pre-Pottery Neolithic sites in the southern Levant (c. 15,000-10,000 ya). Though based on qualitative observations and on refining current typologies, future quantitative additions, like 3D and GIS data, may benefit this approach further. This type of analysis and approach to GST may thus serve as the basis for further assessments on other GST assemblages, periods and sites in the SWANA region, and elsewhere.

1.2. A new approach

As Risch (2008) notes, archaeological objects, like the processing stone tools dealt with here, are a matter that has been made into a product, an object, and at the same time a means of production that is used and consumed, in a process of social reproduction. Consequently, this production process is not only restricted to manufacture, but also use and how tools absorb this use (and is itself consumed by), in a labour process. The presence of GST not only suggests the processing of certain materials (observed as use-wear and from microremians and residues, e.g. Dubreuil 2001, 2004; Portillo et al. 2017; Hayes et al. 2021; Fullagar et al. 2015), but also as representative of the social production of a labour process, including a wide range of tasks (like procurement, initial processing etc. Alonso 2019; (Hayden et al. 2016; Hodder 2018). The tools dealt with here were involved in what one may term the pre-consumption processing (Twiss 2012), among of course other tasks not necessarily connected to food processing (e.g. Dubreuil and Grosman 2009). This kind of food processing involves taking procured, harvested or stored raw material (or initially processed/prepared materials see Hodder 2018; Pedersen *forthcoming*; Twiss 2012), and making them ready for cooking, mixing or further storage etc. My focus then is on the ground stone tools involved in this kind of processing.

Though the material I cover here is from the Late Epipalaeolithic and the Early Pre-Pottery Neolithic (PPNA to Early PPNB) of Southwest Asia (SWA) and therefore focus on "pre-agricultural" food processing, I am trying to address and formulate a more general approach. I therefore will generally skip the details and particularities of the setting of Late Pleistocene and Early Holocene Eastern Jordan and the Southern Levant, to focus on this generalised approach to food processing tools. Elsewhere, I have dealt in more detail with the period and the specific developments and changes happening in that region during the transition from these late forager societies and into early or incipient agriculture (e.g. Pedersen 2021; *forthcoming,* Pedersen et al. 2016; Pedersen et al. *forthcoming*). So though based on specific kinds of tools in a specific setting I leave these strategies open, so that they may be changed, amended and adopted to other assemblages elsewhere.

The tools thus represent a specific element, a specific step or task, of long and potentially complex labour processes and foodways. And though it may be difficult to see the entire process, we may see how a particular step in the process affects specific tools over time through use. This is because, importantly for this study here, there exists a dialectic relationship (or an "entanglement" *sensu* Hodder 2011, 2018) between manufacture and the shaping of tools through use.

Tools will often be initially shaped before use, but also continually while in use, which is in particular true of GST (e.g. Adams 2002; 2014; Delgado-Raack and Risch 2016; Stroulia et al. 2017). This shaping happens through gestures (Leroi-Gourhan 1993) in both cases: gestures shape the tools into the desired form, and the gestures applied during use changes the shape and surfaces of the tool. But the shape may also determine what gestures may be used, as the tool may guide or confine what movements are possible. So these elements: manufacture and use, morphology and gesture constantly influence and negate each other. Further within this, there exists another dialectic relationship between the overall morphology and surface of the GST and the microscopic wear. As will be elucidated below the changes to the overall shape is a result of continuous cycles of microscopic wear, wearing out the features of the stone surface, the texture of the stone surface, affecting grains, phenocrysts, matrix, groundmass and interstices, along with shape or weight of the stone etc. These features are what make the tools function.

Thus, what I focus on in this paper is the specific ways GST are used to process material and how this use is absorbed and expressed in/on the tools (as morphology and wear). Achieved by looking at the tools themselves and not the raw material input (e.g. plants) nor the end-product (e.g. flour). Hence, leaving for now the contact material(s) and focusing on the objective relationship with subjective actions and movements: gestures. I will here thus highlight the ways social reality, i.e. technological traditions and techniques, affects production processes taking place, seeing tools as reciprocals-, as the results of bodily movements (gestures) with which they were involved.

The basis of this approach to analysing processing tools and strategies is influenced by work done by a range of scholars. The concept of technological gestures, I principally take from the French anthropologist Andre Leroi-Gourhan (1993), which has been previously applied to the study of ground stone tools by Sophie de Beaune (2004), and in SWA by Laure Dubreuil (see e.g. Dubreuil 2001, 2008; Dubreuil & Plisson 2010; Dubreuil & Nadel 2015), and see also Marie-Claude Nierle (2008). Somewhat independently of this French tradition, but with similar attention given to the importance of movements, their effect on tool morphology and wear, is the work done by Jenny Adams (e.g. 1993, 1999, 2002) in Southwest USA, as well as by scholars in Western Europe (e.g. Delgado-Raack & Risch 2009, 2016). An example following Adam's approach is also found in SWA see Kadowaki (2014). What I argue for then is really a synthesis of these approaches with my own modifications (see also Pedersen 2021; Pedersen *forthcoming*)[1].

What it is also meant to do is update (or refine) the previous work on GST in a SWA context, though this paper is meant to apply more broadly. The excellent work done by K. Wright in the 1990s (e.g. Wright 1991, 1992a, 1992b, 1993, 1994) has been the basis for most GST research conducted in SWA. The classifications and typologies provided there have greatly enhanced the reporting on and analysis of GST. Many terminological and typological issues were remedied by that work.

However, little has since then been added in the way we approach morphology and the established typologies, at least in SWA. Barring the application of use-wear, and residue studies (e.g. Bofill 2012; Dubreuil 2004; Dubreuil and Grosman 2009; Martinez et al. 2013; Portillo et al. 2017; Terradas et al. 2013). This paper is thus meant to enhance and refine the original typologies of Wright by centering the concept of gestures, and emphasising the importance of the progression and trajectories of wear and wear management. At the same time it is also a way to make large and diverse datasets more concise and easier to compare. By focusing on the gestures and the active part of the tool (the utilised surface, or face, or even whole tools in the case of some handstones) it allows a concentration of tools into broad ways of processing, rather than focusing solely on the vast array of typological details. This is not to say that detailed typologies are not important, rather it is a (new) way of applying these detailed typologies. A bifacial handstone of a certain shape and with a certain profile is interesting exactly because it represents certain actions (ways of processing) and particular ways of managing wear.

By introducing the *processing strategies* described below (and also applied in Pedersen 2021 and Pedersen et al. *forthcoming*), there may be a new way, a new approach, to deal with past foodways, technological innovations and sociotechnical change. This is at least the ambition.

Furthermore, I would argue the full potential of coupling the study of gestures with more standard techno-typological and microscopic use-wear approaches in ground stone tool research is generally neglected, as was also established above, and this is especially evident in studies of SWA assemblages (Bofill 2012; Martinez et al. 2013; Terradas et al. 2013, but see Dubreuil & Nadel 2015; Kadowaki 2014).

It may be noted that there appears to be a tendency within microscopic use-wear to attempt to get closer to use through using higher magnifications, more powerful and advanced methods of microscopy (both qualitative and quantitative). The better the equipment, the more advanced the method the better the results it would seem. This is despite issues within qualitative use-wear research, both with regards to reproducing results and in

[1] Also appeared as an earlier, less developed version in my unpublished MA-thesis (Pedersen 2017)

recognising more ephemeral contact materials (Hamon and Plisson 2008; Hayes et al. 2017; Hamon et al. 2021; Hayes et al. 2021), and similar issues may be observed in quantitative use-wear studies, where specific gestures may be difficult to reconstruct (Zupancich and Cristiani 2020) or raw material properties cloud results (see Chondrou et al. 2021). The risk is that these newer and advanced methods become the main way of exploring use, neglecting a morphological analysis and typology, and the assessment of the overall active used surfaces of tools and consequently the dialectic relationships between tools, movements and wear. In any case, one technique should not be used without the other, but I see potential in arguing for a focus of and including the movements and bodies involved; the prime mover in any tool moved human power alone.

1.3. Integrating movements, morphology and macro- and microscopic wear: the dialectics of tools and gestures

As Dubreuil and colleagues (Dubreuil et al. 2015) also recognise, there seems to be no general framework for analysing movements or gestures and consequently integrating these with microscopic use-wear approaches (but see Delgado-Raack & Risch 2009). The lack of research into the interaction between movements and tools is somewhat puzzling. There is often great and detailed focus on wear on individual tools, but movements remain: *"[...] an important and often overlooked aspect, which can only be fully assessed by combining the use–wear approach with morphological analysis."* (Dubreuil et al. 2015: 108).

With some exceptions (e.g. Adams 1993; Delgado-Raack & Risch 2009, 2016; Dubreuil and Plisson 2010; Dubreuil & Nadel 2015; Stroulia et al. 2017), research has often failed in recognising processing tools as part of tool pairs associated with specific gestures and as representative of specific processing strategies. Instead attention is principally afforded to what material was processed. Both "kinetics" and "movements" are thus often mentioned in ground stone use-wear protocols (see Adams et al. 2009; Delgado-Raack & Risch 2009, 2016; Dubreuil & Savage 2014; Dubreuil et al. 2015) but how implements in tool pairs interact with one another and with the material they are processing through movements can be stressed further in some interconnecting ways.

Firstly, grinding and pounding processing tools function as pairs and only as pairs to alter intermediate material (e.g. see in Adams 2002). What upper and lower tools go together in the assemblage? For example what type of handstone fits with what type of lower grinding stone? Here which tools fit together is affected *both* by initial shaping and by the gestures continuously applied during use (Adams 1993, 1999). Pairing tools together (upper and lower) thus informs us about what processing strategies are present at the site and at what ratios. Secondly, wear progressively changes both the overall morphology of the tool and surface as well as the surface microscopically. Tools are both shaped by and operated with gestures, i.e. labour both affects and is affected by the morphology of used surfaces. *Gestures* are manifested and "trapped" materially in the shape and morphology of tools and their used surfaces at both a macro- and microscopic level (Adams 1993; Adams et al. 2009;

Delgado-Raack and Risch 2009; Dubreuil et al. 2015). Tools are thus the objectified result of techniques (Dietler and Herbich 1998).
As is noted by Marx (1887: 128) in the quote at the beginning of the paper: what appeared as movement in the labourer (i.e. gestures), subsequently appears in the product. This includes the morphology of the tools (a result of making and using tools through gestures) and in the processed end-product, e.g. flour, meal, meat, mineral (i.e. as altered contact material). The morphology and wear of the "*instruments of labour"* (*sensu* Marx 1887) are therefore representative of human actions.

The surface wear of these tools thus allow us to estimate and examine the movements used, the progression of wear (over time and use) and their relationship with the intermediate material, and with paired/related tools, through morphological and macro-, microscopic use-wear analysis. Combining these parts of the approaches above *i.e.* assigning tools to pairs, related gestures and resulting tool shape and morphology of used surfaces we may create larger analytical units: "processing strategies".

These units can then be further combined with more detailed microscopic use-wear and residue analysis for a more comprehensive picture of past processing strategies and foodways. This lets us ask questions like: are changes in overall processing strategies mirrored in changes in the microscopic wear or in residues? Do these strategies diversify or concentrate over time, resulting in more or fewer coexisting strategies? What can this tell us about labour specialisation or standardisation? Is wear/residues different between coexisting processing strategies? To name just a few potential avenues of research.

A more comprehensive study should of course try to extrapolate what each process dealt with, what was processed, and in forthcoming articles this will be expanded upon (Arranz-Otaegui et al. *submitted*; Pedersen et al. *forthcoming*).
However, we may not necessarily be able to find exact recipes and food processing steps, but rather we will see larger processes that these strategies will help to contextualise.
Recent attempts to pinpoint specific products and the exact processes behind, are commendable (see Dietrich et al. 2019; Dietrich and Haibt 2020; Dietrich et al. 2020; Eitam 2016; Hayden et al. 2013) but potentially too ambitious, prone to bias and thus narrow in focus: i.e. cereals, bread, porridge and beer production. Thus, the humble goal here is this: understand the function of GST, extrapolating the movements involved and the thus choices of agents behind, from the perspective of the material object, from the perspective of the tool.

What qualitative low-power microscopic use-wear is used for here in this study is to substantiate (assumed) gestures and checking the validity of suggested *processing strategies*, using these as broad categories that illustrate *ways of use*. It is, along with overall morphology and surface shape and wear used to explore the progression of wear: how this affects surfaces and tool shapes. One of the main contentions of this papers is that by examining *processing strategies* holistically, instead of just individual tools' wear and morphology as part of a (standard) typology, and by analysing this at several scales, i.e. overall morphology and surface morphology (generalised and idealised as is presented below), along with analysis of use-wear traces at macro- and microscopic level, we greatly increase our understanding of the use of these tools. The ways tools are used to process.

Based on what I have outlined above, *gestures* together with the tools they operate have the potential to tell us much about past technological choices, past labour processes and consequently past food processing strategies. Here it is again important to recognise and emphasise that changes observed in the tools are the result of changing gestures (techniques in both making and using), but a change in technology is not merely objective (*i.e.* in the tools) existing in a separate technological realms, it is subjective and social, it is an expression of human social behaviours (Ingold 2002; Pfaffenberger 1998).
It is a change in a sociotechnical system. What is presented below is therefore an attempt to remedy what I perceive as a discrepancy in the research and to provide a framework for such analyses.

2. Basis of *processing strategies*

2.1. Towards a gestural analysis of processing tools

Having now alluded to the relationship between microscopic and more generalised use-wear, what is presented below is thus an outline of the principles behind this approach that combines movements, body positions, tool pairs and resulting wear, and classifies them as specific *processing strategies*.

Firstly, *gestures* are estimated from the shape of each individual tool and their active surface(s). Importantly this also includes the overall wear and the progression of this, in conjunction with macro- and microscopic wear traces. The overall morphology of tools and used surface(s) in plan and profile(s) is used as the basis of discriminating between different strategies, following Wright's typology (Wright 1992a). This is thus meant as an addition to a "standard" typology of tools (here using Wright's . Though the sizes of the tools and of the active surfaces are also recorded, the most important element is the shape of the tool, especially of the active surface, but also plan and profiles (see below).

In addition, macro- and microscopic wear correlates are used to indicate and validate the use and correct placement of a tool-type within a strategy. This is achieved through *low-power* use-wear analysis, using a stereomicroscope at x7-x40 magnification, and following the protocols of (Adams et al. 2009; Dubreuil et al. 2015). The microscopic use-wear was applied to a selected sub-sample of the Shubayqa 1 and 6 food processing ground stones, representing each strategy.[2] Again this sub-sample is used to confirm the correct placement of tools in a strategy and the correct pairing of upper and lower tools within each strategy. The pairing of upper and lower tools based on this morphology and these wear traces. Combining these elements it is argued to constitute a p*rocessing strategy*, with differences in these elements forming the basis of each separate strategy (see below).

[2] See use-wear protocol, tool sampling, including residue sampling strategy and workflow in Appendix Ia

This approach was developed on the basis of two assemblages, one Early to Late Natufian, one the Late Natufian-Early PPNA to Early PPNB, from the sites Shubayqa 1 and 6 respectively, from modern day eastern Jordan. I have previously applied a version of this approach, see (Pedersen 2021), this was based on work done for my unpublished master's thesis (Pedersen 2017).[3] This elaborated approach, (now) features several elements that make up and influence the different strategies including the progression of wear (in idealised stages) and the macro- and microscopic correlates of strategies (see below).

The tool types mentioned (including morphological shapes) follow Wright's (1992a) classification system for SWA ground stone assemblages, noting when types were added or amended. I believe this approach focusing on strategies could be adjusted to fit any assemblage, as it is inspired by the approaches to "tool pairs" seen in Adams (2002). As mentioned, its future potential application on other SWANA GST assemblages, may reveal more detailed information about the practises of (food) processing, and how they changed more broadly in the region, during the Late Pleistocene and Early Holocene.

2.1.1. The background: what makes a "strategy"? - Elements that form the basis of strategies

a. Gestures

As noted above and elsewhere (e.g. Pedersen 2017, 2021, *forthcoming*) technical behaviours and choices are social. This includes gestures, the bodily actions and movements that make tools work. They are learned and applied in ways that will, or will not depend on individual or collective choices, and adhere to certain social norms (Mauss 1979; Leroi-Gourhan 1993; Pfaffenberger 1988, 1992). What Bourdieu (Bourdieu 1977) would call *habitus*. socio-technical practises and behaviours. Thus, by examining morphology and macroscopic and microscopic wear on tools resulting from use, we are "reading" material, or objectified expressions of labour (i.e.technical traditions and gestures). These gestures are social behaviours of individual subjects. Social behaviour, in the sense that gestures and the used tools not only deliver physical force, they deliver intention (Ingold 2002), the subjective purpose of individuals (Marx 1965: 86).
The specific movements, *i.e.* technical gestures, are therefore extremely important to the understanding of how tools and activities differ and ultimately how, and why technological systems change (Lemonnier 1992: 50; Leroi-Gourhan 1993: 237).

As already argued, morphology of ground stone tools is greatly impacted by actions during use (Adams 2002, 2014). In addition to the initial shaping of artefacts through abrasion, grinding, polishing, through thrusting, percussion, pecking, a ground stone tool is also continuously shaped by use (seein Adams 1993; Delgado-Raack and Risch 2016; Delgado-Raack et al. 2009; Kadowaki 2014). They thus become *"repositories of subjective activity"* (Marx 1965: 86). The shape of used surfaces, here of food processing ground stone tools, therefore express social behaviours materially in morphology. Different types of

[3] This previous approach (Pedersen 2017), was also based on gestures, calling them "pulverizing strategies", has however been further developed and elaborated greatly.

gestures are specific styles of actions (Dietler and Herbicht 1998), techniques (Ingold 2002) and also different technological choices (Lemonnier 1992).

Importantly processing tools work in pairs, with human gestures acting as the motive force behind the upper mobile stone with the lower acting in unison. Note that sometimes one of the tools in the pair may be of wood, or even both (e.g. Delgado-Raack and Risch 2016; Shoemaker et al. 2017). The intermediate matter absorbs the kinetic force (gesture and weight) of the upper tool resulting in reduced particle size of this matter through continuous impaction or abrasion against the surfaces of both upper and lower tools. This labour is then deposited as morphology, as micro- and macroscopic wear, on/in both the upper and lower tools, in differing ways, and also even in the body of the operator, as I also address in (Pedersen *forthcoming*; and see also Eshed et al. 2004; Hodder 2018; Molleson 1994; Sadvari et al. 2015).

Consequently when examining the *gestures* involved in operating grinding and pounding tool pairs it is pertinent to define them in detail. A study of ground stone and gestural evolution has been presented by S. de Beaune (2004) and other similar studies on ground stone, and as mentioned can be found in Kadowaki (2014), Nierle (2008), Delgado-Raack and Risch (Delgado-Raack and Risch 2009, 2016; Delgado-Raack et al. 2009) and Adams (1993, 1999) from which I draw inspiration.
However, this current approach, using de Beaune's (2004) terms, fits into Leroi-Gourhan general gestural scheme (Audouze 2002; de Beaune 2004; Leroi-Gourhan 1993). The gestural scheme I propose can be divided into three types of "diffuse resting percussion" and one type of "diffuse thrusting percussion"[4] (see the several figures below and Appendix II). The following description of gestures is largely based on Sophie de Beaune (2004) work, which in turn is based on Leroi-Gourhan's (1993): *"Diffuse resting percussion"*, grinding, that crushes and pulverises matter through abrasion. An individual using the upper body (and its weight), hands, arms and shoulders, moves an upper mobile stone tool (or wooden) across the lower stationary stone, in circular and/or reciprocal movement pulverising the intermediate material through abrasion. "*Diffuse thrusting percussion "* is usually referred to as pounding. An individual using the upper body (and weight), hands, arms and shoulders, moves a mobile upper stone tool (or wooden) with a forceful downward motion against a lower stationary stone cracking and crushing intermediate material.

It is important to note that these two categories are not mutually exclusive, tools used for grinding may also be used for pounding and vice versa (e.g. see in Nierle 2008; Wright 1992a). It will always be a dynamic system of movements controlled by subjects, objectifying a labour process in the tools, and as will be argued below, there will of course always be overlaps between different techniques and consequently strategies. What is then discernible from the archaeological remains is only the final use before discard, breakage, abandonment. However, it will be shown below exactly how the strategies differ, both in

[4] When it appeared in the unpublished MA thesis (Pedersen 2017) it included one more percussion: OPO (pounder and anvil), but as it is a relatively rare category in the Shubayqa assemblages, it is excluded here.

terms of gestures used, the resulting material wear patterns and how this progresses, is a result of using the tools in specific normative ways to process matter.

I also add a category of *discrete motions* to the overall gesture. What I term “discrete” motions are movement carried out in addition to or conjunction with the main gesture: e.g. in addition to moving the upper stone back and forth also flexing the wrist and rocking or dragging the stone creating specific and recognizable profiles and wear distribution (see for example Adams 2002: 102-106 and fig. 5.2-3. + 5.7 and my examples below). “Discrete” therefore denotes an elaboration of the overall movement, a minor or “discretely” performed action, with the hands for example, under the general gesture, that engages mainly larger members (again see descriptions in the figures and tables below along with Appendix II). This further highlights the preferences of individual operators to modify or elaborate how they engage their body with the tools they use. These “discrete” movements will not always be recognisable on the morphology, but are none-the-less important. An example can be seen further below (Figure 9.A2), where continuous/repetitive flexing the wrist, rocking the upper stone during reciprocal grinding caused a lipping of the surface levelling that extends over the proximal margin and gives the surface a curvature. Resulting then in an oval transverse profile *sensu* Wright (1992a).

Before presenting in detail the different proposed (or recognised) strategies, I want to briefly elaborate on what other elements, in conjunction with gestures, affect the tools and consequently the strategies. These are essentially elements related to the progression of wear: the management of wear, raw material properties, “use-life”/”life-histories” and how tools are “paired” in use, i.e. classed/associated within each of these strategies.

b. The progression of wear in use

i. Applied gestures and choices, production and use

Gestures are expressed and seen in the overall morphology of tools and used tool surfaces. In addition to the initial shaping of the tool, certain movements (techniques) and upper tools (one half of the instruments of labour) create certain surfaces on the lower tool and in turn this determines what movements and upper tools may be used effectively with the lower (e.g. Delgado-Raack and Risch 2009 and references therein). This is not to say one cannot change the (normative) *way of use* (i.e. the labour) and consequently the surface and the tools, rather this would simply require an active choice on behalf of the subject using the tool. For example, quite a few grinding slabs from the Early Neolithic (PPNA-PPNB) of SWA have a cupmark or mortar holes at their centre (Nierle 2008; Wright 1992a, 1993), something also quite prevalent in our assemblage from the Pre-Pottery Neolithic A to Early PPNB phases at Shubayqa 6. This represents a conscious choice of changing the surface. Indeed even the same strategy targeting the same surface and using the same gesture(s) will require constant modification and maintenance. The surface may be re-widened (Adams 1993, 2002) and continuous re-pecking/rejuvenation of the surfaces is needed for it to continue grinding satisfactorily (Nixon-Darcus 2014; Robitaille 2016). If the used surface or “face” continues to become deeper, narrower, shorter, it results in a “stepped" face where the “newer” face pierces the old (see Pedersen et al. 2016 and examples further below in Figures 6, 21, 22B and 26).

How the operator chooses to react to the wear that is produced as it progresses is sometimes called "wear management" (Adams 2002). This is the individual subject in dialogue with their tools and material (Leroi-Gourhan 1993; Wobst 2000), guiding and controlling wear in ways that are deemed correct in that situation. An example would be bifacial handstones, a common tool in the assemblages here examined (at Shubayqa 1 and 6 more than 50% of handstone examined have two active surfaces or more): these handstones are both a result of wear management; choices relating to the progression of wear through use, *and* a main feature determining shape and appearance of the tool, resulting in specific planar, longitudinal and transverse morphology (see also Adams 2002: 102–144; Wright 1992a). An approach recently put forth by L. Dietrich (Dietrich and Haibt 2020) suggests a "stratigraphy" of use phases, that is somewhat similar to wear-management of Adams (2002) and the "progression of wear"/"wear stages" approach that is suggested in this paper here.

ii. Raw material properties

Raw material properties are often underappreciated and unfortunately will not be elaborated to a great extent here either. However, I do note that raw material is an important factor in at least two ways: firstly, the mechanical-material properties of the chosen rock-type is a material factor that determines and influences wear and the wear process. Secondly, there are social, ecological, material and cultural reasons why people would choose a certain rock type or a certain rock outcrop over another. Conscious agents interact with the material and its properties: not only are these rocks embodied with desired properties, i.e. how well they perform in completing specific tasks, but also how they wear over time. These properties are actively chosen by selecting rocks for tool making and use.

The assemblages I deal with here consist of basalt almost exclusively, barring a handful of limestone and sandstone tools (including some of soft stone) and a few unidentified fragments. But why choose basalt? In the case of the Shubayqa ground stone assemblages, it is perhaps most easily answered with proximity. Though proximity may not necessarily be a reason for choosing a specific source (e.g. Rosenberg et al. 2021).

The basalt the tools of this study are made of, come from the two Qa' Shubayqa sites: Shubayqa 1 and Shubayqa 6. The sites are situated on the edge of a mudflat (a *Qa'*) in the *"Northern Plateau Basalt province"* of Jordan (Bender 1975), the so-called *harrat-ash-shams* desert. A basalt desert that spreads from modern day SE Syria and the extinct volcano *Jebel Druze,* through eastern Jordan and into NW Saudi Arabia. The basalt cover was formed by volcanic activity from the late Tertiary and into the Quaternary (Pliocene-Pleistocene) c. 8.9 to 0.1 million years ago (Allison et al. 2000).

Chemically the basalt of the *harra* can be defined as mafic alkali to sub-alkali basalt or basanite (Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006; Krienitz et al. 2007; Shaw et al. 2003). The texture of the *harra* basalt is porphyritic with phenocrysts primarily of olivine (and may be termed: alkali olivine basalt), but also common plagioclase phenocrysts, and clinopyroxene phenocrysts (Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006; Shaw et al. 2003). The groundmass is microcrystalline to cryptocrystalline (Al-Malabah et al. 2002; Odat 2015; Shaw et al. 2003) and also consists of plagioclase (primarily), olivine and clinopyroxene (remaining groundmass crystals), as well as glass and Fe–Ti oxides (Al-Malabah et al. 2002; Krienitz et al. 2007; Odat 2015; Shaw et al. 2003). The basalt is often vesicular though not exclusively. Some of these vesicles feature amygdules, probably of calcite. Basalt generally has a hardness of 6 on the Mohs-scale (Wright 1992a). Though visually diverse, the different basalt flows (Miocene-Pleistocene) are relatively, chemically similar (Shaw et al. 2003). In the assemblages the basalts are also classified in addition to the petrography, based on visual naked-eye observations based on the relative presence of vesicles (see also Pedersen et al. 2016).

In addition to proximity however, why is basalt a useful material for ground stone tool making? Basalt has natural roughness, especially vesicular basalt, which it maintains through wear, and along with its high resistance to friction it results in an excellent abrasive capacity (Delgado-Raack, Gómez-Gras, and Risch 2009). This means that less maintenance of the working surface is needed than other GST raw materials, e.g. a sedimentary rock like limestone and sandstone, volume is lost more slowly, meaning that the shape from use and wear will take a long time to form and/or intensive and extensive use (Delgado-Raack et al. 2009). The shapes that form may have a closer relationship to repeated cycles of intentional re-pecking and shaping than just the volume of basalt rock lost during use. However, importantly this is still closely entangled with gestures, through labour, both in use and the gestures performed when re-pecking, -shaping, -sharpening tools and surfaces.
The fact that this paper deals with basalt thus has a profound impact on the different wear processes and the gestures. It is not a given that the processes would happen in the same way or at least at the same rate as with other rock types.

iii. Use-life, artefact biographies, pairing tools and the dynamism of strategies

There are several interconnected and entangled in dialectic relationships at play: the material properties, the gestures and the resulting wear over time and management of this. Again here I want to reiterate that tool surface morphology (Level 0, see Appendix II) is both created before commencement of labour and that these change progressively, meaning that there is a fluidity to the objects of which we only see the final stage, i.e. after breakage (unintentional and/or intentional), discard, abandonment. This is related to the idea of artefact "use-life", "life history" or "artefact biographies" (e.g. Adams 2008; Dubreuil and Grosman 2013; Dubreuil and Plisson 2010; Dubreuil and Nadel 2015).

What studies of use-life or artefact biographies of tools often deal with however, is the different "periods" tools go through in their "life" often at a archaeological location, i.e. manufacture, use, re-use, breakage, destruction and discard of GST (see Adams 2008; Dubreuil and Grosman 2013; Dubreuil et al. 2019). While these aspects and perspectives on tool use, re-use and discard are extremely important and insightful, what I aim at here is different. Wear progression, as suggested here, is an integral part of a strategy and highlights how a tool changes through the "same" (or similar) repetitive and continuous use. The focus is thus somewhat different, and I therefore generally avoid these concepts (i.e. use-life/artefact biography/life history) so as not to confuse these perspectives. They are however highly related, comparable and compatible, and future studies should no doubt integrate them.

Here I note that there exists a history/progress of use of tools. This wear progression is an "individual" wear history on each tool. It includes the overall morphology of the tool, from use and wear, and at a different scale, the microscopic wear on each tool, i.e. microfractures, edge rounding, grain levelling, and macroscopic, i.e. surface topography, pecking marks, macrostriations etc. This is of course highly affected by the intermediate contact material, which is traditionally focused on in functional use-wear analysis, but importantly also by this interplay between the upper and lower tool and their active surfaces.

So even before the overall morphology of the tool is affected (e.g. width, length, depth thickness, concavity/convexity etc.) there will be several rounds of microscopic wear happening on the active surface. The re-pecking/rejuvenation of surfaces, restoring the abrasive properties then "erase" previous individual micro- and macroscopic traces (see Appendix II). "Individual" wear of tools of course happens simultaneously and dialectically with the overall wear of the morphology of both tools. So "individual" is meant as it is observable on each individual tool, objectified individually on the active surface; a result of subjective action using two individual tools and the intermediate material subjected to processing. Note here that handstones (upper stones) will generally wear out faster (Delgado-Raack and Risch 2009; Martinez et al. 2013).

Concurring with Kadowaki (2014), it is my impression that the concavity of lower tools, querns and slabs, represent different stages of use-life. However, this does not mean that the use-surfaces of lower tools are not pre-planned or manufactured. A certain shape and concavity may be prepared before use (Adams 1999).
Mortars are a good example of use surfaces being manufactured in their entirety beforehand. But surface shape is also dialectically the result of continuous and accumulated technological choices, that both affects and is affected by morphology, macroscopic and microscopic wear in a reciprocal interdependent process. As mentioned, in SWA assemblages, it is quite common to see a second narrower face set into the original (see in Pedersen et al. 2016; Wright 1992b; Rosenberg and Gopher 2010) or sometimes a much deeper mortar face set into an grinding slab or quern (see Nierle 2008; Wright 1993). As noted by Adams (1993, 2002) of North American assemblages, sometimes the lower tools will have to be "re-widened" to fit the upper stone and allow for movement.

Furthermore, ground stone tools may often be used not just by individual operators and those producing them but also their contemporary social group, as well as be used for generations (Hayden and Nelson 1981; Searcy 2011). This entails that the tools are not only shaped by each individual person as they are grinding or pounding, but also potentially by generations of different people and different kinds of processing: e.g. hide-working, cereals processing, hammering etc. in succession. People thus potentially carry on specific types of actions or labour and gestures, or change or adapt the tools' purpose or the gestures for the same purpose. They consequently "inherit" technological traditions/practises (e.g. gestures and tools) of their forebears, but also engender these traditions and this technology themselves. Again gestures are socially conditioned movements (Leroi-Gourhan 1993; Mauss

1979), operated by individual subjects; but these movements and actions happen within a sociotechnical system (Pfaffenberger 1992). The resulting tools and surfaces we examine are thus not results of accidental, unintentional processes, though at times choices may be somewhat subconscious (Lemonnier 1992; Sillar and Tite 2000), they are the results of knowledge, skills, norms and intentions. But may also transfer the intentions and traditions of multiple individuals and potentially generations of agents.

Finally, morphologically similar tools may have diverse and dynamic functions within their use life. A tool may be used/reworked or re-used for different purposes, and thus, both morphology and function are dynamic and influence each other. Form may change over time but function or purpose stay the same or a task may change but overall morphology remains unchanged. For example a handstone may cease to be used with a quern and then be used as an abrader, for processing hide. The overall morphology will then stay the same, the hide may not be mechanically strong enough to alter the morphology, but the wear on the surface will potentially change enough to be distinguishable. This then becomes clear through microscopic analysis. A specific strategies' uses are not necessarily uniform. Some tools have remains of pigment, that can be seen in the interstices of the surface, but its use-wear is not that characteristic of ochre processing, so the presence of this may represent a previous phase of use. Some tools have residues of one plant, but the use-wear indicates mainly the processing of another (see Hamon et al. 2021).

So it is also important to understand that wear may take a long time to form and these tools can be used for several decades, sometimes hundreds of years, depending of course on the intensity of use as well as the properties of the rock used (Delgado-Raack, Gómez-Gras, and Risch 2009; Delgado-Raack and Risch 2009; Hayden and Nelson 1981; Searcy 2011; M. Wright 1993). As mentioned the shapes that form may be related to the repeated cycles of intentional re-pecking and shaping rather than just the loss of volume of the rock during use at least with highly friction resistant rocks like basalt (Delgado-Raack et al. 2009).

Furthermore, some types here defined may actually represent a blank or may be in an initial stage of use. This has implications for carrying forward ways of use, practises and "traditions", as GST may be trans-generational. As use continues, the tool and its used surface would gradually take shape that conforms to other types as a result of the gestures and the upper stone used. Meaning if the operator continually used a short handstone, with reciprocal movements on a restricted (confined) area of the surface of the block, a narrow depression would form (see Adams 2002: 100 fig. 5.1; Kadowaki 2014; Dietrich and Haibt 2020). A elongated handstone type (e.g. a Loaf-type Wright 1992a) used across the entire surface would then cause a flat, or eventually convex, use face (e.g. Delgado-Raack and Risch 2009) and so on. Individual operators thus, can vary between tools and movements, it is dynamic, however at a certain point as is illustrated below, they would become ineffective: a handstone used in a narrow elongated depression/basin cannot be moved in circular motions *etc*. This leads us to how to pair tool sets.

iv. Pairing tools

The shape of the lower tools' active use-face is determined by the gestures and by the upper tool involved, and this will in turn determine what upper tool and gestures can be used effectively with the lower stone. This is what allows us to "pair" upper and lower stones, i.e. establish what tool types, what upper and lower tools go together and are associated with what type of gesture (forming a strategy). Sometimes this is fairly self evident: we can be quite confident that a pestle goes with a mortar, in what is here called a "confined pounding strategy" (CPR - see below), as pestles, generically speaking, would function within any lower stone featuring a mortar hole (e.g. Adams 2002; Wright 1992a)[5]. This does not entail that we can determine exactly what two tools go together "*this pestle must have been used with that mortar"*. Rather they represent a specific reduction/processing strategy present at a site at a certain time.

Accessing what upper and lower grinding stones go together can be slightly more difficult. Although extensive work on this has been conducted in the North American southwest (see Adams 1993, 1999, 2002; Mauldin 1993) as well as the Aegean (Chondrou et al. 2021; Stroulia et al. 2017) and Iberia (Delgado-Raack and Risch 2009, 2016), such approaches has rarely been applied in a SWA context, where most reports refrain from associating any particular handstone with any specific lower tool (e.g. Edwards and Webb 2013; Martinez et al. 2013; Rosenberg et al. 2012; Rosenberg and Gopher 2010). Fortunately, a few studies have been conducted on SWANA assemblages by Kadowaki (2014), Nierle (2008), Banks (1982) and Dubreuil and Plisson (2010)[6] that do consider this.
Length and width of the upper stone (handstone) and the active face of the lower stone, as well as planar shape of both, can be good indicators of what upper and lower grinding tools go together (Adams 1993, 2002; Kadowaki 2014; Pedersen 2021). In addition to this is the transverse and longitudinal profile of the used surface informs what tools may be "paired", for example a flat and flat profiles upper and lower often go together (either transversely or longitudinally or both), as do convex-concave and concave-convex (Adams 1993; Delgado-Raack and Risch 2009, 2016; Kadowaki 2014; Stroulia et al. 2017) (see Table 1 and Appendix II and Pedersen 2021). Most pairs will hopefully become evident/clear as we go through them below and from the figures and appendix (Appendix II).
Further, I also base these pairings on published ethnographic observations, conducted at various places across the globe, as these aid in establishing both pairs and associated gestures/movements (e.g. Ertug 2002; Hamon and Le Gall 2013; Nixon-Darcus 2014; Nixon-Darcus and D'Andrea 2017; Robitaille 2016; Schroth 1996; Searcy 2011). These inform the schematic/idealised tool pairs I suggest for the assemblages I work with below. Some exploratory experiments have also been performed (see Arranz-Otaegui et al. *submitted* and see also Appendix III).

Pairing the tools and strategies is thus a synthesis of a qualitative examination of planar shape and use surface profiles, along with macro and microscopic wear correlates from low-power

[5] Though this will of course be constrained by factors like the length of the pestle and the depth of the mortar hole
[6] As well as recently by (Dietrich et al. 2019; Dietrich and Haibt 2020).

magnification, this wear resulting from specific gestures and processing. I briefly present, after each strategy, data from the Shubayqa sites that form the basis of these classifications, and may aid others in forming similar categories.

Thus, to summarise, the pairings and the *processing strategies* as a whole, are based on observations from my own work with assemblages from eastern Jordan, as well as the work of others on similar (spatially, temporarily and/or morphologically) processing ground stone (past and present). Again, these morphologies are not accidental, but the result of choices and decisions made by conscious agents materially interfering with matter in ways they find satisfactory or correct to achieve the change desired and the result of several elements (see Figure 1). Tools are influenced by continuous technical choices (Lemonnier 1992, 1993) and as previously established, they are the physical representations of a system of social behaviours (Pfaffenberger 1988, 1992), by being part of a labour process (or multiple) see in (Pedersen *forthcoming*).
A *strategy* thus represents: *a way of altering a material, a food processing strategy aimed at changing the textures or physical attributes of foodstuff.* It is representative of a labour process and that may, or may not, be associated with any specific processed raw material. As many previously have noted: tool shape and morphology; does not necessarily reveal what they were used for (Adams 1999; Pedersen et al. 2016; Schroth 1996; Searcy 2011; Wright 1991, 1994).

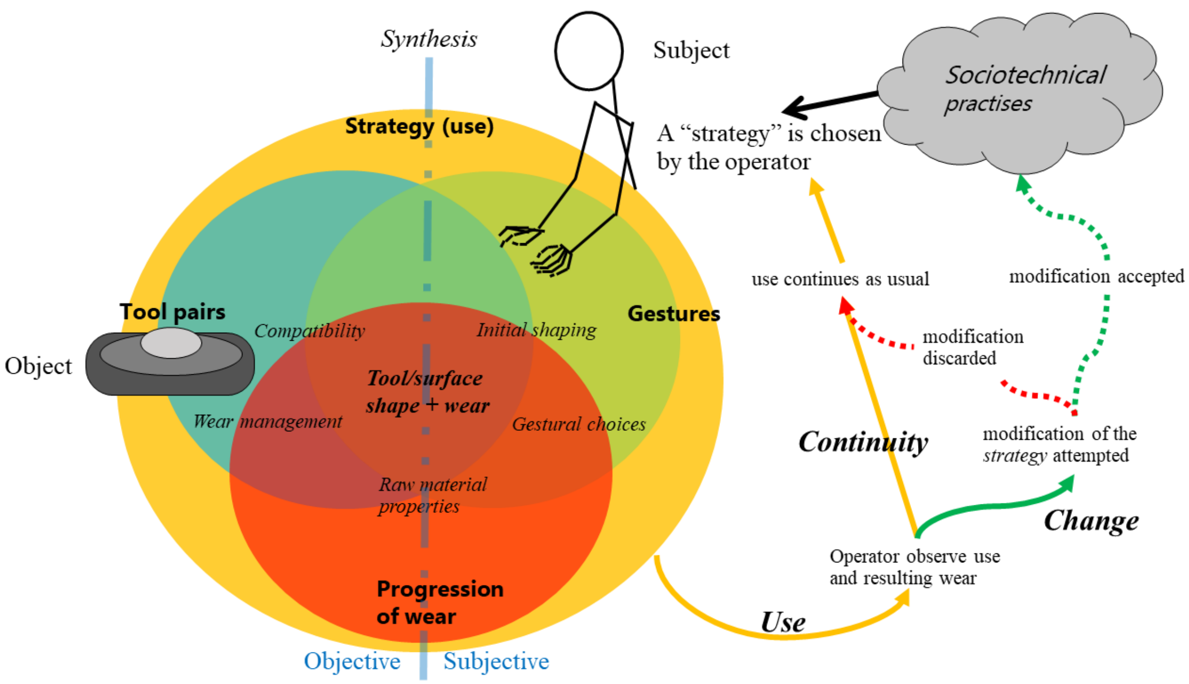

Figure 1: What makes a strategy? A strategy is the synthesis of several elements: of dialectical relationship(s). The strategy is related to the *chaîne opératoire* of non-mechanical pre-agricultural food processing (see Pedersen *forthcoming* along with Table 1 and Figure 1 + 2).

Rather these tools and strategies tell us *how things were processed*. Microscopic use-wear and residue analysis may aid in identification of the exact raw material processed (e.g. Ma et al.

2019; Lucarini and Radini 2019; Zupancich and Cristiani 2020). In a forthcoming paper I apply microscopic use-wear and residue analysis to find the subject of labour; *i.e.* the raw material processed (see Pedersen et al. *forthcoming*). But, as I would caution, it will not tell us the whole story, and thus here, I focus on how tools are used, leaving for now *on* what they were used on. Establishing how tools were used is important, I would argue, as it aids analysts to understand what labour processes are present at site or sites and their relationship with each other.

3. The *processing strategies*: ways of use - the gestural analysis in action

3.1. Methods - basic observations[7]

Creating or using an approach based on processing strategies, as the one given here (and this goes for "regular" tool typologies as well) should include and consider all of the above elements as far as possible. What I lay out here is a presentation of the strategies I find at the Shubayqa sites and thus also part of an analysis of that material as this is what prompted the creation of these strategies. Therefore, at the end of the presentation of each strategy I also present the data behind it (see also Appendix II). All data comes from the analysed ground stone from Shubayqa 1 and 6. In addition, as mentioned above, the creation of these strategies have also been based on the other peoples work, besides merely the Shubayqa data, hence archaeological and ethnographic references are also given to exemplify strategies, gestures, tools when deemed pertinent.

3.1.1. Gesture and Morphology

Based on the foregone discussion in this assemblage I distinguish three main types of grinding (diffuse resting percussion) and one main type of pounding (diffuse thrusting percussion). These distinctions are essentially differences of dialectical relationship between the tool shape and gestures used: tools pairs and movements of the two stones against the contact material and against each other, the resulting morphology. Table 1 provides an overview. It shows use, wear and wear management, expressed as overall morphology, shape: plan and profiles. Microscopic use-wear traces and their patterning is dealt with further down below and in each category/strategy.

Diffuse resting percussion

A1. Confined Reciprocal Grinding (CRG)
A2. Open Reciprocal Grinding (ORG)
A3. Rotary Grinding with some pounding (RGP)

Diffuse thrusting percussion

B. Confined Pounding with some rotary grinding (CPR)

[7] As mentioned a previous version of this *"strategies"* approach, including initial analysis of the tools, appears in Pedersen 2017 and 2021.

Strategy	Primary function	Overall movement	Gesture	Upper tool	Lower tool	Upper surface shape	Lower surface shape
A1. Confined Reciprocal Grinding **(CRG)**	*Diffuse resting percussion* Grinding, abrading	Linear, reciprocal, movements within a depression, which constricts movements	Performed with one or two hands, pressure exerted from the shoulder(s)	Ovate handstone	Basin *or* trough slab	*Planar:* Ovate/oval/ rectilinear *Transverse:* Flat (>) to convex *Longitudinal:* Flat (>) to convex	*Planar:* Elongated, oval, elliptical *Transverse:* Concave *Longitudinal:* Concave or sloped
A2. Open Reciprocal Grinding **(ORG)**	*Diffuse resting percussion* Grinding, abrading	Linear, reciprocal, movements on the open surface. Movements relatively free across the surface of the lower	Action primarily performed using two hands. Pressure exerted from the shoulders, most of this created proximally closest to the operator	Loaf handstone	Flat Block slab *or* Saddle slab	*Planar:* Elongated rectilinear, rectangular *Transverse:* Flat *Longitudinal:* Flat (>) to concave	*Planar:* Elongated rectilinear, square, rectangular *Transverse:* Flat (>) to convex *Longitudinal:* Flat (>) to concave
A3. Rotary Grinding (with some pounding) **(RGP)**	*Diffuse resting percussion* Grinding, abrading	Rotating or circular. Movements within a depression, but the upper stone	Action primarily performed using one hand. Pressure exerted by the arm, with less and less pressure the farther it moves from the operator	Discoidal handstone	Basin quern, *or:* block quern	*Planar:* Circular or oval *Transverse:* Convex (>) to flat *Longitudinal:* Convex (>) to flat	*Planar:* Circular (discoidal) or oval *Transverse:* Concave (>) to shallow *Longitudinal:* Concave (>) to shallow

		is moved freely within					
B. Confined Pounding (with some rotary grinding) **(CPR)**	*Diffuse thrusting percussion* Pounding, crushing	Downward stroke, thrust Movements within a depression, the upper stone is moved somewhat freely up and down. The base and sides of the hole allows for some grinding by twisting the upper stone within lower	Action, performed with one hand or two, force exerted using both elbow(s) and shoulder(s)	Pestle	Mortar	*Overall:* Cylindrical or conical *Profile:* Circular, sub-circular, oval, square, rectangular *Terminus transverse:* Convex (>), flat or concave	*Planar:* Circular, sub-circular, oval *Transverse:* Concave or conical

Table 1: Strategy overview based on the Shuabyqa assemblages (see also Pedersen 2021). Note for lower tools (slabs, querns, mortars): Flat is defined as a surface as a max depth of less than 4 mm, at the longitudinal/transversal centre of the surface (this definition is used for all lower tools). Shallow less than 15 mm(4-14mm), concave 15 mm (>15 mm). Surface is convex if it rises 1 mm or more above margins.

Assemblage basis

The two sites used, in a regional context, date from the Late Epipalaeolithic to the Early Pre-Pottery Neolithic (PPN) of the Southern Levant. As previously mentioned both the sites are located in the *harra* basalt desert in modern day eastern Jordan. They are situated on the edge of the Qa' Shubayqa, a twelve square-kilometre large mudflat basin, fed with water from nearby wadi systems.

The entire assemblage of food processing ground stone tools is from securely, well dated, contexts from the Early Natufian to Late Natufian phases at Shubayqa 1 and from the Late Natufian into Early and Late PPNA (and possibly Early PPNB) at Shubayqa 6 (see Table 2). An overview of the Shubayqa 1 and 6 ground stone assemblages their composition, diversity, provenance, context and an initial analysis of processing strategies present at the sites appears in (Pedersen 2021[8]; *forthcoming*). Space limits a detailed description of the sites these tools come from but see Pedersen et al. 2016; *forthcoming;* Pedersen 2021; Richter et al. 2016, 2017. However, I briefly summarise the provenance of the assemblages below.

Site	**Phase(s)/Space(s)**	**Period**	*Date range cal. BP at 68.2 % probability*
Shubayqa 1	Phase 4-7	Early Natufian	~14,800 - 14,100
Shubayqa 1	Phase 2-3	Late Natufian	~13,300 - 13,100
Shubayqa 6	Space 4 (lower infill + floor)	Late Nat.-Early PPNA	~11,820- 11,300
Shubayqa 6	Space 4 (upper infill) + Space 3	Late PPNA/EPPNB	~11,000 - 10,600

Table 2: Shubayqa sites and assemblage dating (Dating from T. Richter).

Provenance of tools

The Shubayqa 1 tools

Material from the Early Natufian phase was retrieved from the midden infill of Structure 1 (Phases 6) at Shubayqa 1, a large roughly oval-shaped stone built structure of upright basalt boulders with a basalt flagstone floor and a central hearth (see Richter et al. 2017). Additionally, a large portion of the tools come from the construction backfill of the wall of this building (Phases 7). Another paved area featuring a hearth was situated above and within Structure 1 (Phase 5), this paved area featured burials beneath. Above this was another

[8] This publication did not feature the tools from the floor of Space 4 at Shubayqa 6, as well as a few other pieces analysed and added to the data later

infilling event (Phase 4) which ended the Early Natufian occupation. Ground stone associated with the Late Natufian period were retrieved from another structure superimposed on the previous building. This, Structure 2, again featured a flagstone floor and a hearth. Several ground stone tools (especially querns and mortars) were incorporated into the floor of Structure 2, a floor that also featured burials beneath (Richter et al. 2019). Some of the tools associated with this Late Natufian phase have previously been published see Pedersen et al. (2016).

The Shubayqa 6 tools

The Shubayqa 6 GST assemblage featured in this study here comes from two structures: Space 3 and Space 4 and the infill of these. This can be tentatively divided into two main phases. The GST from the older part of the occupation comes from the lower infill of Space 4 and its floor and is dated to the transition from the Late Natufian to the Early PPNA (possibly Khiamian), see Table 2. The floor of Space 4 floor included several tools (c. 20) in its surface, both grinding slabs and querns (n = 9) that would have been fully functional upon abandonment, as well as broken grinding slabs and handstones incorporated as part of the floor surface. The youngest phase Space 3 and the infill within is associated with the Late PPNA (possibly Early PPNB). Included in this occupation phase is the upper infill of Space 4.

763 can be identified as processing tools (i.e. pestles, handstone, mortars and querns/slabs). These were extracted from 1335 analysed pieces of other tool types, debitage and unidentified worked stones.[9] 85 “irregularly” shaped upper grinding tools (handstones), both complete and fragments, were excluded from the analysis as they do not fit in the categories below. The overall assemblage of (food) processing tools and tool fragments used in this analysis is therefore 678 (see Table 3 below), all of these can be associated with one of the proposed strategies.

Assemblage bias

In this analysis there is a bias towards food processing tools. Though most are identified as such, some of the headstones here classified as food processing tools for example, might rather be abraders, burnishers etc. used for processing e.g. hides, skins or minerals. It will often be difficult to distinguish between these uses, though this may be revealed through microscopic use-wear analysis and residue analysis (Adams 1988; Hayes et al. 2021). This issue of contact materials is something that will be addressed in future papers (see Pedersen et al. *forthcoming*). That forthcoming paper, using the same sub-sample of tools subjected here use-wear analysis (see below), focuses on determining the contact materials. This current paper's focus (including use-wear) is on *ways the tool pairs are used* (i.e. as part of a strategy).

[9] The entire analysed assemblages count is 1671 GST, if including material from topsoil, surface and mixed or heavily disturbed contexts. Parts of this data previously analysed in Pedersen 2017, 2021 and Pedersen et al. 2016.

Since not all tools could be subjected to this analysis, it means only “clear” polishers and abraders (e.g. grooved stone) have been excluded. Tools with traces of pigment (e.g. ochre) are not excluded as this mineral processing may have been in addition conducted in addition to other (food) processing activities.
According to this initial categorization well over half of the assemblages consist of tools classified as food processing tools. This both shows that GST’s are more than just food processing tools, but also that different kinds of food processing appear as the main activities carried out with GST at the two sites.

Overview		**Tool** *type*			**Tool** *type*					
	A1. CRG	**HS** *ovate & rectilinear*			**Slab** *basin & trough*			**all**		
	Period	comp	frag	total	comp	frag	total	comp	frag	**total**
	E.Nat.	19	1	20	0	1	1	19	2	**21**
	L.Nat.	16	13	29	2	2	4	18	15	**33**
	L.Nat.-EPPNA	39	9	48	7	4	11	46	13	**59**
	PPNA-EPPNB	10	1	11	0	2	2	10	3	**13**
Total		**84**	**24**	**108**	**9**	**9**	**18**	**93**	**33**	**126**
	A2. ORG	**HS** *loaf, loaf tapered*			**Slab** *block & saddle*			**all**		
	Period	comp	frag	total	comp	frag	total	comp	frag	**total**
	E.Nat.	6	55	61	5	2	7	11	57	**68**
	L.Nat.	13	191	204	3	7	10	16	198	**214**
	L.Nat.-EPPNA	0	11	11	2	7	9	2	18	**20**
	PPNA-	0	6	6	1	5	6	1	11	**12**

	EPPNB									
Total		**18**	**263**	**281**	**11**	**21**	**32**	**29**	**283**	**313**
	A3. RGP	**HS** *discoidal, spherical*			**Quern** *Basin, block & boulder*			**all**		
	Period	comp	frag	total	comp	frag	total	comp	frag	**total**
	E.Nat.	2	1	3	3	3	6	5	4	**9**
	L.Nat.	12	9	21	8	14	22	20	23	**43**
	L.Nat.-EPPNA	7	3	10	4	3	7	11	6	**17**
	PPNA-EPPNB	3	4	7	1	3	4	4	7	**11**
Total		**24**	**17**	**41**	**16**	**23**	**39**	**40**	**40**	**80**
	B. CPR	**Pestle** *All*			**Mortar** *All*			**all**		
	Period	comp	frag	total	comp	frag	total	complete	frag	**total**
	E.Nat.	21	19	40	3	25	28	24	44	**68**
	L.Nat.	10	18	28	6	20	26	16	38	**54**
	L.Nat.-EPPNA	5	7	12	3	5	8	8	12	**20**
	PPNA-EPPNB	3	7	10	3	4	7	6	11	**17**
Total		**39**	**51**	**90**	**15**	**54**	**69**	**54**	**105**	**159**
	all									**678**

Table 3: Tool and Processing strategies overview from Shubayqa 1 and 6. Tools and subtypes (in *italic*) follow Wright (1992b). **Period (site):** Early Natufian (Shubayqa 1) = E. Nat., Late Natufian

(Shubayqa 1) = L. Nat., Late Natufian to Early PPNA (Shubayqa 6) = L.Nat.-EPPNA, later PPNA to Early PPNB (Shubayqa 6) = PPNA-PPNB

3.1.2. Macro/Microscopic use-wear correlates[10]

Macro- and microscopic use-wear data underlies each strategy as well. The analysis of these wear traces is meant to support the distinctions between strategies in addition to the overall morphology. The micro-, macroscopic use-wear correlates found below are based on the low-power use-wear analysis of a select subsample of 64 tools from Shubayqa 1 and 6, covering all *strategies*.

Provenance and selection of use-wear subsample

In the selection of tools to be subjected to use-wear there was a bias towards complete tools that could comfortably be put into one of the strategies suggested. This bias towards complete tools in the use-wear analysis was to allow for multiple locations of each tool to be examined and recorded, e.g. the margins, centre, distal ends etc. Helps with understanding the progression and location of wear and their directionality. This selection is however a bias that needs to be recognised. Complete tools are a relatively small part of the assemblage, however their usefulness in understanding then the fragments of similar tools related to the same processing strategies, is here the reason why they are prioritised. The complete tools are thus used as proxies for whole strategies and related fragments, but admittedly represent a smaller part of the overall assemblage. The provenance of this sub-sample of tools is the same as the rest of the assemblage as described, extracted from the same contexts, and they cover all the phases from the Early Natufian to the Late PPNA at Shubayqa 1 and 6. An overview and functional analysis of these tools is found in the forthcoming paper: Pedersen et al *forthcoming*, but this present study here deals instead with aspects of wear progression and management and idealised processing strategies and their correlates.

Macroscopic wear traces were observed with the naked-eye and at low magnification (x7) and recorded. Microscopic observations were made using low-power microscopy at magnifications ranging from x7-x40 using a OLYMPUS SZ-III/SZ-Tr - Zoom-Stereo microscope. I follow the protocol established and detailed in (Adams et al. 2009; Dubreuil et al. 2015).The protocols were adjusted and specific data was selected, to focus on use-wear traces that inform us about gestures or kinetics (Adams et al. 2009; Dubreuil et al. 2015), i.e. ways of use, peoples movements and the management of wear (Adams 2002).

The first three main traces are: pecking pits and macro striations (on the used surfaces), surface and grain levelling (of the used surfaces).
Impaction/pecking pits, some macro-striations, and surface levelling are all observable with naked-eye (Level 0), or low magnification (Level 1, Adams et al. 2009). Levelling of

[10] See detailed use-wear protocol in Appendix Ia and raw material notes in Appendix Ib

individual grains (like phenocrysts in a micro- to cryptocrystalline groundmass) mainly visible at higher magnification e.g. x40 (Level 2-3, Adams et al. 2009)

Important for the reconstruction of gestures and kinetics, is the presence or absence of traces and, if present, their location. Locations are divided between: covering (the whole of the surface), central, lateral margins, distal/proximal margins or mixed.
Naked-eye and low magnification observations were thus made at the approximate centre, lateral, distal, proximal margins, to see whether use-wear was uniform across the surface, i.e. covering, or what variations in traces were identifiable.
The presence or absence of traces and where these traces are located inform us about the location of use (the location of contact material between the stones): the sites where there may be stone-on-stone contact, and the places where traces may have been present but where they have been worn out *by use*. This is covered in more detail below, but for example the pecking marks of the margins of a discoidal handstone may have been worn away and replaced by grain levelling, striations, edge rounding, grain extraction etc. from intense use, including occasional (maybe frequent) and accidental stone on stone contact, in addition to the wear absorbed from the contact material.

A second feature is patterned traces (PT), which provide information about the direction of use. These traces are: striations, fracture-, grain extraction- and pit-orientation which all inform kinetics and use following (Adams et al. 2009). Some, like macro-striations are again, visible with the naked-eye or at low magnification, whereas*, traces* like levelling of individual grains, fractures, grain extraction and pit orientation were detected by the use of stereo-microscope (at c. x7-40x), (Level 2-3, Adams et al. 2009).
These traces, like the ones above, also result from repetitive and frequent movements. A striation for example is the result of an abrasive agent (e.g. a grain/crystal etc.) scratching/scoring the surface it is being moved against. This movement is the operator performing gestures moving the two stones (tools) in the pair against the intermediate material and against each other. Now not all "strokes" will result in that striation, the right conditions will have to be there. You may use a grinding gesture several times on a (e.g. soft) material and no striations appear. It only happens when the abrasive agent is hard enough and/or the surface can no longer bear the load of the tool, material and movement (Adams 1989, 2002, 2014). Meaning sometimes through these repeated actions, the gestures, will result in a striation being scratched in the surface (or a fracture/chipping) and going in a certain direction. Note that gestures cause specific traces, i.e. grinding or abrasive movements and activities will make a striation, rather than impaction scars like pounding movements will.

The direction or directionality of these actions leave what I call patterned traces (PT). A trace, e.g. striations, grain extractions and pits patterning in a certain direction. Thus, the number presented in the use-wear tables below is a total of observed traces with discernable direction/orientation. It is sometimes separated into upper and lower tools. For example one observation of transversal striations equals one PT. but it does not count each individual striation. An additional observed presence of several transversal grain extractions would give

that tool two transverse PT and so on. So two transverse striations still only count as one patterned trace (PT).
Traces with no information about direction are not counted, nor are traces where there is no clear directionality (too few, unclear, too damaged etc.), however a random or mixed patterning does count.

Both of the above elements, location of traces and their directionality (PT) of is of course a qualitative assessment. For an illustration of what this directionality of traces means, see Figure 2 below, which illustrates different degrees of directionality: *none, beginning, pronounced* and *worn-out*. These affect the observation of macro/microscopic correlates of the processing strategies. So no directionality can both be a result of no discernable repetitive gestures or the "stage" of wear: directionality has not yet formed or rejuvenation of the active surface has removed previous traces. Generally speaking this directionality is thus related to the overall progression of wear.

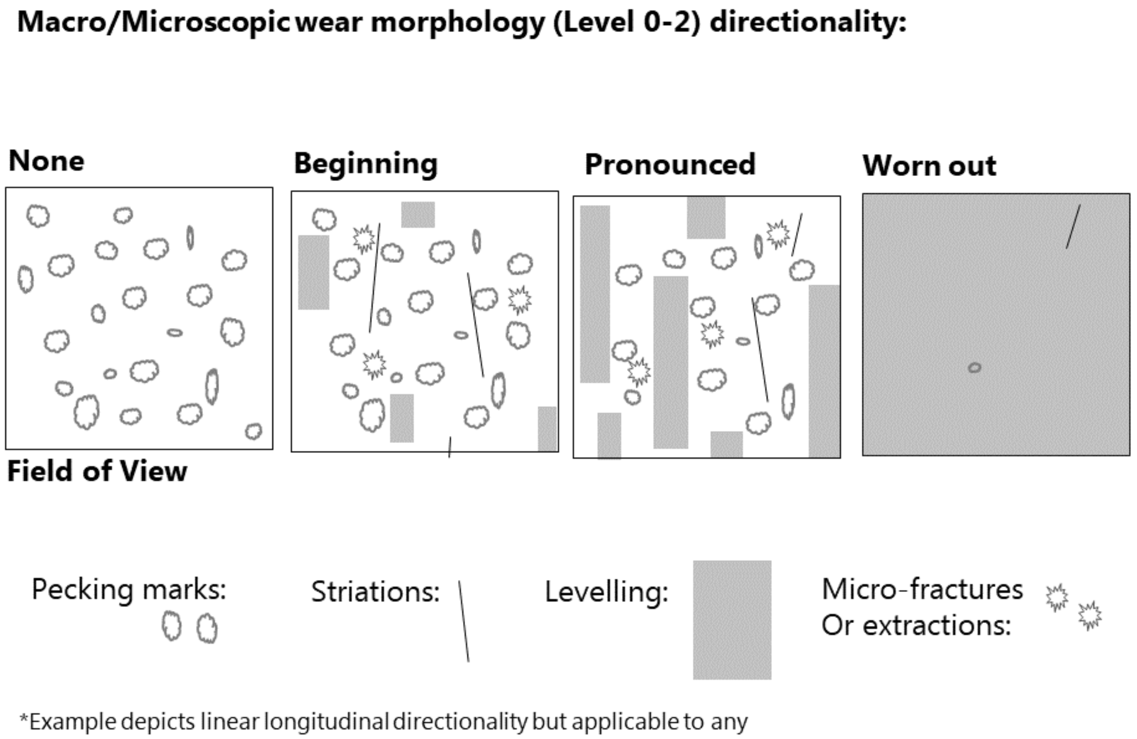

Figure 2: At Levels 0-2 following (Adams et al. 2009).

3.1.3. On progression of use-wear and wear management

The progression of wear described below is presented in "Stages". Note that depending on which "stage" of use the tool is in, e.g. lightly used stage (Stage 2, see below in figures and tables) or intensively/extensively used (Stage 3, see below in the figures and tables), affects how developed and thus recognisable the macroscopic and microscopic correlates are, and also the overall shape, morphology and consequently the strategy. As is explained in the

individual stages below, specific patterning will appear, become pronounced, then (almost) wear out, and repeat, affecting morphology.
These stages aid in classifying a tool to a specific strategy but, importantly these stages should not and will not be referred to as a set of fixed categories. These are rather a dynamic continuum, a qualitative point of observation (see Figure 3).

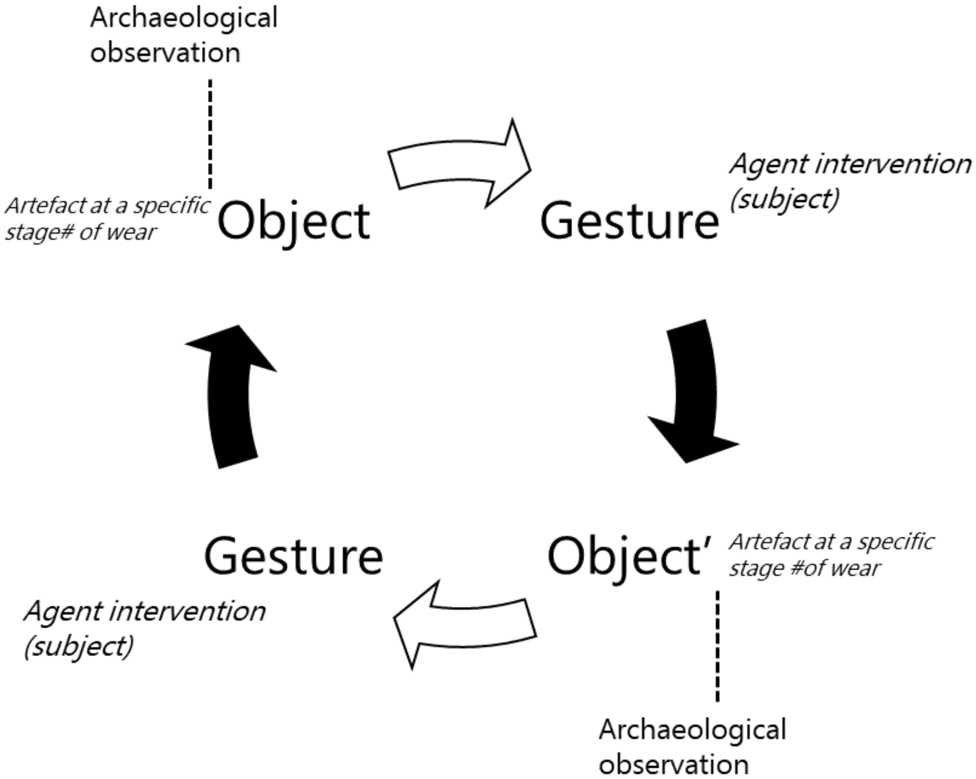

Figure 3: The point of observation of "stages" of wear.

The presentation of the "stages" below is simply to highlight the progressive and dynamic nature of wear and how individuals manage that wear.
Similarly, both microscopic use-wear, macroscopic wear and overall morphology represents a snapshot of current wear (see Figure 3 above), but also a window into past wear, be it a hazy or fuzzy view (see in Adams 2002). In the end this is what may inform us of past foodways; ways of processing material and indicate what foodstuffs were processed.

The stages follow some of the same qualitative variables posited by Adams (2002, 2014). Adam's *"light wear"*, refers to wear not distinguishable with the naked-eye and the Stage 1 I suggest, is a surface that is prepared for use (e.g. shaped and pecked), but not (very) used. My Stage 2 would conform to Adam's definition of "*moderate wear"* i.e. *"...leave[s] obvious damage..."* (Adams 2014: 136) but with some effect on tool shape, and my Stage 3 would be the *heavy wear* of Adams: "*...chang[ing] the natural or manufactured shape of the tool.*" (Adams 2014: 136).

The stages I propose here thus help us understand when a tool is: prepared for use (Stage 1), lightly used (Stage 2), intensively/extensively used (Stage 3), and worn out from use (Stage 4) and whether it can be placed in one of the processing strategies. It does not necessarily matter if it may be placed confidently, in any one of the proposed idealised “stages”.

Note that these stages also are also related to the patterned traces (PT) mentioned above, and illustrated in Figure 2 (and Appendix II), i.e. *none, beginning, pronounced* and *worn-out* (equivalent to Stages 1-4). So the stages of overall wear progression are also represented in the macro/microscopic use-wear of the surface (in close-up) by different degrees of directionality. However, they do not necessarily follow each other, as the overall stages are the result of repeated cycles of microscopic wear. Rejuvenation of the active surface, like pecking, will erase the macro/microscopic traces and correlates (Dubreuil and Savage 2014), the levelling and pecking marks and the patterned traces, while the overall wear and morphology may still reflect another perhaps more advanced and used stage.
But, importantly these interact dialectically; both appear and are erased through use, both are material expressions of repetitive actions, observed at different scales.
The stages are representative of, and related to, strategies but if the use changes, it may progress to another strategy, crossing the fuzzy boundary from one processing strategy to the next. Similarly the macro- and microscopic traces, their patterning and directionality are representative of and related to their strategy, but progress, from *beginning* to *pronounced* and back, happens in conjunction with and simultaneously with the overall wear stages.

Finally I note that worn-out (Stage 4) can be understood in two related ways. Firstly a surface that is worn-out and in need of rejuvenation/re-pecking. Or secondly as a tool that is no longer usable (or comfortable to use) in its current state. This latter case may result in discarding, deliberate destruction (Adams 2008; Dubreuil et al. 2019) or changing the tools function or form; a smooth grinding handstone may become a polisher or a abrader of other materials (ceramics, hides etc.), and a lower grinding slab may be turned around or into a mortar, container or vessel etc.

3.2. Strategies[11]

3.2.1. Diffuse resting percussion (A1-A3)

A1. Confined Reciprocal Grinding (CRG)

Gesture: Linear, reciprocal, back-and-forth grinding with an upper stone, within a confined elongated elliptical, oval sub-rectangular (planar) depression; sometimes called a basin (Adams 2002; Kadowaki 2014; Wright 1992a), this is the active surface/face of the lower stone. The transverse profile of the face of the lower tool will generally be concave, rectangular to squarish. The longitudinal profile will range from shallow, to concave or

[11] See summary in Table 1 and see *Appendix II: Processing strategies and idealised use and wear progression* for further details. Tool typology, tool types and tool morphological descriptions generally follow Wright (1992a) unless otherwise noted in the figures and tables.

sloped (see Figure 4, and Table 1). A shallow face is here defined as having a maximum depth of less than 14 mm, at the longitudinal/transversal centre of the surface (this definition is used for all lower tools, going forward).
Initially the depression is relatively shallow, unless an intentional deeper depression has been produced by the maker/artisan. So movements either created this depression, or the depression was intentionally produced before use. The depression in turn constricts these movements, meaning that it is not possible to vary strokes beyond reciprocal, back-and-forth motions (see Figure 5). However, if the gesture used is oblique, sliding i.e. (down and away, back-and-forth) the resulting longitudinal profile will become "sloped". Alternatively if the gesture used is pendular, back-and-forth the result will be concave (see in Figure 4, example in Figure 7C and data in Figure 9).

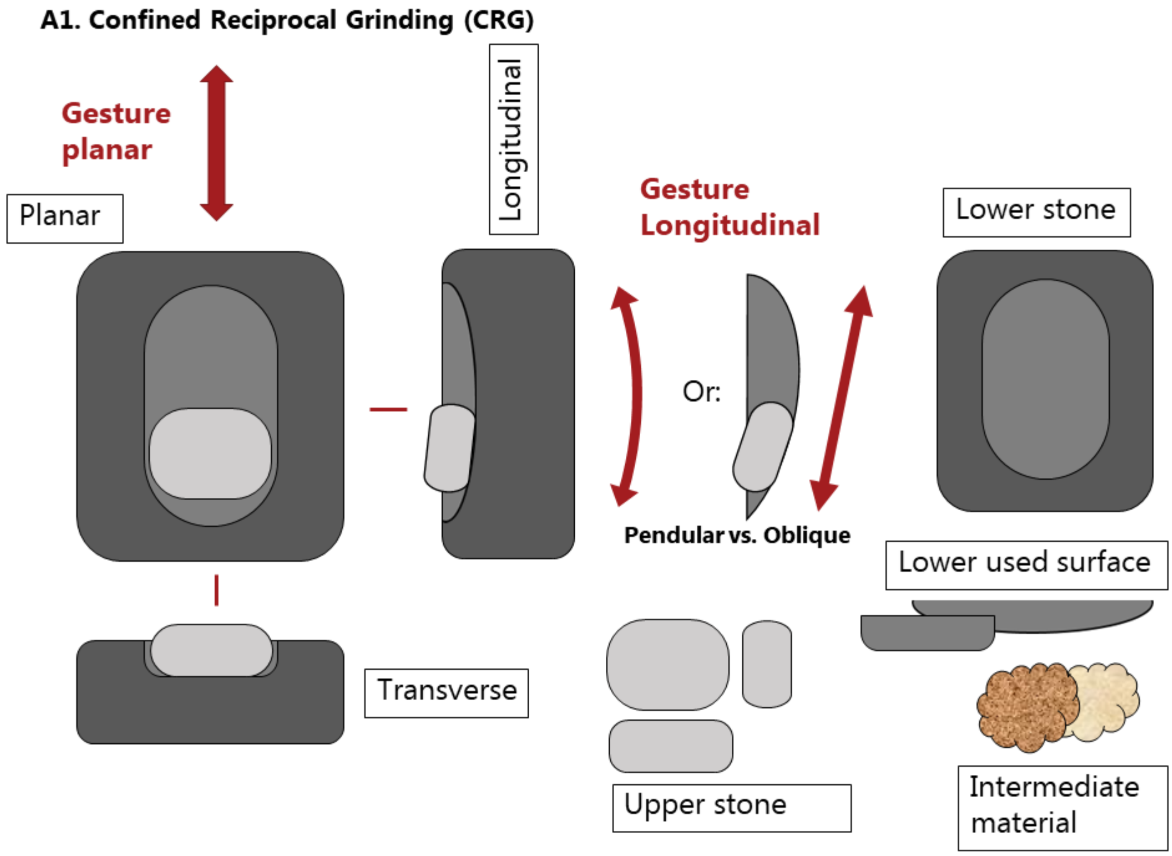

Figure 4: Illustration of A1. CRG. Overall idealised processing strategy and tools: ovate/rectangular handstone (oval/flat profile), basin slab (oval surface with concave profile[s]).

Discrete motion: rocking/dragging, i.e. pressing down with the base of the palm and thumb, flexing the wrist backwards, while stroking away from body, activating the proximal end of the upper tool (proximal right side if right hand is used) and then pressing down with the fingers, flexing the wrist forward activating mainly the distal end of the upper tool (distal left side if right hand is used) (see close-up in figure 5). This action can be performed using one or two hands, depending on the length of the handstone (see Adams 2002), with pressure exerted from the shoulder(s) using the upper body's weight (see figure 5). If only one hand is used while dragging this may promote an oblique lipping (or twisted convex transverse profile).

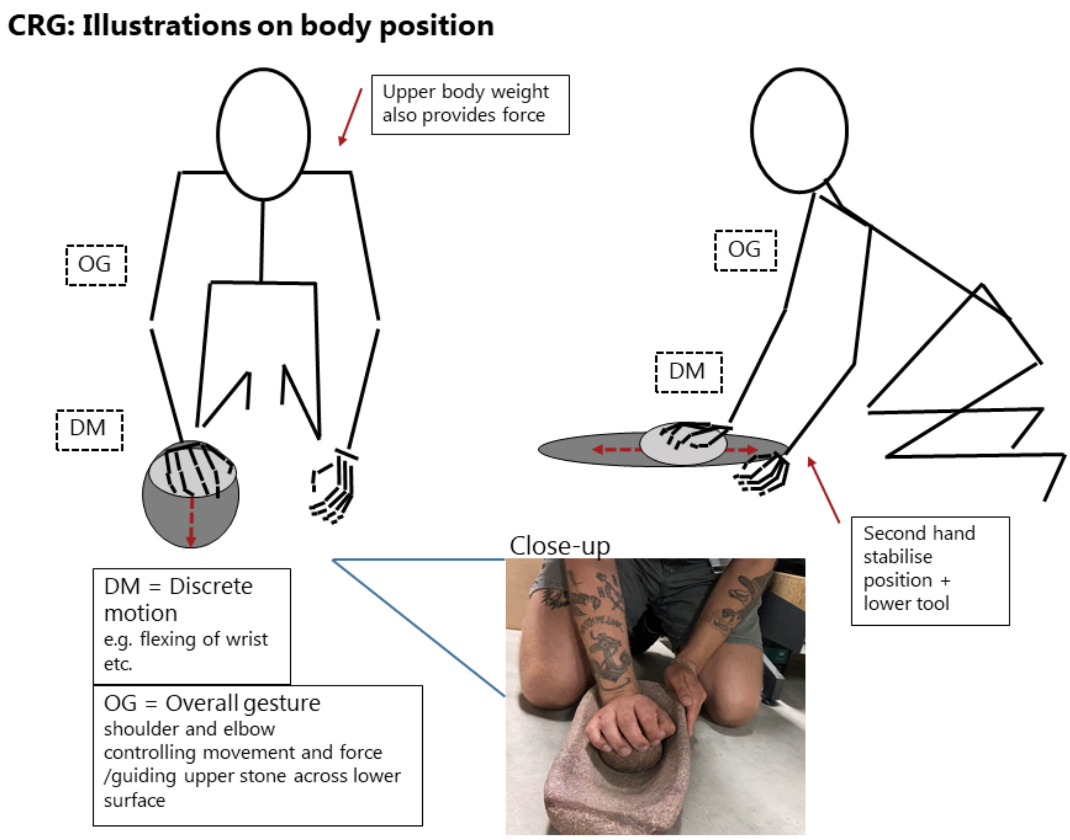

Figure 5: A1. CRG Body positions, gesture

A1. CRG - wear progression summary

1. **Before use**
    a. Lower tool (Level 0): The used surface of the lower tool is at maximum width and length (planar) and at minimum depth and minimum longitudinal and transverse concavity.
        i. **Macro/micro** (Level 1-2): pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
    b. Upper tool (Level 0): : is at maximum width and length (planar), minimum longitudinal and transverse convexity as well as maximum thickness
        i. **Macro/micro** (Level 1-2): Pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
2. **Initial use stage**

As the two stones (upper & lower) engage each other and the intermediate material the following happens:

a. Lower tool (Level 0): depth and longitudinal and transverse concavity will begin to increase as the tool loses mass. The used surface's maximum width (planar) will at the same time decrease with this process, but the length will stay more or less the same
    i. **Macro/micro** (Level 1-2): Overall levelling begins at distal and proximal margins along with a wearing out of pecking pits. The lateral margins are also affected, but less and more slowly than the others. Striations and/or sheen may also appear at

these margins (possibly a result of most stone/stone contact). Some striations and/or sheen may also appear along these margins.
Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be most intense at the distal and proximal margins as these receive more pressure. A beginning linear longitudinal distribution/patterning of the wear.

b. Upper tool (Level 0): Thickness will begin to decrease as the tool loses mass. The used surface's maximum length (planar) will decrease with this process, but the width stays more or less the same. Minimum longitudinal and transverse convexity will increase. However, see *Surface wear management upper* further below for details. Upper stone may also become more ovate and less rectangular as the corners of the stone wear; from stone-stone contact with walls and edges of the confined depression/basin.
    i. **Macro/micro** (Level 1-2): Overall levelling begins at the distal and proximal margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). The lateral margins are also affected, but less and more slowly than the others. Depending on contact material beginning micro-fractures, grain rounding and/or grain levelling across the surface. May be more intense outside of the centre and at distal and proximal margins as these receive more pressure. A beginning linear, transverse patterning in the distribution of wear

3. Continued use stage

As use continues through cycles of processing with the tools and re-pecking of both upper and the lower tools, both lose mass. However as the lower face becomes deeper (a new upper tool can always be introduced), a technological choice has to be made to continue to use the same face or to establish a new face somewhere else on the tool. Here I have assumed use continues on the same face, in a smaller area (but see a more detailed explanation below in *Surface wear management*). Either way on the new face, the previous process repeats itself. The following happens:

a. Lower tool (Level 0): Depth and concavity of the original face stop increasing as or if (!) a smaller area is used and a "new" face starts, set through the old face. This has a new minimum depth, longitudinal and transverse concavity and maximum planar size.
    i. **Macro/micro** (Level 1-2): previous process repeats on this new face, erasing older wear. First of overall levelling again begins at the proximal and distal margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at all margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense around the centre and at proximal and distal margins as these receive more pressure. More pronounced linear, longitudinal patterning in the distribution of wear. Possibly intensifies on this new face.

b. Upper tool (Level 0): Length and thickness continue to decrease as the tool loses mass, also erasing older wear. Convexity, especially transverse, will continue to increase (again see *Surface wear management upper*).
    i. **Macro/micro** (Level 1-2): Overall levelling continues at the margins along with a wearing out of pecking pits, only a few now left at centre. Striations and/or sheen may also appear at margins, possibly moving further in. Depending on contact material more pronounced micro-fractures, grain rounding and/or levelling across the surface. May be more intense outside of the centre and margins as these receive more pressure. More pronounced linear, transverse patterning in the distribution of wear. Upper stone may also become oval to discoidal, rather than ovate, as the corners of the stone continue to wear, again a result from stone-stone contact with walls and edges of the confined depression/basin.

4. Worn out stage

The final stage, i.e. before a new round of pecking or breakage (unintentional and/or intentional), discard, abandonment. Pits all worn out. Intense overall levelling across the face. Depending on contact material a microtopography of covering intense: grain rounding or levelling, and/or sheen across face. This stage is rarely found archaeologically, this is possibly because of intentional breakage(?) or immediate re-pecking/re-use.

Table 4: Wear progression summary for A1. CRG (see also *Appendix II: Processing strategies and idealised use and wear progression* for further details).

Surface wear management upper (individual wear)

The type of wear management and technological choices of the operator will have an effect on the morphology of the upper stone (see Figure 6) if, for example, wear is managed by exploiting both sides (faces) of the handstone. This will reduce the thickness faster as both faces lose mass and slow down (or negate) the increase in the convexity. Continued use on two faces will probably continue to decrease thickness and increase convexity steadily. If on the other hand the same face is used constantly, mainly the margins of the tool will lose mass, thickness decreasing slower, while convexity increases more quickly.

Presence of pecking pits at centre and most levelling at proximal and distal margins, as well as some on the edges of lateral sides may be a result of the least stone/stone contact happening at centre (Martinez et al. 2013) or rather more contact with the intermediate material there (as noted in Table 4, see also Figure 11, Area 1).

Most of the grinding happens at the margins as the upper stone is moved, pressing forwards and backwards by the operator (Dietrich et al. 2019; Dietrich and Haibt 2020), material being pressed down with the proximal and distal margins. Some ovate handstone examined from Shubayqa 6 (Late Natufian-EPPNA phase) feature one flat-flat surfaces and one opposed face that is convex, indicating that one of the surfaces was used in an initial stage where the lower stone surface was flat or very shallow or: on a lower face (tool) of that morphology. This highlights the dynamism and progression of wear, from shallow to concave/sloped, from flat to convex and so on.

Surface wear management lower (individual wear)

Again we may note that the way wear is managed, will have an effect on the lower stone). Wear may be managed by using a smaller area on the same surface (Figure 6, "stepped" face and see examples in Adams 2002, fig. 5.8; Wright 1994, fig. 3.) or by opening a new surface (e.g. on the opposite side). As the first lower face becomes deeper this active surface (through agent/operator choice) will also progressively get narrower (smaller). The ridges/edges/rim become higher and the shape more concave, and grinding is possibly more comfortable (or easily) achieved in the centre within a narrower/smaller surface, an area smaller than the previous face maximum extent. These choices and related limitations, thus creates a "stepped" face as seen here in Figure 6 (see also archaeological example in Figure 18B, though from a different strategy), with a more confined face, that "restarts" the first stages of wear. Notably, most of the grinding happens at the margins, (as with the upper stone) as the material is moved, pressing forwards and backwards by the operator causing the material to be pressed against the lateral sides (walls) of the lower face as well as against the proximal and distal margins (cf. Dietrich et al. 2019; Dietrich and Haibt 2020).

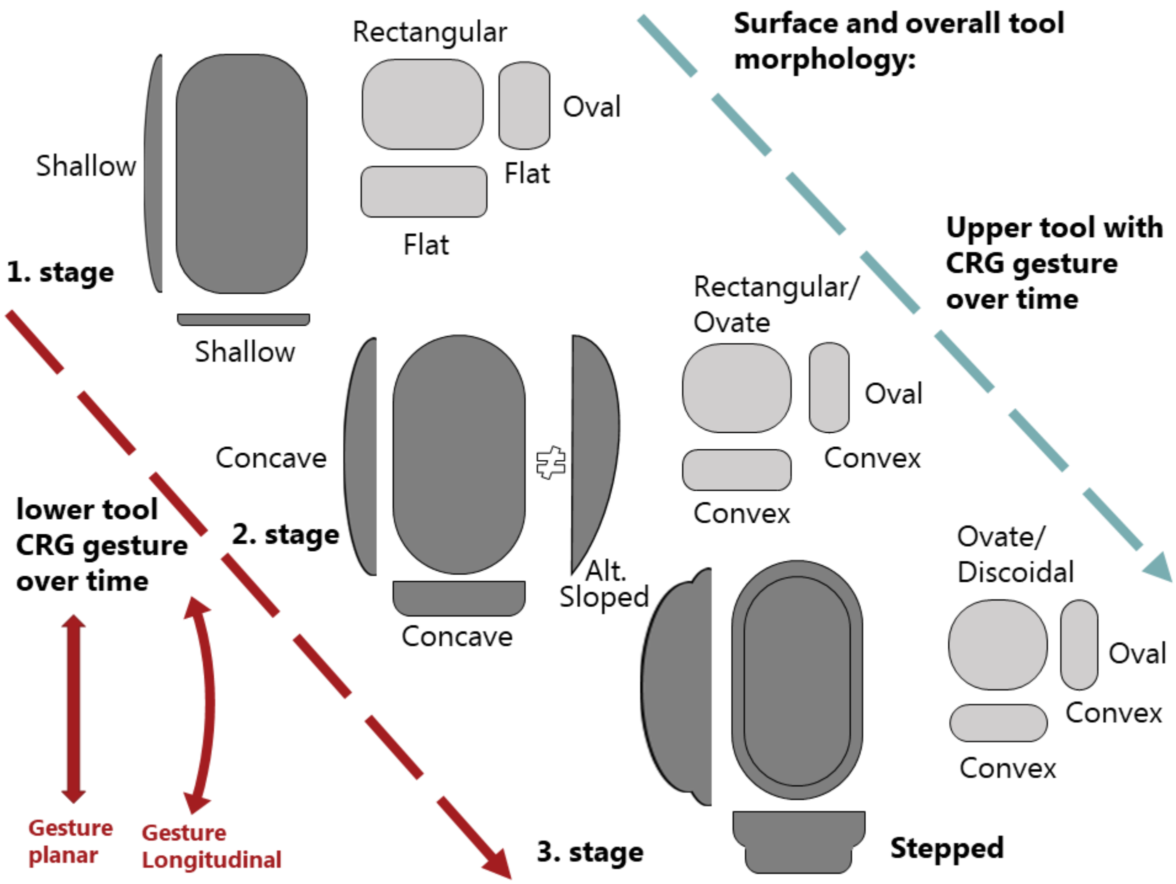

Figure 6: Idealised trajectories of both upper and lower tools individual wear, in an overall view. Note the difference in pendular vs. oblique gesture, i,e. concave vs. sloped longitudinal profiles. Note also the opening of the second face within the previous surface. All fall within the CRG strategy.

The A1. CRG strategy is made of the following tool pairings (or "resulting" tools). Upper stone tool types are Ovate, Rectangular or Square handstones, the lower stone tool types are Basin slabs or Trough slabs (see Figure 7, 8 and 9). Shapes (especially transverse and longitudinal) change as the wear progresses through the different stages.
It is suggested here that Ovate-type handstones are most commonly used in confined reciprocal grinding, in narrow basin type slabs (see Figure 6 and 7). If so they should be dominated by flat longitudinal profiles (see Table 1 and Figure 8) but also being confined within a narrow depression, they will feature some convexity (see Figure 8), especially as the depression becomes deeper (transversely) from shallow to concave (as mentioned in Table 4 and see Figure 9). Transverse profiles should tend to be convex (i.e. oval, lens or tapered profiles, following Wright 1992a), which is caused by the handstone being pushed from the proximal end and then dragged back from the distal end of the confined basin (see Table 4 and Figure 5). The length of a particular hand stone compared with the width of use faces of the suggested corresponding lower tool, may also be used as an indicator as to whether these

upper stones would fit into their corresponding lower tools (Kadowaki 2014) which the Shubayqa 6 Ovate-type handstone appear to do (see Table 5 and Pedersen 2021).

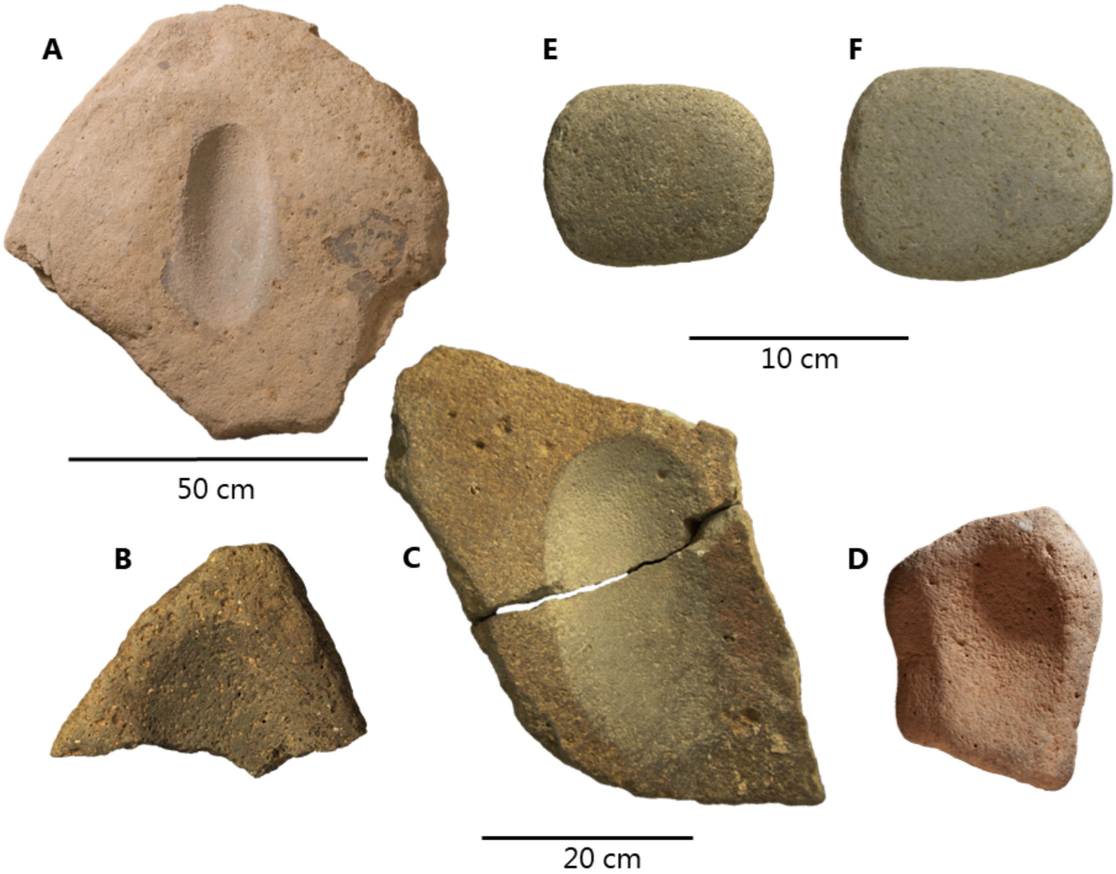

Figure 7: Archaeological examples of A1. CRG basalt tools from Shubayqa 1 and 6: A-C + E-F La te PPNA-Early PPNB examples, D Late Natufian phase. A-D lower tools, basin slabs E-F Upper tools, ovate/rectilinear handstones. (photos A. Pantos / Shubayqa Archaeological Project).

A1. CRG	sub-types (*n* =)	complete	fragments	**total**
Handstones	ovate = 93 rectangular = 11 other = 4	84	24	**108**
Slabs	basin = 16 trough = 2	9	9	**18**
total		**93**	**33**	**126**
Size *Only from complete (n = of complete)*	**length** mm	**width** mm	**thickness** (upper) or depth (lower) mm	**surface area** (calculated as ellipse: a x b x π). In cm²

Upper tool Handstone (n = 84)	max.: 150 min.: 46 avg.: 103,1	max. 120 min. 36 avg. 82,7	max. 99 min. 18 avg. 49,5	a 65,05 mm x b 41,35 mm x π = avg. **84,50 cm²**
Lower tool Slabs (n = 9)	max. 400 min. 305 avg. 354,4	max. 252 min. 140 avg. 178,3	max. 70 min. 13 avg. 39,2	a (177,20 mm) x b (89,15 mm) x π = avg. **496,28 cm²**

Table 5: Overview of CRG tools in both Shubayqa 1 and 6 assemblages, all phases (see also Table 3). Including tool sub-type and sizes. Sizes are based on complete tools. max. = maximum, min. = minimum, avg. = average.

I note that there is probably some overlap between the upper stones (handstones) that were used for different strategies (like: ORG, CRG and RGP, see below). There are *fuzzy* boundaries (see Adams 2002: 1-16) between tool categories and between each strategy and these boundaries are, as mentioned, both dynamic and progressive. Elongated upper stones, like the ovates, here attributed to the CRG strategy, could potentially also be used in ORG (larger, longer ones) and in RGP (shorter, more oval ones). Concurrently, some discoidal or circular upper stones may have been used in confined reciprocal, but I here contend that most ovate are used in reciprocal grinding and most discoidal in circular grinding strategies (as does Kadowaki 2014) and this is supported by the use-wear data from Shubayqa (see Table 6). Further archaeological and ethnographic examples of basin/trough confined reciprocal grinding paris can be found in: (Adams 1993, 2002; Kadowaki 2014; Nierle 2008; Rosenberg and Gopher 2010; Dietrich et al. 2019; Dietrich and Haibt 2020).

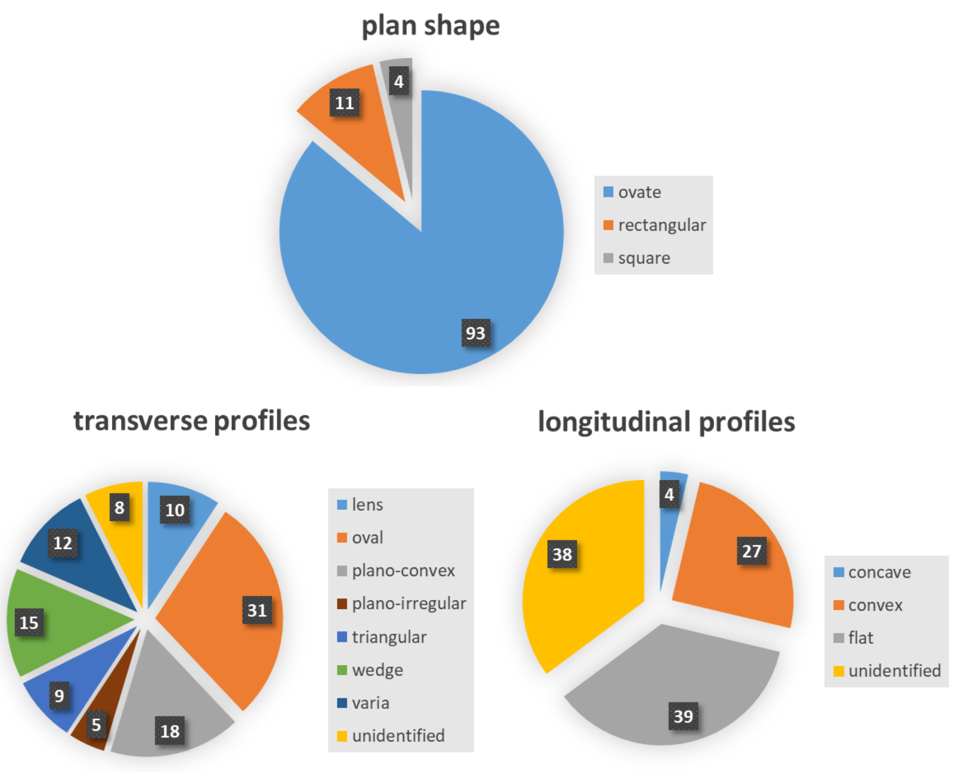

Figure 8: CRG upper tools shapes, handstone plan and transverse and longitudinal profiles of active surfaces

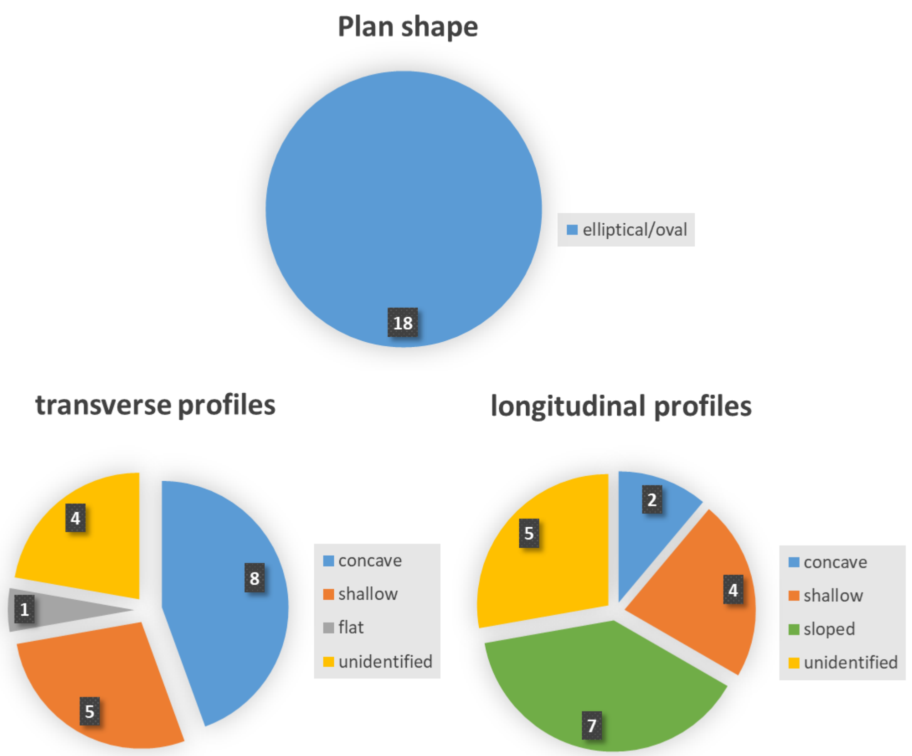

Figure 9: CRG lower tools shapes, handstone plan and transverse and longitudinal profiles of active surfaces

For the CRG strategy, important macro/microscopic correlates are:
1. Pecking pits concentrated longitudinally at centre
2. Overall levelling ("homogeneous zones") most pronounced at proximal and distal margins.
3. Striations and/or sheen at proximal and distal margins
4. Pronounced linear, transverse distribution/pattern of striations and other types of wear
5. (overall) Use face profiles are Convex (upper, transverse) and Concave or Sloped (lower, longitudinally).
At least three of these characteristics should occur in combination.

Note that in the following tables (starting with table 6), that the *traces* is the total of all traces with discernable direction/orientation. Here, they are separated into upper and lower tools. The separation between upper and lower tools within the CRG strategy, and within reciprocal grinding tools generally (see also A2. ORG), is pertinent because for the upper tools transverse traces indicate the same use direction as longitudinal traces do in lower tools. Meaning that transverse (upper)/longitudinal (lower) equals reciprocal along the same axis (see Table 6).

			Location				
Selected Overall Traces	*present*	*absent*	Covering	Centre	Lateral margins	Distal proximal margins	Mixed
Pecking pits	85%	15%	33%	**52%**	-	-	15%
Levelling	100%	0%	92%	-	-	**8%**	-
Striations	15%	85%	67%	-	-	**33%**	-
No. of tools: 30 **Upper:** 25 **Lower:** 5			**Direction**				
Examined Surfaces: 39	**Patterned traces* (PT)**		Random	Transverse	Longi-tudinal	Circular/ concentric	Oblique

	Upper tools (n of PT =60)	5%	**75%**	7%	5%	8%
	Lower tools (n of PT =10)			**100%**		
	Total (n=70)	4%	**65%**	**20%**	4%	7%

Table 6: Macro/microscopic correlates of CRG strategy, data from Shubayqa 1 and 6. *A total of all traces with discernable direction. From: striations, fractures, grain extraction and pit orientation

The *traces* examined, as mentioned are: striations, fractures, grain extraction and pit orientation, which all inform kinetics and use (i.e. gestures and labour) following (Adams et al. 2009).

Some archaeological examples

Figure 10 and 11 show some archaeological examples of the abovementioned wear stages, where some of the macro/microscopic correlates and some of the patterned traces may be observed. An archaeological example of a broken lower tool (grinding slab) at (wear) Stage 1 is seen in Figure 8. It shows a heavily pecked use face; with pecking marks across the use face, but especially concentrated near the centre (Area 1 and 2 in Figure 10). No clear directionality can be discerned from these traces. However, there appears to be a beginning “rounded” levelling as well as grain rounding at the margin Area 3 (see Figure 10, Area 3). This would suggest that the tool has seen some light use. Concurrently the presence of this levelling and rounding at the margin shows a progression, the beginning of Stage 2, starting at the margins as is also described in Table 4.

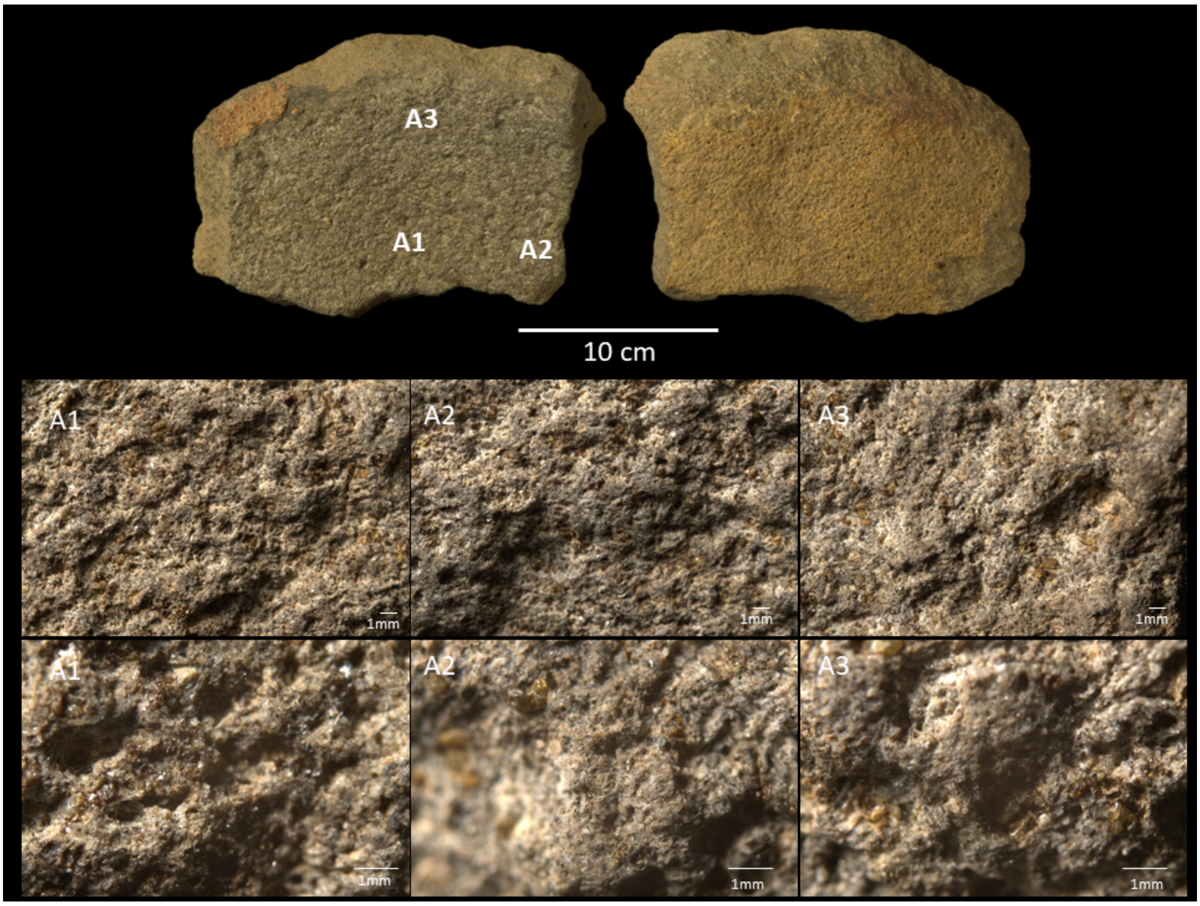

Figure 10: CRG: Archaeological example "Stage 1" lower tool (Shubayqa 6: PPN). Microscopic use-wear photographs. Areas 1-3 (A1-3) indicates "Areas" on the tool, see the plan overview (above) for location. First row shows areas at low magnification, the second row shows the same areas at higher magnification (see scale bar). Photos A. Pantos / Shubayqa Archaeological Project.

In contrast, to the unused (or lightly used) example above, Figure 11 below shows a handstone that has seen extensive use, classified as Stage 3 here (see also Table 4). This can be seen in the intense levelling of both groundmass and phenocrysts across the use-face (Figure 11, Areas 1-3). The directionality of traces is here pronounced (as defined in Figure 2), note for example the transverse macro-striation in the centre of the handstone (Figure 11, Area 1, white arrow) and the distribution of the few remaining pecking marks across the use-face (Figure 11, Area 1-3). Very few pecking marks or interstices are present, especially at the proximal/distal margin (Figure 11, Area 2). The macroscopically visible "lipping" of levelling over the proximal/distal margin, (Area 2 in Figure 11, top row, white arrow) also indicates both a use direction and also the above mentioned "discrete" motion: the "rocking" of the handstone on the back-and-forth stroke causing levelling to extend beyond the proximal/distal margins. Furthermore, the slight lipping on the lateral margin (Figure 11, Area 3 top row), indicates its probable use within a confined basin.
The pronounced wear, again, is an indication of the progression of wear, in contrast to the above example and figure, with no discernible patterning or directionality.
These traces appear to confirm the gesture and strategy. The overall morphology of this handstone however, suggests heavy use but within a still shallow basin. The handstone is

fairly long (over 10 cm) and though it features a convex transverse profile, the longitudinal profile is still flat, indicating a "shallow" lower basin. This again hints at the dynamic dialectical relationship between the overall morphology and the macro/microscopic wear: the overall morphology changes much slower and changes *precisely* through *repeated cycles* of macro/microscopic wear *stages*: initial and continued use, wearing out, re-pecking and then starting again. A basin will take a "long time" (though this is of course relative) to become deeper, unless the basin was intentionally re-pecked/re-worked into being deep/deeper.

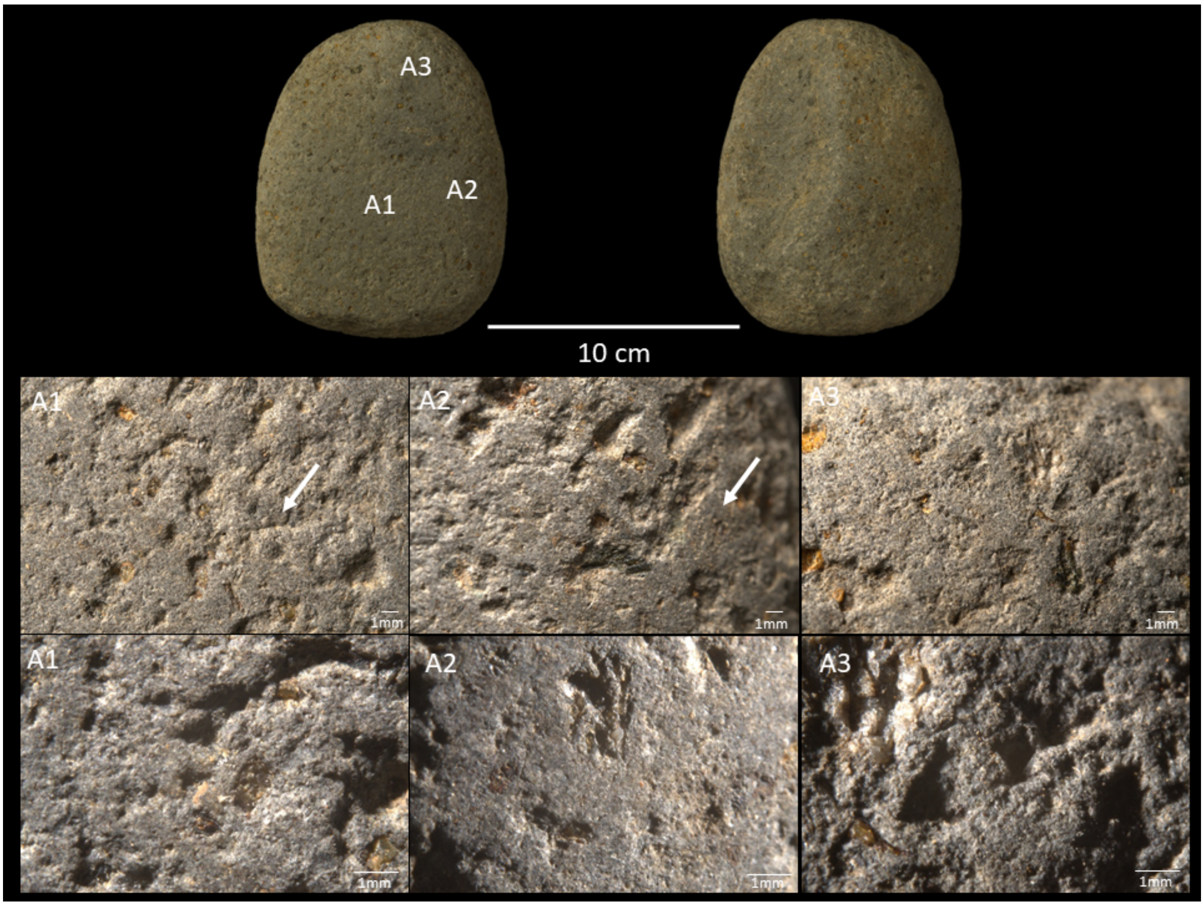

Figure 11: CRG: Archaeological example "Stage 3" upper tool (from Shubayqa 6: PPNA-phase). Heavily used across the use face (in contrast to "Stage 1" in Figure 8 above). Areas 1-3 (A1-A3) indicates "areas" on the tool, see the plan overview (above) for location. First row shows areas at low magnification, the second row shows the same areas at higher magnification (see scale bar). White arrow in Area 1 (top row) highlights a transverse striation. White arrow in Area 2 (top row) highlights transverse lipping extending over the proximal/distal margin. (Photos A. Pantos / Shubayqa Archaeological Project).

A2. Open Reciprocal Grinding (ORG)

Gesture: Linear, reciprocal, back-and forth grinding with an upper stone against a flat to convex (transversely) surface of the lower stone. The active surface covers more or less the entire surface of both lower and upper tools. In this strategy the lower tool surface is sometimes longitudinally concave, like in "saddle"-slab pairs (e.g. Delgado-Raack and Risch

2009; Lidström Holmberg 2004; Stroulia et al. 2017) however, in the Shubayqa assemblage most have lower tools have flat surfaces (see below). The upper stone may be moved freely across the entire surface of the lower allowing some variation in strokes, e.g. diagonal. The action will primarily be performed using two hands, to control the elongated upper stone (Figure 12). The force and pressure in this gesture is exerted from the shoulders, also using the weight of the upper body. Most of this force is created proximally, closest to the operator, but force may also be produced distally, if the upper stone is dragged and pressed down on the backwards stroke (see in Adams 1993, 2002 and also "discrete motion" below). The upper tool mainly operated with two hands (e.g. Alonso 2019; Robitaille 2016; Shoemaker et al. 2017) (see Figure 13).

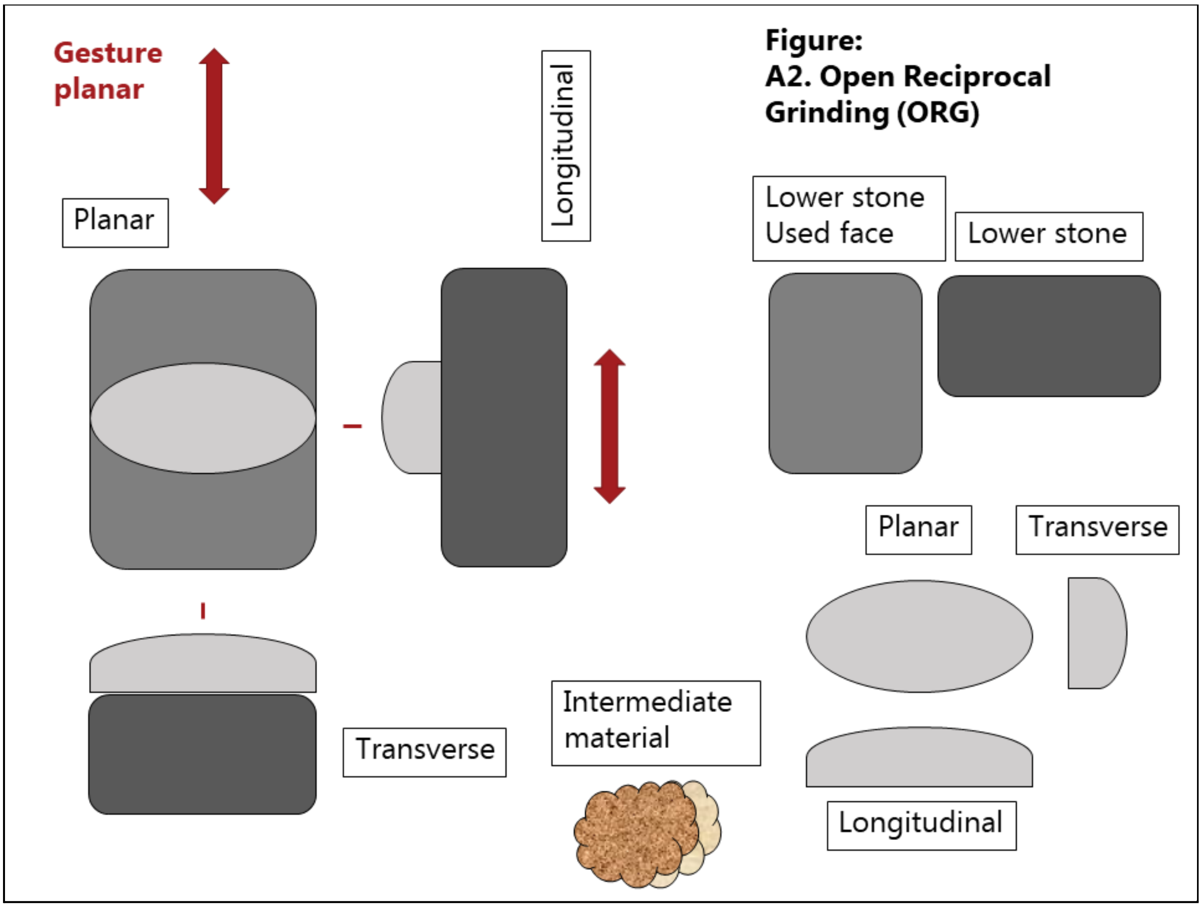

Figure 12: Illustration of A2. ORG. Overall idealised processing strategy and tools: Block slab and loaf shaped handstone (plano-convex/flat profile[s]).

Discrete motion: Rocking/dragging, i.e. pressing down with the base/proximal part of the palm and thumb, flexing the wrist backwards, while stroking away from body, activating mainly the proximal margin of the upper tool and then pressing down with the fingers, flexing the wrist forward activating mainly the distal margin of the upper tool.[12]

[12] In some places, e.g. Mesoamerica and East Asia, upper stones are "rolled", i.e. a cylindrical/cigar/barrel-like handstone (circular transverse profile) is rolled by operator as it is moved back and forth, seen in some types in Eastern Asia and Mesoamerica (see Liu et al. 2010 and Searcy 2011 for examples)

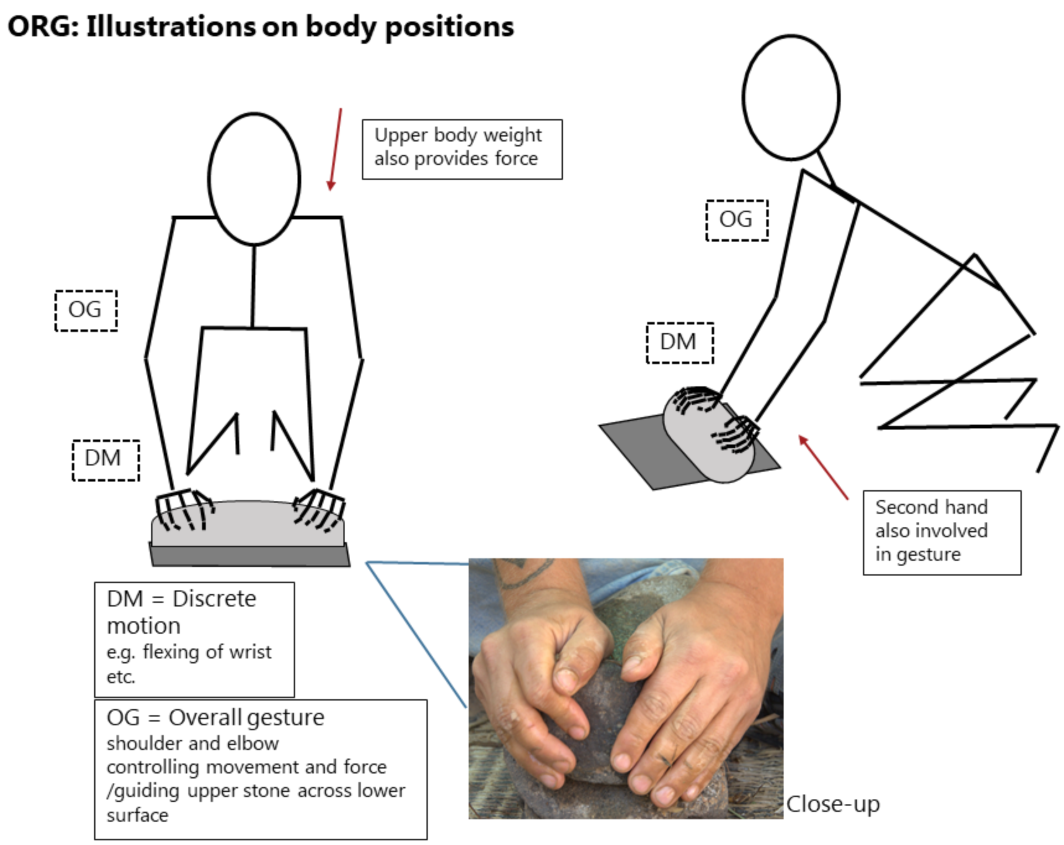

Figure 13: A2. ORG - Body positions, gesture

A2. ORG - wear progression summary

1. **Before use stage (equal handstone)**
    a. **Lower tool** (Level 0): The used surface of the lower tool is at maximum width and length (planar)and minimum transverse convexity.
        i. **Macro/micro** (Level 1-2): pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
    b. **Upper tool** (Level 0): Tool is at maximum width and length (planar)minimum longitudinal convexity and maximum thickness
        i. **Macro/micro** (Level 1-2): Pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
2. **Initial use stage**
    a. **Lower tool** (Level 0): The used surface width and length (planar) is more or less unchanged but thickness decreases as mass is lost. Possibly beginning of a slight increase in transverse convexity of lower tool
        i. **Macro/micro** (Level 1-2): Pecking pits start wearing out at distal and proximal margins. Overall levelling (and possibly also striations and sheen) at these margins, especially the proximal. A beginning linear (longitudinal direction) pattern and distribution of wear

b. **Upper tool** (Level 0): The used surface of the upper tool width and length (planar) is more or less unchanged. Possibly beginning of a slight increase in transverse concavity of the upper tool. Thickness decreases as mass is lost.
   i. **Macro/micro** (Level 1-2): Pecking pits start wearing out at distal and proximal margins. Overall levelling (and possibly also striations and sheen) at these margins, especially the proximal. A beginning linear (transverse direction) pattern and distribution of wear

3. **Continued use stage**
   a. **Lower tool** (Level 0): The used surface of the lower tool, width and length (planar) is more or less unchanged. Thickness continues to decrease. Possibly a continued slight increase in transverse convexity of the lower tool.
      i. **Macro/micro** (Level 1-2): Pecking pits continue wearing out at distal and proximal margins, as well as lateral margins (if transverse convexity increased). Overall levelling (and possibly also striations and sheen) continues to be more pronounced at these margins, especially the proximal. Also more pronounced linear (longitudinal direction) pattern and distribution of wear
   b. **Upper tool** (Level 0): Either use continues and thickness decreases but with plano-convex transverse profile intact or a new face on the opposite side (or elsewhere) may also be opened. Either way the used surface of the upper tool is at maximum width and length (planar) is more or less unchanged.
      i. **Macro/micro** (Level 1-2): Pecking pits wearing out, mostly gone at proximal and distal ends, distributed near centre longitudinally interrupted by more and more pronounced transversely distributed overall levelleled and homogeneous zones and possibly striations, polish and sheen. Striations and sheen may be especially pronounced proximally. A generally pronounced linear (transverse direction) pattern and distribution of wear.
4. **Worn out stage**

Same as the table above.

Table 7: Wear progression summary for A2. ORG (see also *Appendix II: Processing strategies and idealised use* for further details).

Wear management (individual wear) upper and lower

Wear management appears to be very much dependent on the size of the upper stone used (Delgado-Raack and Risch 2009, 2016; Lidström Holmberg 2004; Stroulia et al. 2017). For example movements with an upper stone that is longer than the width of the lower tool will create a convex (transversal) lower used surface and a concave (longitudinal) handstone. Movements with an upper stone that is equal to the width of the lower will create a flat or concave (longitudinal) surface and a flat (transversal) used surface of the lower tool. The use profile of the upper tool will be flat (longitudinal) to slightly convex (transverse) (see Table 7 and Figure 14). Movements with an upper stone that is shorter than the width of the lower tool will promote a concave longitudinal and concave transversal surface of the lower tool, with ridges on the edges of the used surface, creating a "basin" over time (potentially becoming a CRG tool). The upper tool profile will be convex both longitudinally and transversely (*e.g.* oval or lens shaped). Here I chose to engage only with a trajectory of wear based on a handstone of equal length, for the sake of brevity and as this is the type that seems to appear at Shubayqa, but see (Delgado-Raack and Risch 2009, 2016; Stroulia et al. 2017) for details on these other types. Opening of a second face on the upper stone seems to be very common among the handstone at Shubayqa 1 (Pedersen et al. 2016). This causes the transverse profile to change to triangular (see Figure 12) if held at an angle, or results in an "oval" or "flat" profile (Wright 1992a) with two directly opposing used surfaces if held "straight" (see also Adams 2002, fig. 5.12).

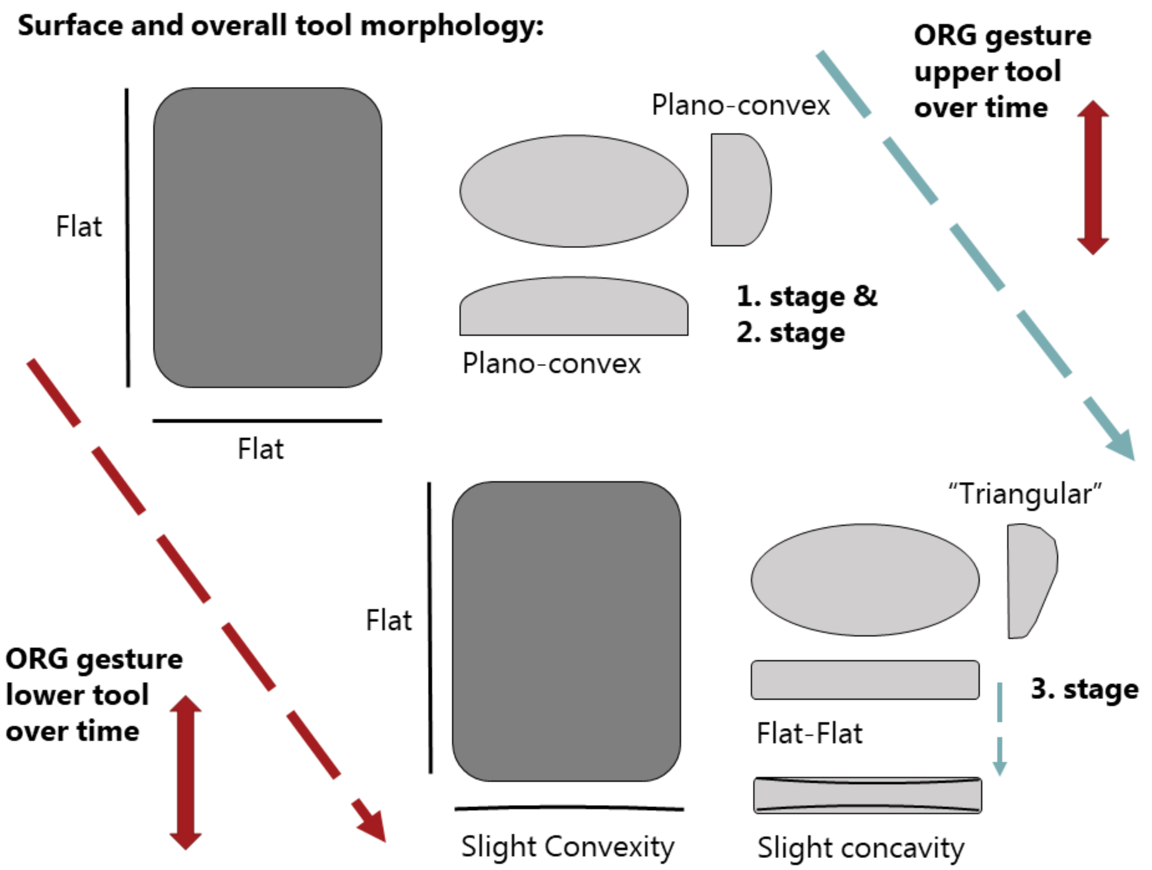

Figure 14: Idealised trajectories of both upper and lower tools individual wear, in an overall view.

The A2. ORG strategy is made of the following tool pairings (or "resulting" tools) in the Shubayqa assemblages. The upper stones are loaf-type handstone (including loaf tapered loaf-type see in Pedersen et al. 2016) and the lower stones are block-type or saddle-type grinding slabs. Primarily, these are flat block-type grinding slabs in the case of the Shubayqa assemblages (see Figure 15 below). The planar shape of the upper tool within this strategy is by definition elongated.The loaf-type handstone may vary in exact shape between: rectilinear, rectangular, oval or elliptical (loaf-tapered) however, all are longer than they are wide and usually longer than 10-12 cm (see Table 8, also by Wright 1992a). In conjunction, these handstones feature transverse profiles that are flat to slightly convex (e.g. triangular or plano-convex) and longitudinal profiles that are flat to slightly concave (see Figure 14 above and Figure 16 + 17). These profiles would suggest use, gestures that are mainly reciprocal motions. Concurrently the lower tools' use-faces should then be (longitudinal and transverse): flat-flat, concave-flat, flat-convex following (Delgado-Raack and Risch 2009, 2016; Lidström Holmberg 2004; Stroulia et al. 2017). This seems to be the case at Shubayqa, that most of these ORG pairs are flat-flat upper tools and flat-flat lower tools (see Figure 16 and 17), with a slight tendency towards transverse convexity for lower tools and slight longitudinal concavity for upper tools (see Figure 16).

Again, there may probably be some overlap in the upper stone used for ORG and CRG (see below). Some ovate type handstone may have been used in open grinding, either before a depression formed or where none was ever prepared.

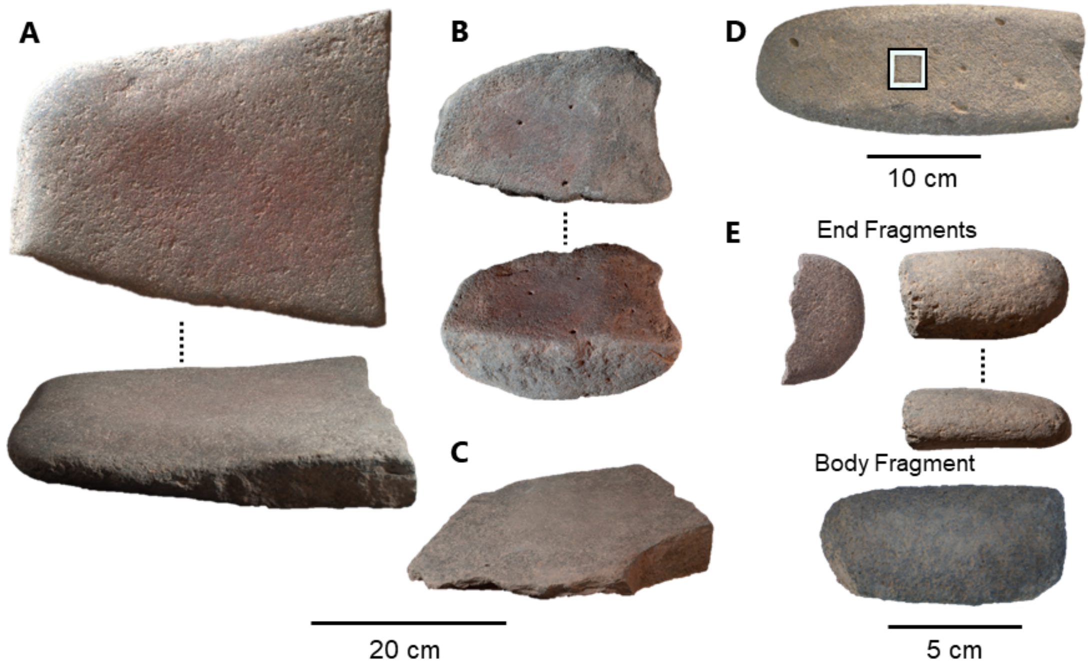

Figure 15: Archaeological examples of A2. ORG basalt tools from Shubayqa 1: all Late Natufian phase. A-C lower tools, D-E upper tools. A + B feature pigment (ochre) on their surface. D is a large multiple-tool both used for grinding and pounding (the square indicates one of the use-wear locations). Note the end and body fragments (E) of loaf-type handstone, a type which was frequently retrieved from the Late Natufian phase at Shubayqa 1. (photos A. Pantos / Shubayqa Archaeological Project).

A2. ORG	sub-types (*n* =)	complete	fragments	**total**
Handstones	loaf (+ loaf tapered) = 281	18	263	**281**
Slabs	block/boulder = 25 saddle = 7	11	21	**32**
total		**29**	**284**	**313**
Size *Only from complete*	**length** mm	**width** mm	**thickness** (upper) or	**surface area** (calculated as

(n = of complete)			depth (lower) mm	rectangle: a x b) In cm²
Upper tool Handstone (n = 17)[13]	max. 200 min. 57 avg. 117,9	max. 87 min. 33 avg. 55,7	max. 48 min. 20 avg. 33	a 117,9 mm x b 55,7 mm = avg. 65,67 cm²
Lower tool Slabs (n = 11)	max. 370 min. 147 avg. 249,6	max. 320 min. 87 avg. 189,1	N/A	a 249,6 mm x b 189,1 mm = avg. 471,19 cm²

Table 8: Overview of ORG tools in the assemblages of both Shubayqa 1 and 6, all phases (see also Table 3). Including tool sub-type and sizes. Sizes are based on complete tools. max. = maximum, min. = minimum, avg. = average.

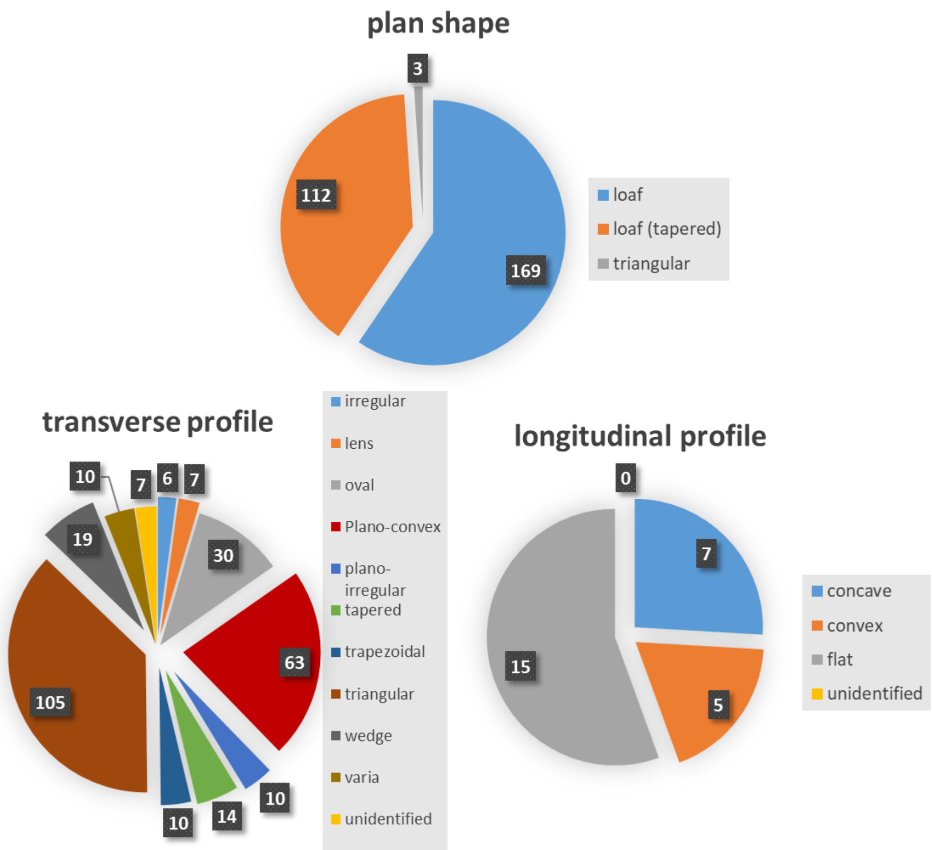

Figure 16: ORG upper tools shapes: handstone plan and transverse and longitudinal profiles of active surfaces. Unidentified longitudinal profiles (*n= 254*) excluded.

[13] *Excluding one re-used fragments*

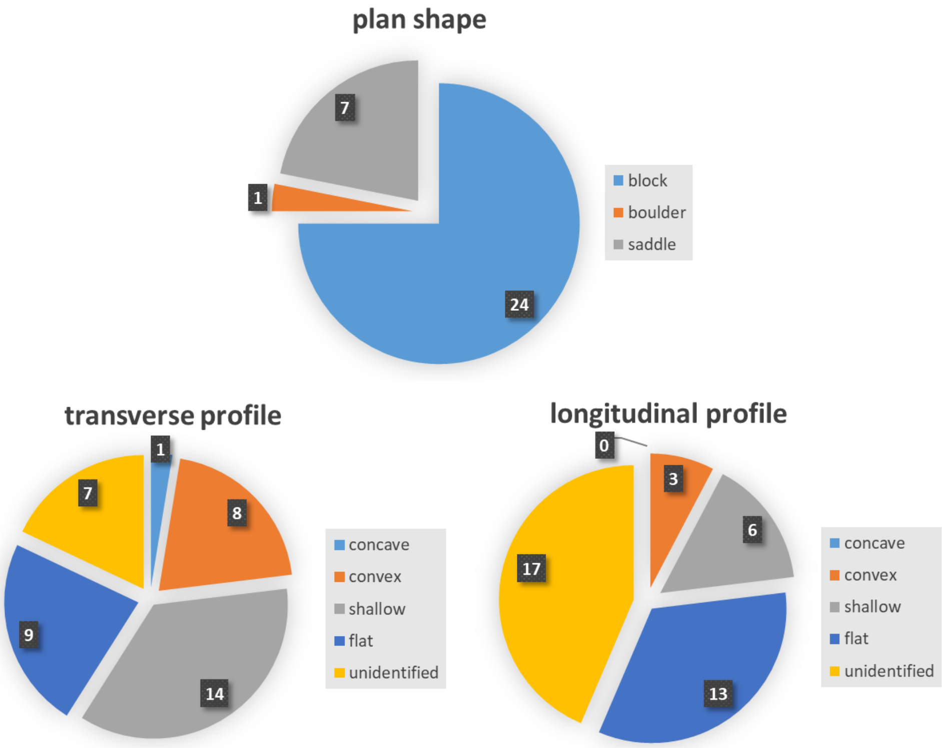

Figure 17: ORG lower tools shapes: grinding slab plan and transverse and longitudinal profiles of active surfaces

For the ORG strategy the important macro/microscopic correlates are:
1. Pecking pits concentrated longitudinally at centre
2. Overall levelling ("homogeneous zones") most pronounced at proximal and distal margins.
3. Striations and/or sheen at proximal and distal margins
4. Pronounced linear, transverse distribution/pattern of striations or other types of wear
5. (overall) Mostly flat/flat transverse and longitudinal profiles of both upper and lower tools.
At least three of these characteristics should occur in combination.

			Location				
Selected Overall Traces	*present*	*absent*	Covering	Centre	Lateral margins	Distal proximal margins	Mixed
Pecking pits	44%	56%	50%	50%	-	-	-
Levelling	100%	0%	78%	-	-	**22%**	-
Striations	33%	67%	**67%**	33%	-	-	-

No. of tools: 7 **Upper:** 6 **Lower:** 1		**Direction**				
Examined Surfaces: 9	**Patterned traces* (PT)**	Random	Transverse	Longi-tudinal	Circular/ concentric	Oblique
	Total (n of = 12) note only upper		**92%**	8%		

Table 9: Macro/microscopic correlates of ORG strategy, data from Shubayqa 1 and 6

*A total of all traces with discernable direction. From: striations, fractures, grain extraction and pit orientation

Some archaeological examples

Extensive work has been done on this type of processing strategy (see: Delgado-Raack and Risch 2009, 2016; Holmberg 2004; Lidström Holmberg 1998; Stroulia et al. 2017). It is not an uncommon strategy during the Late Epipaleolithic and Early Neolithic periods, both at Shubayqa and in SWA generally see (Dubreuil and Plisson 2010; Pedersen et al. 2016; Moore 2000), but the large saddle-type grinding slab and loaf-type handstone in particular became very dominant by the Late Neolithic (Wright 1992b, 1993; Ebeling and Rowan 2004), Chalcolithic and Bronze age in Western Asia (Rosenberg 2012), as well as in Northern Africa (Ebeling and Rowan 2004) and also in Europe (Alonso 2019; Delgado-Raack and Risch 2009, 2016; Stroulia et al. 2017; Lidström Holmberg 2004). Modern ethnographic examples of this processing strategy and its tools are still very common (e.g. Alonso 2019; Hamon and Le Gall 2013; Nixon-Darcus and D'Andrea 2017; Robitaille 2016; Searcy 2011; Shoemaker et al. 2017). Consequently, the relationship between upper and lower tool, gesture and resulting morphology, i.e. where wear starts to appear on the use-face (Delgado-Raack and Risch 2016), what gesture is behind the tools and what upper and lower use-faces is quite well understood by GST specialists (see Delgado-Raack and Risch 2009, 2016; Lidström Holmberg 2004; Stroulia et al. 2017). Therefore, a closer examination of this strategy is not elaborated here. Suffice to mention, as was also noted above, that in the Shubayqa assemblage most of the ORG pairs are flat-flat (longitudinal-transverse) pairs.

An archaeological example of such a flat-flat grinding slab from Late Natufian Shubayqa 1 is seen in Figure 18 below. This example, in contrast to the progression of wear suggested above (see Table 7) and the suggestions of (Delgado-Raack and Risch 2016), has its wear (in this case levelling) concentrated at the centre (Figure 18, Area 1). This could suggest use of a handstone shorter than the lower stone, and perhaps with a longitudinal convexity. In most cases however wear is pronounced across the surface(see Table 9) and at distal and proximal margins margins (see in Delgado-Raack and Risch 2016), see also slabs A + C in Figure 15).

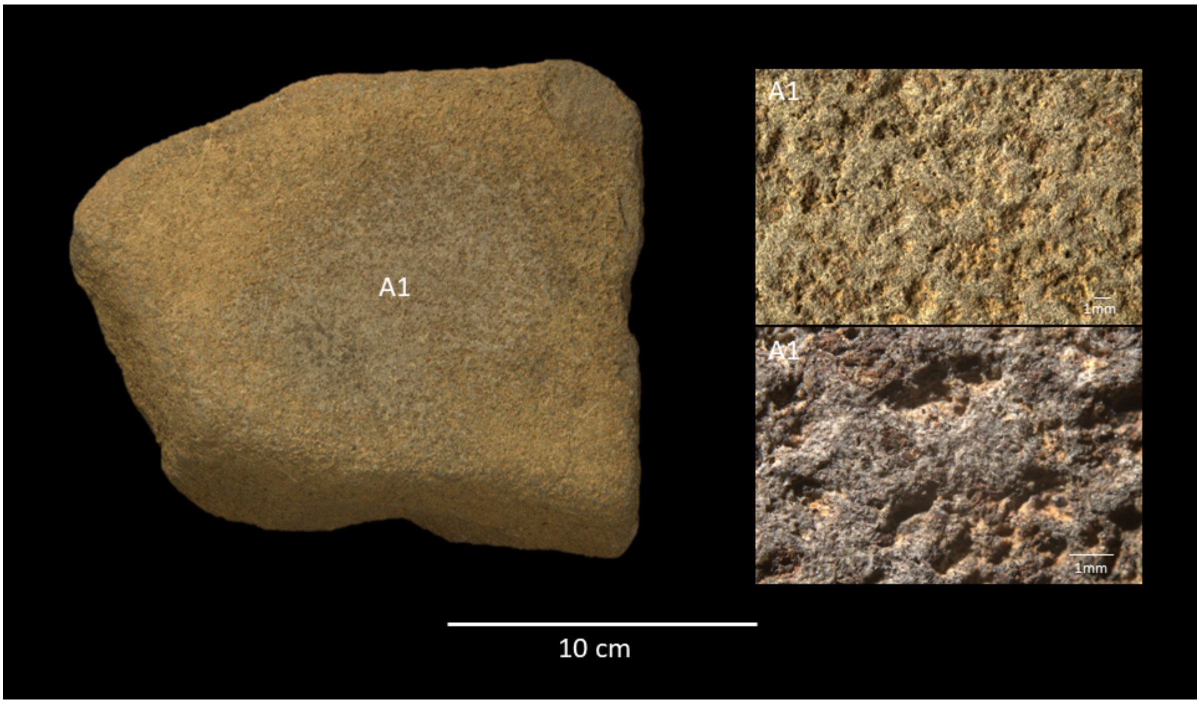

Figure 18: ORG: Archaeological example “Stage 2” lower tool (Shubayqa 1: Late Natufian). Area 1 (A1) indicates “area” on the tool subjected to microcopy, see the plan overview for exact location. Top shows area at low magnification, the second shows the same areas at higher magnification (see scale bar). An ad-hoc used slab. The use appears concentrated around the centre. Beginning linear directionality in traces, a beginning smooth levelling. (photos A. Pantos / Shubayqa Archaeological Project).

A3. Rotary Grinding with some Pounding: RGP

Gesture: Rotating, circular grinding using a circular/sub-circular upper stone in a shallow to concave (profile), circular to sub-circular (planar) depression of a lower stone. Stroke may vary greatly since the upper stone is moved more or less freely within this depression, i.e. circular, elliptical gestures while also allowing for linear or diagonal, reciprocal motions (Adams 1999). In addition, it may also include thrusting percussion within the lower tools active surface using the centre and or margins of the upper stone to crush/crack larger materials. Action primarily performed using one hand, pressure exerted by the arm, from shoulder and upper body (see Figure 19 and 20).

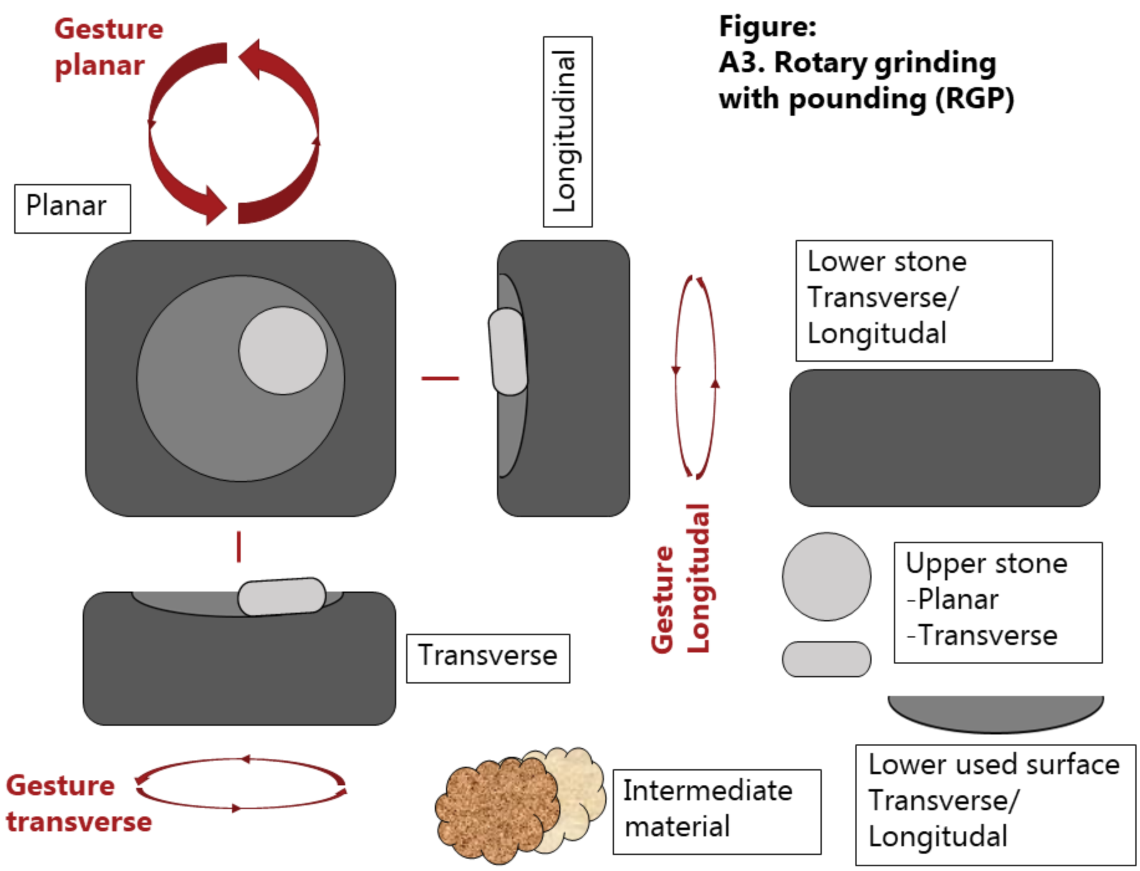

Figure 19: A3. RGP Overall idealised processing strategy and tools: discoidal/circular) handstone (oval/flat profile), basin quern (circular/oval surface with concave profile).

Discrete motion: The wrist is flexed backwards and the base of the hand presses down at the proximal margins of the tool as it moves away from the operator in a curve. On the return the pressure of the stroke is switched to the distal margins as the wrist flexes slightly forward dragging back in a curve (see also example in Adams 2002: 102, fig. 5.2).

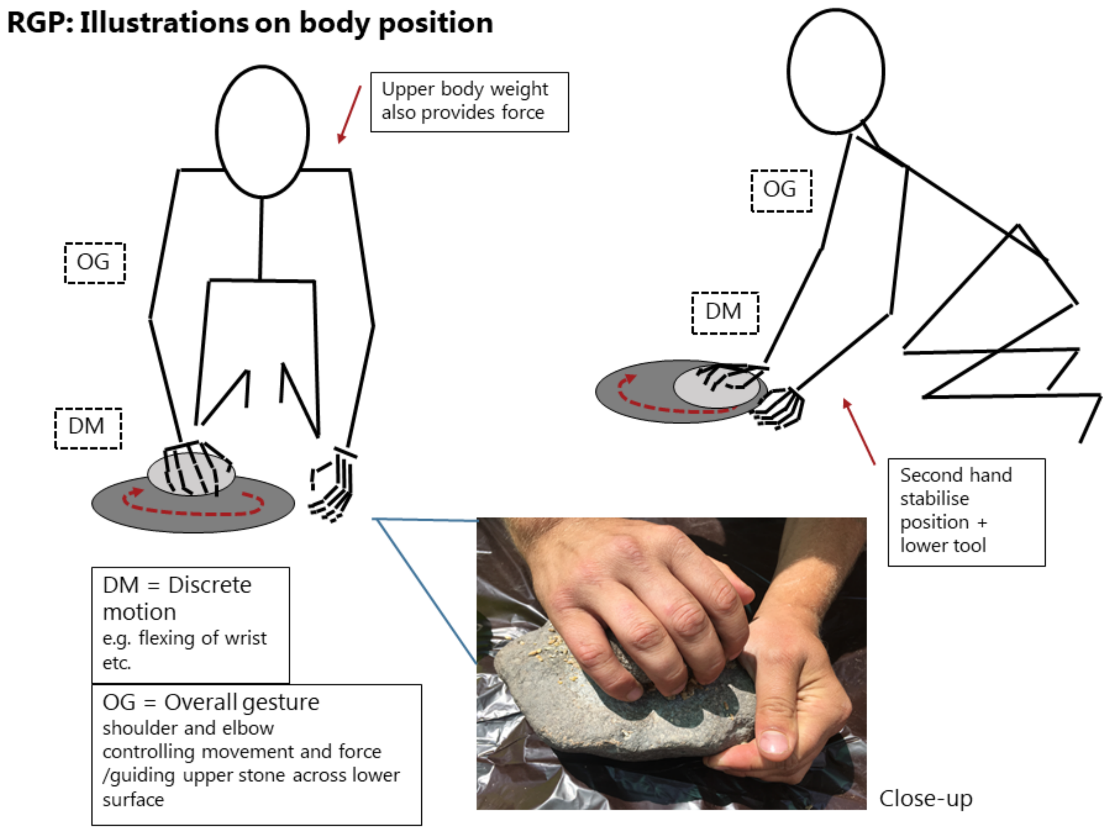

Figure 20: A3. RGP - Body positions, gesture.

A3. RGP - wear progression summary

1. **Before use stage**
   a. **Lower tool** (Level 0): The used surface of the lower tool is at maximum width and length (planar) and at minimum depth and minimum.
      i. **Macro/micro** (Level 1-2): pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
   b. Upper tool (Level 0): : is at maximum width and length (planar), minimum convexity, maximum thickness
      i. **Macro/micro** (Level 1-2): Pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass

2. **Initial use stage**

As the two stones (upper & lower) engage each other and the intermediate material the following happens:
   a. Lower tool (Level 0): depth and concavity will begin to increase as the tool loses mass. The used surface maximum width and length (planar) will at the same time decrease with this process.
      i. **Macro/micro** (Level 1-2): Overall levelling begins at the margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more

intense around the centre and margins as these receive more pressure. A beginning circular/concentric (patterning) in the distribution of wear.

   b. Upper tool (Level 0): Width and length (planar) and thickness will decrease as tool loses mass, convexity will increase too (however, see *Surface wear management upper* below). Convexity will increase too. However, see *Surface wear management upper* further below.
      i. **Macro/micro** (Level 1-2): Overall levelling begins at the margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense at distal or proximal ends and at margins as these receive more pressure. A beginning circular/concentric (patterning) in the distribution of wear

3. **Continued use stage**

As use continues through cycles of processing with the tools and re-pecking of both upper and the lower tools, both lose mass as was explained above. However as the lower face becomes deeper (a new upper tool can always be introduced), a technological choice is faced to continue use on the same face or to open up a new face somewhere else on the tool. Here I have assumed use continues on the same face, in a smaller area (but see a more detailed explanation below in *Surface wear management*). Either way on the new face the previous process repeats itself. The following happens:

   a. Lower tool (Level 0): depth and concavity of the original face stop increasing as a smaller area is used and a "new" face starts. This has a new minimum depth and concavity and maximum planar size
      i. **Macro/micro** (Level 1-2): previous process repeats on this new face, erasing older wear. First of overall levelling begins at the margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense around the centre and at margins as these receive more pressure. Circular/concentric (patterning) in the distribution of wear. Possibly intensifies on this new face
   b. Upper tool (Level 0): Width and length continue to decrease as tool loses mass, also erasing older wear. Convexity continues increase, but again see *Surface wear management upper*
      i. **Macro/micro** (Level 1-2): Overall levelling continues at the margins along with a wearing out of pecking pits, only a few now left at centre. Striations and/or sheen may also appear at margins, possibly moving further in (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense outside of the centre and margins as these receive more pressure. Circular/concentric (patterning) in the distribution of wear.

4. **Worn out phase**

Same as the table above.

Table 10: Wear progression summary for A3. RGP (see also *Appendix II: Processing strategies and idealised use and wear progression* for further details)

Surface wear management upper (individual wear)

If wear is managed by exploiting both sides (faces) of the handstone, this will decrease the thickness faster as both faces lose mass and slow down (or negate) the increase in the convexity. Though, continued use on two faces will probably continue to decrease thickness as well as some steady increase in convexity (see Figure 21). If on the other hand the same

face is used constantly, mainly the margins of the tool will lose mass, thickness decreases slower, while convexity increases faster (see tool sizes in Table 11).
The presence of pecking pits at centre and levelling at the margins (see Table 12 and example in Figure 25), may be a result of the least stone/stone contact happening at the centre (see Martinez et al. 2013) or rather more contact with the intermediate material there. Most of the grinding happens at the centre as the stone is moved, pressing outwards by the operator (Dietrich et al. 2019; Dietrich and Haibt 2020). Potentially, the centre is being used to pound as well, causing the presence of pits, including deeper pitting.

Surface wear management lower (individual wear)

Again we may note that the way wear is managed will have an effect on the lower stone: if wear is managed by using a smaller area on the same surface or by opening a new surface (for example on the opposite side). As the first lower face gets deeper the active surface, either by choice or progressively gets narrower (smaller), the ridges/edges/ rim become higher and more concave , and grinding is possibly more comfortable (or easily) achieved in the centre within a narrower/smaller face a new but smaller area than previous face. This thus creates a stepped face as we see here (Figure 21 and 22B). Alternatively a second face on the opposite side may be established (e.g. tool in Figure 22A, actually has a face opposite the one shown) restarting the first stage of wear but potentially at equal size as the first. In this case no step is formed (initially at least) and the wear on the two surfaces develop independently of each other.

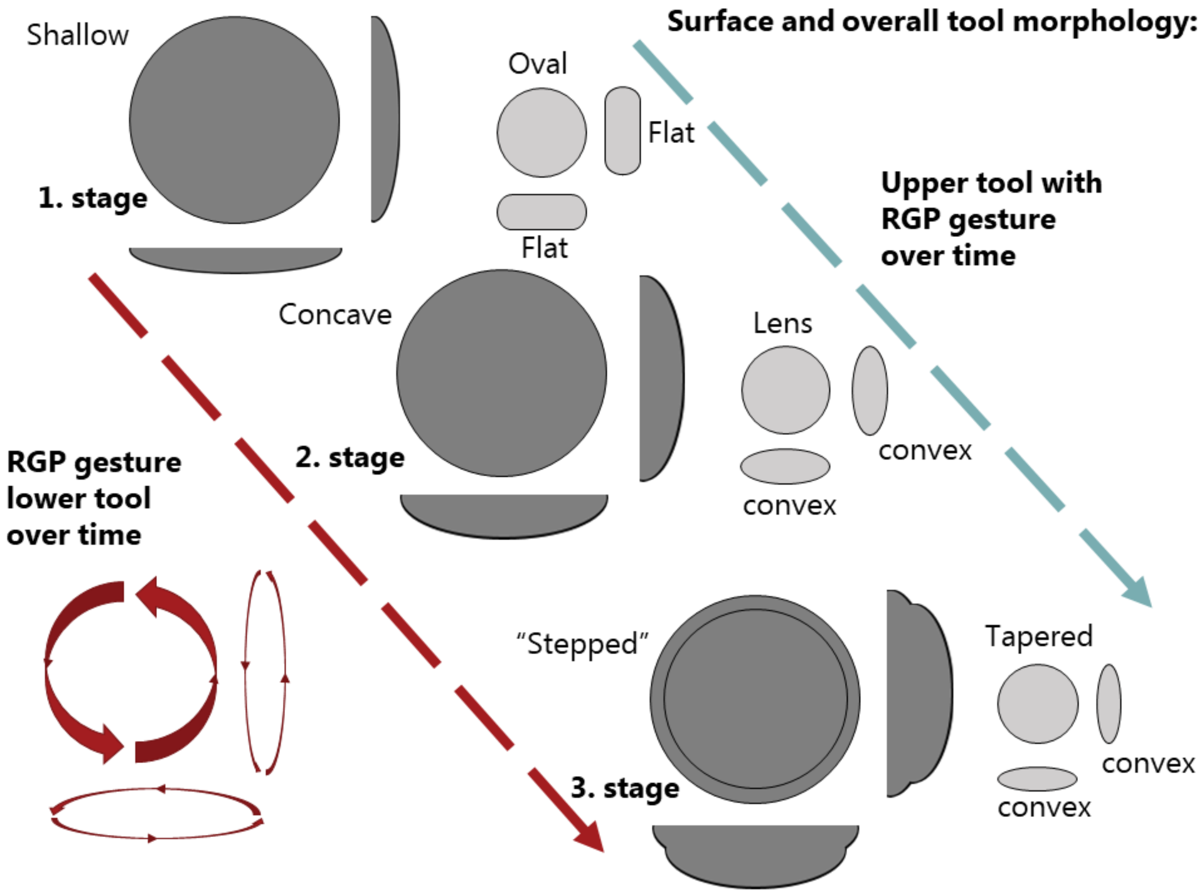

Figure 21: Idealised trajectories of both upper and lower tools individual wear, in an overall view. Note the opening of the second face within the previous surface. All fall within the RGP strategy.

The A3. RGP strategy is made of the following tool pairings (or "resulting" tools). Upper stones are Discoidal ("Circular")-type handstone. Lower stones are Basin-type and Block-type querns. The planar shape of discoidal handstones, being circular or sub-circular in shape (see Table 1, Figures 21 and example in 22D and 25), suggests rotary, circular movements where the entire circumference of the stone continuously comes in contact with the edges of the circular depression of the lower tools face (see also (Adams 1993, 1999; Nierle 2008). This also creates predominantly convex use faces of the upper stone, resulting in an oval or lens transverse profile (see Figures 23) also (Kadowaki 2014). This seems to be confirmed in our assemblage from both overall and use-wear data (see Figure 23 and 24 and Table 12).
Thus, discoidal handstone can be fairly confidently associated with circular grinding, though some may have been used in confined reciprocal grinding (Kadowaki 2014).
Similarly some ovately shaped handstones (here associated with CRG) may have been used in circular grinding (RGP), so considerable overlap between these two strategies' upper tools exist. There is a *fuzzy* boundary (Adams 2002), between these two tool sub-types and their uses.This is where the macro/microscopic use-wear helps in distinguishing between the two strategies, when handstones overlap in general shape. Here, I will however argue that *most* discoids were used in circular grinding (RGP) and *most* ovates were used in confined reciprocal grinding (CRG) thus negating the overlap by discriminating rigidly between the two.
Concurrently the face of the lower tool has a morphology that is a shallow to concave (in profile) depression and circular to oval (in plan) indicating rotary/circular grinding, defined as a *quern* in SWA assemblages (Wright 1992a). This is a fairly clear indication for circular grinding. Again, a fuzzy boundary exists between depressions with an elongated oval planar shape. Some may be RGP, some CRG. Archaeological and Ethnographic examples of this strategy are mentioned in: Dietrich et al. 2019; Kraybill 1977; Schroth 1996; Wright 1992b, 1993, 1994.

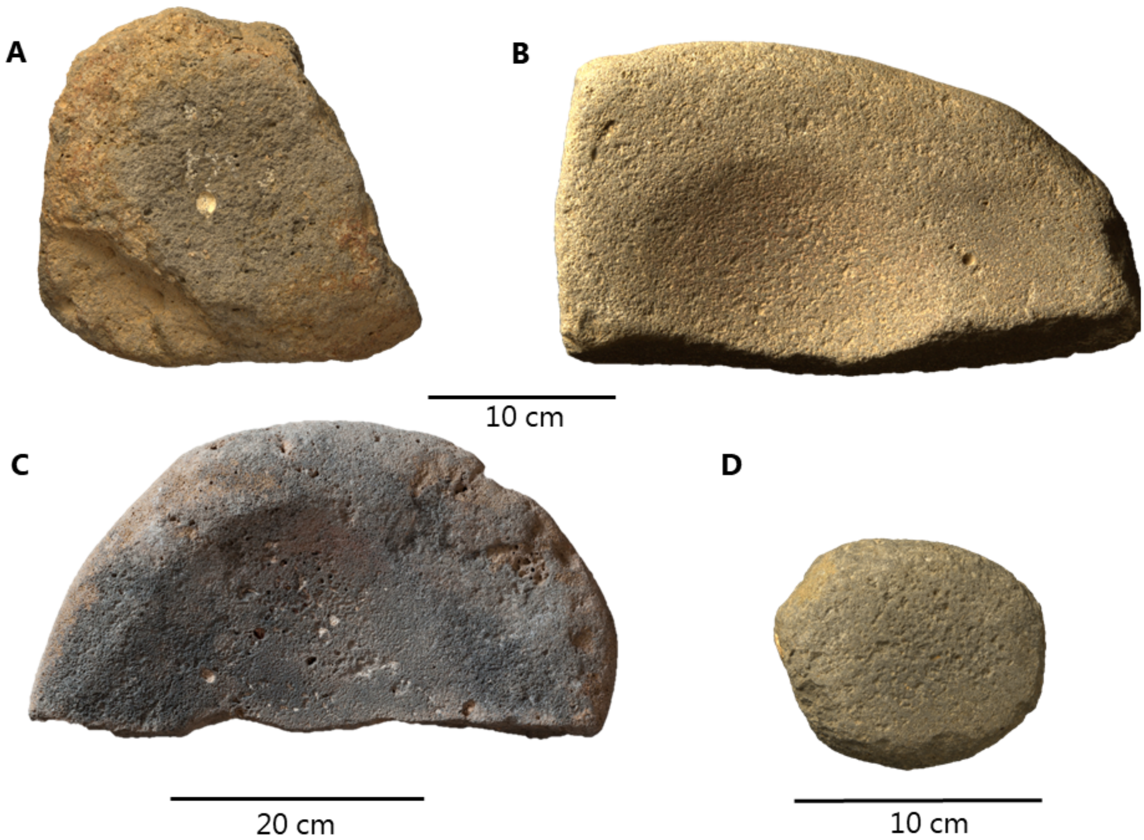

Figure 22: Archaeological examples of A3. RGP tools from Shubayqa 1: A) is from Early Natufian phase, B-D) Late Natufian phase. Note the smaller and deeper surface within the previous grinding surface on quern B). A) has a second face on opposite side. (picture G. A. Pantos / Shubayqa Archaeological Project).

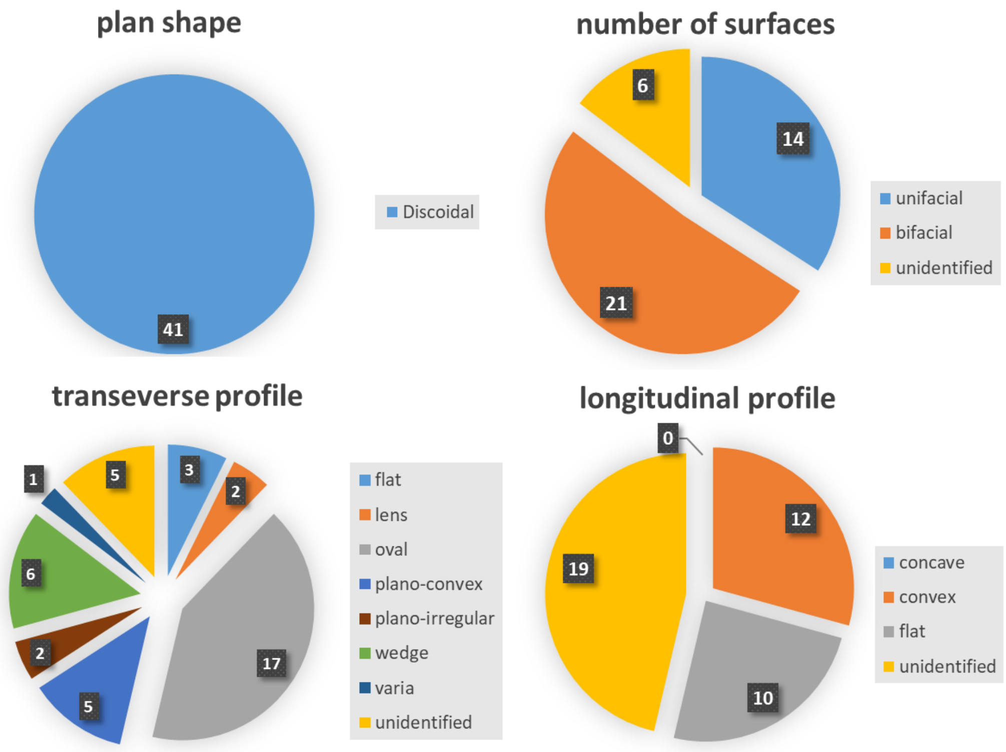

Figure 23: RGP upper tools shapes: handstone plan and transverse and longitudinal profiles of active surfaces

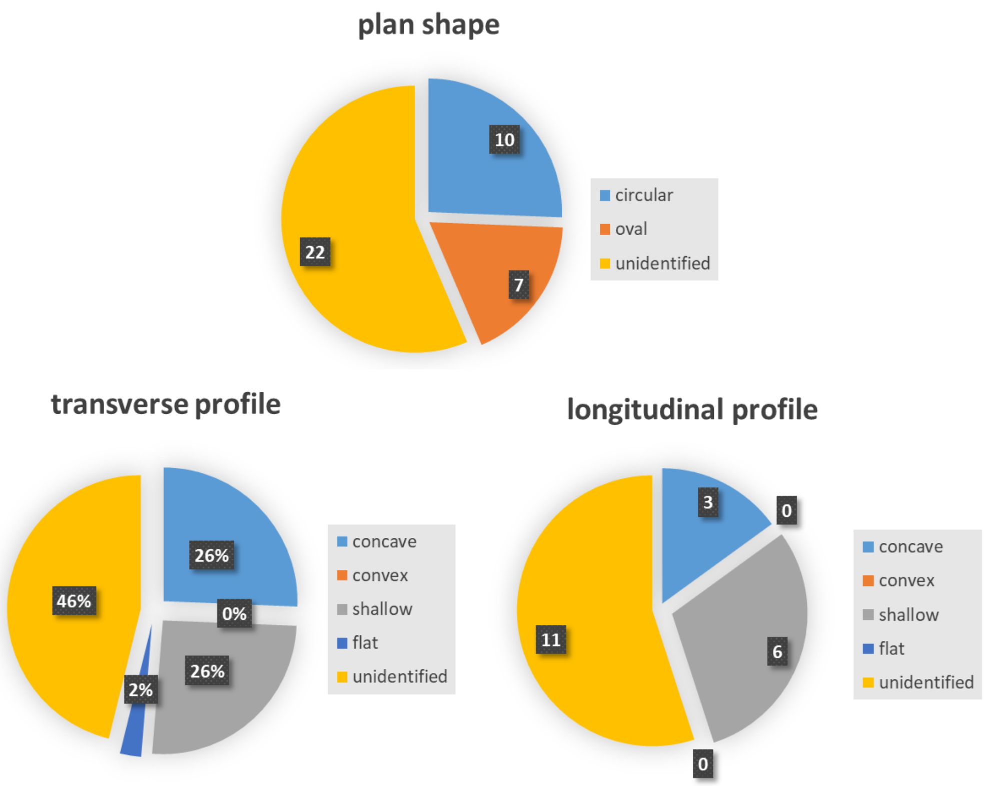

Figure 24: RGP lower tools shapes: quern plan and transverse and longitudinal profiles of active surfaces

A3. RGP	sub-types (*n* =)	complete	fragments	total
Handstones	discoidal (all) unifacial = 14 bifacial = 21 unidentified = 6	24	17	**41**
Quern *(circular = 10,* *oval = 7,* *unspecified = 22)*	basin = 13 block/boulder = 21 flagstone = 3 irregular = 2	16	23	**39**
total		**40**	**40**	**80**
Sizes *Only from complete* *(n = of complete)*	**length** mm	**width** mm	**thickness** (upper) or depth (lower) mm	**surface area** (calculated as ellipse: a x b x π) In cm²
Upper tool *Handstone (n =24)*	max. 170 min. 54 avg. 79,1	*See previous column*	max. 70 min. 37 avg. 41	a 39,55 mm x b 39,55 mm x π = **avg. 49,14 cm²**
Lower tool *Slabs (n =15)*[14]	max.396 mm min. 54 mm, avg. 181,1 mm	*See previous column*	depth max. 36 mm, min. 4 mm, avg. 14,7 mm.	a 90,55 mm x b 90,55 mm x π = **avg. 257,6 cm²**

Table 11: Overview of RGP tools in the assemblages of both Shubayqa 1 and 6, all phases (see also Table 3). Including tool sub-type and sizes. Sizes are based on complete tools. max. = maximum, min. = minimum, avg. = average.

For the RGP strategy the important macro/microscopic correlates are:
1. Pecking pits concentrated at centre
2. Overall levelling ("homogeneous zones") most pronounced at margins.
3. Striations and/or sheen at margins
4. Circular/concentric distribution of striation or other types of wear
5. (overall) Convex (upper), Concave (lower) use face profiles.
At least three of these characteristics should occur in combination.

[14] 1 very small cupmarks excluded

			Location				
Selected Overall Traces	*present*	*absent*	Covering	Centre	Margins	Mixed	
Pecking pits	71%	29%	10%	**60%**	30%	-	
Levelling	100%	0%	**72%**	7%	**21%**	-	
Striations	0%	100%	-	-	-	-	
No. of tools: **Upper:** 5 **Lower:** 5			**Direction**				
Examined Surfaces: 14	**Patterned traces* (PT)**		Random	Transverse	Longi-tudinal	Circular/ concentric	Oblique
	Upper tools (n of PT =7)		29%	-		**71%**	-
	Lower tools (n of PT = 14)		14%	-	-	**72%**	14%
	Total (n= 21)		19%	-	-	**71%**	10%

Table 12: Macro/microscopic correlates of RGP strategy, data from Shubayqa 1 and 6 *A total of all traces with discernable direction. From: striations, fractures, grain extraction and pit orientation.

Some archaeological examples

An archaeological example of a handstone from the Shubayqa assemblage where we may observe the proposed Stage 2 of wear is seen in Figure 25 below. It features a rounded levelling at the centre (Area 1, Figure 25) and the beginning of a more flat levelling at the margins (especially Area 3, Figure 25), including phenocryst levelling. This tool also has a clear patterning and distribution of the traces: pecking pits and interstices are concentrated near the centre, i.e. Area 1, and almost worn out at margins: in Area 2 they are only present towards the centre and in Area 3 almost completely gone (see Figure 25, Area 2 and 3). Wear thus seems to be progressing faster at the margins, probably as more abrasion and pulverising, and stone to stone contact is happening there. The observation of the centre wearing "slower", from a macro- and microscopic perspective, is also noted by (Dietrich and

Haibt 2020) in their work on Neolithic ground stone from Göbekli Tepe. This example thus shows quite well the suggested progression of wear, both the "initial" stage of use (Stage 2), as well as the "beginning" directionality, patterning and distribution of macro/microscopic traces (as suggested in Figure 2).

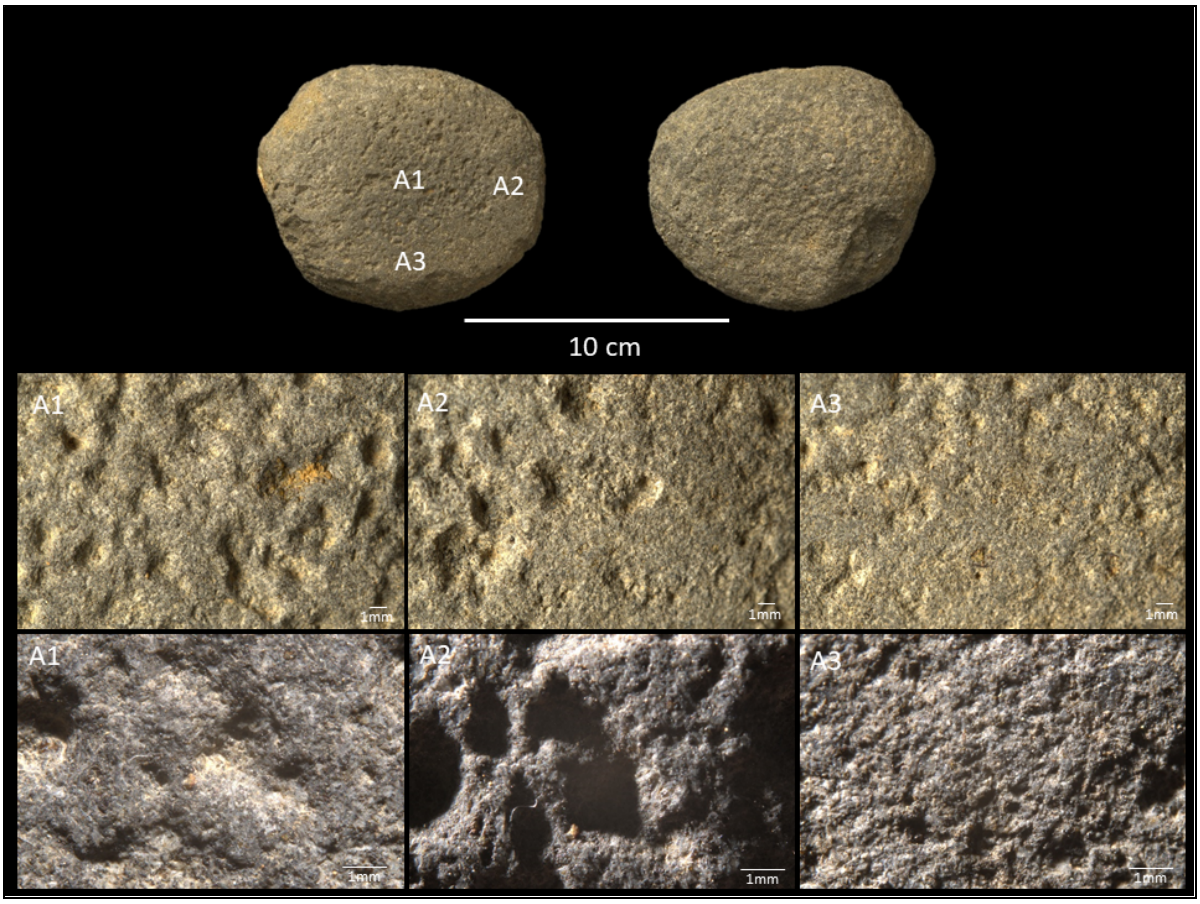

Figure 25: RGP: Archaeological example "Stage 2" upper tool (Shubayqa 1: Late Natufian). Areas 1-3 (A1-A3) indicates "areas" on the tool, see the plan overview (above) for location. First row shows areas at low magnification, the second row shows the same areas at higher magnification (see scale bar). (photos G. A. Pantos / Shubayqa Archaeological Project).

A lower tool example of the Stage 3 stage of wear can be seen in the next figure below (Figure 26). In this late Natufian quern we can observe that the operator(s) have chosen to make, or make use of, a new use-face within an older use-face. The new face is "cutting" the earlier face and is both smaller, more round and deeper. From a microscopic perspective rounded levelling can be observed in the centre (Figure 26, Area 1) compared to a more "flat", more worn levelling located at the margin of the old face (Figure 26, Area 2). The presence of a distribution and "beginning" directionality in traces is also clearly related to the RGP strategy: pecking pits and interstices are worn out at the margins of the old face, Area 2 (centre and right) and the new, and pits are concentrated near the centre (Figure 26, Area 1), concurrent with what was described in Table 10.

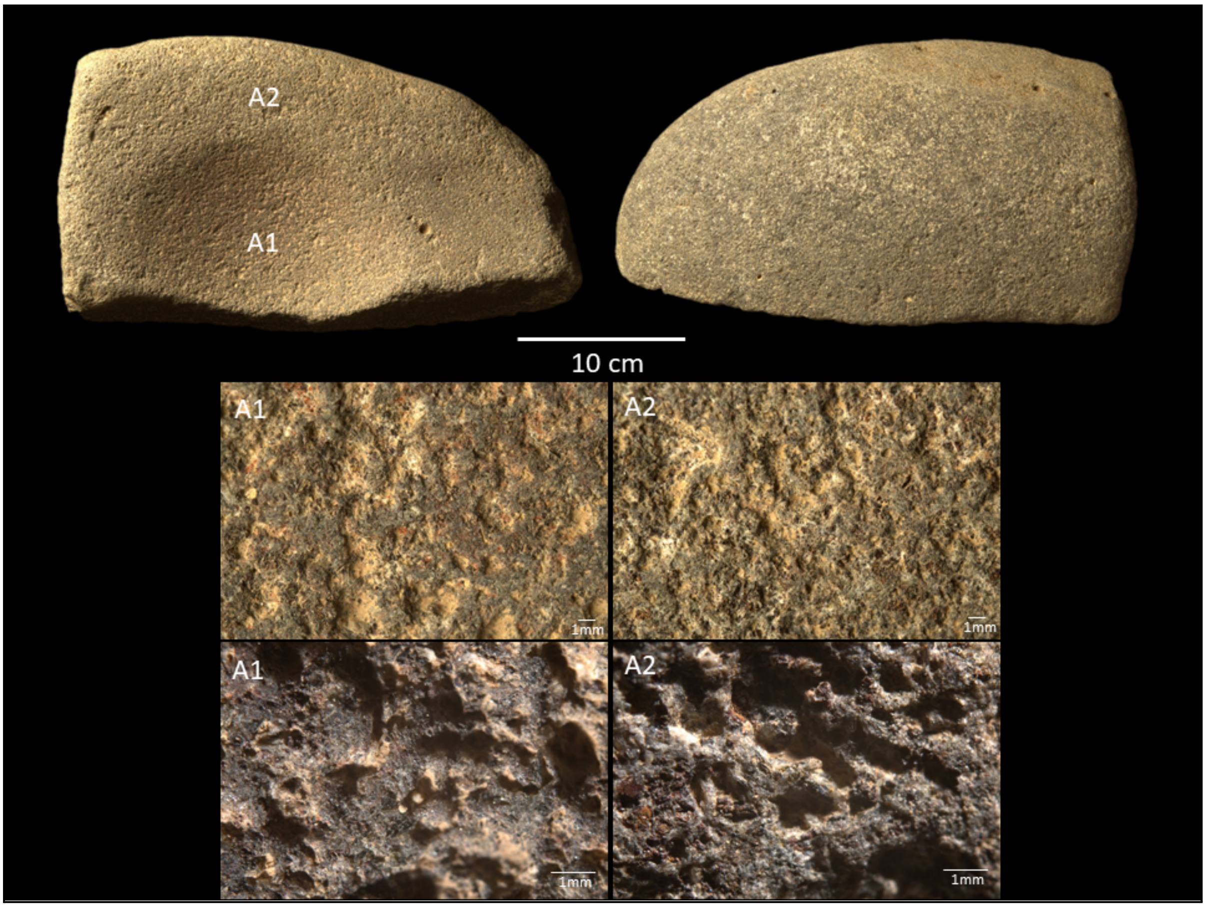

Figure 26: RGP: Archaeological example "Stage 3" lower tool (Shubayqa 1: Late Natufian). Areas 1-2 (A1-A2) indicates "areas" on the tool, see the plan overview (above) for location. First row shows areas at low magnification, the second row shows the same areas at higher magnification (see scale bar). (photos G. A. Pantos / Shubayqa Archaeological Project).

3.2.2. Diffuse thrusting percussion (B.)

B. Confined Pounding with some rotary grinding (CPR)

Gesture: Downward stroke/thrust, with an elongated upper stone (pestle) against a concave or conical (profile), with a circular/sub-circular (planar) use face. The lower use face, a deep depression, or mortar hole, is intentionally created before use commences. The stroke/thrust of the upper stone is confined by this hole within the lower stone (Figure 27).

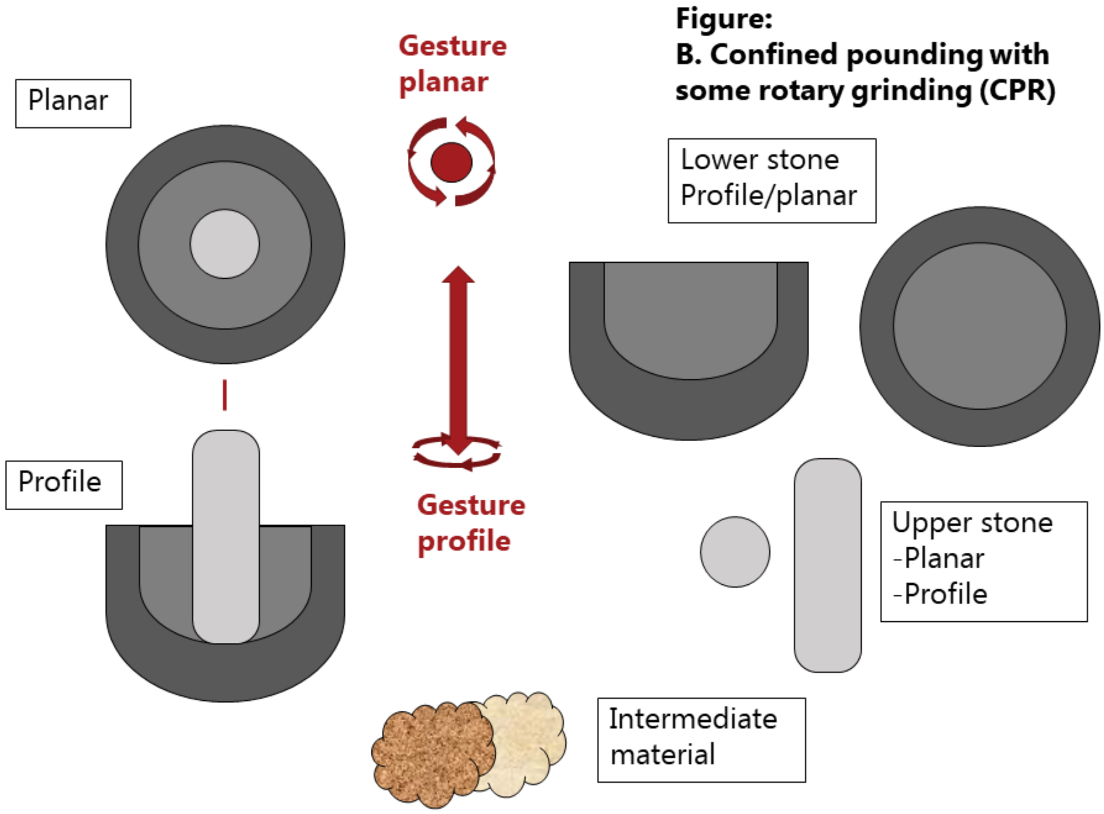

Figure 27: B. CPR, Overall idealised processing strategy and tools: cylindrical pestle handstone (circular profile, flat to convex terminus), vessel mortar (circular surface with a concave profile).

Discrete motion(s): The base and sides of the mortar hole allows for rotary grinding by pressing, twisting the upper stone against these within the hole to abrade the intermediate material. Accuracy is not hugely important as the lower use face guides and confines where the strike may fall. Action, performed with one hand or two, force is exerted using both elbow(s) and shoulder(s) (see Figure 28).

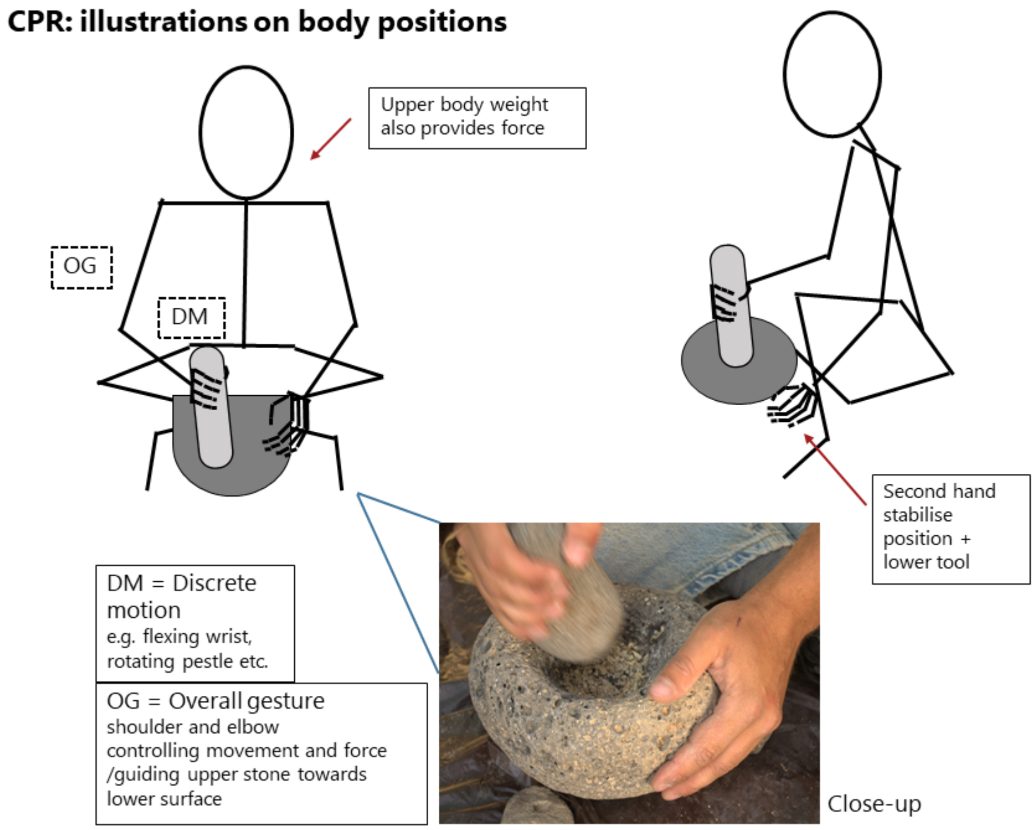

Figure 28: B. CPR - Body positions, gesture

B. CPR - wear progression summary

1. **Before use stage**
    a. Lower tool (Level 0): The use surface of the lower tool is at minimum depth and minimum concavity and the bottom of the face is at maximum diameter
        i. **Macro/micro** (Level 1-2): Either levelled from smoothening finish (both interior + exterior) or pecking pits across surface. Here the example is assumed "finished". A few pits with no apparent directionality may remain, pit edges rugged: i.e. no wear from contact with intermediate material, only production traces.
    b. Upper tool (Level 0): : is at maximum length, minimum convexity and maximum diameter
        i. **Macro/micro** (Level 1-2): Either levelled from smoothening finish (both interior + exterior) or pecking pits across what will become the active surface. Here the example is assumed "finished". A few pits with no apparent directionality may remain, pit edges rugged: i.e. no wear from contact with intermediate material, only production traces.
2. **Initial use stage**

As the two stones (upper & lower) engage each other and the intermediate material the following happens:

    a. Lower tool (Level 0): depth and concavity will begin to increase as the tool loses mass. The bottom diameter will at the same time decrease with this process
        i. **Macro/micro** (Level 1-2): Expansion of percussion pits, starting with few at the centre to several spreading concentrically from the centre. Levelling begins at the margins along with possibly striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across

the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A beginning circular/concentric (patterning) in the distribution of wear

b. Upper tool (Level 0): Length will very slowly begin to decrease as the tool loses mass from flaking, percussion (mainly centre) and abrasion (mainly margins). Convexity of terminus will increase. However, see *Surface wear management* further below.
    i. **Macro/micro** (Level 1-2): Expansion of percussion pits, starting with few at the centre, then to several spreading concentrically from the centre. Levelling begins at the margins along with possibly striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A beginning circular/concentric (patterning) in the distribution of wear

3. **Continued use stage**

As the lower face becomes deeper, use continues but on a smaller area).

a. Lower tool (Level 0): depth continues increasing and concurrently pounding happens in a smaller area reducing bottom diameter. Here if mainly involved in pounding the face becomes more conical and less concave, if both used in pounding and grinding (as assumed here) concavity continues to increase (see a more detailed explanation below in *Surface wear management*)
    i. **Macro/micro** (Level 1-2): Reduction of area with percussion pits: still several near the centre, but levelling (potentially also sheen) at the margins(possibly a result of stone/stone contact), increasing concavity and decreasing the area of percussion pits. Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A pronounced and concentrated circular/concentric (patterning) in the distribution of wear

b. Upper tool (Level 0): Length continues to decrease as the tool loses mass from flaking (mainly margins), percussion (mainly centre) and abrasion (mainly margins). Convexity will increase too (again see *Surface wear management* further below).
    i. **Macro/micro** (Level 1-2): Reduction of area with percussion pits, still several near the centre, but levelling at the margins along with micro and macro flaking (possibly a result of stone/stone contact) here increasing convexity, decreases the area of percussion pits. Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A pronounced and concentrated circular/concentric (patterning) in the distribution of wear

4. **Worn out phase**

The final stage, i.e. before a new round of pecking or breakage (unintentional and/or intentional), discard, abandonment. Heavily pitted and flaked. Intense levelling/sheen at margins on lower tool face. Depending on contact material a microtopography of covering: micro fractures, grain rounding or levelling, a sheen seen across the face. Rarely found complete archaeologically, possibly because of intentional breakage or immediate re-pecking/re-use.

Table 13: Wear progression summary for A1. CRG (see also *Appendix II: Processing strategies and idealised use* for further details)

The confined pounding strategies and individual wear management

Here we may again argue that there are the same dialectical relationships at play: shaping before use and shaping through use.

For the upper tools, pestles, repeated cycles of abrading margins of the face and crushing fractures at the centre of the active face or terminus, over time reducing length and promoting convexity (see Figure 29). As (Buonasera 2013) observes:

> "*[P]estles that exhibited fractured and crushed grains in the central portion of the distal end, but showed levelling and polish around the margins. This pattern indicates that both pounding and a rotary grinding motion with substantial rock-on-rock contact may have been employed.*" (Buonasera 2013): 199)

Pestles only used for pounding however, would promote a relatively flat terminus (end) (see Figure 30F + H). This is a result of crushing fractures etc. concentrating around the centre, but no abrasion at the margins (i.e. little or no levelling along margins), thus reducing length but not promoting convexity. Flaking of terminus margins is present in both situations. The area with percussion marks first expands, in Stage 2, then subsides in Stage 3, as convexity increases and levelling and flaking around the terminus reduces most protruding parts. Then the process repeats itself.

Regarding the wear management of the lower face, it has been suggested that (some) mortars with concave profiles may become deeper over time and through use and end up becoming mortars with conical use profiles (Buonasera 2013). Meaning that at least some concave mortar types are just at an "earlier" stage of wear and will become conical types over time. Here a linear relationship between diameter and depth within an assemblage, may suggest that depth is a result of use rather than manufacture (Wright 1991).

Again, use and manufacture are interdependent. Manufacture is a prerequisite for use, while use contributes to shape. What it does tell us, is a confirmation of this dialectical relationship found within the grinding tools (and perhaps we might even say tools in general). Changes or modifications both prior to, and during use, are along with the gesture itself, determined by material conditions. The tools, their shape, their wear material expressions of the gesture, the labour they have absorbed.

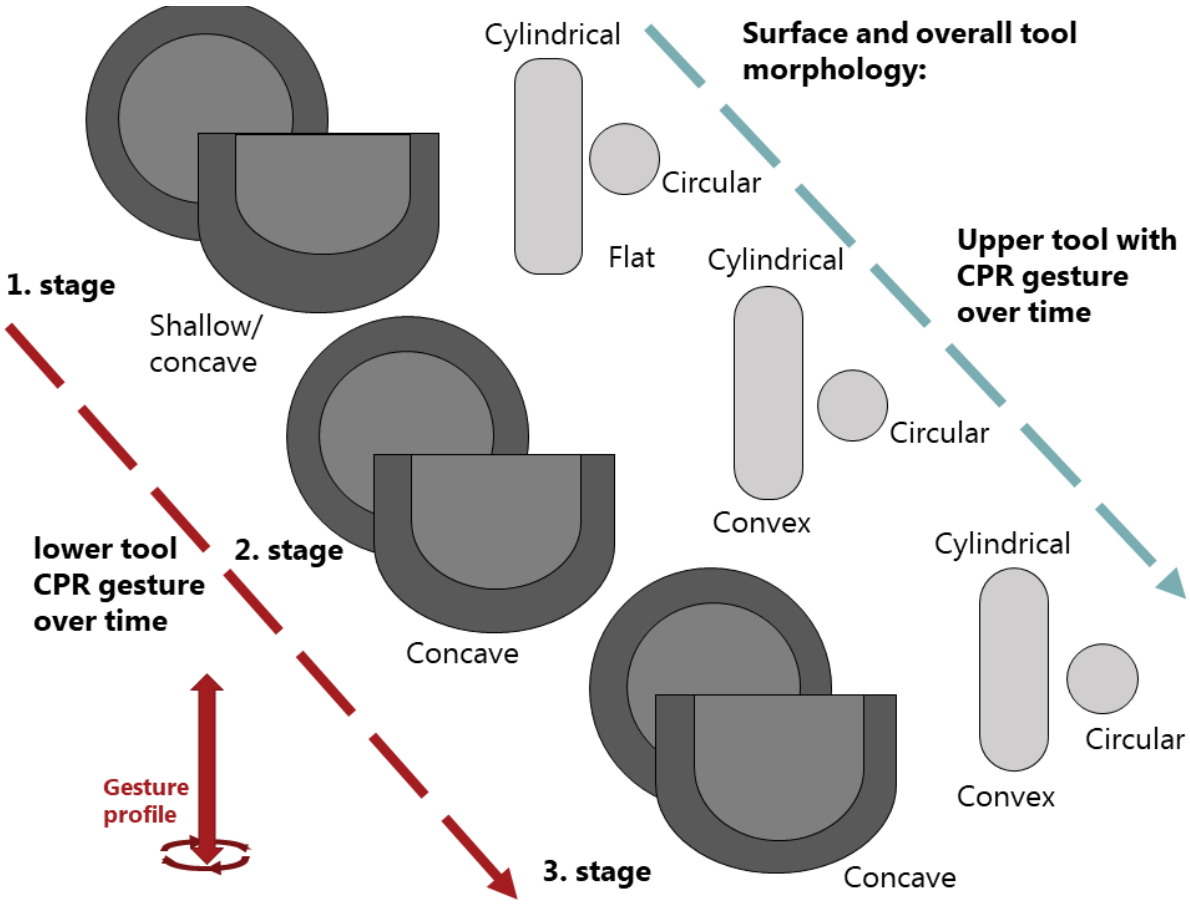

Figure 29: B.CPR: Idealised trajectories of both upper and lower tools individual wear, in an overall view.

The B. CPR strategy is made of the following tool pairings (or "resulting" tools). Upper stones are pestles, mainly Conical- and Cylindrical-types, and lower stones are mortars, mainly Boulder- and Vessel-types (see Figure 31-32). Any pestle and mortar falls under this strategy and represents a confined pounding activity, with a diffuse thrusting percussion. Whether pestle *x* would necessarily be usable with mortar *y*, is of course constrained by factors like the length of the pestle and depth of the mortar hole and also to an extent the shape of pestle and hole. However, in the case of the Shubayqa 1 and 6 assemblages all pounding tools (except pounders and anvils) are grouped under this strategy (see examples in Figure 30, and data in Figure 31 and 32).

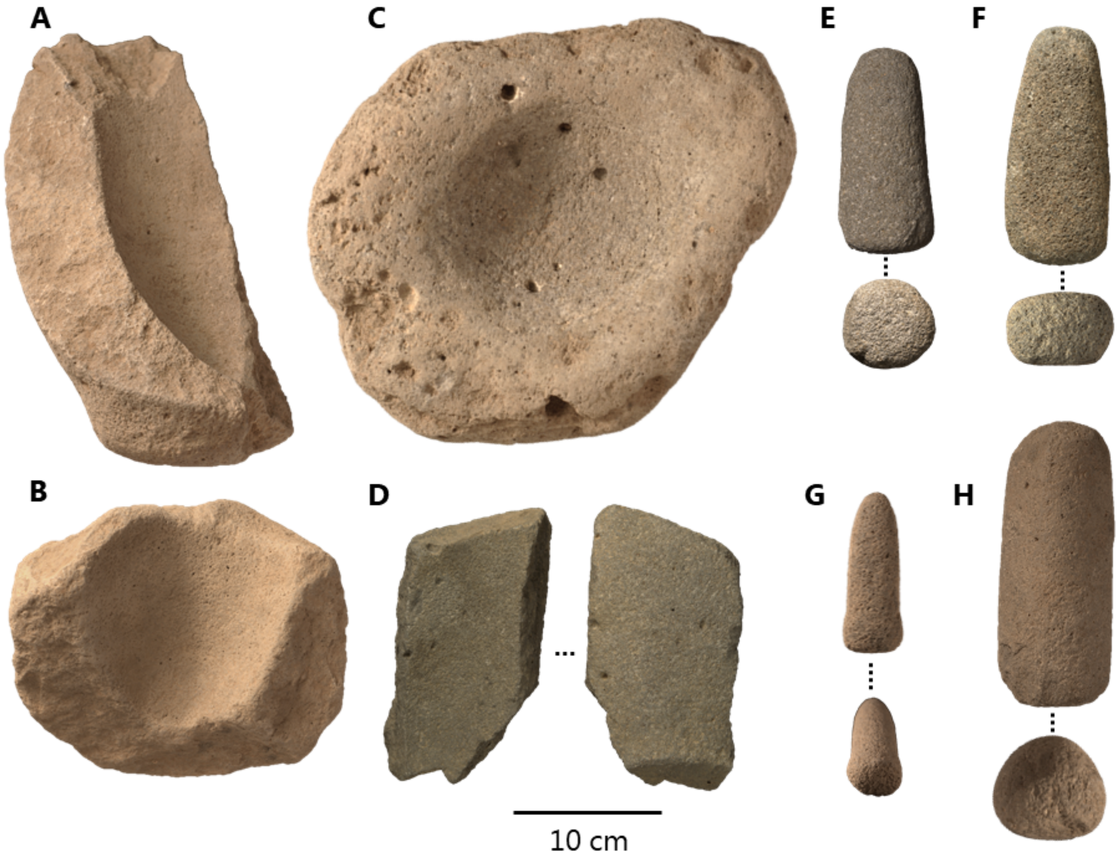

Figure 30: Archaeological examples of B. CPR. Basalt tools from Shubayqa 1 and 6: A-D lower tools, mortars E-H upper tools, pestles. A, C, D, H, Early Natufian examples. B and F, Late Natufian. E and G from PPN, Shubayqa 6. (photos A. Pantos / Shubayqa Archaeological Project).

Using additional criteria one might subdivide this pounding strategy further, yet for our purpose here and going forward, I have opted not to. As I have touched briefly on above, one possible distinction is: pounding or pounding/rotary grinding sets (see examples Figure 33). However, for now, the pairing with this strategy is simple: upper tools are pestles and lower tools mortars. This is done to understand the relationship between pounding processing and the different grinding processing techniques present at the site. So though size and exterior shape changes, the internal shape (mainly concave or conical) and most importantly the gesture applied, is the same through the different phases.

The gestures are the main interest here. The microscopic correlates and data are given below to illustrate the usefulness of these criteria (see below, Figure 33 and Table 15). The archaeological examples illustrate the difference between only pounding and pounding along with grinding. On the archaeological pestle example to the left in Figure 33, there percussion marks are concentrated around the centre, with some rounded levelling at margins, suggesting at least some rotary grinding taking place (see Figure 33, Area 1, and related close-up of terminus). Conversely, the example to the right (Figure 33, Area 2, and related close-up of terminus) has percussion marks across the face, suggesting only pounding.

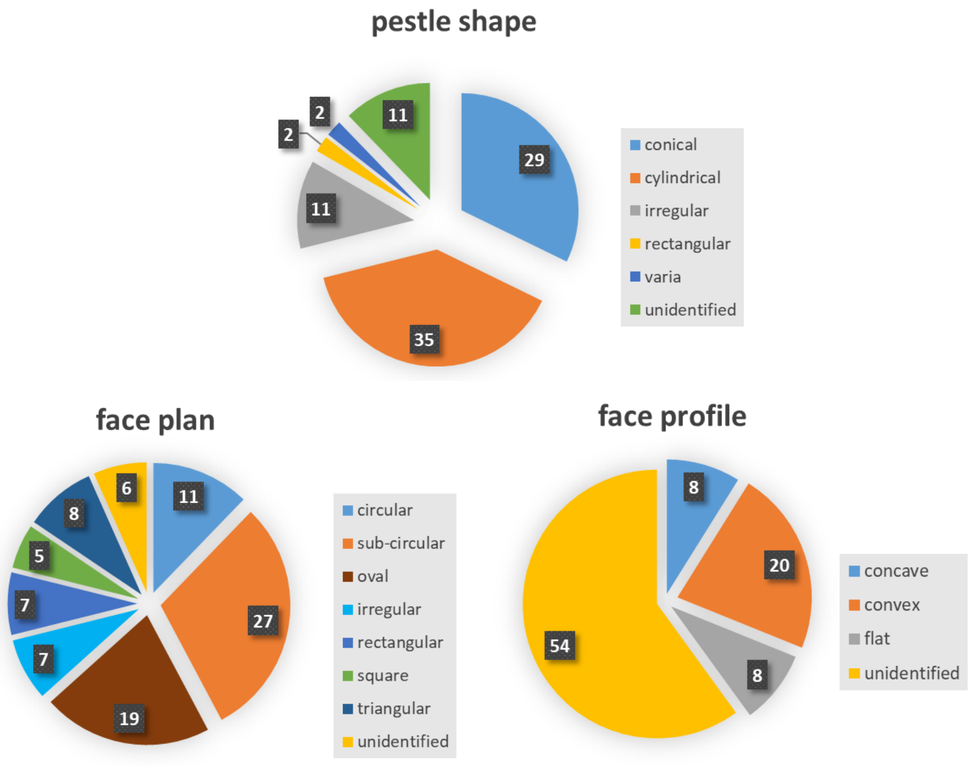

Figure 31: CPR upper tool shapes: pestle type, plan and profile of active surface.

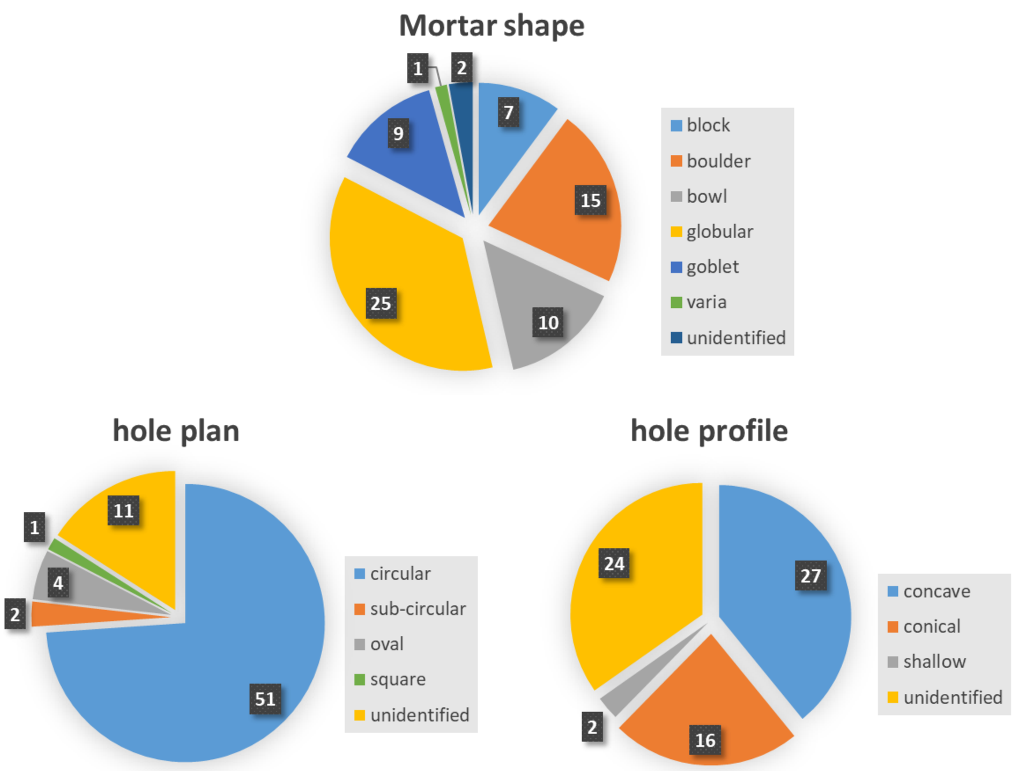

Figure 32: CPR lower tool shapes: mortar type, plan and profile of active surface.

<table>
<tr><td>B. CPR</td><td>Sub-types (n =)</td><td>complete</td><td>fragments</td><td>total</td></tr>
<tr><td>Pestles</td><td>conical = 29
cylindrical = 35
rectangular = 2
irregular = 11
varia = 2
unidentified = 11</td><td>15</td><td>54</td><td>69</td></tr>
<tr><td>Mortars</td><td>block = 7
boulder = 15
bowl = 10
globular = 25
goblet = 9
varia = 1
unidentified = 2</td><td>39</td><td>51</td><td>90</td></tr>
<tr><td colspan="2">total</td><td>54</td><td>105</td><td>159</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Size
Only from complete
(n = of complete)</td><td>length
mm</td><td>width
mm</td><td>thickness (upper) or depth (lower)
mm</td><td>surface area (calculated as ellipse:
a x b x π). In cm²</td></tr>
<tr><td>Upper tool
Pestles (n = 39)</td><td>max. 230
min. 51
avg. 124,5 mm</td><td>max. 125
min. 35
avg. 67,8</td><td>See previous column</td><td>a 33,9 mm x
b 27,9 mm x
π =
31,84 cm²</td></tr>
<tr><td>Lower tool
Mortars (n = 22)</td><td>max. 310
min. 40
avg. 188,3</td><td>See previous column</td><td>max. 346
min. 6
avg. 148,5</td><td>N/A</td></tr>
</table>

Table 14: Overview of CPR tools in the assemblages of both Shubayqa 1 and 6, all phases (see also Table 3). Including tool sub-type and sizes. Sizes are based only on complete tools. max. = maximum, min. = minimum, avg. = average.

For the CPR strategy the important macro/microscopic correlates are:
1. Percussion pits concentrated at centre of face/base
2. Circular/concentric distribution of pits: “frosted zone”
3. Levelling (“homogeneous zones”) at interior base margins
4. Striations and/or sheen at these margins
5. (overall) Convex or flat (upper), concave or flat (lower) use face profiles.
At least three of these characteristics should occur in combination.

<table>
<tr><td rowspan="2">Selected Overall Traces</td><td colspan="7">Location</td></tr>
<tr><td>present</td><td>absent</td><td>Covering</td><td>Centre</td><td>Margins</td><td>Mixed</td><td></td></tr>
<tr><td>Pits</td><td>100%</td><td>0%</td><td>22%</td><td>72%</td><td>-</td><td>6%</td><td></td></tr>
<tr><td>Levelling</td><td>61%</td><td>39%</td><td>9%</td><td>-</td><td>91%</td><td>-</td><td></td></tr>
<tr><td>Striations</td><td>0%</td><td>100%</td><td>-</td><td>-</td><td>-</td><td>-</td><td></td></tr>
<tr><td rowspan="5">No. of tools: 16
Upper: 8
Lower: 8
Examined Surfaces: 18</td><td colspan="7">Direction</td></tr>
<tr><td colspan="2">Patterned traces* (PT)</td><td>Random</td><td>Transverse</td><td>Longi-tudinal</td><td>Circular/ concentric</td><td>Oblique</td></tr>
<tr><td colspan="2">Upper tools (n of PT =14)</td><td>14%</td><td>-</td><td>22%</td><td>64%</td><td>-</td></tr>
<tr><td colspan="2">Lower tools (n of PT =17)</td><td>12%</td><td>6%</td><td>-</td><td>82%</td><td>-</td></tr>
<tr><td colspan="2">Total (n=31)</td><td>13%</td><td>3%</td><td>10%</td><td>74%</td><td>-</td></tr>
</table>

Table 15: Macro/microscopic correlates of CPR strategy, data from Shubayqa 1 and 6 *PT = A total of all traces with discernable direction. From: striations, fractures, grain extraction and pit orientation

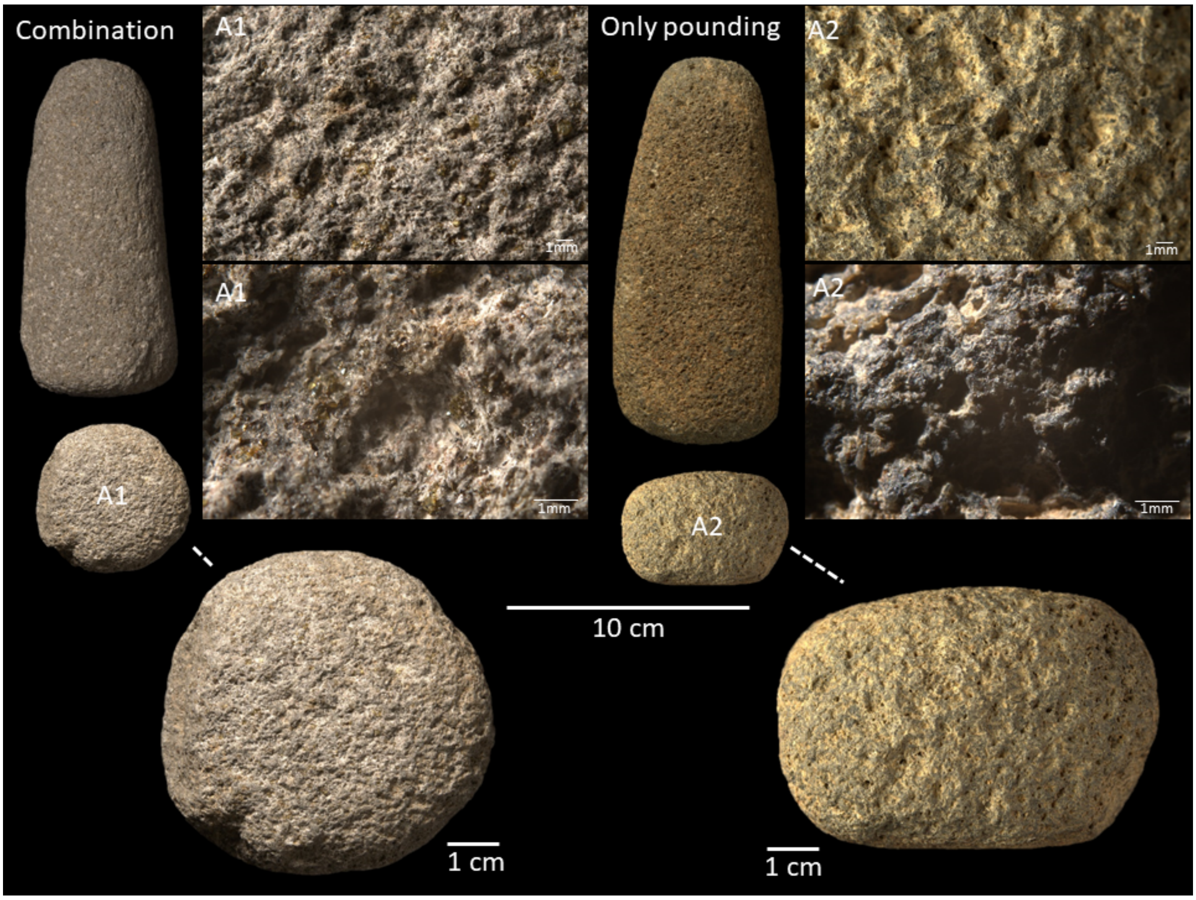

Figure 33: Archaeological examples of B. CPR. “Stage 2”. Left from PPNA, Shubayqa 6, right Late Natufian, Shubayqa 1. Areas 1-2 (A1-A2) indicates “areas” on the two tools, see the plan overview (above) for location. First row shows areas at low magnification, the second row shows the same areas at higher magnification (see scale bar).(photos A. Pantos / Shubayqa Archaeological Project).

3.4. A brief summary of experiments: body positions, use-wear and processing strategy use

Some exploratory experiments were also conducted in conjunction with this project (see Arranz-Otaegui et al. *submitted*) that support the differentiation of the various strategies and wear stages. The experiments were conducted as part of an experimental program to recreate the process of making tuber-cereal bread, like the food remains found at Shubayqa 1 (Arranz-Otaegui et al. 2018). During the experiments notes were taken of the gestures, body positions and this also informed the body positions suggested above (see example in Figure 34), use effectiveness and resulting use-wear of the experimental tools. The experiences pertinent for the approach outlined here, bears a brief review.

Use-wear analysis was carried out before and after the use (though only three of the four strategies were used: RGP, CPR, ORG). The strategies conform to the main strategies present at the Early Natufian phase at Shubayqa 1 (see Pedersen 2021) since the bread remains date from this phase (Arranz-Otaegui et al. 2018).[15]

[15] See Appendix III: Experiments conducted 2019 for further details

The use-wear results were generally consistent with the analysis above (see Table 16 below), generally suggesting that the observations of the archaeological tools and associated gestures and overall strategies are at least somewhat corresponding, and thus applicable and useful.

3.4.1. Body use and position

The CPR strategy's main mode of processing is pounding as described above. In our experiments the body was sitting or squatting (though it may be done standing, with large mortars and pestles). Both arms were used when pounding with a long (>50cm) wooden pestle, or only one arm when using a short basalt stone pestle (both weigh approximately 900 gr). The upper arm(s) and elbow(s) are the motive force behind the forceful downward stroke, hand(s) firmly grasping the pestle, during motion. The upper body, we noted, also produces additional weight behind the thrust.

With the RGP strategy the circular grinding was done in a clockwise or counter-clockwise direction motion using one hand (the main hand, left or right depending on preference). The body was in a kneeling position (or sitting) as the arm was moving the upper stone in these circular motions (i.e.diffuse resting percussion), the hand was firmly gripping the upper stone. The arm (shoulder and elbow) is the main motive force behind the processing, though again the upper body may provide additional weight and pressure when needed. The other arm stabilised the quern and balanced the body while grinding. Some pounding (i.e. diffuse thrusting percussion) with the handstone’s margins and its centre was also performed (especially when processing club-rush tubers), to break up these larger plants into smaller more manageable and grindable pieces.

Figure 34: A3. RGP: Body position, gesture and the experimental tool example. Used in processing Bread wheat and *Cyperaceae* tubers. (photos Shubayqa Archaeological Project).

In ORG strategy the body was in a kneeling position, upper body over the grinding pair, and using both hands to grip and push, then drag the upper stone back-and-forth with the shoulders and elbows. The upper body provided additional weight and pressure, rocking forward and back during the reciprocal movements: sitting almost upright on the backwards stroke, when the upper stone is at the proximal edge of the lower tool, and then extending the upper body and arms on the forwards stroke.this back-and-forth stroke and movement (diffuse resting percussion) moves the upper stone over the open slab and pulverise the intermediate material.

In all cases some discomfort and fatigue occurred already after brief use (*c.* 5-10 minutes), but this is most likely due to the inexperience of the operator(s). Both the CPR and RGP strategies allowed for the switching of the active hand and arm, or using both arms, to relieve some of the fatigue. None-the-less the experiences hint at the hard and complex nature of the tasks related to food processing (Hayden et al. 2016; Wright 1994; see also Pedersen 2021; *forthcoming*; Pedersen et al. *forthcoming*).

3.4.2. Wear

Wear it would appear is highly contingent on where on the tool it is analysed. This was evident from the archaeological examples above, and as was also expected from the progression of wear/stages of wear suggested above: *e.g.* margins wear faster and thus have a slightly different wear pattern, than the centre of the tool(s). As seen in Table 16, sheen (i.e. tribochemical wear) appears at the margins, distal ends and high points on the surface, and was only present on the tools used in grinding (see Figure 35). This is probably a result of more intense use and more stone-to-stone contact along the margins, sides and distal/proximal ends (Adams 1989). In the case of pounding tools (CPR), the intermediate material may protect against this stone contact, leading to less of certain types of wear on each tool surface. More so than during grinding at least. However, signs of beginning sheen were present after continuous tuber processing on the margins of the pestle, as this part of the pestle also is involved in some grinding, and presumably more use would have produced such wear there. On the lower grinding tools (querns and slabs) the sheen is accompanied by a more intense, rounded to flat levelling of both groundmass and phenocrysts. Like sheen, levelling is also mainly observed at the margins, e.g. the use face edges on the quern surface (used in circular grinding) and the distal part of the grinding surface on the slab (in the ORG pair). This again corresponds with the schematic view of the RGP and ORG strategies presented above. The sheen is only slightly reflective and is exclusively present on the grinding tools, and only specific parts of the surface. This indicates that grinding gestures and strategies create more sheen than pounding gestures do (see sheen in Figure 35). This is despite the processing of the same material (tubers), and in the same states (e.g. dried or roasted) (see Arranz-Otaegui et al. *submitted*). It is in the highest areas of both the upper and lower tool surfaces and along the margins, sides and (distal) ends that it appears. As mentioned above, it is probably a result of stone-stone contact together with the contact with specific intermediate raw materials.

Though most tools were only used briefly, most less than an hour (only two were used for more than two hours) some preliminary observations are that the RGP and CPR strategies have quite similar wear patterns. This is unsurprising as both are used in circular grinding especially along the margins and different degrees of pounding near the centre. The centre however is also where a discrete difference may be observed: the CPR tools main activity at the tool surface centre is pounding, which is then mainly expressed as fatigue wear, whereas the RGP primary activity on the central tool surface is grinding, which concomitantly is expressed as primarily featuring abrasive wear (see Table 16). That margins of the RGP tools feature tribochemical wear and the margins of the CPR pair features abrasive wear, is probably also related to the time used, the RGP tool pair was used for well over twice as long as the CPR pair (2,75 h vs 0,83 h). The tribochemical wear may have formed eventually on the CPR pair, if the tuber processing had continued. Though it is not certain, none of the pounding (CPR) tools from the assemblage subjected to use-wear analysis showed sheen/polish on the active face (see Pedersen et al. *forthcoming*). Thus, the centre of the surface along with the presence/absence of sheen, may be helpful for distinguishing between RGP and CPR strategies.[16]

No macro-striations, scratches or "linears traces' ' appeared on the used surfaces at naked eye or low magnification from this brief experimental use. Striation and scratches are otherwise often attested on grinding tools, especially on tools of sandstone and quartzitic (e.g. Adams 1989; Fullagar and Field 1997; Verbaas and van Gijn 2007; Zurro et al. 2005). Linears traces were also expected to appear, according to the use-wear progression (see above), but did not. It may be due to the briefness of the experiments, but it also does not appear to be as common on basalt, as some volcanic rock may have higher resistance to wear (Chondrou et al. 2021) and friction (Delgado-Raack et al. 2009), and thus linear traces are not as common on basalt. Though they do appear as microstriations in polishes in high-power microscopy and on abrading tools, (e.g. (Bofill and Taha 2013) and thus rarely found on basalt grinding tools. Only 10% of the tools analysed for use-wear from the Shubayqa assemblage (all upper stones, handstones), show evidence of striations, some in conjunction with well developed reflective sheen, that could suggest abrading activities (e.g. hide/skin-processing) rather than grinding (Pedersen et al. *forthcoming*).

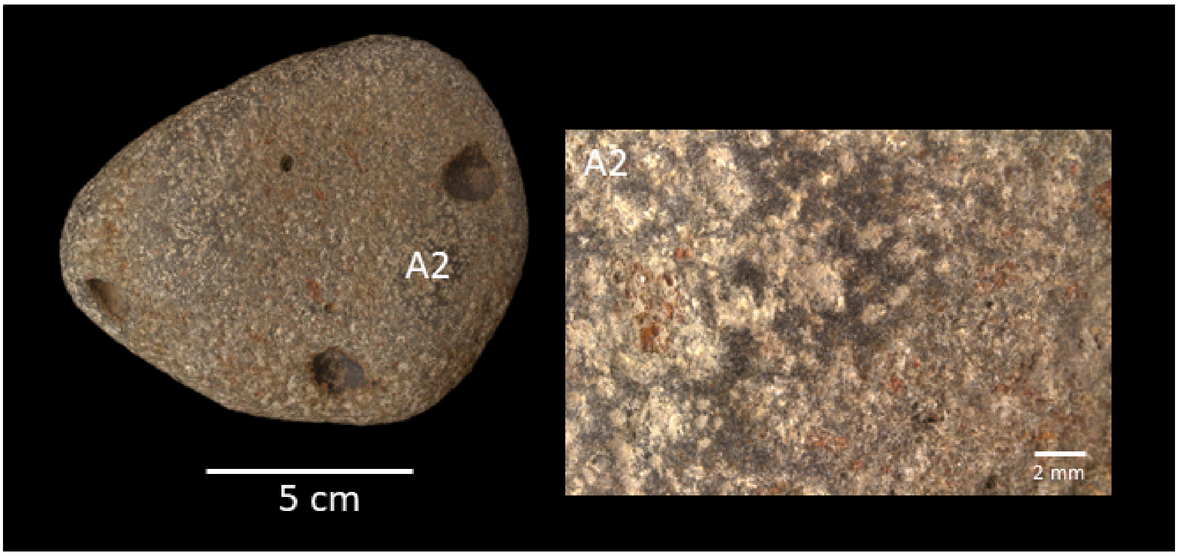

Figure 35: Experimental example of A3. RGP strategy, showing levelling and sheen appearing first and being most pronounced at the margin. (photos P. N. Pedersen / Shubayqa Archaeological Project).

Activity (strategy)	**RGP (one tool pair)**	**CPR (one tool pair)**	**ORG (one tool pair)**	**Pecked surface before use (all)**
processed material (time in hours h.)	grain (2 h.) + roasted tubers (0,75 h)	dried and roasted tubers (0,65-0,83 h)	wet tubers (0,5 h)	N/A

[16] Discriminating between the two can be difficult from the overall tool morphology, for example with cupmarks, which sit at the intersection of pounding and grinding tools, and are often classified as neither or both.

topography	rounded	rounded	flat to rounded	uneven/ rugged
impaction pits	present	present	present	present
orientation	concentric	concentric	longitudinal/ transverse	random
location	centre	centre	centre and proximal end (lower tool)	across
levelling	present	present	present	absent
groundmass/phenocrysts	groundmass (at margins both	groundmass (at margins both	groundmass (on distal end and margins both)	
distribution	covering	covering	covering	
location	across	margins	distal end and lateral margins	
phenocryst fractures	present	present	present	present
orientation	concentric	concentric	random and transverse	random
location	across	centre	across	across
polish/sheen	present	absent	present	absent
distribution	loose to closed		concentrated	
location	margins		distal ends	
Striations	none	none	none	none
tribological Wear	centre = abrasive margins = tribochemical	centre = fatigue margins = abrasive	centre and lateral margins = abrasive distal end = tribochemical	across = fatigue

Table 16: Experimental use-wear overview/summary

To summarise: wear at the margins of tools appears faster and is expressed somewhat differently than near the centre (see Figure 35), this is in line with my schematic idealised presentation of wear stages above (and see Appendix II). This is something that is also noted by Dietrich and Haibt (2020). This is of course dependent on the gestures, techniques and tools of the strategy, the processed material and the intensity and extensity of use. However, the variation in wear across surfaces highlights the importance of considering the whole tool, or tool active surface, as a site of analysis, along with the malleable overall morphology and the gestures (and bodies) behind. Together these express intentional strategies of living human agents.

4. Discussion and some conclusions

I hope here to have established a case for the importance of considering the array of factors that affect both tool morphology and use-wear, the overall progressive nature of wear, and its close relationship to the gestures used, i.e. the subject and consequently the body and its actions and choices -the techniques of knowledgeable agents- engaging in technological practises and actions.
This overall understanding is important as it informs us about factors to consider while conducting further functional analysis which, I would argue, represents a crucial addition to macroscopic and microscopic use-wear (and residue) analysis, neither of which is a satisfactory approach on its own.
The four stages suggested here (four if we include the "worn-out", that is rare in some archaeological assemblages) are not necessarily rigorous categories but rather dynamic stages of progressive wear and the management of this, that reflect the dialogue between the user, the material processed and the instruments of labour (that also become reciprocals of labour/ movements). Similarly the macro- and microscopically observed patterned traces provide information about the direction of use, i.e. movements and gestures, and their different degrees of directionality: *none, beginning, pronounced* and *worn-out*.
Generally speaking this directionality is thus related to the overall progression of wear. They are meant to add the macro/microscopic layer to the strategy and progression of wear (the stages), and follow these overall categories of use: prepared for use, beginning use, continued use and worn-out (the Stages 1-4), while also importantly being separate from them, but all dialectically connected.
So both directionality and stage of wear are the material expressions of discernable repetitive gestures. However, I do not assume that it would necessarily always be possible to place an archaeological object securely in one of the stages. There is always a degree of uncertainty and interpretation. At times, as was also evident in the figures, one stone tool may have two faces (or more) at different "stages", observable at the naked-eye, macroscopic- or microscopic level or all of the above. Again this illustrates *the progressive and dynamic nature of wear* and *how individuals manage that wear*, alternating between surfaces for preservation of the properties or for different tasks (for example the production of coarser or finer end-products, e.g. flours).
The stages, and strategies as a whole, thus serve to help elucidate use, ways of processing and how use changes tools through its use-life, at several levels, from a qualitative viewpoint: here simply as illustrations of idealised wear. These were extrapolated from and presented along with their archaeological equivalents, in an attempt to explain a material reality.
The stages are therefore useful as they inform about a relative/qualitative stage of wear, along with what processing strategy the tool was part of, what techniques, gestures and practises it was part of, this can be then compared with the functional use-wear and residue analysis in the attempt find the material processed and the desired end products. The processing

strategies were presented as broad representations of ways to change the physical attributes (process) of materials, but leaving out for now what exactly these raw materials processed could/would have been.

This paper dealt mainly with what happens to active surfaces of tools and the overall morphology of tools where a large part of the tool and its morphology was affected by use (like handstone). And as such, it was argued that the form or morphology external to this active relationship is rather "less" important. For example, in the case of lower tools like mortar and querns the overall boulder or bowl shape was considered less significant than the active surface and its morphology. I did not consider in any great detail the external modifications of the tools, not because these are not inherently important, but rather because the focus here was tools as representations of processing strategies, neglecting "style" somewhat.

Furthermore, it was noted that there exists a fuzzy boundary between each category of processing strategy (as also noted by Adams 2002). So what these are, are a static representation of a dynamic and fluid object moulded by the subject and other objects, but nonetheless as a useful separation of ways of use, approaches to processing. This is of course an exaggeration, as the external morphology or style of the tool is not separate from its function, but a part of it (Lemonnier 1992, 2012). However, the active parts of the tools are prioritised in this approach at the expense of the exterior "style" at least to a certain degree, or rather it sees the most important "style" in its style of action (Dietler and Herbicht 1998), of the gesture, the function and the strategy.

So what is the relevance of this approach to GST analysis going forward? How does this illuminate changes more clearly, accurately etc. comparisons between sites and time periods/regions etc?

I hope to have illustrated with the analysis above the importance of a gestural or body-tool centred approach to these tools. This suggested object-centred approach to the use of the body, allows the integration of considerations of the body, the agency, the sociotechnical knowledge and practises of people.

What this present study leads me to suggest is that wear should be understood as a much more complex process than how it is sometimes presented. Numerous factors affect wear, some factors like the gesture and shape of the tools need to be considered and what processing strategy and tool pair it belonged to is thus very crucial. I also argued that what "stage" of wear the tool is in when it was discarded has an effect on the wear, i.e. that use-wear happens progressively and often over long periods of time (see also Hayes et al. 2018). Tools would go through countless cycles of wear, resharpening and then wear again. Affecting both the overall shape and morphology of the tools as well as the macro/microscopic use-wear. Had the tool been used for grinding grain for 100 hours, or to crack nuts for 2 hours or process tubers for 35 hours or all of those things and more? What was the exact processed material? and what state it was in (dried, roasted, boiled, wet, parched etc.)? All these things are to be considered in addition to the tool itself and its material properties, the material and mechanical properties and petrography of the rock

(Delgado-Raack et al. 2009), Also important would be the weight of the tool and the weight and size of the person(s) using the tool as the body is the “motor” behind the processing.

In addition, one could add that tools would rarely have been used for one task exclusively. Many tools would presumably have been multifunctional. As noted some go from being a grinding slab to becoming a mortar (as also seen in Nierle 2008). This is a clear example of gestures and use changing, however more subtle changes to use over time are harder to recognise. Another example of this is the presence of ochre in the low topography, interstices of the surface of several the tools examined (seven out of 64 tools feature this), hinting at previous mineral processing. Thus, we only observe the latest wear (Figure 3), after the latest round of re-precking, or really we often see an amalgamation of multiple phases of use and stages of wear and use, of curation and wear management. Was it used trans-generationally? How did use change over time between different operators? How well were the tools curated and managed? How, and how well technological practices transferred and changed? As seen in the work by (Hamon et al. 2021) some types of wear may dominate because of their physical and chemical properties. Some harder materials may obscure previous wear from softer materials or these softer materials like leafs, USO’s etc. may not leave traces other than micro residues (see also Santiago-Marrero et al. 2021).
This is however, not a call to pessimism or to admit defeatism, nor necessarily of the shortcomings of use-wear, rather it is to try to understand and delineate what are the things that we actually can say something about. And how our studies enhance our understanding of past (food) practises. What this combined use-wear and a gestural approach does allow to say something about, is how processing was done and how those tools functioned, how they must have been part of a technological tradition, embedded in physical and social relations, between tools and humans, food and raw material and the surrounding society. This provides an avenue in which we can illustrate how these practises changed over time and suggest why these changes occurred. This *is* something.

By using the approach I suggest here we can at least see, or note that several stages of wear and use have happened, so even though we observe only a snapshot, this snapshot hints at previous use, at strategies and ways of use over time, as well as the “final” use. It contextualises use, both within a “life-history” of the tool, the stages of wear and maintenance, but also within the different and diverse practises and strategies taking place at a site and potentially between sites and even regions. The approach here offers a way to assess the progression of wear as part of strategy highlights how a tool changes through the “same” (or similar) repetitive and continuous use. This is an addition (or alternative) to studies that look at changes in use during the “life-history” of tools.
It allows us to suggest that GST was an important and integral part of the society and of their tool-kits. Heavy labour investments were needed both for the production and use (Hayden et al 2016; Wright 1994), in addition to the investments in procuring raw material/foodstuff to be processed. Combining the documentation and analysis of strategies and stages, results can be paired with additional data from a combination of use-wear and residue analysis that then allows us to come closer to the question of foodways, to understand why or why not people were changing how they processed raw materials into desired end-products.

I thus conclude that *ways of use* can be distinguished and categorised into processing strategies that display specific processes (and sub-processes) of wear progression and trajectories, wear management and resulting shape and surface morphology as found archaeologically. This can be observed both from naked-eye observations and recording of overall morphology of tool and surface as well as through microscopic use-wear analysis. It informs us not just about possible contact materials but importantly, the amount/intensity/extensity of use before rejuvenation, as well as the directionality indicating ways of use and trajectories of wear and strategies. In the future this may be aided with 3D imaging and recording, as well as motive-capture techniques and more quantitatively intensive approaches. What was established here was firstly the qualitative low power approach to wear and gestures.

It showed its usefulness in this type of analysis in identifying location and directionality of wear traces, in the future 3D data may further quantify this wear (e.g. Dietrich and Haibt 2020; Caricola et al. 2018; Zupancich et al. 2019). This may allow us to quantify stages and patterns and orientation, how pronounced they are, and things like roughness between areas of the tool. Again however, we should keep in mind the dynamic and fuzzy boundary of these stages and directionality and not attempt to make dynamic categories fixed. I would caution this at least. As for quantitative micro use-wear, as has recently been noted by (Zupancich and Cristiani 2020) quantitative methods for example for microscopic use-wear is not that useful in assessing the gestures used, and was deemed not useful to the study conducted here. As it would then lose the important motive forces that make tool function, the focus of the approach here. Furthermore it also appears the raw material properties and variability greatly influences quantitative results (Chondrou et al. 2021). So even though the assemblages I examine are primarily of one igneous rock-type, the heterogeneous petrographic qualities and properties of these porphyritic and vesicular rocks may create too much noise for consistent quantitative results.

The approach illustrates just how malleable the tools, and their surfaces are both in being shaped through use and change in use. The overall morphology and the micro/macroscopic wear follow each other but at different paces: dependently and dynamically the repeated cycles of micro/macroscopic surface wear are what affects/influences overall morphology. They are “separate” but the same, they are the same surface, wear at different scales of observation, but intimately and intrinsically connected, each a result of the other, as a dialectical materialist approach would posit. The presence of the strategies and their relationship to each other may inform us about what activities may have taken place and their diversity. The processes that change these tools through use and the changes these technologies go through over time are specific and represent technological choices being made by the operators of these tools (e.g. see Pedersen 2021; Pedersen et al. *forthcoming*). In a upcoming study we use this approach along with more traditional use-wear analysis and residue analysis to elucidate contact materials and the changes to foodways and ground stone during the Late Epipaleolithic to Pre-Pottery Neolithic in the Qa’ Shubayqa (see Pedersen et al. *forthcoming*).

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The *chaîne opératoire* of club-rush tuber exploitation (*Bolboschoenus glaucus*), disentangling Early Natufian root-food gathering and processing activities in Southwest Asia

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Abstract
Chaîne opératoire reconstructions for plant exploitation in archaeobotany have primarily targeted common cultivars, like cereals and pulses. This study contributes with new insights into the gathering and processing of a wild plant resource that produces edible rhizome-tubers: Bolboschoenus glaucus (club-rush). This species represents one of the most common taxa documented in Epipalaeolithic and Neolithic sites in Southwest Asia. In particular, thousands of carbonized rhizome-tubers were found in two fireplaces at the Early Natufian site of Shubayqa 1 (northeastern Jordan), indicating their recurrent exploitation 14,600 years ago. To determine how this species could have been gathered and processed in the past, we designed an interdisciplinary study that combined experimental archaeology, with archaeobotany, and ground and chipped stone tool analyses. We conducted more than 50 specific experiments over three years, and determined that 1) the best season for club-rush rhizome-tuber collection in the Black Desert was spring-summer time; 2) that the primary method to harvest the plant was uprooting; and 3) that the most efficient approaches to obtain perfectly peeled and clean rhizome-tubers could have entailed activities like drying, roasting and gentle grinding. The reference materials produced in this study set the basis to classify the archaeological rhizome-tuber assemblage recovered from Shubayqa 1, and so doing start to disentangle some of the activities that Natufian communities undertook in relation to the exploitation of this particular root food.

Keywords:
chaîne opératoire, root foods, club-rush, Epipalaeolithic, experimental archaeology, archaeobotany, stone-tool analyses

1. Introduction

Bolboschoenus glaucus is one of the five species in the genus *Bolboschoenus* spp. (club-rush), a group of semi-aquatic plants of the Cyperaceae family. It is the most thermophilic species, and can be found around the Mediterranean, northern Spain and southern France, as well as in sub-Saharan Africa and parts of Asia (Browning et al. 1998, Wollstonecroft et al. 2011). It primarily grows in freshwater environments, along rivers and river floodplains, but it has also been recorded in secondary habitats (i.e. near villages) and in relatively saline water stands (*ibid*). Although this particular species is not economically used nowadays, the archaeological evidence shows that *Bolboschoenus glaucus* was indeed an intensively exploited source of food in the past (Wollstonecroft et al. 2011). Club-rush nutlets have been recovered from tens of Epipalaeolithic and Neolithic sites in Southwest Asia, sometimes in proportions larger than those recorded for key cereal and legume crops (Arranz-Otaegui and Roe forthcoming). However, the available evidence suggests that the nutlets did not necessarily constitute the main source of food obtained from club-rush plants.

Club-rush and other genera of the Cyperaceae family are primarily known for their edible rhizome-tubers (tubers hereafter) and green shoots. Nutrient analyses of a sister species *Bolboschoenus maritimus* (sea club-rush), showed that these plants have protein, lipid, and carbohydrate contents similar to those recorded for important root-foods like potato (Wollstonecroft 2007, Wollstonecroft and Erkal 1999). Indeed, the use of Cyperaceae tubers as a source of food is recorded in several ethnobotanical accounts around the world (Rivera-Nuñez and Obón de Castro 1991). However, and despite its economic potential, empirical evidence for the exploitation of root-foods in the archaeological record is overall very limited. The fragile nature of underground storage organs, taphonomic processes linked to the formation of the archaeological record, the types of plant recovery techniques applied, and the lack of purposely-trained archaeobotanists have been some of the factors put forward to explain why root-foods are so rarely recovered from archaeological sites (Hather 1993, 1994, 2000, Hillman et al. 1993, Kubiak-Martens 2002, Arranz-Otaegui et al. 2018a). As a result, club-rush tubers have only been documented at a hand-full of sites, including Mesolithic and Neolithic sites in Europe (Perry 1999), Egypt (Hillman 1989, Hillman et al. 1989a, Hather 1995) and Turkey (Hastorf 2000).

Fortunately, recent finds in Southwest Asia are providing fresh new insights into the exploitation of this plant in prehistoric times. At the Early Natufian site of Shubayqa 1, located in northeastern Jordan (Betts 1998, Richter et al. 2017), two large fireplaces were discovered in 2012 that comprised more than 50,000 carbonised rhizome-tubers (Arranz-Otaegui et al. 2018a). The finds represented one of the largest assemblages of archaeological underground storage organs ever recovered. The exceptional state of conservation of the remains allowed for species-level identification of the remains as *Bolboschoenus glaucus*. In addition to the tubers, the two fireplace plant assemblages from Shubayqa 1 comprised carbonised Cyperaceae stems, rhizomes and rootlets, as well as some irregular fragments of burnt clay remains with Cyperaceae stem impressions (Arranz-Otaegui et al. 2018a), and tuber-based food remains (Arranz-Otaegui et al. 2018b, Arranz-Otaegui et al. in prep.).

The assemblage of carbonised club-rush tubers and prepared foods from Shubayqa 1 demonstrated that Early Natufian groups recurrently exploited and consumed this particular species (Arranz-Otaegui et al. 2018a), but it also prompted new questions: why was such a large number of club-rush tubers found carbonised in the fireplaces? Did the assemblages represent the accidental burning of the tubers during the cooking stage, or could they instead belong to the processing stage (e.g. roasting to facilitate peeling)? To answer these questions and determine how Early Natufian communities gathered, processed and transformed this particular plant into food we designed an interdisciplinary experimental program that combined archaeobotany, experimental archaeology, and stone-tool analyses.

To reconstruct the *chaîne opératoire* for club-rush tuber exploitation the experiments were divided into three main blocks: 1) club-rush gathering, 2) processing and 3) cooking. In this paper the first two stages of the *chaîne opératoire* are tackled and several hypotheses in relation to club-rush tuber gathering and processing are tested. Subsequent publications will expand this initial work by covering other key aspects, like the final cooking stages (Arranz-Otaegui et al. in prep.), as well as the comparison of the experimental and archaeological ground stone tool assemblages and the resulting plant residues (Pedersen et al. in prep.).

Overall, this experimental program complements the pioneering studies conducted by M. Wollstonecroft (Wollstonecroft and Erkal 1999, Wollstonecroft 2007, 2009, Wollstonecroft et al. 2008, 2011) and G. Hillman (Hillman 1989, Hillman et al. 1989) on a sister species (sea club rush, *Bolboschoenus maritimus*), which focused on determining general tuber yields, harvesting efficiency, quantitative nutrient composition, digestibility and palatability among other key aspects. Our work contributes with key experimental data and modern reference datasets to interpret the archaeological plant and stone-tool assemblages found at Shubayqa 1. In particular, the experimental plant materials described in this paper enable the initial classification and interpretation of the archaeological rhizome-tuber assemblage recovered at the site, and allow us to start disentangling some of the activities that Natufian communities undertook in relation to the exploitation of this particular root food.

2. Materials and Methods

2.1. Description of the experimental activities

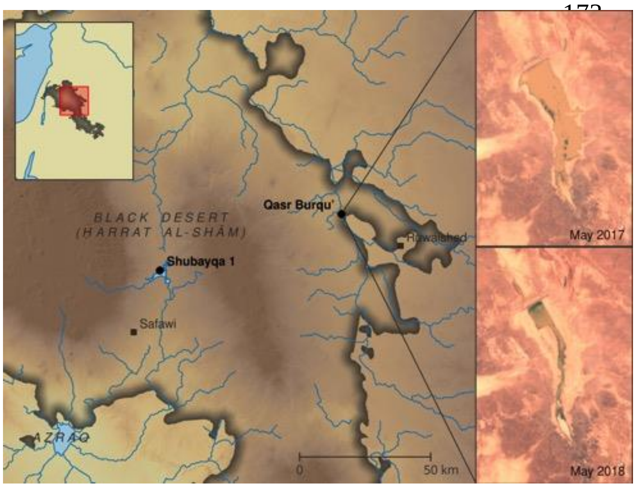
Experimental work was carried out in the Black Desert area of northeastern Jordan in 2017, 2018 and 2019. More than 50 specific experimental activities were carried out, and a total of 22 people participated. For each activity, we recorded the type of activity and its objective, a description of the materials used (number, volume, weight, size), the tools used, the people involved in their use, the duration of the activity, the start and end products and discarded materials. Photographs were taken and logged throughout (see individual image credits in the **Supplementary Materials**). In this work we present the results for 20 of the experiments carried out in relation to club-rush harvesting and processing.

2.1.1. Club-rush harvesting activities

Experimental harvesting of club-rush plants was carried out at Lake Burqu', a rainfed water body on the edge of the Black Desert (Jordan), some 70 km east of Shubayqa 1 (**Fig. 1**). Augmented by a modern dam (Helms 1991), the lake covers up to 32 hectares at its highstand, although its level fluctuates greatly both seasonally and annually, with a maximum depth of c. 4-5 m recorded in the centre of the main water pond. The edge of the lake is dominated by vast monospecific stands of *Bolboschoenus glaucus* plants. The plants grow primarily in the shores of the fresh-water ponds, in thick patches (1-3 m width and maximum of 1.2 m depth), separated by spaces of open water and basalt boulders. The substrate in the area is silt, and includes small amounts of basalt pebbles.

In the different harvesting experiments the total height of the plants and the resulting volume of the plant materials gathered were measured and recorded. The work was commonly carried out by groups of 2-3 people. Club-rush tuber harvesting was carried out in four main harvesting programs: February and May of 2017, May of 2018 and June of 2019, in order to cover the whole life cycle of the plant. It should be stated that the club-rush tuber harvesting activities did not cause damage to the stands. Around 5-8 m^2 of club-rush plant materials were gathered per year, less than 0.1% of the total available stands in the area. Besides, in order to avoid damage, harvesting areas were rotated every year, following protocols established by biologists to safeguard the correct growth of club-rush species (Kantrud 1996). Yet, it has been recorded that controlled human and/or animal predation can stimulate plant growth and increase the overall club-rush biomass (Charpentier et al. 1998, Clevering and van Gulik 1997).

__Fig. 1.__ Location of Shubayqa 1 and Qasr Burqu' within the harrat al-Sham. Inset, right: Sentinel-2 satellite imagery of Lake Burqu'.



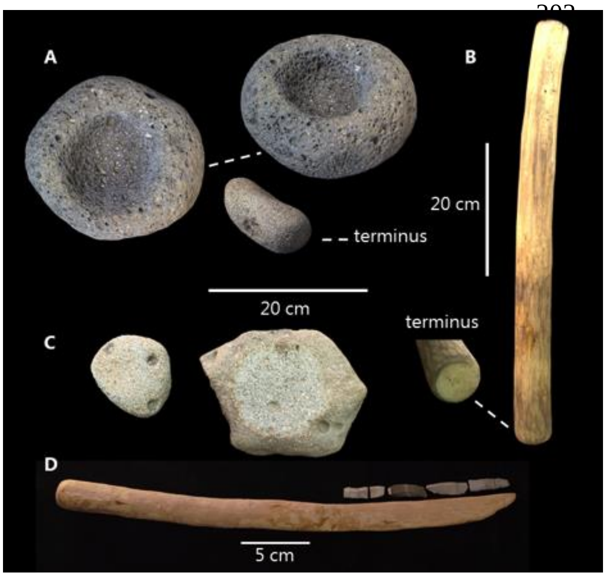
2.1.2. Club-rush processing activities

The second block of activities involved the processing of the plants, which included two main tasks: the separation of the stem from the tuber and the peeling of the tuber to remove the scale leaves, rhizomes and rootlets. The first activity was carried out in the field by 2 people, immediately after the harvesting of the plants. The resulting tuber/root materials, which were still wet, were brought to the scientific base camp in Safawi, where they were further processed by groups of between 2-4 volunteers, most of whom had no previous experience in plant processing. At this stage, the different plant materials produced (wet and dry plants, cleaned and unprocessed tubers, rhizomes, roots, residues etc.) were measured, photographed and weighted. The tuber processing experiments involved cutting, drying, roasting, and grinding/pounding activities. For this purpose specific fire installations and experimental tool replicas were produced.

2.2. Description of the experimental materials and fire installations used

To conduct the experimental activities several tools, including ground stone replicas, a sickle, and a digging stick (**Fig. 2**), as well as several fire installations were produced based on ethnographic sources and the archaeological evidence found at Shubayqa 1 (see **Supplementary Materials** for detailed information on how these tools and installations were made).

__Fig. 2.__ Images of the experimental tool replicas: A) basalt mortar (GSX.9) and pestle (GSX.10); B) wooden pestle; C) basalt quern (GSX.5) and handstone (GSX.6); D) sickle inserts (EXLI66-69, left to right) and wooden handle.



2.2.1. Ground stone tools

Ethnobotanical accounts indicate the regular use of ground stone tools to process underground storage organs (e.g. Gott 1982) and in particular, previous authors suggested that deep mortars with curved internal bowls could have been used to process sea club-rush tubers in the past (Hillman 2006 personal communication noted by Wollstonecroft 2007). To test if ground stone tools could have been used in the processing and peeling of club-rush tubers two tool pairs were manufactured: a mortar and pestle (pounding pair **Fig. 2A**), including a wooden pestle (**Fig. 2B**); and a handstone and quern (grinding pair **Fig. 2C**). The tools were made using local basalt stones, replicating the characteristics of those recovered at the Early Natufian site of Shubayqa 1.

2.2.1.1. Grinding pair

The quern (GSX.5) was 210 mm in length, 16 cm in width and c. 5 cm in thickness, with a weight of 3134 gr. A naturally stable and flat side of the basalt boulder designated the base and a circular depression was fashioned using basalt hammerstones on the opposite side of the flat boulder. The finished circular depression, the quern face, had a diameter of 9.6 cm and a depth of 6 mm. The exterior and sides of the quern were not modified. The handstone (GSX.6) was made on a sub-circular basalt cobble, with a final length of 11 cm, width of 9 cm and thickness of 3.5 cm, weight of 732 gr, with only a single modified surface. A second ad-hoc grinding pair consisting of an elongated slab GSX.7 (24 cm long, width 15-16 cm and thickness 6.5 cm) and sub-rectangular handstone GSX.8 (12 cm, width 9 cm and thickness 6.5 cm) was also produced.

2.2.1.2. Pounding pair

The basalt mortar (GSX.9) weighed 5800 gr, and was 19 cm wide and 12 cm tall. It featured a circular mortar hole (active surface), c. 12.5 cm in diameter, 5.5 cm deep and a volume of 265 ml, with a concave profile. The basalt pestle (GSX.10) had a length of 14 cm, width/thickness of 5.5-6.5 cm and a weight of 900 gr. In addition, a wooden pestle was made out of a large fig-tree branch. It was 6.1 cm long and 5.2 cm diameter/width with a weight of 900 gr.

2.2.2. The sickle

Sickles are traditionally associated with cereal gathering in Southwest Asia (Maeda et al. 2016), but in this case a sickle was produced to test if this type of tool could be used in the processing stage of club-rush, particularly for the separation of the stems from the underground storage organs. The sickle (sickle B) was hafted with four backed bladelets in a parallel line, creating a continuous cutting edge of c. 12 cm (**Fig. 2D**). The type of lithic implement to be used for the experiment was chosen based on the lithic assemblage from the fireplaces of Shubayqa 1 where the club-rush tubers were found, in particular from fireplace A, context 83. The backed bladelets each measured around 3 x 0.7 cm and were shaped by abrupt retouch using direct percussion-on-anvil technique with a finishing pass of pressure technique. Water-soluble rabbit skin glue was used as a hafting adhesive. The chert used for the production of the microliths was sourced locally within the limestone formations of the Al' Azraq Depression in Jordan. The wooden handle was carved from fresh fig wood and measure 35 cm in length with a circumference of 9 cm. Use-wear analysis was carried out using the combined approach of low- and high-power microscopy. A stereoscopic Heerbrugg Wild M38, x6.4, x16 and x40 with View Solutions GXM L12 and fiber optic adjustable light sources was used for the initial low-power investigation, and a Leica DM2700M (x5, x10, x20 and x40 objectives and x10 ocular eyepieces) was used for the high-power examination. Prior to the analysis, the bladelets were cleaned for 30 minutes in an ultrasonic tank in a weak solution of de-mineralized water and detergent. The temperature of the water was set to 50 °C.

2.2.3. Digging stick

Digging sticks have been ethnographically attested as tools to harvest tubers and other underground storage organs (e.g. Vincent 1985), and they have been exceptionally preserved in several archaeological sites across the world starting from the Middle Palaeolithic (Golson 2017, Nugent 2006, Revedin et al. 2019, Rios-Garaizar et al. 2018, López-Bultó et al. 2020a, 2020b). In this study, a digging stick was manufactured to test if this type of tool increased the efficiency during club-rush harvesting. A c. 50 cm long wooden stick with a pointed and slightly rounded active end and a circumference of 8 cm was produced from fresh *Ficus carica* (fig) tree. Although the morphology of ethnographically documented digging sticks range from spatulated to sharpened ends and vary in overall length and thickness, we decided to use the digging sticks used by Hadza women for uprooting tubers as reference for our experiment (Vincent 1985, Revedin et al. 2019).

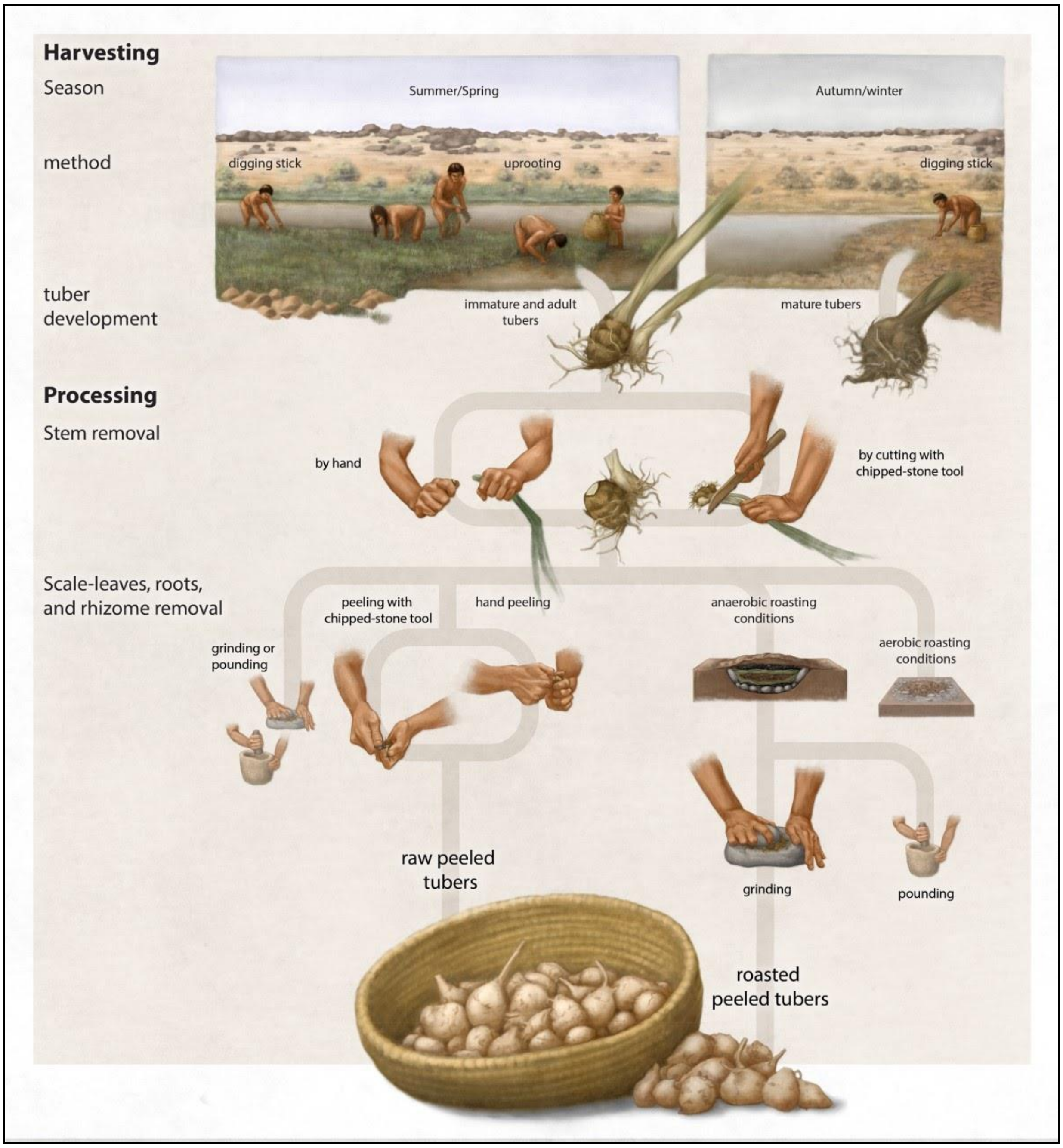
2.2.4. Fire installations

Roasting is reported as an important activity linked to root-food exploitation in various ethnographic, historic and ethnobotanical accounts around the world, although it has been primarily linked to cooking activities (Wollstonecroft 2007 and references therein). In this study, two regular fire pits and two earth-ovens were built in order to roast the club-rush tubers under aerobic and anaerobic conditions and test if this method could optimise the peeling of the club-rush tubers. The fire installations used in the experiments were all made with basalt stones, with the same characteristics as the fireplaces found at the Early Natufian Shubayqa 1 (see full description in Richter et al. 2017, Arranz-Otaegui et al. 2018a). They were concave and circular with the edges lined with basalt rocks. They had between 46-54 cm (external) and 30-34 cm (internals, inside the basalt stone lining) in diameter and a depth of c. 16-17 cm.

3. Results and discussion

In the following sections we describe and discuss the experimental work carried out, list the main activities involved in the gathering and processing of club-rush tubers, and qualitatively evaluate the efficiency of the different approaches tested (**Fig. 3**). We also describe and highlight some of the key traits (taphonomic features on tuber remains, use-wear, etc.) that these activities left in the experimental materials, which are used to interpret the archaeological evidence gathered at Shubayqa 1.

Fig. 3. *Club-rush tuber exploitation scheme. Gathering and processing methods tested and the most likely choices based on the archaeological evidence gathered at Shubayqa 1.*



3.1. Club-rush tuber gathering: timing and methods

The first fundamental step was to gather the tubers, and in so doing provide answers to two main question: (i) which were the most efficient methods/tools to gather club-rush tubers?; and (ii) what was the best time of the year for tuber gathering?.

3.1.1. Evaluating different tuber gathering methods

The initial evaluation of the club-rush harvesting methods involved two main approaches: the use of uprooting and digging sticks (**Fig. 4**).

Fig. 4. *A) Club-rush stands in Qasr Burqu' (May 2017). B) Club-rush tuber gathering by uprooting. C) Club-rush tuber gathering with a digging stick.*

Despite the extended ethnographic and archaeological evidence that relate root-food gathering with the use of digging sticks, our experiments in the Black Desert showed that digging sticks would not have been necessary in the case of club-rush. These tools showed some efficiency during autumn and winter time, when the plants were not yet growing in the water and it was therefore necessary to remove the dry and hard soil to recover the tubers. However, during spring and early summer, that is, when the tubers were at their optimal harvesting season (see section *3.1.2.1.*), the plants grew under water, in soft clay, which allowed direct uprooting by hand. We gathered the plants by holding the basal part of the stem with bare hands, and pulling up groups of 5-8 plants in a slow motion, avoiding the break of the stem and the loss of the underground storage organs. Thus, during this particular time of the year, uprooting was qualitatively speaking faster and more efficient than the use of digging sticks, which showed some advantage primarily to retrieve plants stuck in the mud, like those growing in autumn and winter time.

3.1.2. Differences on the types and quantities of tubers recovered

Previous studies have shown that the sister-species *B. maritimus* produces effective yields that make tuber harvesting a worthwhile activity in comparison to other plant foods (Wollstonecroft 2007, 2009, Wollstonecroft and Erkal 1999). The harvesting experiments conducted so far show production rates (i.e. grams of peeled tubers gathered per hour) and overall numbers (number of tubers gathered per hour) of 1271.8 g/h/person and 367 n/h/person in the Pevensey marsh (England, Wollstonecroft 2007). In the Konya Basin instead, production rates and numbers were found to be 521.8 g/h/person and 226 n/h/person, respectively (*ibid*). However, it is important to note that the availability of club-rush tubers differs by region. In the experimental gathering of *B. glaucus* tubers carried out in Qasr Burqu', the production rates were similar, c. 531 g/h/person on average. Besides, these general production rates should be considered with caution since significant differences were observed in the types, sizes and availability of tubers that could be gathered in Qasr Burqu' depending on three factors: the gathering season, the rainfall conditions prevalent each year, and whether tuber harvesting was selective or arbitrary.

3.1.2.1. Factor 1: Gathering season

The initial objective of this study was to compare the characteristics of the tubers gathered in different seasons of the year, with those recorded in the archaeological assemblage of club-rush tubers from Shubayqa 1, and so doing shed new light on the seasonality of root-food gathering activities carried out during the Epipalaeolithic period. Thus, harvesting experiments involved gathering activities in autumn/winter as well as spring/summer (see **Table 1**, for details on the harvesting times and types of recovered plant materials).

Table 1. *Club-rush tuber collections and timings. * Note that the club-rush tubers in experiment #1 were completely dried at the time of gathering, and the weight makes reference to air-dried plant materials.*

Experiment	**Season**	**Life cycle of the plant**	**Average size of the plants**	**Type of rhizome tubers available**	**People involved in harvesting**	**Total time spent gathering**	**Weight of unprocessed fresh rhizome tubers**	**Grams (fresh peeled)/hour /person**
Gathering experiment #1 (February 2017)	Winter	Hibernacles	-	Old/mature	1	10 min.	80 gr*	256.6*
Gathering experiment #2 (May 2017)	Spring	Juvenile plant growth	c. 35-60 cm	Adult and young	1	75 min.	771 gr	329.8
Gathering experiment #3 (May 2018)	Spring	Juvenile plant growth	c. 20 cm	Adult and young	4	90 min.	7564 gr	673.70
Gathering experiment #4 (June 2019)	Late spring-summer	Adult plant growth, fruiting time	c. 60-70 cm	Adult and young	2	110 min.	4043 gr	589.50

Autumn/Winter time. Autumn is the rainy season in Jordan and it is the seedling season for club-rush. During this time the shores of lake Burqu' are inundated, and only dry plants from previous years are visible. It is possible to gather club-rush tubers from September to March, but the materials recovered in autumn/winter only comprise mature and very fibrous tubers. These mature tubers are overall larger than the adult and young immature tubers available during springtime (c. 2.5-3 cm breadth and 3-4 cm length). They are commonly rounded in shape, with similar breadth and length sizes, and they have a hard and thick dark outer cortex, composed of fibrous materials. These mature club-rush tubers require intensive processing to make them edible, and in some species like *Cyperus rotundus* (nutgrass) they are directly considered as inedible (Hillman 1989).

Spring/Summer time. In springtime club-rush seedlings begin to grow, and apart from mature fibrous tubers from previous years, new adult and young immature tubers can be harvested. Adult tubers are overall smaller in size than mature fibrous tubers (c. 1-2.5 cm breadth and 1-2.7 cm length) and they are commonly elongated, although some round-shaped specimens were also recorded. The outer cortex is commonly light brown to yellowish. Young immature tubers derive from plants that are still growing, the stems of which are still short (c. 20 cm) and thin. They are characterised by their relatively small size (c. 0.3-0.7 cm breadth and 0.3-1.5 cm length), round shape and soft and white outer cortex, which unlike in adult tubers, it can be easily removed by hand rubbing. Wollstonecroft (2009) reports that in the case of the sister-species *B. maritimus* immature tubers can be eaten raw without peeling or processing. She further indicates that although they could have constituted an occasional food, it is unlikely young tubers contributed significantly to human diets due to their overall low nutrient value. We also noted that in summer time, the plants that were already fruiting had on average smaller tubers (c. 1 cm in breadth) than the plants that were still in the process of maturation, which had tubers with an average breadth size of 2-2.5 cm. This is due to the fact that the plants use the energy stored in the underground storage organs for flowering and fruiting, leading to a general reduction in tuber size. Nevertheless, previous studies show that tubers available during spring and summer time would have been overall richer in carbohydrates, easier to process and more palatable than old autumn/winter tubers (Hillman et al. 1989, Wollstonecroft 2007, 2009).

To provide additional insights into the possible season of harvesting of the club-rush tubers at Shubayqa 1, a preliminary comparison of the size of the charred archaeological and modern specimens was carried out. The modern specimens were carbonised under low heating regimes (see details in Table 3, processing experiment #14). Width and length of a total of 103 archaeological and 179 modern specimens were measured digitally, using Helicon Remote (ver. 3.9.0 W). Average, maximum and minimum measurements are shown in **Table 2**. The results indicate slight differences in the width and lengths of the tubers measured (see also scatter plot in **Supplementary Materials**). The club-rush tubers from Shubayqa 1 were larger in average breadth size (0.9-1 cm), than modern carbonised tubers gathered in lake Burqu’ (0.8 cm), but the main difference relied on the length-width ratios. The club-rush tubers from Shubayqa 1 showed average length-width ratios of 1.35 and 1.39, meaning that most of the tubers were round shaped (i.e. similar width and length sizes). The length-width ratios in modern carbonised tubers were instead of 1.67 and 1.68 respectively, meaning that they exhibited an elongated shape (i.e. they were considerably longer than wider).

Table 2. *Comparison of modern and archaeological size of carbonised club-rush tubers.*

Club-rush assemblages	**Number**	**Maximum (mm)**		**Average (mm)**		**Minimum (mm)**		**Lenght/Width ratios**
		Width	Lenght	Width	Lenght	Width	Lenght	
Modern 2018 (spring)	*67*	17.84	27.31	8.54	13.41	2.90	5.68	1.67
Modern 2019 (late spring/summer)	*112*	13.92	33.43	8.29	13.90	4.93	5.35	1.68
Shubayqa 1 (early phase)	*52*	17.28	23.72	9.37	12.35	4.60	8.20	1.39
Shubayqa 1 (late phase)	*51*	14.85	20.09	9.97	13.04	5.49	7.97	1.35

However, during the fieldwork two factors were documented that could have conditioned the size of the tubers gathered, and that should be considered in order to interpret the results obtained at Shubayqa 1.

3.1.2.2. Factor 2: Rainfall conditions

The growth of club-rush plants in the Qasr Burqu' area depends to a large extent upon the rainfall conditions prevalent each year. For example, experiments #2 (2017) and #3 (2018) were both conducted in May, but the year 2018 was significantly drier than 2017, and even hampered the cultivation of cereal crops by local Bedouin communities in the Black Desert. The nearest weather station (at Ruwaished, c. 24 km southeast of Burqu') recorded a total of 42 mm of rain in the year preceding May 2017, and 26 mm in the year preceding May 2018, compared to an annual average of 46 mm over the period 2000-2019 (Menne et al. 2012a, 2012b). As a result, clear differences in the total heights of the plants were observed during the field experiments. In 2017, which was an average year in terms of precipitation, plants in the first week of May had already reached c. 60-70 cm in height, whereas in May of 2018 they were only 20 cm tall. Besides, the minimum and maximum sizes of the tubers gathered in 2017 was of 0.5-2.5 cm width and 1.5-3.7 cm length (*n= 35*), compared to 0.3-1.8 cm width and 0.7-2.7 cm length (*n= 67*) in 2018. Thus changes in the amount of precipitation conditioned the availability of club-rush stands and the size of the tubers that could be recovered each year.

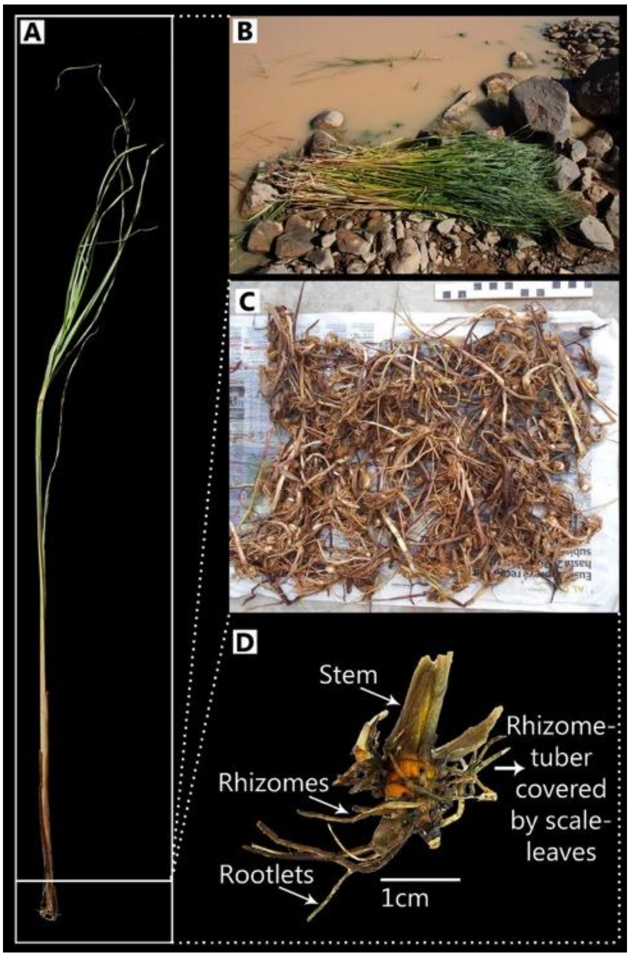
3.1.2.3. Factor 3: Selective gathering and management practices

Differences on the size of the tubers could also be dependent upon selective v. arbitrary harvesting of the plant materials. It has been previously suggested that hunting and gathering groups could have recognised whether tubers were worthwhile harvesting based on the characteristic of the stems arising above the ground (Wollstonecroft 2009). During our field observations we noticed that the larger the overall height and thickness of the plant stems arising above water, the larger the tubers underneath. This pattern has also been pointed out by other authors, which indicate that the annual aboveground growth of sea club-rush occurs in conjunction with specific patterns of below-ground production (Kantrud 1996, Lieffers and Shay 1982). In addition, we also documented differences in the size of the tubers depending on the growing location of the plants within the lake. The plants that grew far away from the shoreline, that is, plants that were permanently under-water, were overall largest in size. These plants had an average of c. 60 cm in height, whereas those that were closest to the shoreline were half the size (c. 35 cm long in average).

Apart from these, plant management activities could have also conditioned the size of the club-rush tubers available in Shubayqa 1. Denham et al. (2020) note that increased number of edible organs and the increased size of edible vegetative organs (the organ used for clonal propagation) are some of the key domestication traits in asexually propagated plants. Indeed, changes in the morphology of plants and tubers have been noted in root crops like *Dioscorea* yams (Hather 2000). Besides, it is well-documented in several root-foods like nutgrass, club-rush, yam, and *Typha* (cattail) that tuber production is stimulated due to soil disturbance, like the one produced during tuber digging (Hillman 1989, Hallam 1983, Holm et al. 1981, Gott 1982). An intensive exploitation and selection of club-rush tubers during the Natufian could therefore constitute a possible factor to explain the overall larger average size and more rounded shape of the tubers found in Shubayqa 1.

Fig. 5. *A) Unprocessed club-rush plant, showing aerial and underground parts; B) separated*

stems and C) underground storage organs; D) detail of a rhizome-tuber covered by scale-leaves, basal part of the stem, rhizomes and rootlets.



3.2. Club-rush processing activities

Once club-rush plants were harvested, the gathered materials had to be further processed. These processing activities involved two main tasks: 1) the separation of the aerial (stems) from the underground parts (rhizome, tubers, roots); and 2) the processing of underground parts to remove scale-leaves, roots and rhizomes to obtain clean tubers (**Fig. 5**). In **Table 3**, the results of the main tuber processing methods and activities carried out are detailed.

Table 3. *Club-rush tuber processing activities, timings, products and by-products.*

Experiment	Objetive	Method/tools	Materials	State	Amount of material processed (gr)	Number of people involved in processing	Total time spent processing	Product	By-product
Processing experiment #1 (2017)	Separate aerial and underground parts	Cutting tool	Mature club-rush tuber plants (Stem + USO)	air-dried	290	1	5 min	USO + basal part of the stem	Stems
Processing experiment #2 (2018)		By hand	Adult and immature club-rush tuber plants (Stem + USO)	fresh wet	23693	3	330 min	clean USO	Stems
Processing experiment #3 (2018)		Cutting tool	Adult and immature club-rush tuber plants (Stem + USO)	fresh wet	9567	1	350 min	USO + basal part of the stem	Stems
Processing experiment #4 (2019)		By hand and cutting tool	Adult and immature club-rush tuber plants (Stem + USO)	fresh wet	18478	4	193 min	clean USO + some with basal part of the stem still atached	Stems
Processing experiment #5 (2018)	Peel the tubers: remove scale leaves, roots, rootlets and stem bases	By hand/ use of knife	USO: Primarily adult tubers, with some mature and immature tubers	fresh wet	15876	5	5.5 hours	Fresh pealed tubers	Scale leaves, roots, rhizomes, basal stems
Processing experiment #6 (2019)		By hand	USO: Primarily adult tubers, with some mature and immature tubers	fresh wet	6258	2	5 hours	Fresh pealed tubers	Scale leaves, roots, rhizomes, basal stems
Procesing experiment #7 (2019)		Pounding in a basalt mortar	USO: Primarily adult tubers, with some mature and immature tubers	fresh wet	253	1	5-10 min	-	Smashed tubers, mixed with rhizomes/roots
Processing experiment #8 (2019)		Grinding in a slab	USO: Primarily adult tubers, with some mature and immature tubers	fresh wet	248	1	5-10 min	-	Both smashed and semi-pealed tubers, mixed with roots and rhizomes
Processing experiment #9 (2019)		Pounding in a basalt mortar	USO: Primarily adult tubers, with some mature and immature tubers	air-dried (12 hours)	148	1	5-10 min	-	Cracked tubers, mixed with roots and rhizomes
Processing experiment #10 (2019)		Grinding in a slab	USO: Primarily adult tubers, with some mature and immature tubers	air-dried (12 hours)	147	1	5-10 min	-	Slightly cracked, semi-processed tubers, mixed with roots and rhizomes
Processing experiment #11 (2018)	Roast the tubers	Roasting in aerobic conditions	USO: Primarily adult tubers, with some mature and immature tubers	air-dried (7 hours)	168	1	15 min (c. 500-540º)	-	Carbonised tubers, roots, scale leaves, roots, basal stems
Processing experiment #12 (2018)		Roasting in aerobic conditions	USO: Primarily adult tubers, with some mature and immature tubers	air-dried (7 hours)	75	1	15 min (c. 240-280º)	-	Semi-dry tubers, roots, scale leaves, roots, basal stems
Processing experient #13 (2019)		Roasting in anaerobic conditions	USO: Primarily adult tubers, with some mature and immature tubers	fresh wet	256	2	120 min (c. 340º)	-	Semi-dry tubers, roots, scale leaves, roots, basal stems
Processing experient #14 (2019)		Roasting in anaerobic conditions	USO: Primarily adult tubers, with some mature and immature tubers	air-dried (7 hours)	80	2	120 min (c. 334º)	Roasted tubers	Carbonised tubers, fragmented roots, scale leaves, roots, basal stems
Processing experiment #15 (2019)	Peel the tubers: remove scale leaves, roots, rootlets and stem bases	Pounding roasted tubers in a mortar	USO: Primarily adult tubers, with some mature and immature tubers	roasted	10	1	5 min	-	Cracked tubers, mixed with roots and rhizomes
Processing experiment #16 (2019)		Grinding roasted tubers in a slab	USO: Primarily adult tubers, with some mature and immature tubers	roasted	10	1	15 min	Peeled roasted tubers	Scale leaves, roots, rhizomes, basal stems

3.2.1. Separating the aerial and underground plant parts

For this activity two main methods were tested: pulling the stems out by hand and cutting the stems using tools (**Fig. 6**).

Fig. 6. *A) Separating aerial and underground plant parts by hand. B) Sickle B used to cut and separate the stems approximately one centimetre above the tuber; Use-wear traces from experimental tools EXLI67 showing C) scalar and trapezoidal scarring, silica gloss and longitudinal striae (scale 200 µm), and D) edge-rounding and silica gloss (scale 100 µm; E) Use-wear traces from an inversely retouched bladelet found in the fireplace A at Shubayqa 1 (ID004, scale 200 µm).*

Initially, the stems were separated from the underground storage organs by hand, when the plants were still wet (**Fig. 6A**). This activity was carried out immediately after harvesting the tubers in the shore of the lake, by small groups of 2-3 people. This method was particularly suitable to process spring-summer club-rush plants that had green stems. The main advantage of separating the stems by hand was that when pulling out the green stem, the basal part was completely removed from the top end of the tuber, leaving a clean abscission scar (see **Fig. 3** "stem removal"). The main disadvantage was that hand pulling required some strength and was not practicable for every participant.

An alternative method for separating the aerial and underground parts was to cut the stems (**Fig. 6B**). Both chert tools and modern metal knives were used for this purpose, although no clear differences in terms of efficiency were noticed between the two. Cutting the stems with a knife/chert tool was overall faster than hand-pulling, especially in winter-time, when the stems were dried and hard to separate by hand. However, the main disadvantage was that the basal part of the stem remained attached to the top end of the tuber, and had to be removed in subsequent processing stages (see **Fig. 3** "stem removal"). To test whether the microliths found in conjunction with the tubers could have been used for this purpose, a sickle (sickle B) was used to cut green stems for 63 minutes in a longitudinal, unidirectional movement in order to produce reference use-wear. At this point, three out of the four sickle inserts had developed macroscopically visible silica gloss as well as scarring. Macroscopically visible silica gloss was identified along the active edge combined with a light rounding of the edge as well as rather small scalar and trapezoidal scarring (**Fig. 6C** and **D**). The high power microscope confirmed the findings, and also made visible faint, longitudinal striations (**Fig.**

6C). The use-wear was generally more developed on the side of the tool facing the thumb (in this case the dorsal side). A comparison between the experimental and archaeological tools in **Fig. 6C-E**, shows similar wear-trace development in terms of scarring and gloss, suggesting that the archaeological implement could have been used to cut silica rich plants like club-rush. This is further indicated by laser scanning confocal microscope analyses of archaeological tools from Shubayqa 1 and the nearby Shubayqa 6 (Ibañez-Estévez et al. 2021). Using this method, which allows assigning silica gloss to a specific plant type (Evans and Donahue 2008, Ibáñez, Lazuen and González-Urquijo 2018, Stemp and Chung 2011), the study shows that ten artefacts recovered from Shubayqa 1 and 6 were used to cut a number of silica rich plants (cereals, grasses and reeds), which could potentially include club-rush.

3.2.2. Removing scale leaves, roots and rhizomes

Club-rush rhizome tubers comprise tight scale leaves, rhizomes and rootlets that have to be removed in order to access the starch-rich parenchymatous tissue. For this purpose a number of different experiments were carried out, including the processing of tubers in different states (wet, air-dried, roasted), with different tools (hands, knives, ground stone tools) and processing techniques (grinding, pounding) (see details in **Table 3**).

Overall, the most suitable processing techniques for club-rush tubers depended on the season of collection and the state of maturity of the tubers: old/mature fibrous tubers, adult tubers, and young and/or immature tubers (**Fig. 7A**). Mature tubers from autumn-winter time were dried at the time of collection, and due to their thick and fibrous epidermis, a cutting tool was necessary to remove the outer scale-leaves (**Fig. 7B**). In contrast, adult and immature tubers from spring-summer time could have been processed both whilst fresh (i.e. wet) and after drying. In the following lines we discuss the different processing techniques applied to these latter group of tubers.

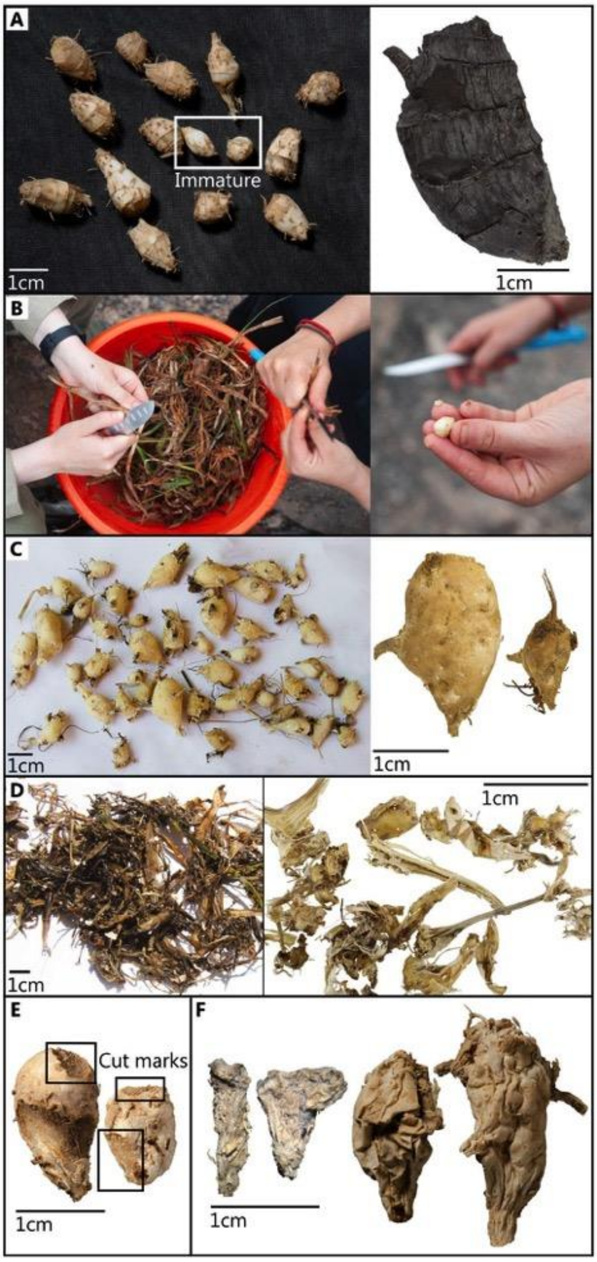


Fig. 7. *A) Image of unpeeled spring-summer time adult and immature tubers (left) and autumn-winter time mature tubers (right); B)*

Peeling of tubers with knives/cutting tools; C) Fresh peeled tubers; D) Plant residues derived from tuber processing: scale leaves, roots and rhizomes; E) Tubers with cut marks made by cutting tools during peeling; F) Immature (left) and adult (right) tubers dried before processing, showing characteristic shrinkage and wrinkles.

3.2.2.1. Peeling fresh and air-dried tubers by hand and using cutting and ground stone tools

Experiments #5-10 intended to evaluate the processing of the tubers straight after they were gathered, whilst the tubers were still fresh and wet, as well as after drying. For this purpose three main approaches were tested: 1) processing the tubers with bare hands; 2) using a cutting tool to remove the scale leaves and rhizomes; 3) and using ground stone tools, both grinding and pounding implements.

The first set of experiments (#5-8) was carried out with fresh tubers. To remove the scale leaves, rhizomes and rootlets we used bare hands, inserting the fingernails into the surface of the tuber and scraping (processing experiment #5 and 6). This process was time consuming (e.g. 5 hours, 2 people for c. 600 gr of unprocessed tubers), but the resulting product were perfectly cleaned tubers (**Fig. 7C**), and a residue composed of scale leaves, roots and rhizomes (**Fig. 7D**). Some participants preferred the use of cutting tools like a knife, as the constant friction with the hard outer surface was damaging for the fingernails. Besides, a cutting tool was sometimes necessary to remove the hard rhizomes. Interestingly, the use of a cutting tool left clear-cut marks on the surface of the tubers that could be recognised in the archaeological record (**Fig. 7E**).

Processing experiments #7-10 were carried out to evaluate whether the thousands of ground stone tools found at Shubayqa 1 could have been used, amongst other activities, to process club-rush and obtain peeled tubers. We tested the use of a basalt mortar and wooden pestle (experiment #7), as well as a grinding slab (experiment #8) as a means to separate the fresh tubers from the root and the rhizomes. However, tubers were overall too wet and sticky to be ground, and the resulting product was a mush of unprocessed tuber materials (see detailed description of these experiments in **Supplement Materials** and **Table 3**).

These experiences led us to dry the tubers in the sun, and try to process them once the water content had evaporated (experiments #9 and 10). After c. 12 hours in the sun, the tubers became too hard and none of the different types of tubers (i.e. mature, adult, immature) could be processed either by hand or with cutting tools. Besides, many of the adult and immature tubers had completely shrunken, showing characteristic wrinkles (**Fig. 7F**). When trying to process them with pounding and grinding tools (experiments #9 and 10, see detailed description of these experiments in **Supplement Materials** and **Table 3**) air-dried tubers fragmented into small pieces, leaving a mix of cracked tubers, along with fragments of roots, rhizomes and scale leaves (see examples of cracked tubers in **Fig. 9**).

From these sets of experiments we learnt that the best strategy to remove the scale leaves, roots and rhizomes from club-rush was to peel them soon after they were harvested, when they were still fresh and preserved the water content, either by hand or using cutting tools.

However, tuber peeling was the most time-consuming aspect of the *chaîne opératoire*, as it required considerably more time and energy than the gathering of the plants (see **Table 3**, Wollstonecroft 2007). As such, we decided to test a final processing method that could potentially optimize the exploitation of this plant-food resource.

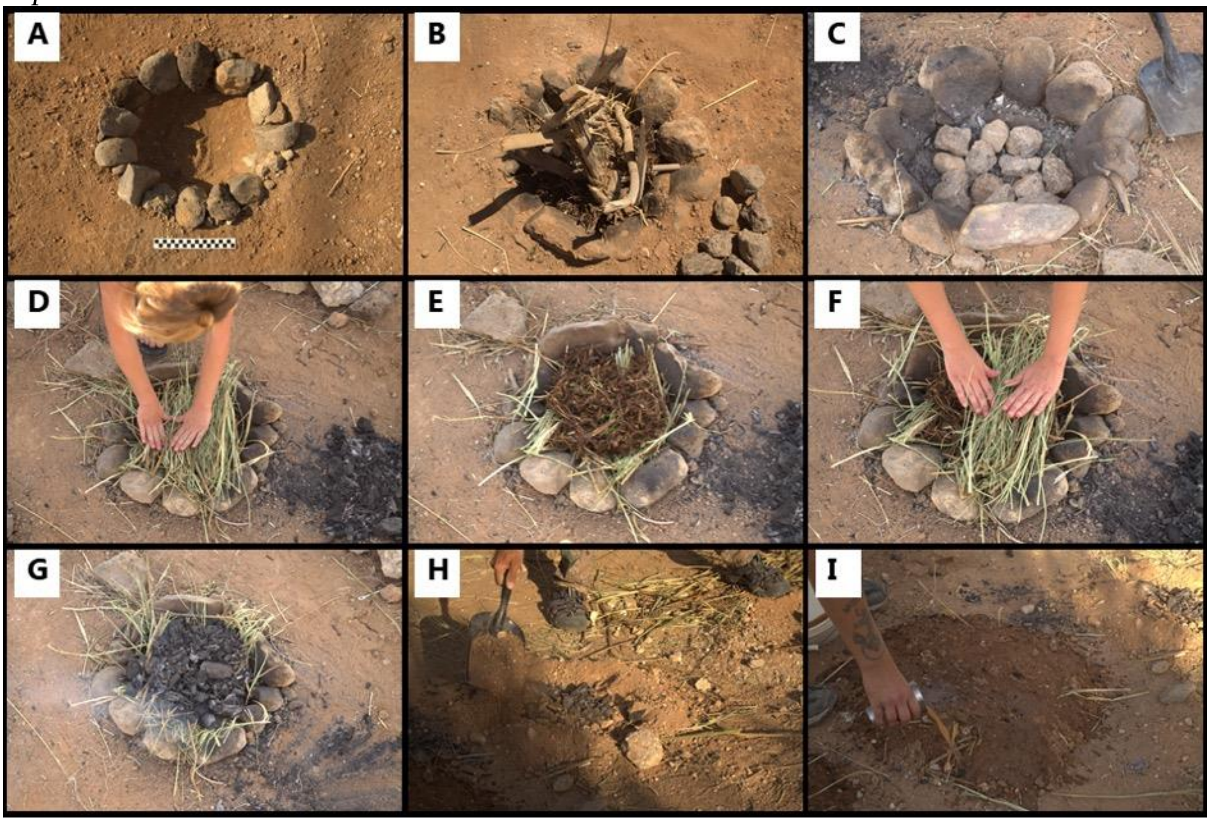
3.2.2.2. Roasting club-rush tubers

In this study we sought to test if roasting could facilitate the de-husking process of club-rush tubers, as this methods is reported in several ethnographic studies related to the processing and cooking of root-foods. To do so, four main experiments were carried out to find out which was the best procedure to obtain perfectly roasted club-rush tubers (see **Table 3**, experiments # 11-14). The step-by-step description of the different roasting experiments can be found in the **Supplementary Materials**.

Overall, roasting activities involved unprocessed fresh and air-dried club-rush tubers. In the study area, drying of tubers was relatively fast. For example, in late springtime, when day temperatures vary between 30 and 40º, a sub-sample of c. 3065 gr was dried after c. 7 hours (from 8 am to 3 pm). Besides the tubers were burnt in both aerobic conditions and anaerobic conditions. In experiments #11 and 12, the tubers were roasted in the hot ashes, whereas in experiments #13 and 14 we used earth-ovens for this purpose (also known as "pit oven" or "roasting pits" **Fig. 8**). These earth-ovens were made of: 1) a layer of wood charcoals and pre-heated basalt stones in the bottom; 2) followed by layer of club-rush tubers wrapped in stems; 3) and a top layer of wood charcoal remains and soil, which after adding water became hardened and sealed the pit deposit (see detailed step-by-step description of the construction of the fire installations in the **Supplementary Materials**). The fuel used in all the experiments was the same and included wheat straw and club-rush stems as starters, and fig and Chenopodiaceae (goosefoot family) wood. In experiments #13 and 14, commercial fuel wood (olive and oak) was additionally used. The amount of club rush tuber material included in each of the roasting pits and the temperatures in the different stages of the process (initial lighting of the fire v. end), and burning elements (flames, soil, wood charcoals and the basalt stones) were individually recorded.

The results show important differences in the state of the tubers from experiments #11-14. Roasting of air-dried tubers in the hot ashes (aerobic or semi-aerobic conditions) for 15 minutes at temperatures of 500-540º resulted in completely carbonised tubers, whereas temperatures of 240-280º in the same conditions were instead insufficient, and resulted in semi-wet tubers. However, roasting of the tubers in anaerobic conditions proved more successful. The tubers from experiment #13, which had been gathered from the lake and directly put into the fireplaces whilst wet, were still damp after 2 hours of cooking at a starting temperature of c. 340º. These tubers were semi-cooked, but their texture was quite hard, and the tuber's roots and rhizomes were humid and soft. Finally, the tubers from experiment #14 were perfectly roasted, although by the time the earth-oven was opened, 1/5 of the tubers had been completely carbonised. The procedure was the same as in experiment #13, but in experiment #14 the tubers had been previously air-dried to evaporate most of the water content, which allowed their roasting. However, the resulting tubers still contained scale leaves and root/rhizome remains that had to be removed, and for which an additional processing step was necessary.

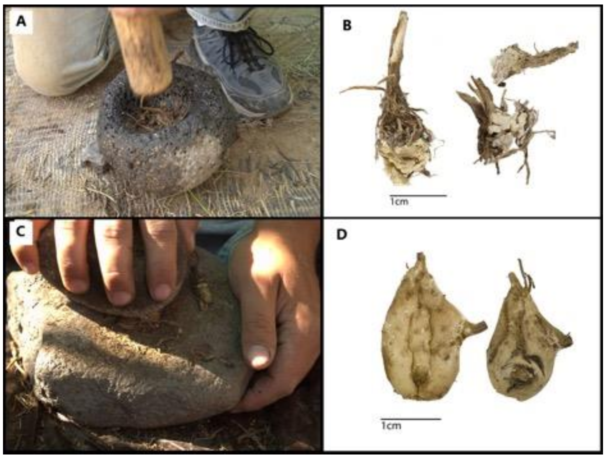
Fig. 8. *Earth-oven construction, experiments #13 and 14. A) A c. 50 cm diameter wide and c. 30 cm deep pit with angular to sub-angular cobble-sized basalt stones; B) Fuel wood ready to be burnt; C) Burnt wood charcoal pieces and small cooking basalt stones (note thermal alteration in the pit lining stones); D) First layer of club-rush stems; E) Unprocessed club-rush tubers ready to be roasted; F) Second layer of club-rush stems; G) Remaining wood charcoal fragments; H) Covering of the pit with soil; and I) Addition of water to seal the deposit.*



3.2.2.3. Peeling roasted tubers by pounding and grinding

Once the tubers were roasted, we intended to test whether the use of ground stone tools, in particular mortars and querns, could help remove the hard scale leaves that were still attached to the tubers (Experiments #15-16, **Fig. 9**, see detailed description in **Supplementary Materials**).

Fig. 9. *Roasted tubers from experiment #14 A) being pounded in a mortar, leading to B) cracked tubers; C) being ground in a quern, leading to D) perfectly peeled tubers.*



We took the experimental basalt mortar and wooden pestle to pound the roasted tubers from experiment #14 (**Fig. 9A**). However, after only 5 minutes of pounding, the tubers were completely fragmented and cracked, and the different parts of the plant, that is, the tuber, the scale leaves, and small fragments of semi-carbonised roots and rhizomes were mixed (**Fig. 9B**). In experiment #16, we used the quern and a stone basalt hand stone to process 10 gr of roasted tubers (**Fig. 9C**). The resulting abrasion removed the roasted scale leaves efficiently, obtaining 4 gr of completely clean tubers (**Fig. 9D**). In addition, the peeling/grinding of the tubers in the quern allowed separating the clean tubers from the remaining residue, something that was not possible using the deeper-faced mortars.

4. Final conclusions: first insights into club-rush tuber exploitation at Shubayqa 1

Based on the experimental work and the evidence found at Shubayqa 1 we can start to draw some initial conclusions about how club-rush tuber exploitation activities could have taken place during the Early Natufian period.

In terms of gathering methods, we consider that uprooting was the most efficient method to harvest club-rush plants in the Black Desert, whilst digging sticks could have been useful specifically to harvest specimens that remain stuck in the mud or that were not growing under-water (i.e. like those available during autumn-winter time). If we accept that the rainy season at the end of the Late Pleistocene was the same as today (i.e. October-November), it is most likely that the harvesting of club-rush tubers was carried out during spring-summer time (May-June), before the plants started to flower, and at the time the tubers were most succulent. An interesting aspect that emerged from the comparison of the size of the archaeological and modern tuber assemblages is that the archaeological specimens were overall more rounded in shape and slightly larger in width, than tubers that derive from modern unmanaged stands. Future studies should therefore be aimed at evaluating the possible factors behind these differences, both in terms of environmental conditions, selective gathering and possible root-food management practices.

After gathering the plants, the Natufian communities would need to separate the aerial and underground parts. This activity was most likely carried out immediately after the harvesting, that is, before the stems become dry and hard to remove, and it could have been done either by hand or using chipped stone tools. The on-going use-wear analyses of the chipped stone tools found at Shubayqa 1, and the application of confocal microscopy are expected to provide additional insights into which procedure was potentially preferred during the Early Natufian period.

The final and most-time consuming stage of the processing was the peeling of the club-rush tubers. The experimental data gathered in this work allow us to discard some of the methods put forward by previous studies, as well as to suggest new procedures that could explain the archaeological evidence recovered at Shubayqa 1:

1) According to our work, ground stone tools would not have been used in the processing of club-rush tubers, as direct grinding and pounding of fresh and air-dried tubers did not facilitate the removal of the scale-leaves, roots and rootlets. However, further experiments are necessary to evaluate if other ground stone types attested at the site, like the deep conical vessel-mortars, could be of any use for this specific activity.

2) We consider that individual peeling of club-rush tubers, either by hand or using chipped-stone tools, could have been an option during the Natufian, but in the particular case of Shubayqa 1 this practice could be initially discarded for three main reasons:

   a. Absence of cut-marks. The experimental plant materials produced in this work showed the presence of cut-marks in the tuber assemblages peeled using cutting tools. However, such taphonomic features are so far absent from the archaeological club-rush tuber assemblage recovered at the site.

   b. Size of the assemblages and time involved in their processing. In the experimental club-rush peeling activities carried out so far, the assemblages processed were relatively small (c. 200-300 in average Wollstonecroft 2007 and c. 700-1800 tubers in this work). However, each of the fireplaces at Shubayqa 1 comprised c. 3,000 complete/semi-complete tubers, along with more than 23,000 fragments. If we consider accidental burning, the original tuber assemblages must have been considerably larger, comprising at least 15,000 complete tubers (possibly 2-3 times more, as this number is calculated based on a potential lose rate of 1/5 indicated by our roasting experiments, and does not include the minimum number of individuals represented in the c. 23,000 tuber fragments). The results obtained in this and previous studies (see Wollstonecroft 2007) indicate that one person can peel by hand between 70-177 tubers per hour. This means that to hand peel each of the tuber assemblages at Shubayqa 1 one person would have spent at least 84.7 hours, that is, c. 10 days.

   c. The possibility to apply more efficient processing methods. Our experiments have allowed us to come up with an alternative processing method that would have enabled the large-scale processing of the tubers. The experiments showed that drying, roasting and subsequent grinding would have been less demanding, both in terms of time and effort, than peeling the tubers one-by-one, and therefore, specially suited to be applied in the case of large tuber assemblages.

Despite the fact that it is not yet possible to fully ascertain how the inhabitants of Shubayqa 1 undertook the final processing of the tubers, the experimental club-rush tuber classifications produced in this work allow us to provide key interpretations for the assemblages for the first time (Arranz-Otaegui et al. 2018a). The experimental and archaeological materials show clear equivalences (**Fig. 10**) and they indicate that the largest part of the tubers found at the site was completely peeled by the time they were placed into the fireplaces (**Fig. 10E-F**). In other words, they were carbonised after the processing stage, probably during their final cooking. However, a small number of the tubers preserved the scale-leaves, meaning that they were yet unprocessed (**Fig. 10A-B**); and some showed the characteristic wrinkles associated with the drying of the tubers prior to carbonisation (**Fig. 10C-D**). In this sense, the presence in the fireplaces of unprocessed and dried tubers along with other elements like stems, roots and rhizomes (see and Fig. 3A-R, in Arranz-Otaegui et al. 2018a) suggests that the fireplaces could have been used for multiple tasks related to the exploitation of club-rush tubers, including both roasting of unprocessed tubers and other cooking activities.

As such, the final step in our experimental program will be to evaluate how the club-rush tubers were transformed into plant-foods, and as well as to identify the specific cooking practices and characterise the types of foodstuffs produced. We will ask: why were the club-rush tubers peeled and subsequently roasted? What types of cooking techniques were used in their transformation? Ultimately, this detailed interdisciplinary experimental program will enable not only to reconstruct the complete sequence for club-rush tuber gathering, processing and cooking during the Early Natufian, but also to start disentangling the social, economic and cultural practices (e.g. the amount of labour involved, work-organization, planning and resource selection) associated with the routine exploitation of wild plant resources in the past.

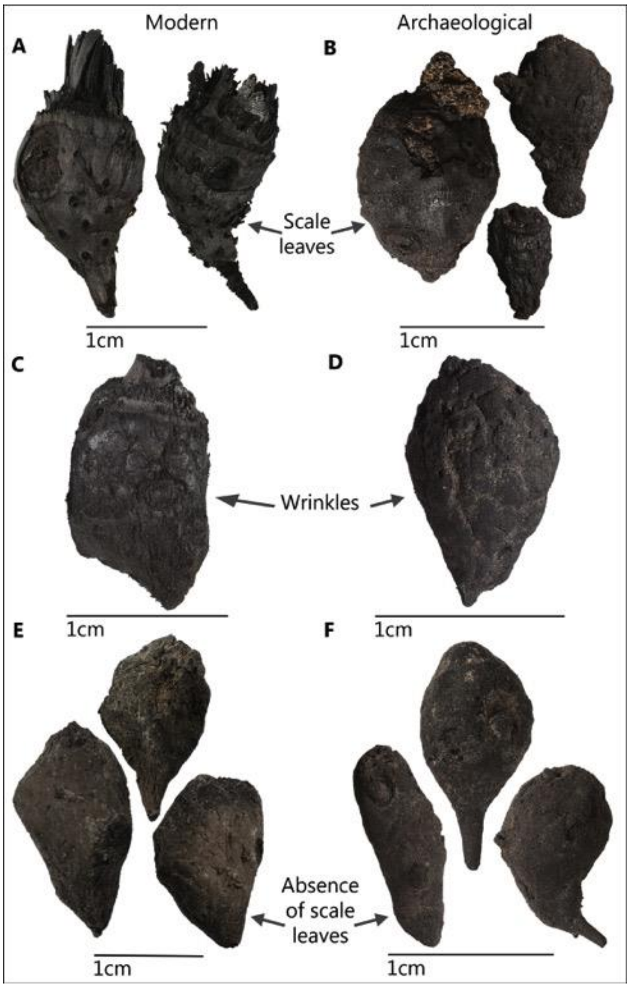


Fig. 10. *Comparison between modern and archaeological carbonised club-rush tubers. a) Modern unpeeled carbonised tubers from pit X; B) Unpeeled tubers from Shubayqa 1, sample 30 (2012); C) Modern peeled club-rush tubers from experiment #11; D) Archaeological peeled tubers from Shubayqa 1, sample 90 (2013); E) Modern wrinkled tuber from experiment #13; F) Wrinkled tuber from Shubayqa 1, sample 90 (2013).*

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Supplementary Materials

The chaîne opératoire of club-rush tuber exploitation (*Bolboschoenus glaucus*), disentangling Early Natufian root-food gathering and processing activities in Southwest Asia

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2. Rationale for the production of the experimental stone tools: description of the raw materials selected and the manufacture process

2.1. Ground Stone tools

The ground stone tool assemblage found at Shubayqa 1 (Patrick et al. 2016) and other contemporary sites (see Wright 1991, 1992), as well as several ethnographic sources (e.g. Schroth 1996; Shoemaker et al. 2017) were considered in creating the experimental grinding and pounding tools used in this study.

2.1.1. Making the grinding tools

GSX.5 and 6 are a quern and handstone grinding pair and follow Wright's "boulder quern" and "unifacial handstone" (Wright 1992, A. no. 3 and C. no. 58 respectively).

The quern (GSX.5) was made on an angular, relatively flat basalt block. The quern use face was fashioned with basalt hammerstones. One fist-sized cobble with angular "sharp" edge ("chopper") hammerstone was used for delineating and starting the depression and one slightly smaller (palm-sized) "pointed" hammerstone was employed for more discrete pecking. In addition to pecking, and alternating with this, a third sub-angular stone was used together with water, a little soil and sand to abrade the depression. Both techniques were effective in manufacturing the depression and worked well in unison (although pecking was most fruitful in deepening). The manufacture of this small quern took roughly 2 hours.

Many sparsely used handstone from the Shubayqa 1 assemblage feature weathered, unmodified surfaces (Pedersen et al. 2016). This suggests that Natufian communities in the Black Desert followed a semi *ad hoc* approach for handstone production. They took advantage of the large amounts of suitably sized and shaped cobbles found across the *Harra* desert, selected those that they considered most suitable based on their natural shapes, and made modification on faces to be used. In our reconstruction we followed the same strategy. The handstone (GSX.6) was made on a sub-circular basalt stone, chosen for its suitable shape and which therefore required less modification. It was manufactured in about an hour and it had a single modified surface, roughened by pecking with the hammerstones described above.

GSX.7 and 8 are ad-hoc grinding tools made from natural block-shaped (Wright 1992) boulder as slab and a naturally rectilinear cobble as handstone. They both were produced from suitable shaped local basalt rocks, with little more manufacture than pecking the active surfaces, and some shaping of the margins in the case of handstone GSX.8.

2.1.2. Making the pounding tools

The pounding pair GSX.9 and 10 are comparable to Wright's (1992) types B. no. 17 and D. no. 68 respectively.

The mortar (GSX.9) was made of a blank that was 9000 gr. heavy, 22 cm wide, 15 cm tall basalt boulder. It took over c. 7 hours of work time to manufacture it, spread over two days of work. A steel hammer and chisel were used in the initial stages (first 1,5 hours) to save time. The rest of the modifications were made with basalt hammerstones and abraders. Finishing off the exterior, hole and rim took up half of the time 3,5 hours.

The pestle (GSX.10) was made of a suitably shaped elongated basalt cobble. The blank was 16 cm long, 6-7 cm width/thickness and weighed 1100 gr. It was fashioned using only basalt hammerstones, a basalt slab as whetstone and a hammerstone to abrade the body of the pestle. Both water and mud were used as abrasive agents. Dry abrading with the hammerstone also proved effective. The pestle took almost four hours of manufacture.

2.2. The sickle and backed blades

The type of lithic implement to be used for the experiments was chosen based on the lithic assemblage of one of the two aforementioned Early Natufian fireplaces (fireplace A, context 83) where thousands of carbonised club-rush tubers were found (Arranz-Otaegui et al. 2018). This context contained a large amount of microliths where different types of backed bladelets dominated, followed by lunates. Use-wear analysis identified at least one artefact with silica gloss and several pieces that had been used on soft and soft-medium materials, such as most plant materials (Jörgensen-Lindahl forthcoming). Aiming primarily to evaluate the efficacy of lithic implements for the harvesting and processing of tubers, but also to test the results of the use-wear analysis, a sickle with backed bladelets was manufactured.

The sickles handles found at the Natufian levels of, among others, Nahal Oren, Kebara Cave, El-Wad cave and Wadi Hammeh 27 were used as references for the handle (Edwards 2012, Garrod 1932, Stanin 2012, Stekelis and Yizraeli 1963, Turville-Petre 1932, Anderson 1999 and Ibañez et al. 2007 for more details on the chronological changes in morphology of sickles during this time period), while replicas of the aforementioned backed bladelets dominating context 83 were chosen as sickle inserts.

The nearest chert sources to Qa' Shubayqa, located around 70 kms south of the site (Richter et. al. 2014), were chosen to produce the bladelets. The chert available in this area corresponded well with the material found at Shubayqa 1 in terms of coarseness. This was important as we strived to account for the role of raw material properties in use-wear development (Lerner *et al*. 2007, Marreiros *et al*. 2020). However, at this early stage in the experimental programme no further analysis beyond ocular inspection of the raw materials was carried out.

The microliths were produced by means of direct, medium hard technique using hammerstones of locally sourced, vascular basalt. Through a comparative analysis of attribute statistics on bladelets sampled from the Shubayqa 1 assemblage and bladelets experimentally produced (Villemoes 2020, for further details on lithic comparative statistical attribute analysis see Madsen 1989, 1992, Sørensen 2006, 2014, Damlien 2015, Pelegrin 1992, 2000, 2013, Inizan 1999, Andrefsky 1998), this reduction technique was identified as most probable during the Natufian period of Shubayqa 1. The bladelets were struck off a narrow fronted pyramidal core with a single platform. This method of core reduction is only one out of the several types identified within Natufian chipped stone assemblages (Garrard and Byrd 2013, Garrard 1991, Goring-Morris et. al. 1998, Henry 1989, Shea 2013) and was specifically chosen for these experiments as it is an ideal shape for producing long and narrow bladelets (Sørensen 2006) on the thin chert tabs typical of the Al'Azraq Depression.

2.3. Fire installations

Hearths may be constructed in a number of ways and for a range of purposes (Aldeias 2017, Lowell 1995). Our aim was to test regular fireplaces (aerobic burning) and earth-ovens (anaerobic burning) as means to obtain roasted club-rush tubers. The fire installations we built had the same elements as those found in the archaeological examples from Shubayqa 1, but they were roughly half the size. The earth-ovens took about 30-40 minutes to build, excluding finding rocks for lining. Around 20 minutes were spent digging (with handpick, hand shovel, trowel and brush) and 15 minutes lining the pit with cobbles, of varying sizes, but mostly a bit larger than an adult's fist. In the spaces between the cobbles pebbles were inserted to fix the rocks together and stabilise them so the lining did not collapse. Whilst smaller in size than the archaeological fireplaces found at Shubayqa 1, we consider that that the size of the experimental fire installations built in this study would not have conditioned the results obtained, as it has been shown that the main difference between small and large-sized fireplaces relies on the extension of the heated area, which produces differences in the amounts of materials roasted and fuel required (Aldeias 2017, Bentsen 2012). In our experiments, the quantity of tubers and fuel used were adapted to the smaller size of the fire installations built.

3. Detailed description of processing (#7-10 and #15-16) and roasting experiments (#11-14)

Processing experiment #7: Pounding fresh tubers to remove scale leaves and roots. We used the basalt mortar (GSX.9) and the wooden fig pestle to produce a diffuse thrusting percussion, sitting or squatting and using both arms, as the wooden pestle was quite large. The upper body and arms were the motive force behind the downward stroke. The wet tubers got smashed, and the resulting product was a mush of unprocessed tuber materials.

Processing Experiment #8: Grinding fresh tubers to remove scale leaves and roots. We used the grinding slab (GSX.7) and an elongated handstone (GSX.8) with a reciprocal, back-and-forth stroke and movement (i.e. diffuse resting percussion) to move the upper stone over the open slab (the tubers being the intermediate material). The body adopted a kneeling position over the grinding pair. Both hands pushed the upper stone forward, then dragged it backwards, using the upper body and arm muscles. This time, 1/5 of the tubers were more or less processed, but the largest part was smashed. The tubers were overall too wet and sticky to be ground.

Processing Experiment #9: Pounding air-dried tubers to remove scale leaves and roots. This experiment was carried out following the same approaches described in experiment #7, but using air-dried tubers. Pounding of air-dried tubers did not contribute to dehusking, but it rather fragmented the material. The outcome was a mixture of cracked tubers, roots and rhizomes.

Processing Experiment #10: Grinding air-dried tubers to remove scale leaves and roots. This experiment was carried out following the same approaches described in experiment #8, but using air-dried tubers. Grinding did not allow efficient elimination of dried scale-leaves, roots and rhizomes, which were still attached to the tubers. The result in this case was a mixture of slightly cracked tubers, roots and other debris.

Roasting Experiment #11: Tuber roasting (aerobic conditions). The first experiment was conducted in 2018, using a round-shaped fire pit made with basalt stones. Cereal straw and club-rush stems were used to light the fire and *Ficus carica* (fig) wood was used as a primary source of fuel. After the fire was lit, we waited for almost an hour to get enough charcoals. At this point charcoals had a temperature of c. 480 Cº. We put 168 gr of unprocessed air-dried tubers within the hot ashes of the fire pit. Temperature measurements directly taken on the flames indicated c. 500-540 Cº. We removed the tubers after 15 minutes but they were completely carbonised by then, forcing us to conduct further roasting activities that involved lower heating rates.

Experiment #12: Tuber roasting (aerobic conditions). In the second trial, 75gr of unprocessed air-dried tubers were put within the hot ashes, following the same procedure described in Experiment #11. However, the tubers were roasted under lower temperatures, c. 240-280Cº. The tubers remained in the hot ashes for 15 minutes, but this time the tubers did not roast. They were still semi-wet, brown-coloured and soft in texture. This evidence indicated that under low burning temperatures, longer roasting times would have been necessary.

Experiments #13 and 14: Tuber roasting (anaerobic conditions). The roasting activities continued in 2019, using earth-oven installations (A and B) to roast the tubers in anaerobic conditions. In the first oven fresh-wet tubers were used, whereas in the second one air-dried were tested. In both cases, the same procedure for tuber roasting was followed:

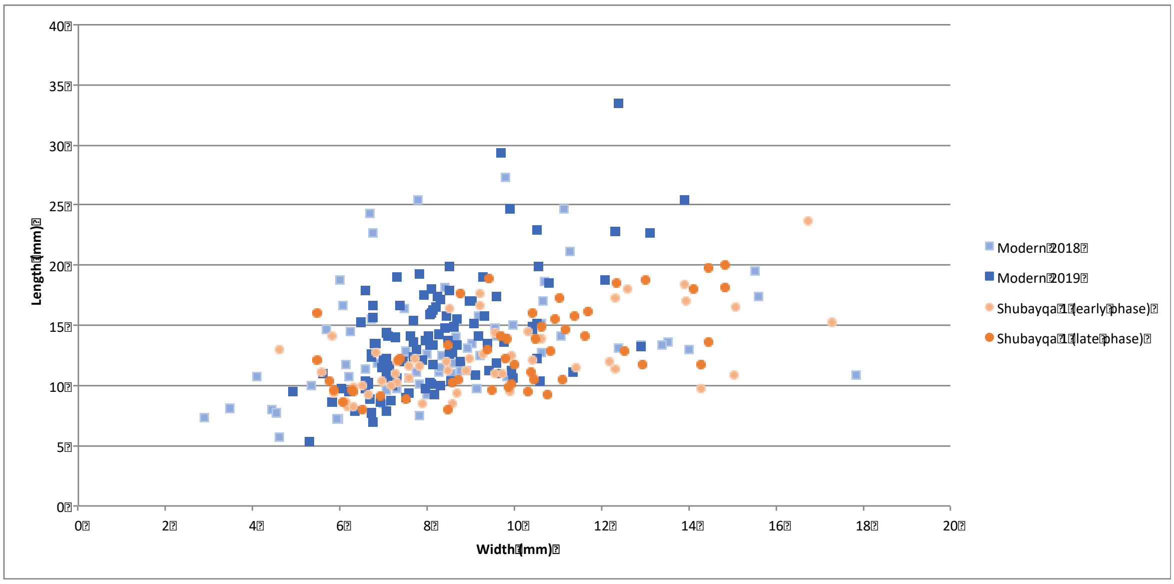
- The fuel consisted of club-rush stems as tinder, dried Chenopodiaceae shrubs and palm tree wood. The temperature of the flames in both installations was of c. 537Cº. Once the wood was burnt and because the charcoals available were insufficient, commercial wood charcoal was added. At this stage, temperatures in the fire installations varied from 577º recorded on the charcoals, to 624º recorded in the flames.

- Following the characteristic of earth-ovens in modern-day hunter-gatherer communities, we put between 12-15 fist to baby fist-sized basalt cobbles in each fire installation to be preheated. We recorded that when the stones were added to the charcoals, the temperatures dropped from 577º to 260-270º.
- Once the basalt cobbles were heated, we removed the contents of the fire installations out, and placed the hot stones in the bottom part of the pits, which at this time marked temperatures between 233 and 240º.
- On top of the pre-heated basalt cobbles, we placed club-rush stems, making a vegetal bed that would prevent the tubers from falling out and getting mixed into the soil underneath. In fire installation A we placed c. 240 gr of wet unprocessed tubers, whilst in B we added 80 gr of air-dried unprocessed tubers.
- We put an extra layer of club-rush stems to cover the tubers, and place a layer or 2-4 cm hot charcoals on top. This procedure allows the tubers to receive heat from both the bottom part of the fireplace (through the pre-heated basalt cobbles) and from above (through the charcoals that covered the tuber layer). At this stage, the charcoals that were placed on top of the tubers showed similar temperatures in fire installation A (340º) and B (334º).
- Covering the charcoal layer, we placed a thin layer of soil (2-4 cm), and added water so that the heat emanating rom the pits hardened the wet mud and sealed the deposits.
- We left the two fire installations active for two hours. After that time, we measured the temperature on the sealing surface, which was of 30º, similar to the temperature measured outside the fire installations, which was 27º. The basalt stones that arise from in the laterals, which were not completely covered by the mud, had temperatures of c. 57º in earth oven A and slightly higher in earth-oven B, 82º. Once we removed the mud and opened the two fireplaces, we recovered the two unprocessed club-rush tuber assemblages.
- The results were remarkably different. The tubers from earth-oven A were still wet, where the assemblage in earth-oven B comprised both roasted and carbonised tubers. Because previous experiments with grinding of unprocessed wet and dried tubers proved unsuccessful, the roasted tubers from earth-oven B were used to undertake experiments #15 and #16.

Processing experiment #15: Pounding roasted tubers to remove scale leaves and roots. We took the experimental basalt mortar and wooden pestle to pound 10 gr of unpeeled roasted tubers from experiment #14 (earth-oven B). Pounding was carried out in diffuse thrusting percussion, sitting or squatting using both arms, as the wooden pestle, upper arm and elbow as the motive force behind the forceful downward stroke, hand(s) firmly grasping the pestle, during motion. The upper body produced additional weight behind the thrust. However, after only 5 minutes of pounding, the tubers were completely fragmented and cracked, and the different parts of the plant, that is, the tuber, the scale leaves, and small fragments of semi-carbonised roots and rhizomes were mixed. The resulting tuber materials showed freshly made regular and straight fragmentation patterns.

Processing Experiment #16: Grinding roasted tubers to remove scale leaves and roots. In a subsequent experiment, we used a quern (GSX.5) and a stone basalt hand stone (GSX.6) to process the tubers through grinding. We took a first batch of tubers (10gr) and ground them for 15 minutes. This action entailed gentle moving the upper stone in circular motions (diffuse resting percussion), sitting, using one hand grasping and arm (shoulder and elbow) the main motive force, but without asserting much pressure, rather simply using the weight of the upper stone (c. 730 gr.) and the lower basalt implement to "roll" the tubers. The resulting abrasion removed the roasted scale leaves efficiently and resulted in perfectly peeled tubers.

Supplement Figure 1. *Diagram comparing the size of modern carbonised club-rush tubers from Lake Burqu´ and the archaeological carbonised tubers from Shubayqa 1 (width and length).*



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"Attribution of authorship should in general be based on criteria a-d adopted from the Vancouver guidelines , and all individuals who meet these criteria should be recognized as authors:

A. Substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work, and
B. drafting the work or revising it critically for important intellectual content, and
C. final approval of the version to be published, and
D. agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved."

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This co-authorship declaration applies to the following:

*Title	The *chaîne opératoire* for club-rush (*Bolboschoenus glaucus*) tuber gathering and processing, an interdisciplinary approach
*Author(s)	Amaia Arranz-Otaegui, Patrick Nørskov Pedersen, Ann Frijda Schmidt, Anne Jörgensen-Lindahl, Joe Roe, Johan Villemoes, George Alexis Pantos, Kathryn Killackey
Journal	Journal of Archaeological Science (JAS)
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Contributions to the paper/manuscript made by the PhD student

What was the role of the PhD student in designing the study?

Directed the groundstone tool parts of the study, including the selection of tool types, raw material, and the production and use of the basalt replicas. And aided in planning and carrying out experiments, collecting data and materials for experiments.

How did the PhD student participate in data collection and/or development of theory?

Participated in the execution of the experiments in Jordan in 2019, in close collaboration with the main author Amaia Arranz-Otaegui. Performing experiments, collecting tubers at Lake Burqu, building fire-pits in Safawi, as well as making and using the groundstone tools in tuber processing as previously mentioned. Also performing use-wear analysis of the basalt groundstone tools, and sampled tools for microbotanical residues.

Which part of the manuscript did the PhD student write or contribute to?

Section *2.2.1.* , *2.2.1.1.* and *2.2.1.2.* authored by this PhD-student (PP)

Participated in the execution of the experiments in sections 3.2. and associated experiments.

Created and arranged figures no. 2, 4, 7, 9 and 10

Generally: edited and commented on previous versions of the paper

Authored parts in the supplementary materials. Specifically 2.1. and its sub-sections and section 2.3.

Did the PhD student read and comment on the final manuscript?

Yes, and throughout the process the PhD edited, contributed, corrected and commented.

Signatures

If an article/ paper/chapter/manuscript is written in collaboration with three or less researchers (including the PhD student), all researchers must sign the statement. However, if an article has more than three authors the statement may be signed by a representative sample, cf. article 12, section 4 and 5 of the Ministerial Order No. 1039, 27 August 2013. A representative sample consists of minimum three authors, which is comprised of the first author, the corresponding author, the senior author, and 1-2 authors (preferably international/non-supervisor authors).

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From Stone to Food:
Foodways and processing during the Natufian and Early Neolithic of eastern Jordan - A ground stone perspective

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1. Introduction

This paper will examine the use of ground stone tools in food processing and foodways during the Natufian, Early PPNA to Late PPNA/Early PPNB in the southern Levant, through the examination of two assemblages from eastern Jordan, Shubayqa 1 and 6, located in the Harrat ash-Shams. A combination of techno-typo-morphological analysis, low-power use-wear analysis and analysis of archaeobotanical microremains (pending), of food processing ground stone tools and their active surfaces is applied to reconstruct past foodways and how they changed over time.

Ground stone tools (GST) play a crucial role in reconstructing past foodways. Foodways are not just a matter of how food is procured, cooked and consumed, but also how it is processed. Querns, mortars and pestles enable the crushing and pulverising of hard seeds, tubers, nuts, leaves, bark, roots, as well as meat and minerals (e.g. Adams 1999; Alonso 2019; Ertug 2002; Pedersen *forthcoming* a; Robitaille 2016; Schroth 1996; Shoemaker et al. 2017). Food processing ground stones are thus a central part of what can be termed the *pre-consumption preparation* of food (Twiss 2012). This step in a "foodway" happens following resource procurement and involves turning gathered (or stored) material (e.g. seeds, pulses) into smaller particles of edible matter, through grinding, pounding or both. This is done as a prerequisite to consumption, cooking or further storage (see also Pedersen *forthcoming* a). In Southwest Asia, the study of Epipalaeolithic and Neolithic GST has tended to associate them mostly with the grinding of cereal grasses (e.g. Dietrich et al. 2019; Dietrich and Haibt 2020; Hayden et al. 2016; Liu et al. 2018; Portillo et al. 2013), and to a lesser extent with legumes and nuts (see Dubreuil 2004; Rosenberg 2008). The focus has mostly been on identifying pathways towards the consumption of cereal grasses and their subsequent cultivation (e.g. (Hayden et al. 2016; Hodder 2018; Portillo et al. 2013). However, a wide range of archaeological and ethnoarchaeological evidence shows that GST were used for processing a wide range of plant matter into edible products, in addition to processing meat and minerals (e.g. Ertug 2002; Gott 1982; Hamon et al. 2021; Hamon and Le Gall 2013; Schroth 1996; Shoemaker et al. 2017). This previously dominant focus on cereal grasses has at times precluded a more holistic study of GST as multi-functional and multi-purpose tools.

Important for the stone tools discussed here, is that they are made and moved by human bodies. The tools are guided by human gestures to alter the properties of a material. This in turn affects the tool at a morphological level, as well as a micro and macro-level as surface "use-wear". Importantly, macro- and microscopic use-wear can inform about both contact material and kinetics, e.g. human movements and gestures (Dubreuil et al. 2015). There has generally been a lack of attention given to kinetics and movements, i.e. *gestures* and their influence on GST use-wear (Dubreuil et al. 2015) and studies considering this element have rarely been conducted before, including in Southwest Asia (but see Dietrich et al. 2019; Dubreuil 2001; Dubreuil and Nadel 2015; Kadowaki 2014). In this study, we aim to combine a gesture-based approach to GST with more "traditional" functional use-wear analysis and residue analysis of phytoliths and starch.

Setting the stage

The Epipaleolithic-Neolithic transition in Southwest Asia between c. 15,000 – 8,500 years ago, is viewed as a period with important and fundamental changes to human diet and food acquisition, culminating in domestication of plants (so-called "founder-crops") and animals. Although this is now generally seen as a complex, long and drawn out process, rather than a revolution (Allaby et al. 2021; Graeber and Wengrow 2021; Hodder 2018; Weide 2021), food practises and relationships to food production underwent important changes during this period (Boyd 2002). What were people processing using GST during the Epipalaeolithic and Early Neolithic and how? What differences do we see between Shubayqa 1 and 6, between the Early and Late Natufian and the Early Pre-Pottery Neolithic? How did foodways change (if at all) at Shubayqa during this period, the Terminal Pleistocene and Early Holocene? Do we see changes reflected in our material and what is the ground stone perspective on these crucial developments? Changes to the way processing happened and/or what was processed thus inform us about changes to the foodways of these past societies. It is this interplay between tool, gestures, use-wear and foodways that we explore in this paper.

Previous use-wear studies of Southwest Asian GST assemblages have often focused on the Epipalaeolithic Natufian period (e.g. Dubreuil 2004; Dubreuil and Grosman 2013; Terradas et al. 2013) but strangely more rarely the Early Neolithic (but see Dietrich et al. 2019; Dietrich and Haibt 2020; Dietrich 2021). As such, use-wear studies of Pre-Pottery Neolithic GST are largely absent in the Southern Levant. Furthermore, when present these also often tend to focus on plants normatively ("founder crops") associated with the Neolithic transition in SWA, i.e. cereals (e.g. Dietrich et al. 2019). Thus our observations of trends over longer time periods, including material from both the Epipaleolithic and the early Pre-Pottery Neolithic, and considering a wide range of contact-materials, add greatly to our understanding of long-term trends and changes, at least in the Qa' Shubayqa.

1.1. Food processing strategies and GST use-wear studies

The *"processing strategies"* concept and approach applied here (see also Pedersen 2021, *forthcoming* a, *forthcoming* b), recognises gestures, and thus individual bodies, as the agents of change, and (ground stone) tools as material expressions of these bodily gestures, this labour, technological choices and intentions of change. These *processing strategies* are reconstructed on the basis of tool morphology and observations of wear. The approach is based on the food processing ground stone from the two sites Shubayqa 1 and 6 that we also examine here. Though based on these Late Epipaleolithic-Early Neolithic assemblages from eastern Jordan, the approach may be applied to any setting or assemblage (see details in Pedersen *forthcoming* b).
The processing strategies-approach is in essence a synthesis combining qualitative examination of planar shape and use surface profiles of ground stone tool pairs, i.e. grinding and pounding pairs (e.g. handstone and querns, pestles and mortars), with macro- and microscopic wear correlates from low power-magnification. Along with previous manufacture, a tool's continued use (i.e. the strategy) creates a specific morphology through repetitive actions and movements, i.e. bodily gestures. The tools' active surface morphology, at both a macro- and microscopic scale are influenced by these continuous technological choices. The tools are thus physical representations of a system of social behaviours (Pfaffenberger 1988, 1992), and part of a labour process (or multiple). The active surfaces of tool pairs are engaged and the resulting wear is first created through use, then curated and managed, all through bodily gestures. Thus, these morphologies are never accidental, but: "*the result of choices and decisions made by conscious agents materially interfering with matter in ways they find satisfactory or correct to achieve the change desired"* (see Pedersen *forthcoming* b: 16).

The starting point for each strategy is thus a gesture. The labour (food processing) needs these gestures to be performed to function and these are socially conditioned and will follow certain norms within a sociotechnical system (see Pfaffenberger 1992). Changes to these gestures, and consequently tools, thus reflect changes to practises and norms. Technological choices (see in Lemonnier 1993; Pedersen *forthcoming* a; Sillar and Tite 2000) are then expressed materially in the tools; a material expression of dialectic relationships between tools, bodily gestures, social technical relationships, raw material.

A *food processing strategy* therefore represents *ways of use*, ways of altering a material, a strategy aimed at changing the texture or physical attributes of foodstuff (or: contact material). It is representative of a labour process (see Pedersen *fortcoming* a). This labour process may, or may not, be associated with any specific processed raw material. As such the strategies can mainly tell us *how* things were processed, i.e. the alteration. This is where conventional microscopic use-wear, functional- and residue analysis of GST may aid in identifying what raw material was processed (Adams et al. 2009; Adams 2014; Cristiani and

Zupancich 2021; Dubreuil et al. 2015; Portillo et al. 2017). As we will see below, considering both processing strategies and contact material, allows us to hone in on what raw materials were transformed through labour using GST, and what was processed for consumption.

1.1.1. Food processing strategies present at Shubayqa 1 and 6

The food processing strategies and related tools present at the two Shubayqa sites may be divided into four main strategies (see Figure 1 and 2) (see also Pedersen 2021; Pedersen *forthcoming* b). The gestures follow the terms posited by Leroi-Gourhan (1993) (see also de Beaune 2004), and encompass three variations of "diffuse resting percussion", i.e. grinding, and one of "diffuse thrusting percussion", i.e. pounding. These are, respectively: A1. Confined Reciprocal Grinding (CRG), A2. Open Reciprocal Grinding (ORG), A3. Rotary Grinding with some pounding (RGP) and B. Confined Pounding (CPR). Further details on the gestures are provided in Figure 1 (and Appendix II). Pedersen (*forthcoming* b) also presents the microscopic wear correlates associated with these strategies.

In addition to being based on gestures and use-wear these strategies are also defined by the progression of wear and it's management. This includes "overall" wear that affects the entire morphology of the tool, e.g. a continuous gestures and use of tools that results in a circular depression etc., as well as the macro/microscopic use-wear of each tools' active surfaces, e.g. linear traces across an active face suggests a reciprocal gesture and strategy etc. (see also *On the stages of progressive wear* section below). These two types of wear, overall wear "stages" and use-wear, of course also influence each other (see Adams 2014; Pedersen *forthcoming* b and Appendix II).

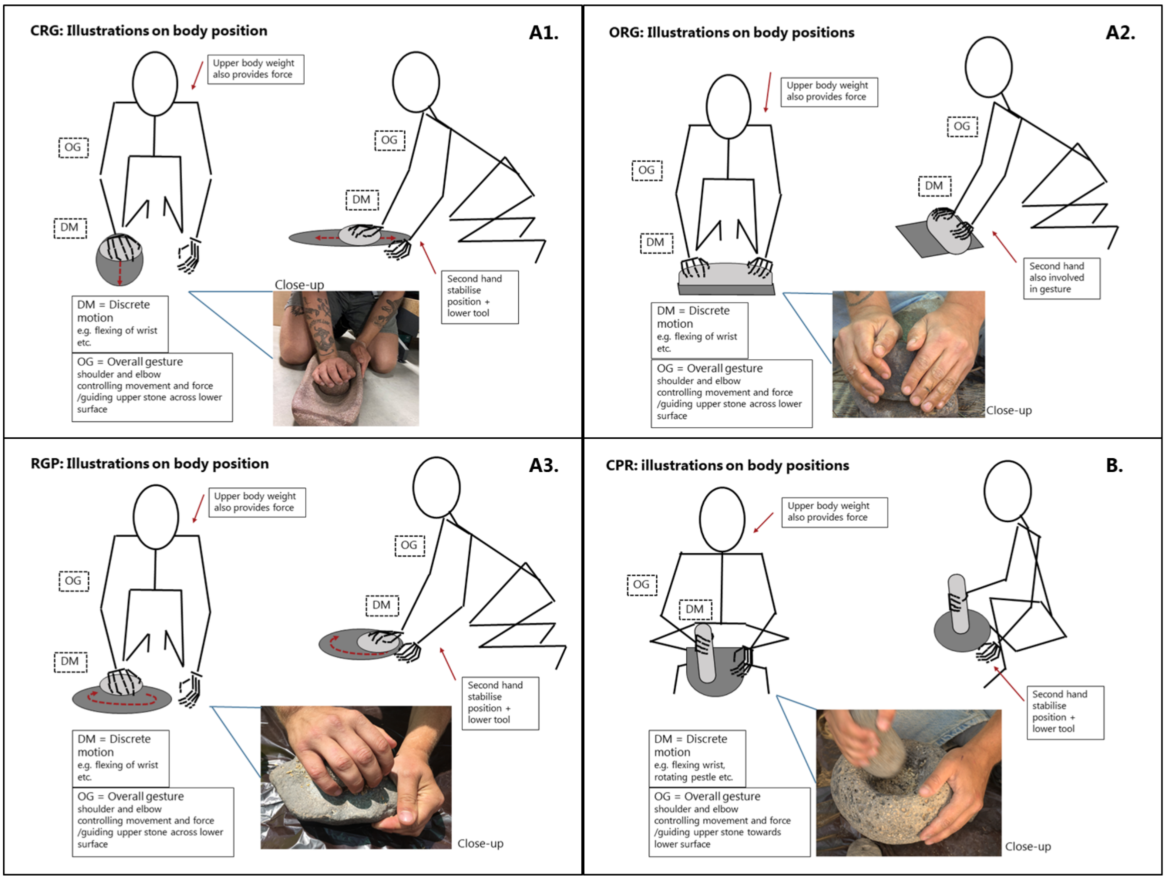

Figure 1: Schematic and experimental presentation of each strategy (photo credit: the Shubayqa Archaeological Project).

Each tool subtype included in the strategies follow Wright's typology for SWA ground stone (Wright 1992a) and the strategies are defined as follows (see data in Supplementary table ST1 and Appendix II):

A1. Confined Reciprocal Grinding (CRG): grinding tool pair, the upper tools are ovate/rectilinear-type handstones and lower tools are basin- and trough-type grinding slabs. Gesture: the upper tool is moved reciprocally (back-and-forth) with one hand, within the elongated depression of the lower tool.

A2. Open Reciprocal Grinding (ORG): grinding tool pair, the upper tools are elongated, usually loaf-type handstones and the lower tools are block- and saddle-type grinding slabs. Gesture: the upper tool moved reciprocally, with two hands, freely across the entire "open" surface of the lower tool.

A3. Rotary Grinding with some pounding (RGP): grinding tool pair, upper tools are discoidal-type handstones and the lower tools are basin- and block-type grinding querns. Gesture: the upper tool is moved circularly and freely, with one hand, but within the circular or oval depression of the lower tool.

B. Confined Pounding (CPR): pounding tool pair, the upper tool is a pestle, usually a cylindrical/conical-type and the lower tool is a mortar, usually a vessel-, block- or boulder-type mortar. The upper stone moved up-and-down in pounding, and can also grind, abrading against the bottom and sides. Gesture: the upper tool is moved with one hand freely but within the depression of the lower tool.

See idealised and archaeological examples of each strategy (and gestures) in Figure 1 and 2.

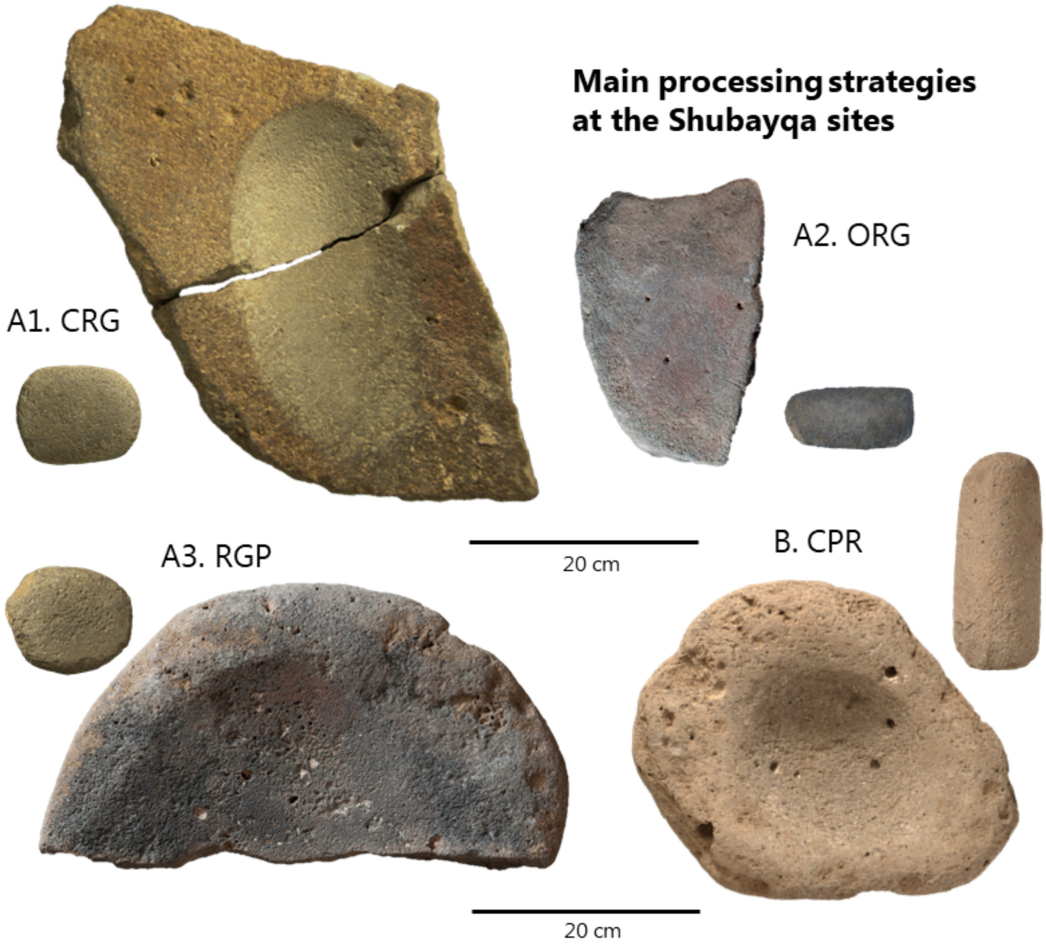

Figure 2: Archaeological examples of strategies from Shubayqa 1 and 6. A1. EPPNA tool pair, Shubayqa 6, A2. Late Natufian tool pair, Shubayqa 1, A3. Late Natufian tool pair, Shubayqa 1, B. Early Natufian tool pair, Shubayqa 1. (photos by A. Pantos / the Shubayqa Archaeological Project)

These strategies are as discussed in (Pedersen 2021; *forthcoming* b) mostly compatible with the typology developed by Wright (1992a) from SWA ground stone assemblages. Therefore it should, in theory, be possible to compare the Shubayqa material and its suggested strategies, to the material and strategies present at other sites in SWA (or rather in the southern Levant) from roughly the same period. This enables us to access changes to the processing foodways at Shubayqa in context with other sites. We address this comparison below in the discussion.

1.1.2. GST microscopic use-wear studies and processing strategies

Focus within GST microscopic use-wear analysis has been mainly on differentiating contact materials, while sometimes neglecting *how* GST were used and how use affects wear. Currently the interest in and use of high-power and advanced types of microscopes and

microscopy, 3D imagery and GIS, and both qualitative and quantitative approaches (Bofill 2012; Caricola et al. 2018; Cristiani and Zupancich 2021; Dietrich and Haibt 2020; Zupancich and Cristiani 2020; Zupancich et al. 2019; Chondrou et al. 2021; Martinez et al. 2013; Benito‐Calvo et al. 2018) within GST use-wear analysis, has perhaps blurred or clouded the importance of understanding how tools are operated through specific "conform" gestures and as technologies are part of larger sociotechnical systems (but see (Delgado-Raack and Risch 2009, 2016). As has recently been noted by (Zupancich and Cristiani 2020) quantitative methods for example, which appear increasingly popular (e.g. (Caricola et al. 2018; Dietrich and Haibt 2020; Chondrou et al. 2021), fall short when assessing the *gestures* used, and thus veils the important motive forces that make tools function, the labour process behind food production. It also appears that raw material properties and variability greatly influence quantitative results (Chondrou et al. 2021). Though the assemblages we examine here are primarily of only one igneous rock-type - basalt - the heterogeneous petrographic qualities and properties of these porphyritic and vesicular rocks potentially would affect the quantitative use-wear too much for consistent quantitative results. A quantitative use-wear approach was therefore disregarded for this study. Though future quantitative studies of basalt may help to remedy the disturbance caused by material properties; a qualitative low-power approach was selected here, as it fits well with our overall *food processing strategy* approach (Pedersen *forthcoming* b).
These *ways of use,* i.e. different gestures, influence material and the formation of surfaces and their wear differently, while also dialectically and continually influencing what gesture is possible. So in addition to examining contact material effects on tools, we must also consider how the stone must have affected the contact material, i.e. how processing was achieved (what way of grinding or pounding) and how the two stones in a food processing tool pair might have affected each other (within a strategy). Only in considering the combination of these factors do we arrive at a more complete view of both use/function and wear. This is done by including the *food processing strategies* in the analysis (see below).

In addition to the "processing strategies" approach (see Pedersen *forthcoming* b) and the use-wear analysis applied here, we also conducted microbotanical residue analysis. There are many advantages to combining use-wear with microbotanical and residue analyses, qualitative use-wear studies has well-documented issues with terminology and reproducibility (e.g. Hayes et al. 2017), while some contact material may only be recognised through residues sampling (Fullagar et al. 2016; Hamon et al. 2021; Hayes et al. 2021; Liu et al. 2014; Santiago-Marrero et al. 2021).[1]

The combination of these approaches provides us with a holistic picture of past foodways at the Shubayqa sites, from the perspective of certain types of pre-consumption food processing (see Pedersen *forthcoming* a; Twiss 2012). The overall goal by combining these different types of analyses is to move closer to a more reliable understanding of the use and function of these tools and the conditions and milleus that they were operated in, through what specific

[1] Unfortunately the residue analysis was not concluded in time to be included at this time. However this final piece of the puzzle will be added in due course.

processing methods they used (gestures), along with what they were used to process (contact material).

We thus (re-)introduce the body and movements as the conductor of change, but from the perspective of the tool and its wear (Pedersen *forthcoming* a; cf.. Molleson 1994; Sadvari et al. 2015), by considering the absorption of gestures (of labour) in the tool morphology and in analysis of tool surface use-wear, and residues trapped in the surface. All of this can be seen as quite literal absorption of activities, body transferring kinetic force, rocks wearing each other, processed raw material wearing down rock, and use being expressed and deposited on the stone tool surfaces and even filling up their interstices (this especially true of porous and vesicular rocks like basalt, see Adams 2014).

2. Sites and materials

2.1. A: Shubayqa sites, setting and dating

The artefacts analysed in this study were recovered from the Late Epipalaeolithic Natufian site Shubayqa 1 and the Late Epipalaeolithic Natufian - Pre-Pottery Neolithic A site Shubayqa 6, which are both located in the Qa' Shubayqa in the Harrat ash-Shams (Black Desert) of eastern Jordan (see Figure 3). The Qa' Shubayqa is a ca. 12 km^2 large basin situated at the confluence of several wadis draining from the Jebel Druze to the northwest, as well as from the north and east. The wadis discharge into the basin and have formed a complex system of alluvial fans and streams. Geomorphological work (Jones et al. 2021) has demonstrated that the sediment filling this nowadays shallow basin reaches depths of at least 4 m below modern surface. Initial dating of the sediments suggests that the basin was filled during the Holocene, although further work is necessary to explore the evolution of the basin in greater depth in the future. Geomorphological, zooarchaeological and archaeobotanical data suggest that the Qa' Shubayqa was frequently inundated and likely a stable wetland in the Final Pleistocene and Early Holocene. This wetland would have provided a rich and stable resource base for human settlement, as reflected in the dense concentration of human settlements along the edges of the Qa' (Richter et al. *in prep*). Surveys along the margins of this Qa' since 2012 have documented the presence of hundreds of archaeological sites dating from the Late Epipalaeolithic to the modern era. More than twenty discreet localities with evidence for Late Epipalaeolithic and Pre-Pottery Neolithic occupations were found, a small number of which have been test-excavated up to now. Only Shubayqa 1 and 6 were subject to large-scale excavations since 2012.

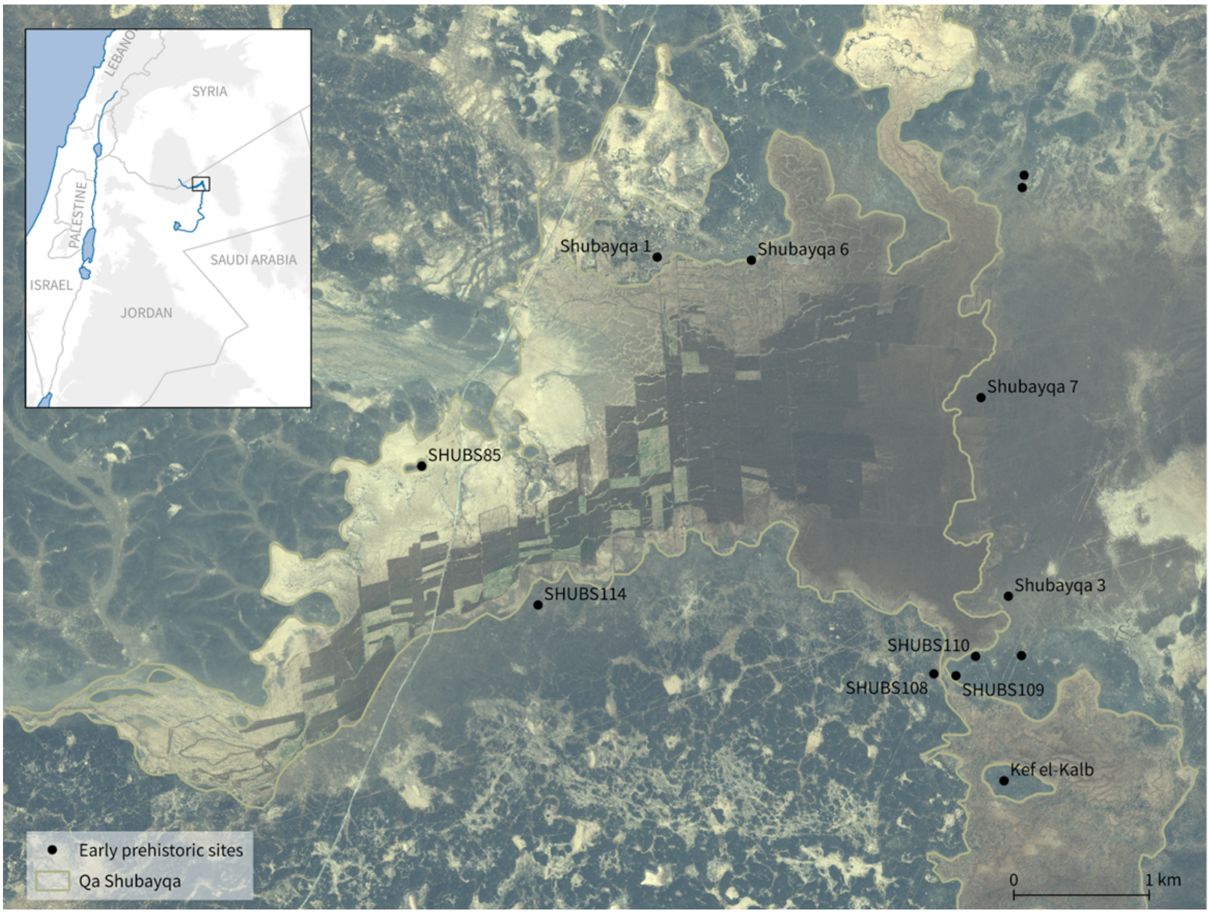

Figure 3: Location of the Qa' Shubayqa and the sites Shubayqa 1 and 6, eastern Jordan

Shubayqa 1 lies at the northern edge of the Qa' within an abandoned Early Islamic and Mediaeval village. The site occupies a low mound that rises ca. 2 - 2.5 m above the surrounding area. A scatter of chipped stone artefacts extends over the top of the mound and below it covering an area of ca. 2000 m^2. A modern tomb built of undressed dry-walled stones with an adjacent curtain wall - characteristic of recent Bedouin tomb constructions in the area - was built on the top of the mound. Around this tomb is a dense field of basalt boulders, some of which represent construction material. Two rectangular buildings were built along the western edge of the mound, and various not well-defined field walls are visible on the surface. Four bedrock mortars, as well as numerous ground stone artefact fragments are scattered across the surface of the mound and were re-used as building material for some of the constructions on the mound.

The stratigraphic sequence at Shubayqa 1 spans the Early to the Late Natufian, and was subdivided into seven major phases of occupation (Richter et al. 2017). Phases 7-4 date to the Early Natufian and were radiocarbon dated to between ~14,800 - 14,100 cal BP (68.2%, INTCal). An oval building - Structure 1 - (see Figure 4) was constructed during Phase 7, subsequently buried (Phase 6), re-used (Phase 5), and the construction of a paved area over the top of Structure 1 (Phase 4). Phase 3 saw the re-use of this pavement and the construction of - Structure 2 - (see Figure 4) and it's subsequent burial (Phase 2). Phases 3-2 date to ~13,300 - 13,100 cal BP (68.2%). There is therefore a gap of c. 1000 years between the end of Phase 4 and the start of Phase 3 going by the C14 dates. A later occupation - Phase 1 - is located to the south of the Structures 1 and 2 and the main excavation area. This phase consists of a series of midden deposits and some not well defined wall segments. It is dated to between ~12,100 - 11,630 cal BP (68.2%) covering the end of the Natufian period. None of the material from this final phase is included in the analysis.

Shubayqa 6 is situated ca. 900 m due east of Shubayqa 1. Like this latter site, Shubayqa 6 was placed adjacent to the northern edge of the Qa'. A wadi course cuts past the site along its southern edge. Shubayqa 6 is a ca. 3,500 m^2 settlement mound that rises ca. 2 - 2.5 m above the surrounding area. Several recent graves were placed in various locations across the top of the mound. An L-shaped, multi-room structure likely related to the Early Islamic/Mediaeval village of Khirbet Shubayqa, was built on top of the mound. A further rectangular building, likely dating to the same period, was constructed at the southern edge. Several circular enclosures of an unspecified later date were built adjacent to the L-shaped building to the west and northwest. A Late Chalcolithic/Early Bronze Age cairn - since partially looted - was built just south of the centre of the mound. This cairn appears to have been the focal point of a larger late prehistoric funerary complex consisting of a circular enclosure wall with additional cairns on the inside. One of these was exposed within the main excavation area where it re-used an earlier Late PPNA building. The early prehistoric sequence covers the Late Natufian to the Late PPNA time frame and can be subdivided into four phases: Late PPNA (henceforth LPPNA), Early PPNA (henceforth EPPNA), transitional Late Epipalaeolithic - PPNA, and Late Natufian. The LPPNA phase consists of several small, oval structures of which two were fully excavated (Spaces 3 and 10) (see Figure 4). It is dated by a series of AMS-radiocarbon dates to between 11,000 - 10,600 cal BP (68.2%), corresponding to the Late PPNA. It is noteworthy that the chipped stone assemblage from this phase contains some Helwan points, which may already herald the beginning of the EPPNB, although use of the naviform technology is not evident at this stage. The EPPNA phase is characterised by the in-filling of two large earlier structures and the use of these areas as open-air activity zones. It is dated to between 11,780 - 11,300 cal BP (68.2%). Two large oval buildings, and several smaller structures, were built and occupied during the Late Epipaleolithic-PPNA phase, dated to ~11,820 - 11,780 cal BP (68.2%). The Late Natufian phase has so far only been exposed in a small sondage at the top of the mound, which produced dates of between ~12,050 - 11,930 cal BP (68.2%).

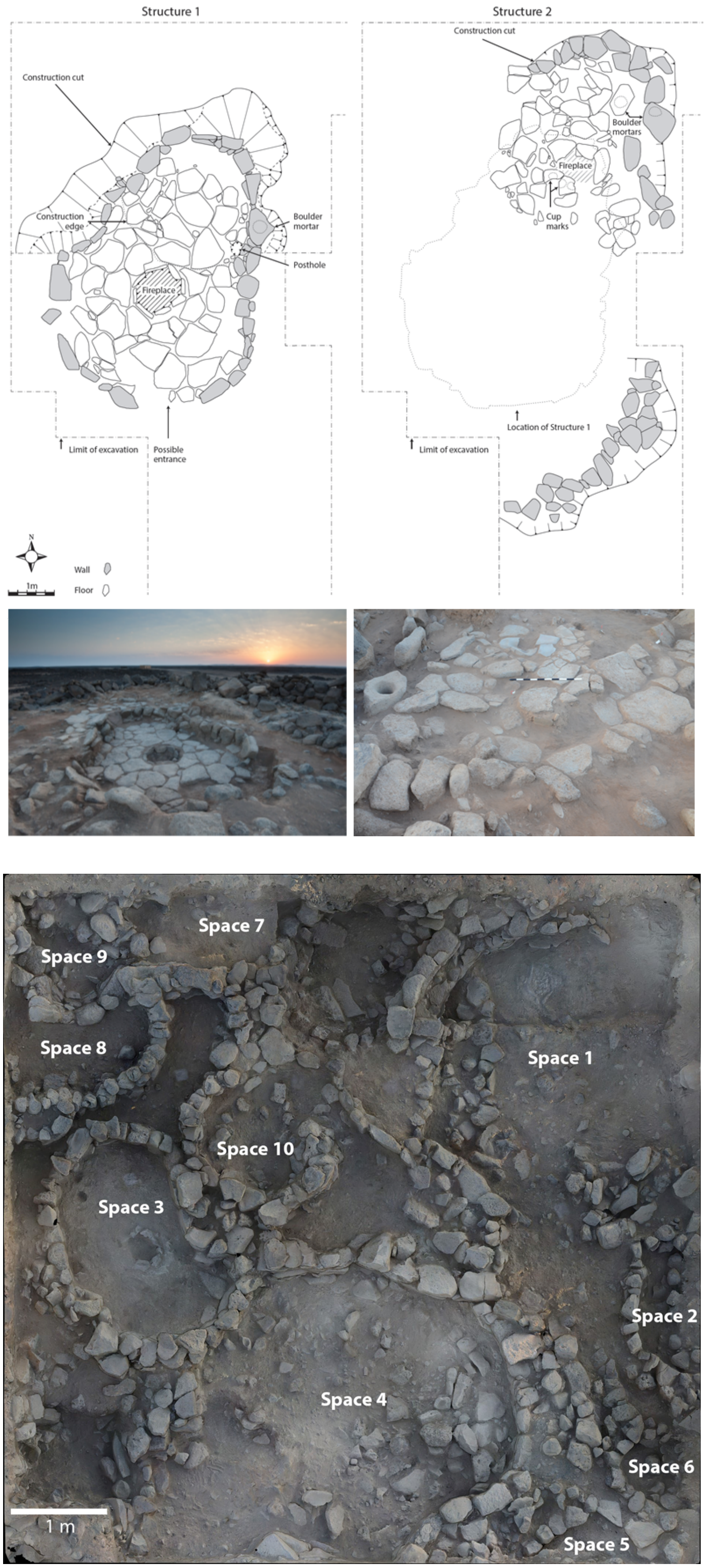

Figure 4: Overview of Shubayqa 1 (top), Structures 1 and 2, and Shubayqa 6, here material analysed comes from Space 3 (LPPNA) and Space 4 (EPPNA).

2.1.1. *Shubayqa archaeobotanical evidence*

The archaeobotanical research in the *harra* has revealed a number of things.
In terms of environment, the initial analyses of seeds, wood charcoal and other plant macroremains from the Early Natufian Shubayqa 1, testifies the presence of more than 80 plant species not reported in the area at present (Arranz-Otaegui et al. 2018a). This evidence supports the hypothesis that, even if traditionally considered as "arid" and "marginal", the Black Desert represented a rich and diverse ecosystem during the Late Pleistocene and included extensive communities of wetlands and grassland plant species, as well as taxa typically adapted to steppe and desert environments. During the Early Holocene, a broadly similar range of plant communities is documented at the site Shubayqa 6. However, final analyses, including the study of all site phases and contexts, are needed to evaluate how the vegetation in the area changed during the major climatic events of the Late Pleistocene/Early Holocene.

In terms of plant-foods, the analysis has so far focused on Shubayqa 1 and the contents of two fireplaces dated to the Early Natufian, 14,400-14,200 cal. BP, which corresponded to two different occupation phases of the site (Arranz-Otaegui et al. 2018a). The fireplaces were *in situ* and more than 65,000 remains belonging to at least 95 taxa were documented, making it one of the largest archaeobotanical assemblages recovered from an Early Natufian site so far. Interestingly, the two fireplaces showed similar plant composition in terms of plant taxa and frequencies indicating persistent patterns in terms of plant acquisition and use over time.

Each of the fireplaces contained around 25,000 rhizome tubers identified as *Bolboschoenus glaucus* (club-rush), a semi-aquatic plant species of the Cyperaceae family. The continuous occurrence of club-rush tubers in two different occupation phases indicates that Natufian communities must have recurrently dug out this plant from the mud, brought it to site, and charred it in the fireplaces. Although charring could have been useful to remove the fibrous scale-leaves, roots and rhizomes, a recent re-analysis indicates that most of the tubers found at Shubayqa 1 were already peeled by the time they were put into the fireplaces (Arranz-Otaegui et al. *submitted*). This suggests that the tubers could have been carbonised by accident during the cooking stage. Indeed, several ethnobotanical records show tubers are commonly dried using different techniques before grinding them to make bread or gruel, mush or cakes (Hillman et al., 1989 and references therein).

In recent years, direct archaeological evidence for the use of club-rush tubers as food has been found thanks to the study of macroscopic (>2 mm) lumps of accidentally burnt food remains (e.g. Gonzalez Carretero et al. 2017, Kubiak-Martens et al. 2015, Arranz-Otaegui et al. 2018b). At Shubayqa 1, more than 640 of carbonised food remains were found in the fireplaces (Arranz-Otaegui et al. 2018b). Until now, the study of 24 remains has been published, all of which showed bread-like microstructures. Considering the size of the plant particles found embedded, it can be inferred that the flour used to make the bread-like remains at Shubayqa 1 was meticulously crushed, pounded and/or ground and carefully sieved to obtain a consistency similar to modern flours. This implies considerable processing and these post-procurement/pre-consumption processing steps would presumably have involved GST. In terms of the ingredients used in the foodstuff, the results indicate the presence of bread-like food remains made exclusively with wild cereals, like two-grained *T. boeoticum* or *T. urartu* (einkorn), *Hordeum spontaneum* (barley) and *Avena* spp. (oat), and others made of a mixture of cereals and club-rush tubers (Arranz-Otaegui et al. 2018b). Interestingly, the recent analyses of 30 additional food remains indicates that club-rush was indeed one of the most common plant ingredients consumed by the Early Natufian communities in the Black Desert (Arranz-Otaegui et al *in prep.*). Nevertheless, in terms of grasses the exploitation of small-seeded taxa could have also been important during the Epipalaeolithic, as evidenced at earlier sites (Weiss et al. 2004).

Finally, in the fireplaces other edible species were attested such as *Tribulus terrestris* (puncture vine) and *Papaver rhoeas* (common poppy), which have edible seeds that, if processed, can be consumed in the form of bread or oil. Seasonal plant-food resources, primarily available during spring time, included the palatable leaves, stems and flowers of *Phragmites australis* (common reed), *Diplotaxis harra* (wall-rocket), *Carrichtera annua* (Wards's weed), *Malva neglecta* and *Malva parviflora* (common and cheeseweed mallow), which are nowadays used as potherbs and in salads (Arranz-Otaegui et al. 2018a).

In terms of fuel resources, the preliminary analysis of wood charcoal remains primarily evidences the exploitation of wetland taxa (Salicaceae-willow/poplar, *Fraxinus* sp., ash), halophytes (*Tamarix* sp.) and steppe/desert vegetation (*Zilla spinosa*). In addition to heat these fuels could have also been used in cooking and other pre-consumption processing.

2.1.2. GST assemblages and provenance

GST data comes from the analysis of 1335 pieces of analysed ground stone, focusing on the 679 identified processing tools ground stone from Shubayqa 1 and 6.[2]

Shubayqa 1 tools. Material from the Early Natufian phase was retrieved mainly from a series of midden infills and the construction backfill of Structure 1, Phases 4-7, Shubayqa 1 (for details see Richter et al. 2017). A large portion of tools were retrieved from the construction backfill of the outer wall of this building (Phase 7), which is the earliest occupation phase. In addition to this are tools from the in-fill immediately above the basalt flagstone floor of this large oval stone-built structure (Phase 6) and material from a later paved area featuring a second hearth situated above and within Structure 1 (Phase 5), see also description above. Several human burials were interred beneath this paved area (Richter et al. 2019). Above this was another infilling event (Phase 4) which ended the Early Natufian occupation. This encompasses all tools defined as belonging to the Early Natufian phase.

Ground stones associated with the Late Natufian period were retrieved from the floor and in-fill of another superimposed structure. This building, Structure 2, was occupied *c.* 1000 years after the Early Natufian ended. It also featured a flagstone floor and a hearth.

[2] The entire analysed assemblages counts 1671 Ground Stone, if including all tool types, miscellaneous artefacts, debitage and varia as well as material from the topsoil, surface and mixed or heavily disturbed contexts.

Several ground stone tools, especially querns and mortars (n= 10), were incorporated into the floor of Structure 2, a floor that also featured several burials interred beneath (Richter et al. 2019). Some of the tools associated with this Late Natufian phase have previously been examined (see Pedersen et al. 2016).

Shubayqa 6 tools. The Shubayqa 6 GST assemblage used in this study is associated with two structures, Space 3 and Space 4. The objects were retrieved both from the post-use infill, as well as floor surface deposits. The GST from the older part of the occupation are from the lower infill of Space 4 and its floor, and are dated to the EPPNA or Late Natufian-EPPNA transitional phase. The chronological sub-division between these two phases is somewhat ambiguous and for the purpose of this study are therefore not distinguished. This phase therefore also includes the lower midden infill(s) and the floor of Space 4. This floor, like the Structure 2 floor at Shubayqa 1, incorporated several tools (n= 20). These consist of both grinding slabs and querns (n= 9) that were fully functional upon abandonment, as well as broken grinding slabs and handstones secondarily used as floor-stones.

The youngest phase is represented by tools from Space 3 and the infill within it. This is associated with the LPPNA (possibly Early PPNB, see above). Included in this occupation phase is also the youngest (upper) infill of Space 4. Supplementary table ST1, shows a breakdown of these tools, sorted according to processing strategies and phase.

2.2. Ground stone tool use-wear analysis

2.2.1. Methods and "characteristic" use-wear overview

In this study, we used a qualitative low-power use-wear approach to gather data on wear-traces, gestures and tool function. The use-wear analysis was conducted with a OLYMPUS SZ-III/SZ-Tr-Zoom-Stereo microscope in the CBRL[3]-laboratory in Amman, Jordan, in 2019. Use-wear analysis of experimental tools (see results below in: *On tubers* and Supplementary table ST2) was undertaken at CSEAS-SWAP Laboratory at the University of Copenhagen, in 2021 using a GX stereoscopic microscope (GXMMZS0745). Use-wear photographs were taken by A. Pantos, in 2019. The low-power use-wear analysis follows the protocols suggested in Adams et al. (2009) and Dubreuil et al. (2015). The observations were recorded at magnifications between 0.8x-40x. (see Appendix Ia and Appendix Ib for further details)[4].

2.2.1.1. Raw material

All of the studied tools are made of basalt, a common raw material in the Shubayqa assemblages, in which out of more than 1000 analysed pieces less than 20 tools fragments and artefacts are of other stone types (e.g. limestone, sandstone and various soft stone). Chemically the Shubayqa basalt is a mafic alkali to sub-alkali basalt or basanite (Al-Malabah

[3] Council for British Research in the Levant, Amman

[4] Supplementary Tables ST3 and ST5 present overviews of the subsampled and residue sampled tools and a breakdown summary of the use-wear analysis

et al. 2002; Ibrahim and Al-Malabeh 2006; Krienitz et al. 2007; Shaw et al. 2003), generically referred to as *alkali olivine basalt*. The texture is porphyritic with phenocrysts primarily of olivine, but also common plagioclase and clinopyroxene phenocrysts. The groundmass is microcrystalline to cryptocrystalline and also consists of plagioclase (primarily), olivine and clinopyroxene (the remaining groundmass crystals), as well as glass and Fe–Ti oxides (Al-Malabah et al. 2002; Odat 2015; Shaw et al. 2003). The basalt is often vesicular though not exclusively as non-vesicular basalt is also common in the assemblage (see (Pedersen et al. 2016; Pedersen 2021).[5]

2.2.1.2. Provenance and selection of use-wear sub-sample

A subsample of 64 tools from Shubayqa 1 and 6 were analysed using the abovementioned use-wear protocol. All of these tools were sampled for residues, using distilled water following a protocol developed by MR (see section 2.3. below as well as Appendix Ia). Afterwards the tools were washed thoroughly with tap water and generic washing-up liquid. Six experimental tools were also subjected to the same sampling and analysis.

Tool selection was biased towards "complete" tools and tools that could comfortably be put into one of the food processing strategies suggested above. This bias towards complete tools in the use-wear analysis was to allow for multiple locations of each tool to be examined and recorded, e.g. the margins, centre, distal ends. This helped with understanding the progression and location of specific wear traces and their directionality. A further bias is the selection of tools associated with specific processing strategies, i.e. tools assumed to be part of "food processing activities" (see Figure 5). For comparative reasons a few other tools types were included in the analysis, e.g. hammerstones, polishers and pounders and some "unused" surfaces, e.g. natural surfaces, broken surfaces and worked surfaces (e.g. the exterior of a mortar), to see how, and if, wear differed. However, this still means that most tools analysed are assumed to be related to food processing (for a more thorough discussion of these issues see Pedersen *forthcoming* a, *forthcoming* b). Nonetheless, as will be apparent below, not all tools were necessarily associated with food processing (or at least not exclusively): some were used for related activities like processing hide etc., or processed inedible materials like pigments.

[5] Basalt "type" is sometimes further subdivided in the recording system based on qualitative naked-eye observations of the relative presence of vesicles (see (Pedersen et al. 2016; Pedersen 2021), but this is not applied and relevant to the use-wear analysis conducted here.

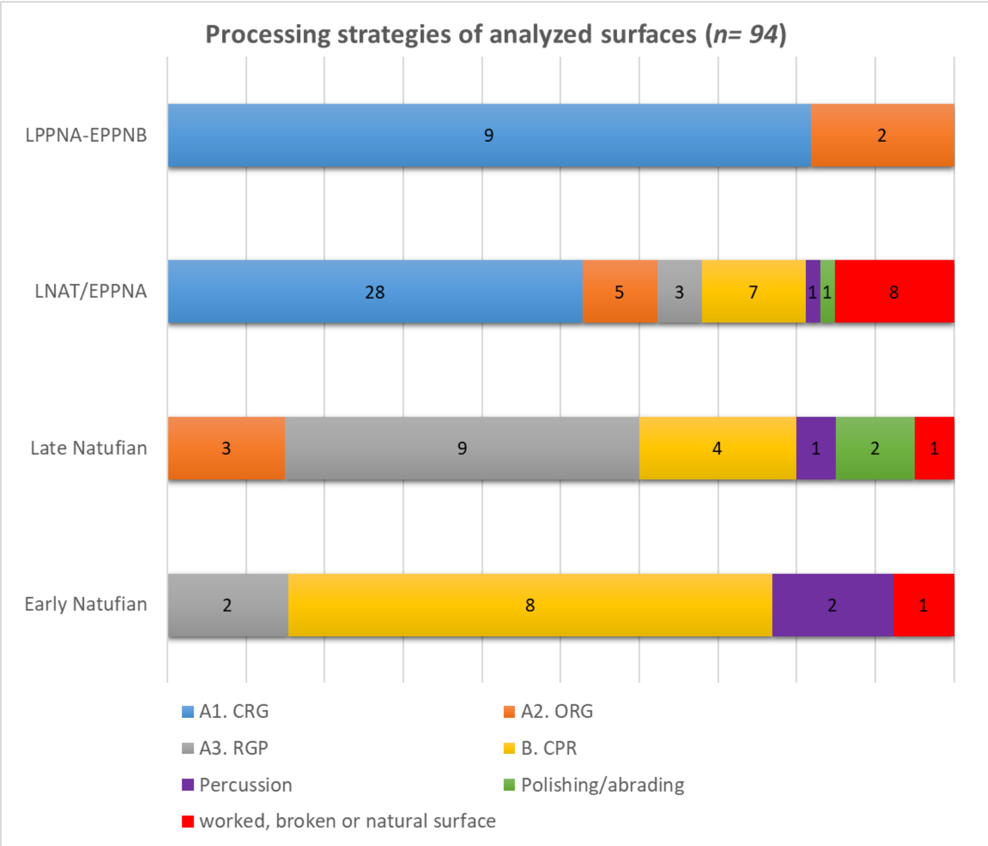

Figure 5: The (assumed) processing strategies of the surfaces subjected to use-wear analysis

The analysed subsample consists of nine tools from the Early Natufian phases at Shubayqa 1, and thirteen from the Late Natufian phases at the same time. From Shubayqa 6, thirty-three artefacts were analysed from the Late Natufian-EPPNA phases, and nine tools from the LPPNA(/EPPNB) phase. In total 64 tools comprising 94 surfaces were examined (see Figure 6 below and Supplementary Tables ST3 and ST5). All strategies are represented in the use-wear sub-sample (see Figure 5). In Pedersen (*forthcoming* b) defining the different strategies was the focus, whereas here we focus on the intermediate contact material. These strategies and activities represent the most prevalent processing strategies in each phase of the two sites, e.g. CRG (i.e. basin slabs and ovate handstone) in the PPNA-phase and so on (see above and also Pedersen 2021). On this basis, we may now attempt to associate strategies and phases with the processing of specific materials. Before discussing this in more detail, we briefly discuss some of the limitations of identifying specific materials processed using GST.

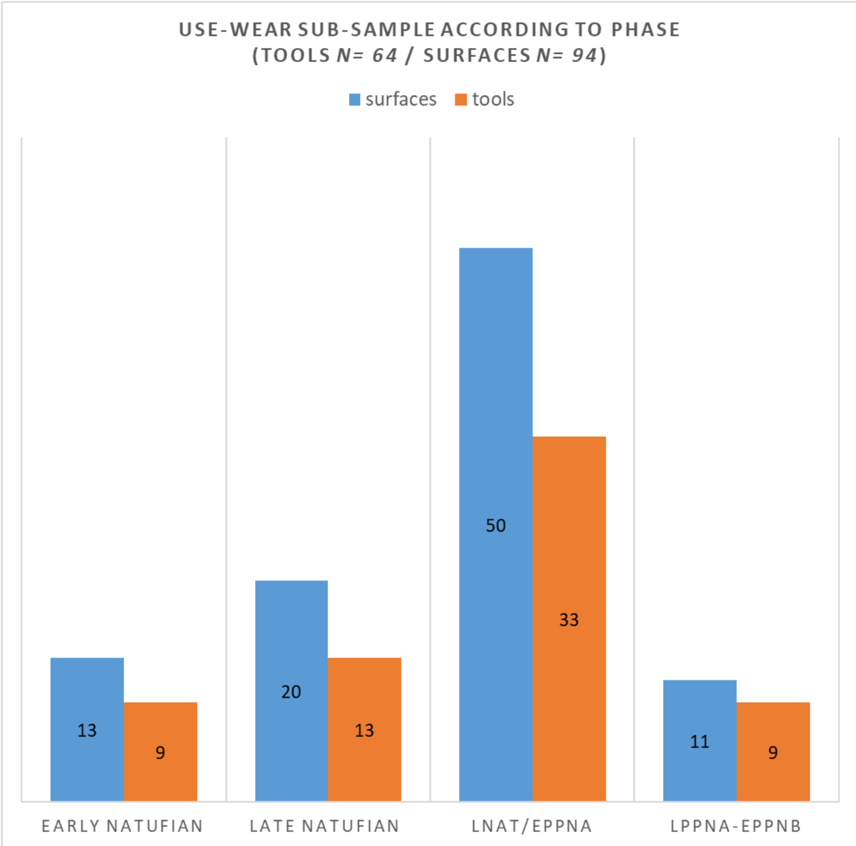

Figure 6: The number of tools and surfaces subjected to use-wear analysis according to phase

2.2.1.3. Characteristic wear

Years of research using a range of methods - e.g. standard low-magnification stereo microscopy, high power metallographic microscopy, advanced microscopy e.g. confocal, SEM for analysing macroscopic and -microscopic topography, microstriations and polishes of the used surfaces from both qualitative and quantitative perspectives - has demonstrated that it is possible to distinguish between relatively broad categories of processing. For example between hard seeds and grains (like cereals), legumes (e.g. Dubreuil 2004) and softer oily matter like nuts, and also distinguish between bone, minerals/stone and animal matter like meat, skins and hides (e.g. see Adams 2014; Dubreuil 2004; Cristiani and Zupancich 2021; Hamon 2008; Martinez et al. 2013). Getting closer to specific contact material, e.g. cereals at taxa level, appears beyond the reach of use-wear alone, no matter how advanced the microscopy that is applied (e.g. Li et al. 2020). Furthermore, some types of use and related use-wear may be more pronounced and leave clear, observable traces (e.g. cereal processing) that can be quantified and qualified (e.g. Hamon et al. 2021; Santiago-Marrero et al. 2021). These limitations do not, however, render the approach pointless, but rather delineate the range of processing activities along a continuum.

The characteristic use-wear we use as the basis of interpreting the wear on the Shubayqa tools is presented in Supplementary table ST4. We have included references of the studies used, as well as raw material and gestures/strategy where pertinent and legible. Many GST of the use-wear studies included in the "characteristic wear" overview (ST4) focus on sandstone implements and open reciprocal grinding. We however, prioritised studies and observations made on basalt, in particular use-wear studies on basalt from the SWA region, in particular Dubruiel (2004), but also (Bofill 2012; Bofill and Taha 2013; Dubreuil 2001; Dubreuil and Grosman 2009; Martinez et al. 2013; Portillo et al. 2013), as basis for our interpretations. We differentiate the use-wear reported in the studies into two main gestures: pounding and grinding. These are then further subdivided into different wear patterns related to contact material.[6] There is a higher degree of uncertainty surrounding the functional interpretation of the pounding tool pairs (i.e. strategy B., mortars and pestles), as less use-wear research and analyses have conducted on pounding tools, but here we draw on observations by (Buonasera 2013; Dubreuil and Nadel 2015; Hayes et al. 2018; Kononenko et al. 2021; de la Torre et al. 2013). In either case, the main difference is where wear is located and how it develops, and how fast etc. So the generic grinding/pounding definition of the gestures must here be sufficient to approach the contact material. The relationship between gesture/strategy and contact material is thus explored after the interpretation of contact material. See results and discussion below.

On the stages of progressive wear

Part of the processing strategies is also the progression of wear and how it affects tool and wear morphology and macro/micro-wear characteristics. Assessing "stages" of wear helps us understand what processing strategy a tool is related to, as well as how recognisable, characteric and diagnostic the macro- and microscopic wear will be (Pedersen *forthcoming* b). As many researchers note from experimental work and observations, wear changes over the course of use: e.g. a polish may only appear after 5 h of work (e.g. Martinez et al. 2013), and some *rounded* levelling becomes *flat* during experimental replication (e.g. Dubreuil 2004). So the "stage" of wear, i.e. how intensively or extensively the tool or tool pair was used will both affect the overall morphology as well as the microscopic wear (Adams 2014; Pedersen *forthcoming* b). Furthermore, there are differences in the use-wear across the active surface of a tool (Pedersen *forthcoming* b), and also observed by (Dietrich and Haibt 2020; Delgado-Raack and Risch 2016; Martinez et al. 2013; M. Portillo et al. 2013). For example the margins, lateral sides, distals ends etc. may, and probably will, wear faster than the centre and central area where traces may appear as slightly "different" than on the margins (Dietrich and Haibt 2020). This is in part due to more stone-on-stone contact occurring at the margins leading to more ("damaging") abrasive and fatigue wear (Adams 1989). Concurrently the centre (may) have the most contact with the intermediate material and the least stone-on-stone contact, suggesting that the centre might be more divergent, and thus diagnostic, of contact material. However, the centre's wear also takes a long time to form and perhaps as a result will not immediately acquire diagnostic or characteristic wear (and see

[6] Further subdivision into types of grinding (e.g. circular vs. reciprocal) is not possible in most cases because either the strategies suggested here are not present or not considered (however see Dubreuil 2004, for wear on flat grinding tools (i.e. ORG-strategy).

also (Pedersen *forthcoming* b; Dietrich and Haibt 2020). Also tools will probably often be used for multiple purposes and tasks throughout their use-life, whereas we only observe a snapshot of the latest use, possibly with some remnants of a previous use (Pedersen *forthcoming* b). The central area and deep interstices, may be the areas in which traces of such previous uses could be preserved more often.

Therefore we suggest that it is pertinent to attempt to make a qualitative assessment of the "stage of wear" the tool is in, and secondly, that the location of the wear and of the wear analysis is highly relevant. This is, as mentioned, because the centre wears slower, but has more contact with the intermediate material, and the margins may wear faster but be more affected by stone on stone contact, clouding the "diagnostic" wear. Margins, on the other hand, may be more diagnostic of strategy and stage of wear, i.e. the ways of use, along with the progression and management of wear (Pedersen *forthcoming* b).

These "stages of wear" (see also Adams 2014: 136) can be briefly summarised as:

> **1.** The tool(s) is shaped into final pre-use form and active surfaces prepared for use (e.g. pecked). There is no clear patterning and directionality to the macro- and microscopic traces. Wear is not yet "characteristic".
>
> **2.** Initial use, material processed, the surface(s) start wearing, probably beginning with the margins, the overall morphology slowly starts to get affected as well as tool, slowly looses mass. There is a *beginning* patterning and directionality to the macro- and microscopic traces. Wear begins to become characteristic.
>
> **3.** Continued use, material is continually processed, the surface(s) wear is more pronounced, the margins very worn, the centre less so, the overall morphology affected as tool, slowly continually loses mass. There is a *pronounced* patterning and directionality to the macro- and microscopic traces. Wear characteristics are increasingly characteristic.
>
> **4.** Worn out, surface traces lose most of their directionality and pattern, levelling may be the most pronounced trace, clouding other wear traces, but some characteristics, like sheen and traces in the low topography (if preserved) may still exist. The overall tool morphology may also be greatly affected by this state. Wear characteristics may now resemble each other wear types. Surface is then re-pecked and the process repeats itself from Stage 1.

The stages are qualitative assessments based on morphology and use-wear analysis (see (Pedersen *forthcoming* b and Appendix II for further details). These stages are expressed as morphology and shape of the tools, but also expressed in microwear of used surfaces. As the later stages indicate there may then be an overlap in the wear through intensive use, e.g. a tool pair used to process something else, could over time and use, end up looking like a pair used in cereal processing, i.e. flat, regular, smooth levelling with striations. This is because abrasive materials like grains or phenocrysts become exposed over time, loosened and released by use, causing striations etc. This is just to say that at a certain point wear may become very similar or even indistinguishable, and thus it is an important facet to consider (see Figure 7). Also as noted by (Hamon et al. 2021; Santiago-Marrero et al. 2021), some wear may be pronounced on tools, while residues of microremains of the same tools tell a different story. Thus, we should be careful in assessing wear, and include consideration of the stages of wear and the location of the wear traces. Finding each exact idealised "stages" is not always possible(Pedersen *forthcoming* b), but a qualitative assessment is nonetheless pertinent. Furthermore, time, effort and intensity do affect wear (e.g. see in Adams 2002; Dubreuil 2004; Martinez et al. 2013), so stages may be results of both intensive or extensive wear (see Adams 2002). Thus, we would argue that the "best" stages to assess wear is in Stage 2 (*beginning* wear) during initial use or in Stage 3 (*pronounced* wear) after continued use and any tools falling in between these stages. These are then the tools whose wear is assessed as developed enough for functional analysis and for suggesting contact material. As seen in the supplementary information (Supplementary table ST5), the stage(s) of wear is noted for (most) of the tools examined. This way diagnostic features of specific wear will (ideally) have formed, but have not been worn out. We have attempted to illustrate these challenges to functional analysis in Figure 7 below:

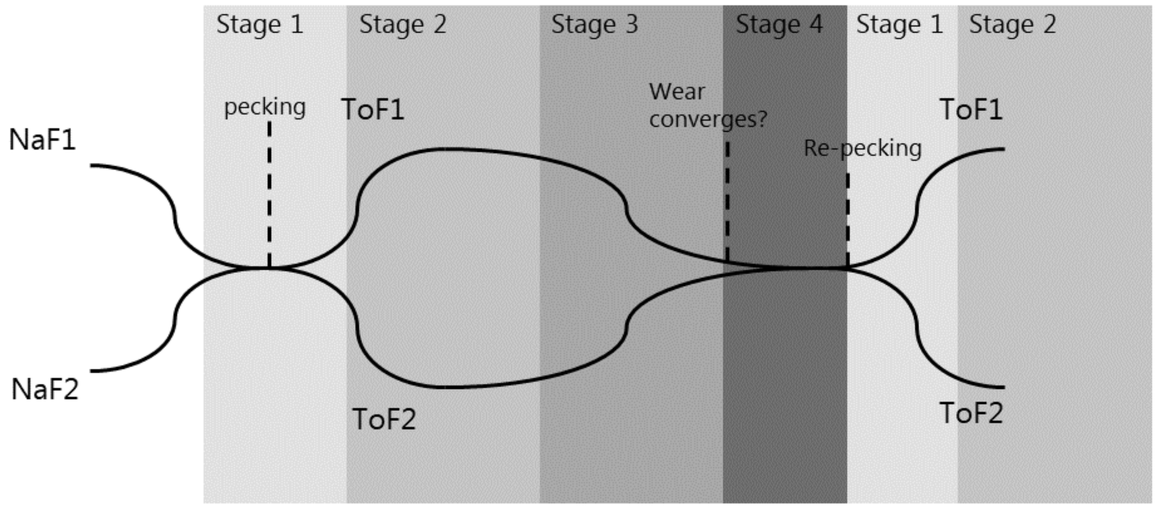

Figure 7: Illustration of the progression of macro-microscopic wear. The line(s) indicate the surface wear/state. NaF = a natural surface/face and ToF = a tool surface/face. Top and bottom lines indicate two different surfaces, first natural, then pecked into a tool surface (ToF1 and 2) ready for use. The two surfaces are then used to process two different materials. It is suggested here that at a certain point wear will be so pronounced and intense that it will begin looking the same despite contact material. The cycle repeats, through a labour process (see Pedersen *forthcoming* a), until breakage and or discard.

2.2.1.4. On tuber/USO processing

One type of characteristic wear conspicuously absent in the literature is tuber/underground storage organ (USO) wear. As recently noted by (Santiago-Marrero et al. 2021), few have studied the use-wear resulting from tubers, roots or rhizomes on GST (but see Fullagar et al. 2016; Liu et al. 2014; Revedin et al. 2010, 2014) and most of these existing studies concern wear on sandstone, a material petrographically quite different from basalt (Delgado-Raack et al. 2009). Thus, little has been established regarding what kind of wear the processing of tubers and USO's create, specifically on GST made from stone other than sandstone. This is a very relevant issue, since tubers are the most abundant plant resource at Shubayqa (Arranz-Otaegui et al. 2018a). Wear associated with USO or tuber processing is therefore summarised here based on the observations found in (Fullagar et al. 2016; Hayes et al. 2021; Liu et al. 2014) and from experiments we conducted in Jordan in 2019 (Arranz-Otaegui et al. *submitted*), using basalt GST to process both wet, dry and roasted tubers (see Supplementary table ST2 and also Appendix III):

Grinding tubers leaves a topography that is rounded and regular and levelling that is moderate, rounded and smooth. Some slight sheen/polish may be present, it is rounded to flat, located on the high topography and only the high points of the surface. There is a prevalent, moderate grain/phenocryst rounding, either in both high and low topography or only in the low. Importantly, there are no grain extractions and no striations and only some microfractures. *Pounding tubers* results in a centre topography that is rounded and regular. Levelling happens mainly (or only) at the margins and is rounded with a smooth texture. The edges of the impation pits are rounded. Phenocrysts/grains show a rounding in the low topography in the interstices and pits. Microfractures are present in both the high and low topography. No polish or sheen is visible. (see Figure 8, below).

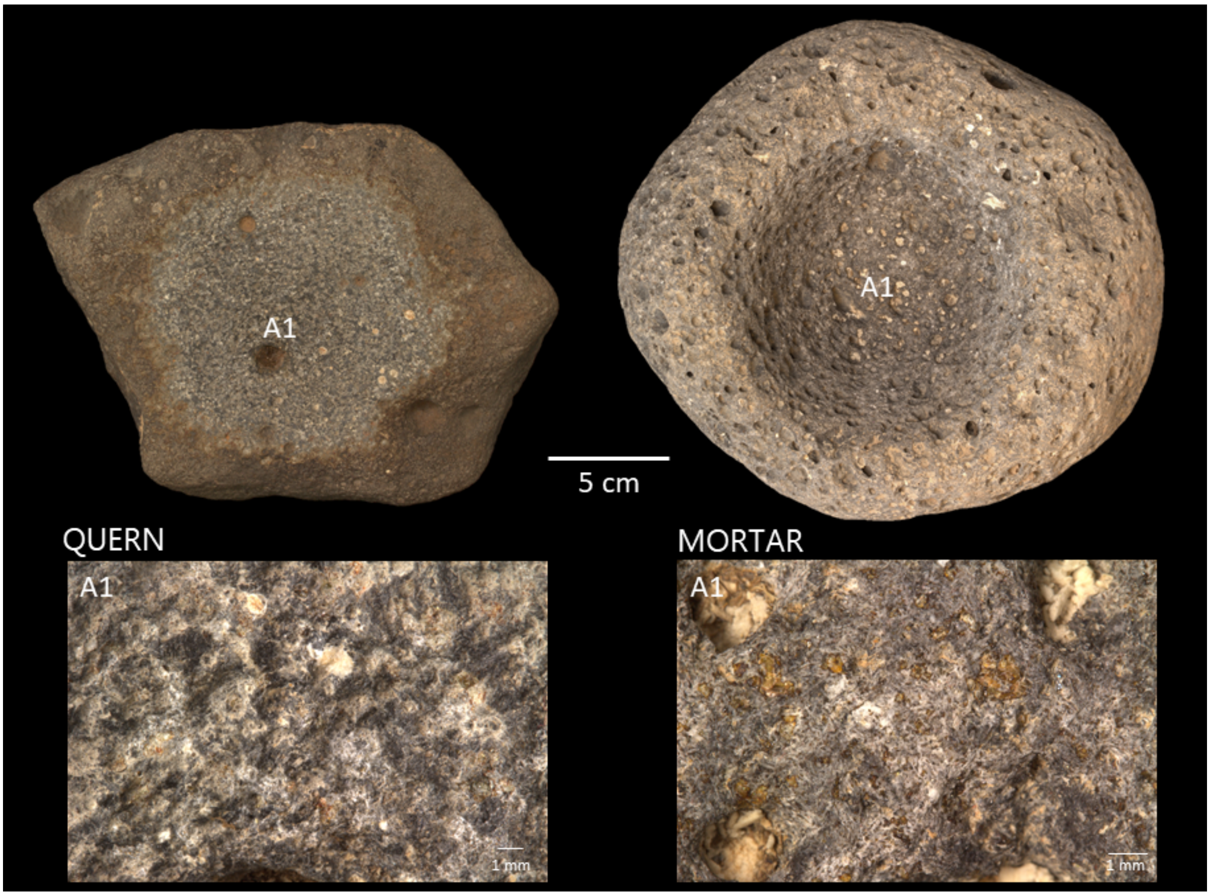

Figure 8: Tuber processing use-wear, from grinding (left, quern) and pounding (right, mortar). (Photos P. Pedersen / Shubayqa Archaeological Project).

Both pounding and grinding use-wear is somewhat reminiscent of processing of larger plants and “softer” plants. As also noted by (Delgado-Raack and Risch 2009): *“levelled zones with a straight section, grain extraction and micro-fractures indicate a contact with hard materials, while edge rounding and no striations are related to contact with softer material.”*

(underline mine). Therefore in the use-wear interpretation these traces are referred to as tuber/soft plant. There are parallels with nut processing, though lacking the (highly) reflective dark sheen created by grinding oily nuts (e.g. Dubreuil 2004; Chondrou et al. 2021; Keiko 2021). The main way to distinguish tuber processing from cereal processing is the absence of grain extraction and striations. This along with a rounded overall topography and a rounded and smooth levelling on the surface, rather than a flat topography with a rounded to flat and smooth levelling and associated grain extraction and striations that is often seen in cereal processing and flour production (e.g. Dietrich and Haibt 2020; Dubreuil 2004; Santiago-Marrero et al. 2021; Martinez et al. 2013; Portillo et al. 2013). The state of the tubers did not seem to influence the wear greatly.[7]

2.3. Low-power use-wear results

2.3.1. Early Natufian use-wear

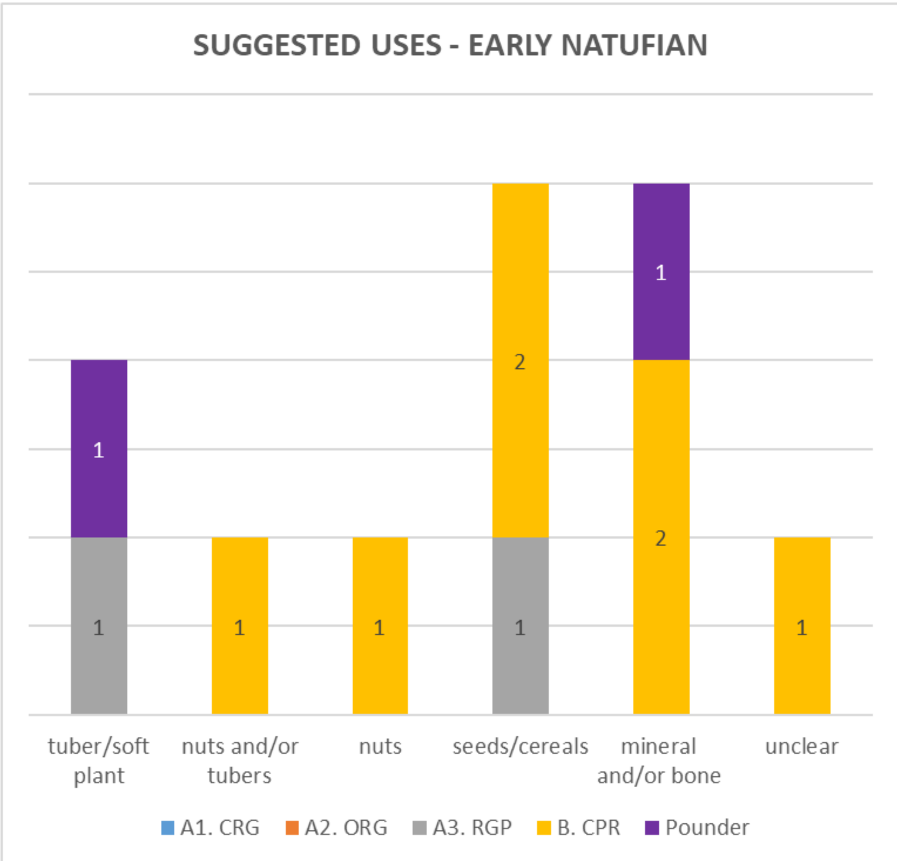

Figure 9: Suggested uses of tools subjected to use-wear analysis from Shubayqa 1, Early Natufian phase

The nine tools (and 11 surfaces) were analysed from the Early Natufian phase at Shubayqa 1 and these indicate an interesting diversity of contact materials. As also noted by Dubreuil (2004) for Early Natufian at sites further to the west, e.g. Hayonim Cave and Ain

[7] However, wet tubers developed some slight sheen on the tools after only 0,5 hours of processing on parts of the high topography. This is relatively fast (see Supplementary table ST2).

Mallaha, there seems to be a wide variety of functions and uses of the processing tools from Early Natufian Shubayqa, including some not directly related to food (see Figure 9). This is although the tools that we examined here were assumed to be in some way, or at some point, involved in processing edible plants or animals. Two CPR-tools (one mortars and one pestle) seem to have been involved in the pounding of minerals and/or bone (e.g. breaking bones?). Bone breaking could have been done to extract marrow and or grease (Yeomans and Richter 2020), while mineral processing may be a non-food activity (see Figure 9). Indications of non-food processing activities in the use-wear of Natufian ground stone is also noted by Dubreuil (2004) and was expected. Many of these processing tools would have seen multiple uses throughout their "life-histories" (Dubreuil and Savage 2014; Dubreuil and Grosman 2013; van Gijn & Annemieke Verbaas 2009). For example, two surfaces of a sub-spherical pounder were examined, and while one was related to pigment (and possibly bone) pounding, the other surface seems to have been used for grinding. The wear on the grinding surface is similar to wear observed experimentally used in tuber grinding. A quern (RGP-strategy) also had wear resembling tuber or soft plant processing (see Figure 10 below). These two tools, the pounder and the quern - a basalt block which also features a mortar face opposite the quern face - were found in the same context relatively close to each other. One could imagine that they may have been used together, or at least in similar ways with similar upper/lower tools. There thus appears to be sound evidence for both the pounding and grinding of tubers (or similar plants) happening at Shubayqa 1 in the Early Natufian (Figure 9).
In addition, one handstone features plant processing wear reminiscent of seeds/cereal grinding (circular grinding, i.e. RGP). However, as this tools was used to the point of being "worn-out" (i.e. Stage 4 wear), this is not entirely reliable. This tool, along with two pounding tools, suggest that cereal processing also took place during the Early Natufian. This is also corroborated by the archaeobotanical analysis (Arranz-Otaegui et al. 2018a). Here evidence of bread-like food remains were found in hearths from the Early Natufian phase. These were made of both tuber and cereal flour. This composite flour could have been produced using a combination of these strategies, e.g. pounding tubers (and seeds) into fragments (or to dehusk) and then grinding them in to a finer flour, and producing the flat-bread-like remain that were retrieved from the Shubayqa 1 hearths . There also seems to be some nut processing happening and nuts are present in the archaeobotanical remains. Acorn nuts were suggested as an important resource during the Early Natufian in the woodlands further west by D. Rosenberg (2008), although this suggestion seems to have been largely ignored in the broader literature.
The low-power use-wear of the Early Natufian ground stone at Shubayqa 1 seems to correspond with observations made by Dubrueil (e.g. Dubreuil 2004) of the diverse functions and tasks these tools were involved in, though plant processing does seem more prevalent at Shubayqa 1 than was noted by Dubreuil and Plisson (2010) for Mediterranean-zone sites.

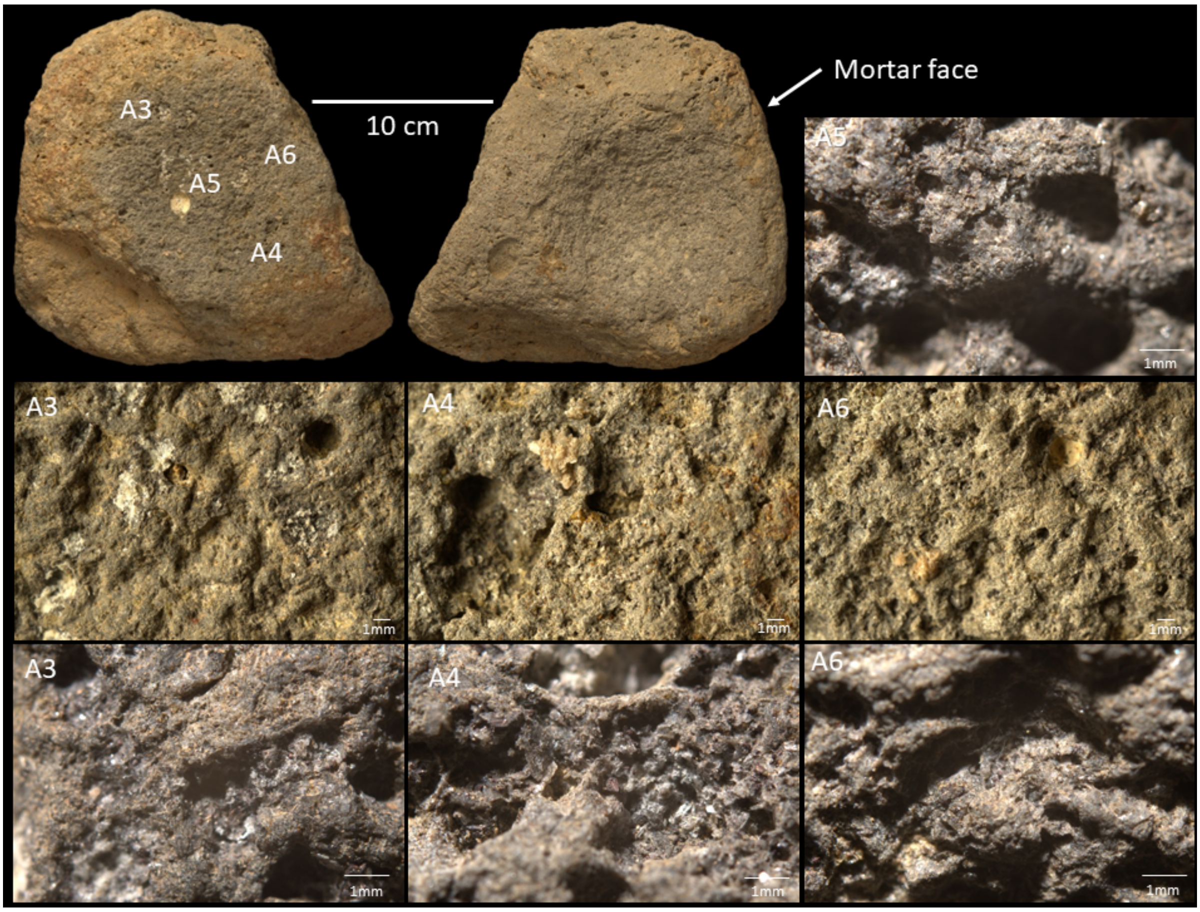

Figure 10: Archaeological example from Shubayqa 1: Early Natufian-phase. Block-type quern/mortar (SHUB01-2015-500) a RGP lower tool. The mortar face use-wear is not pictured. Example of tuber/soft plant use-wear. Tool is at "Stage 2" wear, i.e. beginning wear. A rounded topography with a rounded and rough levelling, with no phenocryst extractions and no striations. Rounding of the low topography (see close-up of Area 5: top right). First rows show areas at low magnification, the second row shows the same areas at higher magnifications (see scale bar). (Photos A. Pantos / Shubayqa Archaeological Project).

2.3.2. *Late Natufian use-wear*

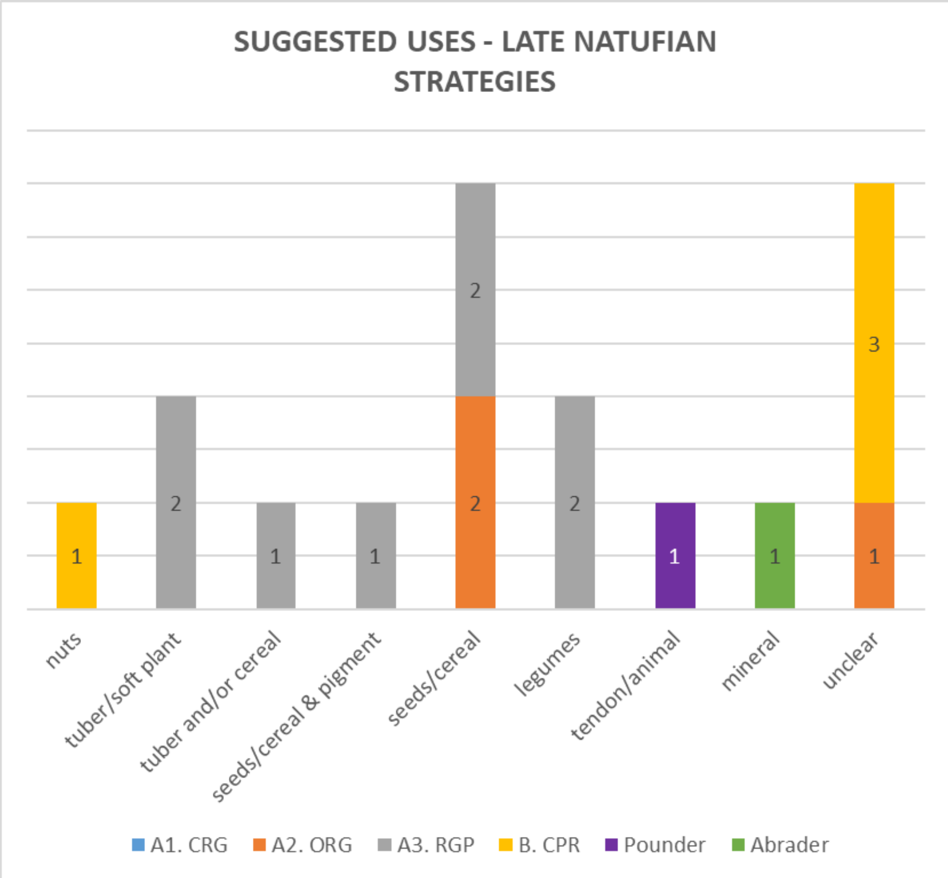

Figure 11: Suggested uses of tools subjected to use-wear analysis from Shubayqa 1, Late Natufian phase

From the Late Natufian 13 tools were analysed, with a total of 19 surfaces, 17 of which were active in some form of processing. Legumes and cereals/seeds processing appears to increase in the Late Natufian (Figure 11), this is a trend also observed by Dubreuil at Ain Mallaha (Dubreuil 2004, 2008). Tuber/soft plants processing however, also appears common, and as common as legume processing. An example of this is seen in Figure 12 below. This a discoidal handstone with wear traces reminiscent of tuber processing, or coarse cereal flour production (see examples in Dietrich et al. 2019; Dietrich and Haibt 2020), or perhaps a combination of both.

Generally it seems that rotary grinding (RGP strategy) was the preferred way to process plants; both tubers, legumes and cereals/seeds, but the latter were also processed using flat grinding implements (ORG), concurring with Dubreuil's observations (Dubreuil 2004).

Though use-wear traces of legume processing are present, legumes are rare (or so far not found) in the macrobotanical evidence from Shubayqa 1 (see the archaeobotanical section above). The presence of this type of wear could be from poppy seed processing, a resource that is present in the botanical assemblage, as these two resources leave similar use-wear traces from grinding (see Supplementary table ST4). Clearer use-wear evidence for oily seed processing (which could be common poppy seeds) is found in the subsequent EPPNA phase at Shubayqa 6 (see below). The pounding tools from the Late Natufian show inconclusive wear, except for a pounder that would appear to have been used to pound animal matter. At least one tool, a discoidal handstone (RGP), was used for both cereal/seed and ochre processing, a trend also observed in the subsequent EPPNA phase (see below). This again highlights the complex and diverse use-life of these tools. Wear is expressed within processing strategies indicate diverse, not singular, tasks (and labour).

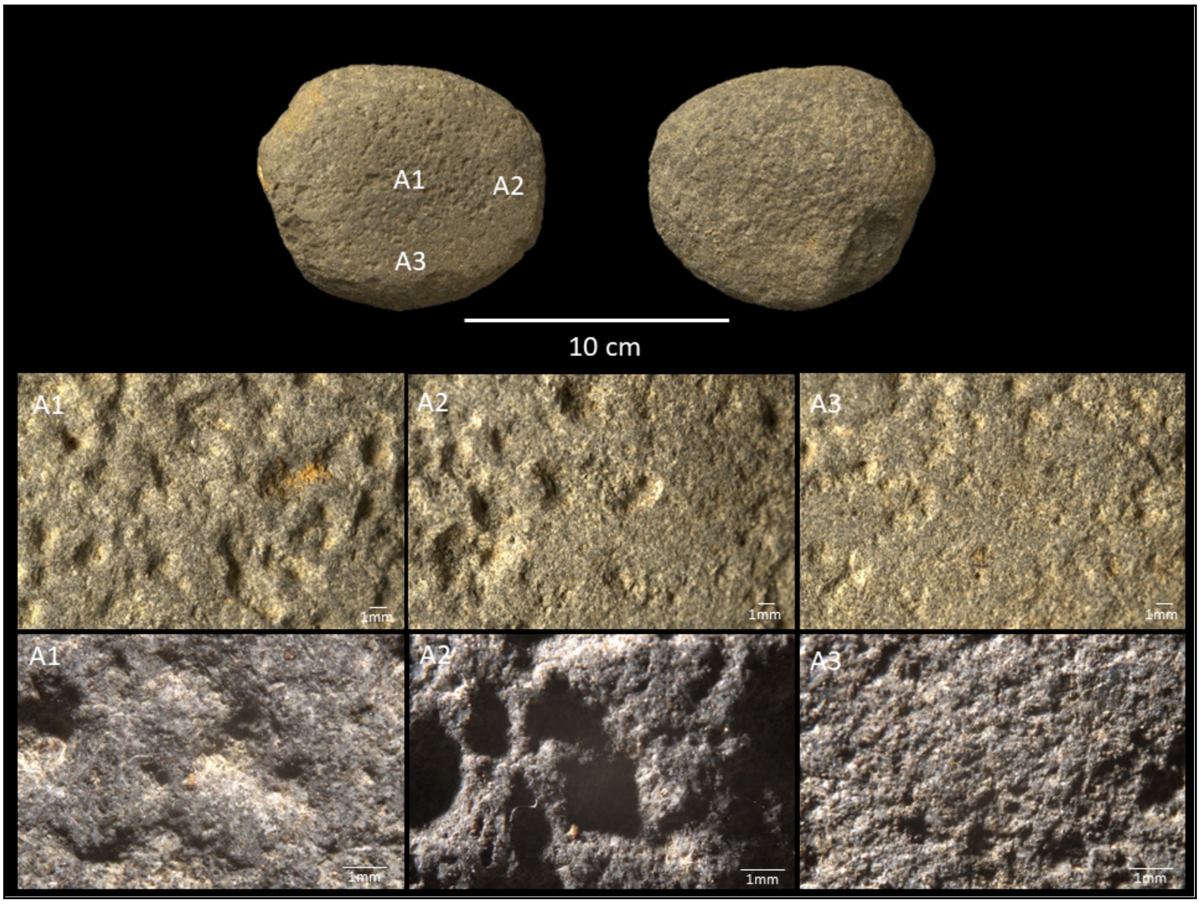

Figure 12: Discoidal-type handstone (SHUB01-2012-312) a RGP upper tool. Archaeological example from Shubayqa 1: Late Natufian-phase of tuber/soft plant use-wear (possibly coarse flour production). The tool is at "Stage 2" wear, i.e. *beginning* wear. It features a rounded topography with a rounded, rough to smooth, levelling with no phenocryst extractions and no striations. Levelling is confined to the margins (Area 2 and 3). Rounding of phenocrysts on both high and low topography at the centre (see Area 1). The centre also still features multiple pecking pits with rounded edges. Compare with Figure 8. First row shows areas at low magnification, the second row shows the same areas at higher magnification (see scale bar). (photos A. Pantos / Shubayqa Archaeological Project).

2.3.3. EPPNA: Late Natufian-Early PPNA use-wear

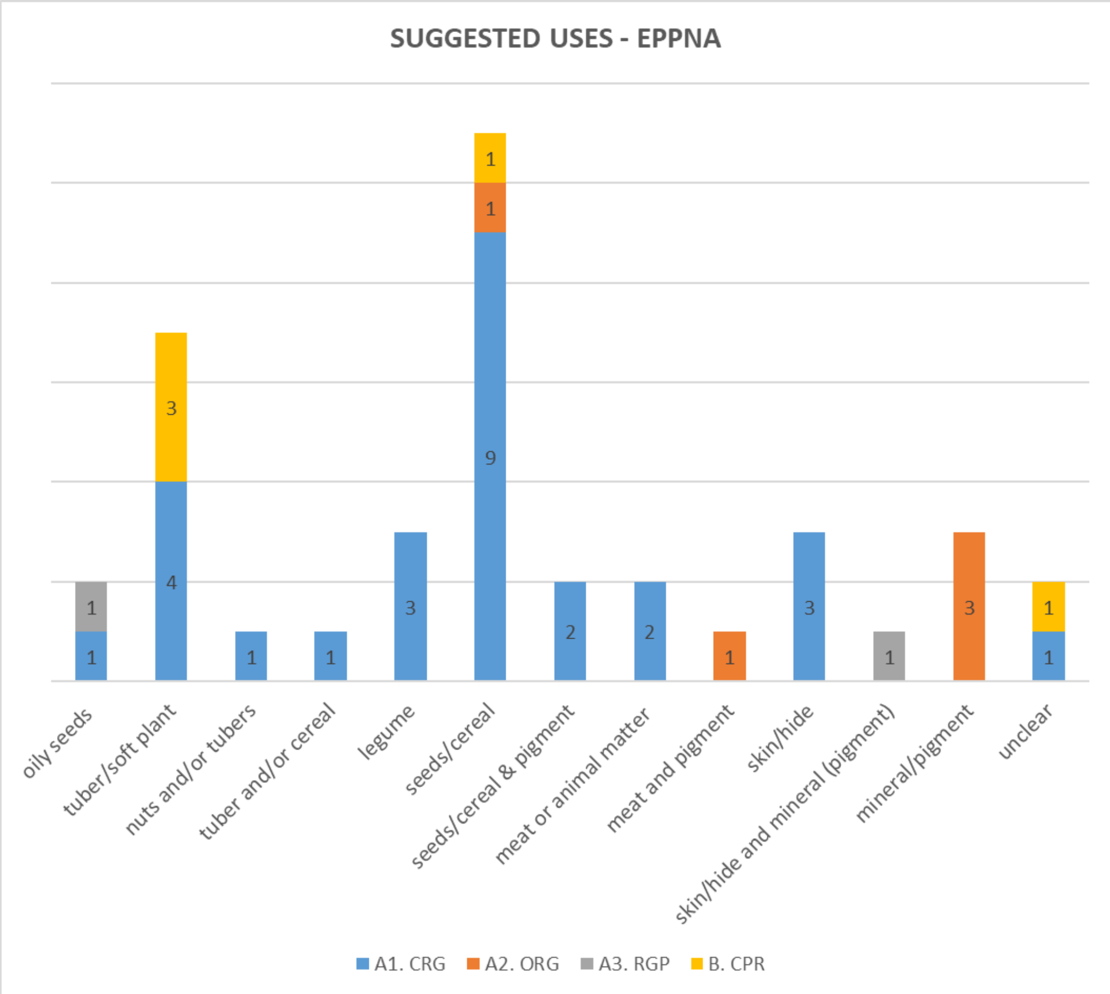

Figure 13: Suggested uses of tools subjected to use-wear analysis from Shubayqa 6, (Late Natufian-)Early PPNA phase

By the EPPNA most tools appear to be involved in seeds/cereals processing along with common tubers/soft plant processing (Figure 13). Figure 14 presents an example of an ovate-type handstone (CRG-strategy) with wear indicative of cereal/seed processing.
The most prevalent strategy in this phase, CRG, seems to be involved in a number of activities, like meat and legumes processing and also non-food activities like hide/skin processing. Three Ovate-type handstones appear to have been used-, or reused, as abraders on hide/skin. In general skin/hide and animal matter processing is rather prevalent, often in conjunction with pigment. This goes to show that a trend towards more reciprocal grinding (i.e. CRG) is not necessarily linked only to specific plant foods.

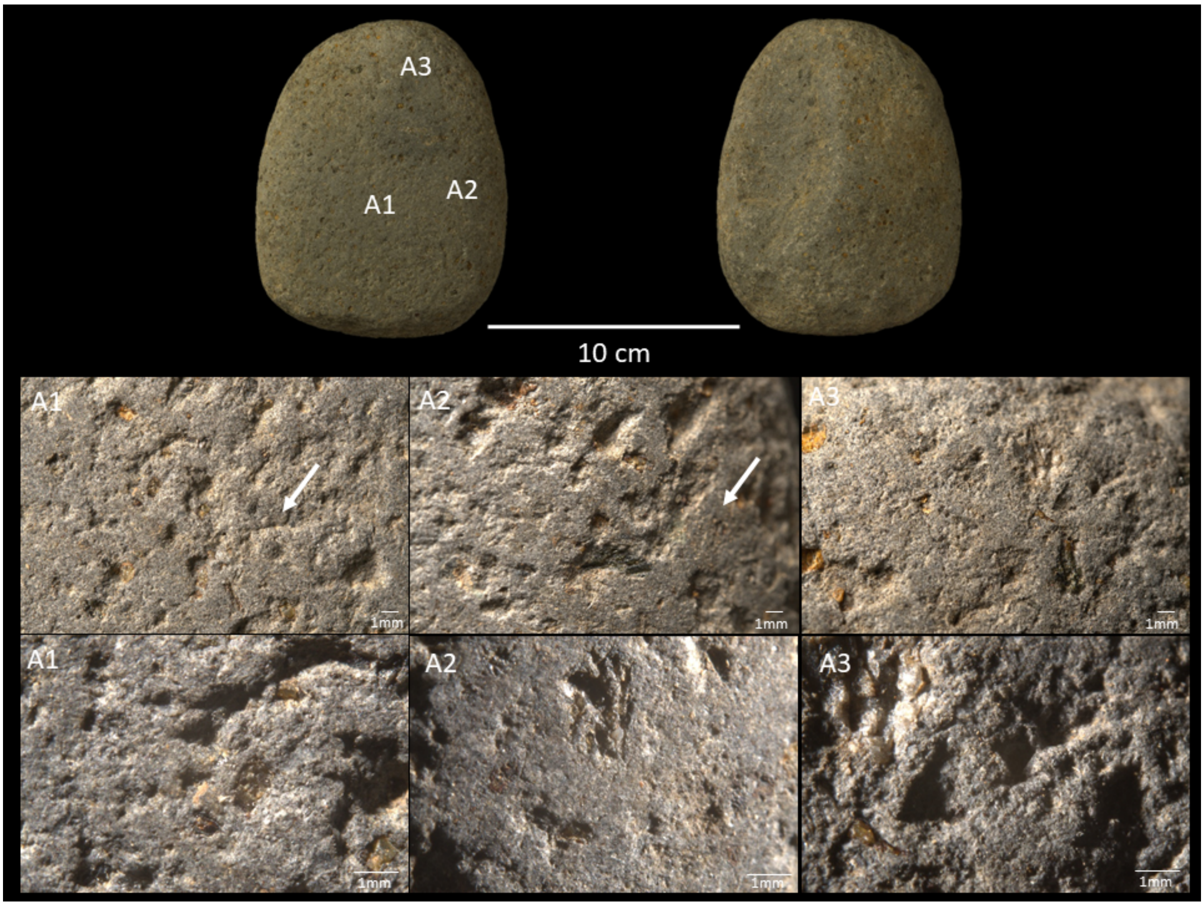

Figure 14: Ovate-type handstone (SHUB06-2016-1095) a CRG upper tool: Archaeological example from Shubayqa 6: PPNA-phase of seeds/cereal use-wear. Tool is at "Stage 3" wear, i.e. pronounced wear. A rounded (centre, Area 1) to flat (distal/proximal ends Area 2) topography and levelling, with phenocryst extractions and some striations. Heavily used across the face. White arrow in Area 1 (top row) highlights a transverse striation. White arrow in Area 2 highlights flat levelling. First row shows areas at low magnification, the second row shows the same areas at higher magnifications (see scale bar). (Photos A. Pantos / Shubayqa Archaeological Project).

Plant processing however, makes up the bulk of the suggested functions. In addition to the prevalent cereals and tuber traces, oily seeds and legumes appear important. Again, these oily seeds/legumes could be (common) poppy seeds as these appear in the macrobotanical assemblage at Shubayqa 1 and thus seem to have been present in the environment surrounding the *Qa'* and therefore also around Shubayqa 6. Nevertheless, legumes may be present at this site and just not yet attested. Pounding pairs, wear suggests, are still involved in tuber/soft plant processing (see example in Figure 15 below).

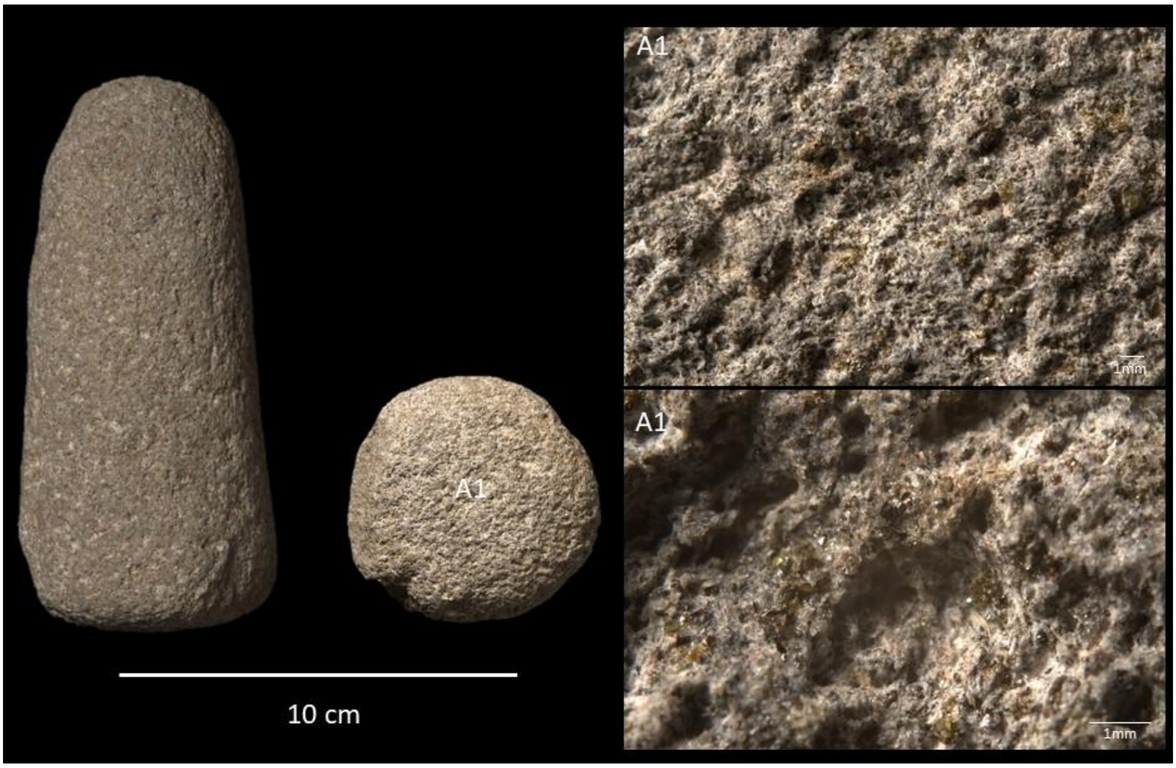

Figure 15: Conical-type pestle (SHUB06-2012-312) a CPR upper tool. Archaeological example from Shubayqa 6: Early PPNA-phase with tuber/soft plant pounding use-wear. Compare with the experimental mortar above (Figure 8, right). Tool is at "Stage 2" wear, i.e. pronounced wear. First row shows areas at low magnification, the second row shows the same areas at higher magnification (see scale bar). (photos A. Pantos / Shubayqa Archaeological Project).

2.3.4. *LPPNA: Late PPNA-Early PPNB use-wear*

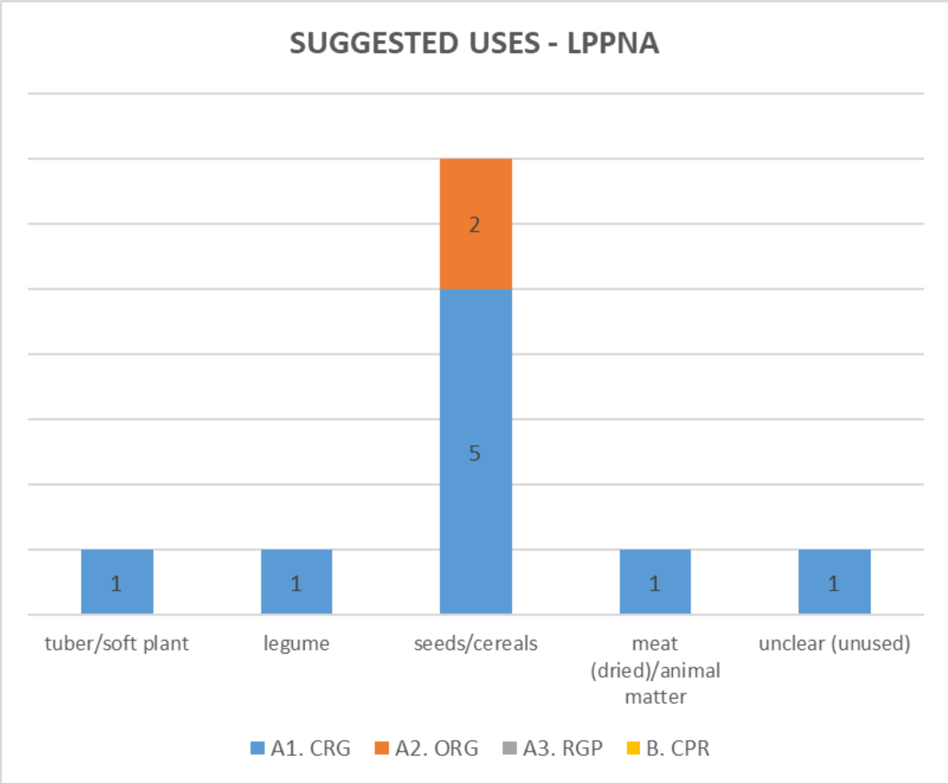

Figure 16: Suggested uses of tools subjected to use-wear analysis from Shubayqa 6, Late PPNA(-Early PPNB) phase

This is the smallest assemblage of tools analysed so far from the Shubayqa sites (*n*= 21) . 11 of these tools were subject to low-power use-wear analysis. All of the use-wear comes from grinding tools and suggests a further concentration on seeds/cereal processing, though tubers/soft plants, legumes (or oily seeds) and meat are also represented. All these contact materials were also prevalent in the previous phase. A concentration on cereal processing by the Late PPNA-Early PPNB is consistent with what has been observed at other sites from the later PPNA to Middle PPNB, e.g. Göbekli Tepe and Ayn Abu Nukhayla (Dietrich et al. 2019; Kadowaki 2014). Though it is important to note that these artefacts (CRG strategy) which include most of the Shubayqa 6, Ayn Abu Nukhayla and Göbekli Tepe grinding tools, would have seen multiple uses as our results also suggest (see our Figure 16, above). There is a tendency to overemphasise cereals, even when multiple other plants, animals and materials would presumably have been processed using these strategies, techniques and gestures.

2.4. Residues Analysis - work in progress

2.4.1. Methods and analysis

2.4.1.1. Selection and sampling of tools *(PP)*

The tools selected for residue sampling were the same as the ones subjected to use-wear analysis and thus have the same provenance and selection bias as presented above. The tool types included the residue sampling thus includes: handstones, querns/slabs, pestles and

mortars, as well as a few polishers, pounders and hammerstones (see Supplementary table ST3). The first four types come from the larger "processing" tool groups presented above while the three latter come from tools mainly involved in stone-to-stone contact or multifunctional (pounder) and were sampled for comparative reasons.
The artefact sampling was based on a protocol provided by M. Ramsey (2019). It included:

a. **Dry Brush:** remove adhering sediments from tool with clean toothbrush. Brush tool gently, collect sediment and transfer into a new 50 ml test tube.
b. **Wet Brush:** using the same toothbrush, scrub the tool with distilled water. Collect all of the aqueous material, and transfer to a new 50 ml test tube.
c. **Point sample with pipette.** Using distilled water take several samples from the clean working surface, and clean non-working surface of the ground stone. Drop several drops of distilled water on surface, use the tip of the pipette (use new pipette for every sample) 'worry' the surface, then pipette up the sample. Transfer sample to new 10 ml test tube. Focus on cracks or crevasses, as well as any visible residues on the working surface. Samples should also be taken from broken surfaces (i.e. post-depositional breaks so we know the surface was not used for processing). Photos and sketches should be used to record sample placement.

Point sampling with pipette was generally prioritised over other sample types. Wet and dry brush sampling mainly only happened if larger chunks of sediment adhered to the surface or was stuck in the vesicles.

2.4.2. *Residue Analysis results* **- work in progress**

3. Observations of contact material, use and function over time and the relationship to processing strategies (PP)

3.1.1. *Overall wear results of all analysed tools: contact material and functional change*

Looking at the overall trends across all periods, ground stone tools were heavily involved in plant processing at the two Shubayqa sites, making up more than 60% in all phases, and in the Late Natufian and LPPNA more than 75% (see Figure 17). Processing meat and animal by-products and minerals, make up the rest of the suggested activities (disregarding unclear and indeterminable wear), including both meat processing, bone processing in the Early Natufian, and non-food activities like skin/hide processing in the EPPNA.
Cereal processing makes up the largest single wear "group" in all phases but is not completely dominant until the LPPNA phase at Shubayqa 6. Note that the LPPNA sample is small and from only two strategies (CRG and ORG). Before this cereal processing makes up 29-31 % of the wear identified. These seeds/cereal traces probably result from the processing

of some kind of a wild cereal found in the area or brought to the site(s), presumably *Triticum boeticum* or *T. urartu* (einkorn), *Hordeum spontaneum* (barley) or *Avena* spp. (oat), which all appear in the macrobotanical assemblage of Shubayqa 1.

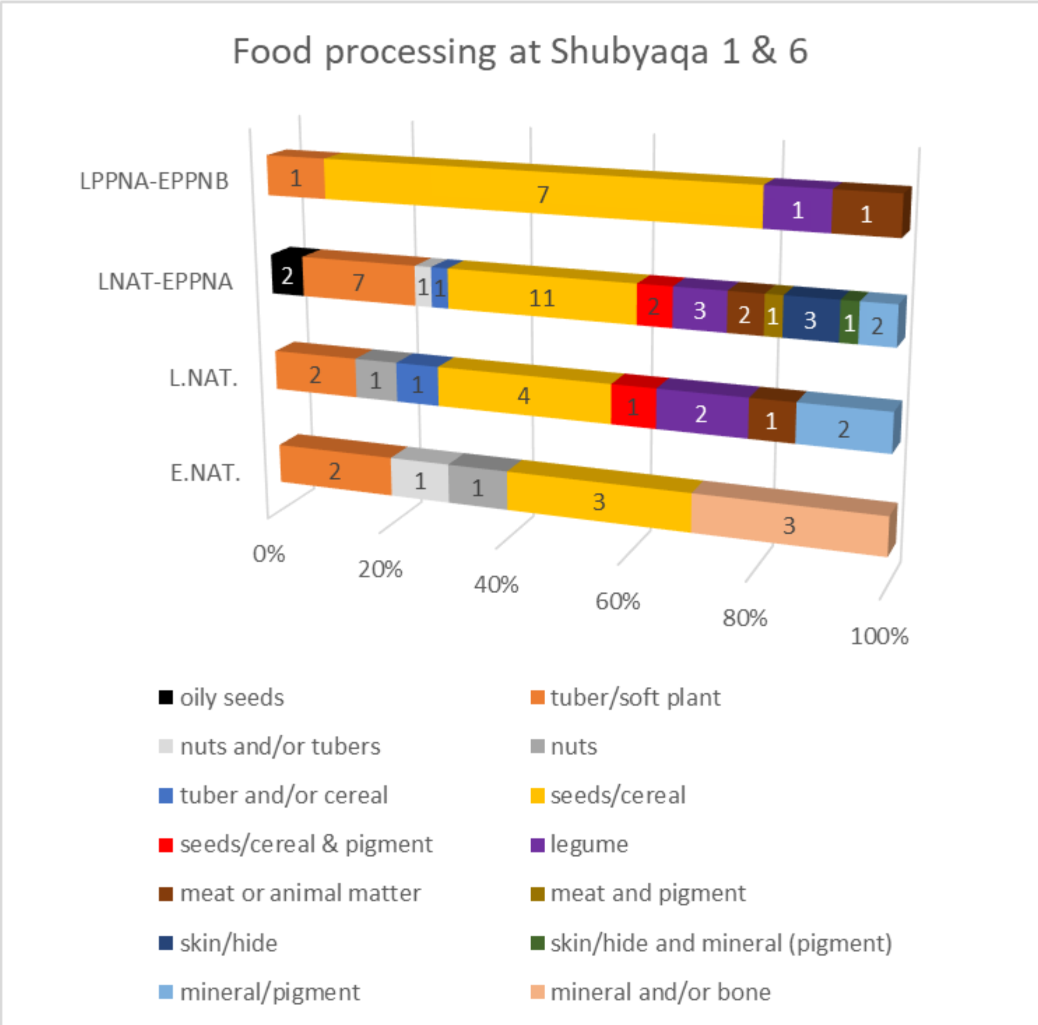

Figure 17: Suggested contact material uses of tools subjected to use-wear analysis from Shubayqa 1 and 6, all phases. Above all processing tools together (without tools with "unclear" wear)

Tuber or soft plants make up 15-20 % from the Early Natufian into the Late Natufian and EPPNA, the same goes for legumes and oily seeds that collectively account for a similar percentage of wear from the Late Natufian into the LPPNA. These tuber/USO's or soft plants are presumably the abundant tubers found in the archaeobotanical assemblage of Shubayqa 1, i.e. *Bolboschoenus glaucus* (club-rush) tubers.

The presence of tuber or "soft plant" use-wear traces on the pounding and grinding tools, would suggest that these were processed into smaller fragments, including flour. Tuber-flour, along with cereal-flour was part of the composite flour used for some of the bread-like food remains found in Early Natufian hearths of Shubayqa 1 (Arranz-Otaegui et al. 2018a). Thus the use-wear seems to corroborate the use of GST in processing this resource, something we have also explored through experiments (see Arranz-Otaegui et al. *submitted*). Our experiments showed that both rotary grinding and (especially) pounding worked well in producing small tuber fragments and even flour, something also seen ethnographically (Gott 1982; Schroth 1996; Shoemaker et al. 2017).

This all shows a relatively significant diversity within the plant processing happening at the sites. A “new” addition to the foodways of the inhabitants of Shubayqa over time, is the legumes and/or oily seeds “group”, which so far is not identified in the Early Natufian use-wear from Shubayqa 1. By the Late Natufian at Shubayqa 1 this processing appears common. The prevalence of wear traces indicative of legume processing in the Late Natufian is also noted by Dubreuil (2004) (e.g. at Ain Mallaha).

In subsequent EPPNA phases at Shubayqa 6, legumes and/or oily seeds also make up a significant chunk of the contact material. These “oily” seeds might be the common poppy, *Papaver rhoeas* or possibly *Tribulus terrestris* (puncture vine) both recognised in the botanical assemblage. The legume traces could be from some so far unidentified legume or there may be some overlap here between oily seed and legume wear traces.

The “introduction” of this plant group may simply be down to the wear not being recognised yet in the Early Natufian at Shubayqa 1, or that not enough of the tools used in this activity appears in that phase, i.e. querns and basin slabs (i.e. RGP, CRG see Figure 17). If more tools of these strategies can be analysed from the Early Natufian phase in the future it may be possible to reveal that this type of plant processing occurred.

In the plant assemblage of Shubayqa several other seasonal plant-food resources also appear, including palatable leaves, stems and flowers, which would have been available during spring times e.g. *Phragmites australis* (common reed), *Diplotaxis harra* (wall-rocket) etc. (Arranz-Otaegui et al. 2018a). Unfortunately such plants appear to leave few use-wear traces on ground stone tools , even if processed into products like salsas/sauces or chutneys (see Hamon and Le Gall 2013; Hamon et al. 2021). This suggests that these tools were probably involved in even more plant processing than can be determined by the use-wear analysis alone.

However, this does not mean that these tools should be seen as exclusively used to process plants. As our evidence above shows, and as noted by other from sites in the region from the Natufian and into the PPN, the processing of animal matter and animal by-products would have also been important activities (Bofill and Taha 2013; Dubreuil 2004; Dubreuil and Grosman 2009; Dubreuil and Grosman 2013; Martinez et al. 2013; Starkovich and Stiner 2009).

The meat, bone (and hide) processing, could have been from many gazelles that appear to have been consumed at the Shubayqa sites, while waterfowl and migratory birds also seem abundant around the Qa’ during the occupations at both at Shubayqa 1 and 6 (Yeomans et al. 2017; Yeomans 2018; Yeomans and Richter 2020). Ground stone tools may have been used to tenderise meat by pounding, grinding dried meat etc. Processed meat may have been consumed as such or combined, mixed with fats, plants or plant products, making *köfte- or kubbiniyeh*-like products, where wheat bulgur is mixed with ground meat and herbs (Ertug 2002). Or processed and mixed for better preservation as with bison-*pemmican* (Bethke et al. 2018).

In addition to processing animals for the meat itself (as use-wear appears to attest in the Late Natufian and EPPNA see below) and hide (seen on some PPNA handstones), animal parts may also have been processed to extract marrow and/or grease. Bone breaking is attested in the GST use-wear form Early Natufian Shubayqa 1 (see Figure 17) and also from the faunal remains (i.e. a high degree of bone fragmentation) from Shubayqa 1 and 6 (see Yeomans et al. 2017; Yeomans and Richter 2020). Yeomans and Richter (2020) suggests that during the Late Natufian and Early PPNA at Shubayqa 6 the seasonally abundant (wintering) waterfowl may have been preserved using grease/fat extracted from ungulate bones. Extracting grease would involve boiling/simmering, fragmented bones.

3.1.2. Overall results according to strategy: ways of use and contact material

In this the following section we ask whether there exists any relationship between any one processing strategy and any one contact material or whether strategies rather represent broad *ways of processing*, not related to any one resource. Were strategies techniques that could change a wide range of resources? Or rather tools limited to single tasks and functions?

In our sample contact material and consequently function seems widely distributed between the different processing strategies (see Figure 18). These tool pairs and the related ways of use; the gestures applied to process a material within a strategy do not seem to be greatly affected by what intermediate contact material was processed.
However, some tools do seem to be used more frequently on cereals/seeds, especially reciprocal grinding tools, either CRG, grinding in a narrow basin or ORG, grinding on a flat slab. But overall the trend is that whichever strategy is most prevalent and common in each phase, appears to also have seen the widest range of tasks, e.g. the CRG strategy in the EPPNA, the RGP strategy in the Late Natufian and CPR in the Early Natufian.
This can be explained in a number of ways. Firstly since most of the examined tools are related to that specific strategy and represent a majority of that given phase, more variety in wear is expected. More tools examined equals a potential increase in diversity. However, if any tool was associated with any one task exclusively this would not result in a lot of diversity. We may examine if the apparent lesser diversity that appears within the two reciprocal grinding strategies (CRG and ORG) is also reflected statistically. If so, we can suggest that though use and contact material is generally diverse within all strategies, some strategies are somewhat less diverse. Thus we may point to a trend towards using these tool types and these strategies for certain purposes. In the case of these two strategies the most common use would then be cereal/seeds processing.

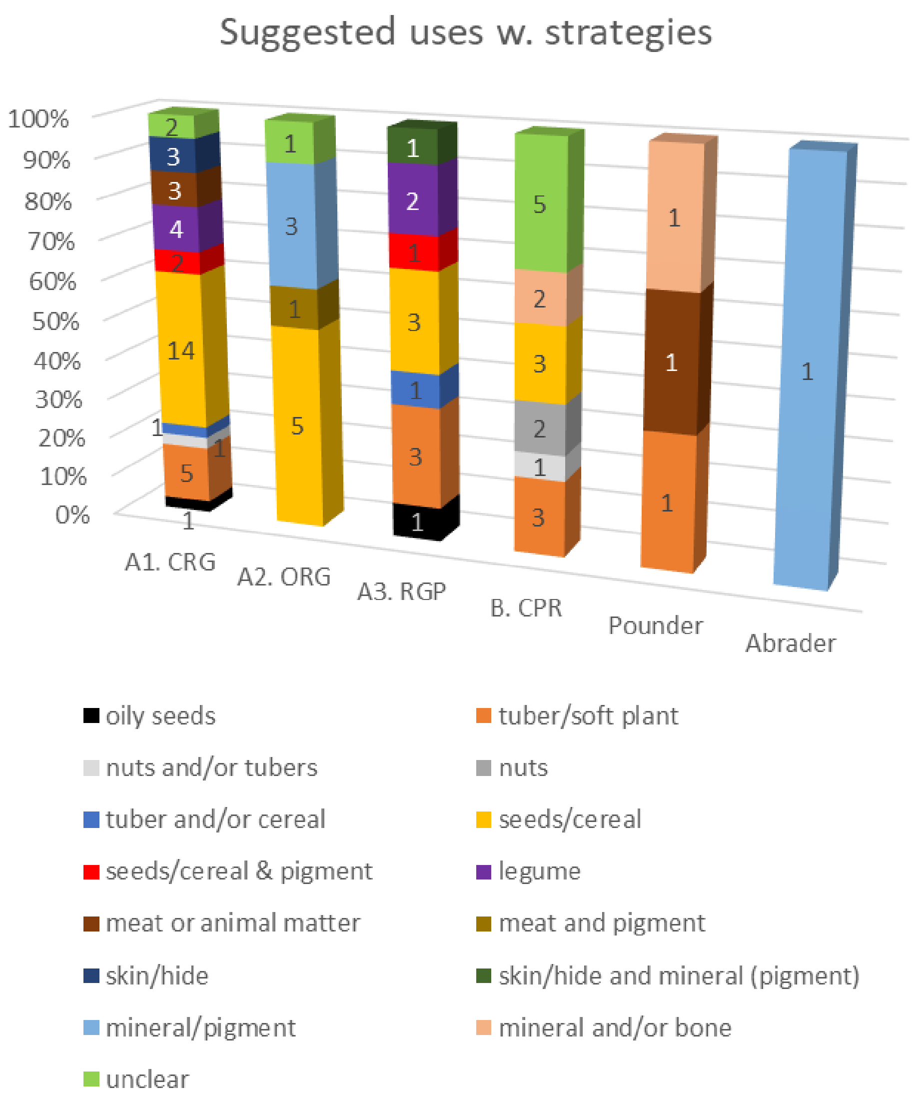

Figure 18: Suggested uses of tools subjected to use-wear analysis from Shubayqa 1 and 6, all phases. Above all processing tools to processing strategy (including "unclear").

If we apply a Simpsons Diversity Index, which can be used to examine biological diversity at a specific location, we may ascertain which of the strategies at the Shubayqa sites are the least diverse. This index follows the statistic formula: $D = \sum(n / N)^2$.

D equals the diversity in a setting - in this case the strategies, at a value between 0 and 1, with 0 representing infinite diversity of suggested/recognised contact material, and 1 being no diversity. n being the number of suggested uses/contact materials observed through use-wear analysis within each strategy. This should, theoretically, even out the differences in the number of tools and surfaces examined of each strategy.

A1. CRG	A2. ORG	A3. RGP	B. CPR
D= 0,20	D= 0,36	D= 0,11	D= 0,13

Table 1: Suggested use/function diversity of strategies. Simpson's Diversity Index, based on all suggested uses/contact materials (excluding unclear/undetermined wear) attested at the sites see Figure 18 above.

As can be seen in Table 1, it appears that the CRG and ORG strategies indeed are the least diverse statistically (in particular ORG). And, as the most common use-wear traces on these strategies are ones that are indicative of seed/cereal processing, we can suggest a slight convergence in function of these two strategies. Interestingly, this implies that CRG, the most common strategy in the PPNA, is slightly less diverse (but still diverse) in use-wear traces and this corresponds with a prevalence of cereal processing in the EPPNA and into later LPPNA/EPPNB (see Figure 13, 16 and 17, 18 above).
This is a slow increase however, and as we see, a lot of other plants, animals and minerals are also processed, both with this strategy and in the Neolithic phases of Shubayqa 6 generally. All strategies are more diverse than not (< 0,5) and thus there generally is a statistical trend towards diversity. Contact materials are in fact diverse in all phases we assume, however this will need to be corroborated through residue analysis, more advanced use-wear methods and further statistical work.

For now we can suggest on the basis of the low-power use-wear and the processing strategies approach that: tools *in general* have diverse functions and are not engaged in only processing certain types of foodstuff. There are a range of plant and animal parts prepared using the Shubayqa GST. Rather, these tools and strategies are engaged in processing food *in certain ways*. These foodways, e.g. ways of using GST, represent what for people were the correct application of gestures and tools for producing certain end-products. These products would have been crushed and fragmented plant and animal matter, probably including ground meal or flour. Tools would have mashed meat and extracted fats from bones etc. Food was likely made of these diverse sets of plants and animals found in the surrounding landscape.

4. Discussion: the Changing Foodways of Shubayqa and the Epipaleolithic-Neolithic transition - a GST perspective

Strategies overview - Changes over time

Supplementary table ST1, provides an overview of the strategies, associated tools and their frequency in each phase from Shubayqa 1 and 6. This data and the changes exhibited in the assemblage and strategies in the assemblage over time sites is covered elsewhere (see Pedersen 2021), and thus we present it here mainly as a background to the subsequent use-wear analysis below and for comparative purposes in the next section. To briefly summarise: at Shubayqa there is an increasing trend towards grinding from pounding over time, pounding (CPR-strategy) dominating in the Early Natufian, then giving way, firstly to circular grinding (RGP-strategy) in querns, then to confined reciprocal grinding in basin-type grinding slabs (CRG-strategy) by the PPNA (see Figure 19). The diversity of strategies begins to rise during the Late Natufian and then drops slightly by the Neolithic (Pedersen 2021).

Figure 19: Processing tools, counting all (top) and complete tools only (bottom), Shubayqa 1 and 6.

Here, in the following we compare the Shubayqa data to other Late Epipalaeolithic to PPNB sites in the Levant. This comparison is however limited, firstly due to the lack of detailed reports and data. Although more research into GST from SWA has been published in recent years, many GST assemblages remain under- or unpublished and important information may thus be missing. Secondly, ground stone tools, like other stone tool classes, exhibit a great deal of diversity. Not all tools and subtypes fit neatly into Wright's ground stone typology for SWA (Wright 1992a). Consequently, it may be difficult to assign some of the tools to one of the proposed strategies. Furthemore, as also noted in Pedersen (*forthcoming* a, *forthcoming* b) the processing strategies approach should really be adapted to fit local variations of tools, techniques and gestures. Labour, the instruments of labour, and practises of procurement and processing will "naturally" differ. However, as long as researchers have applied Wright's typology, or as is the case in parts of this comparison, data comes directly from Wright's unpublished PhD.-dissertation (Wright 1992b), we may be able to provide some tentative (but somewhat incomplete) comparisons.

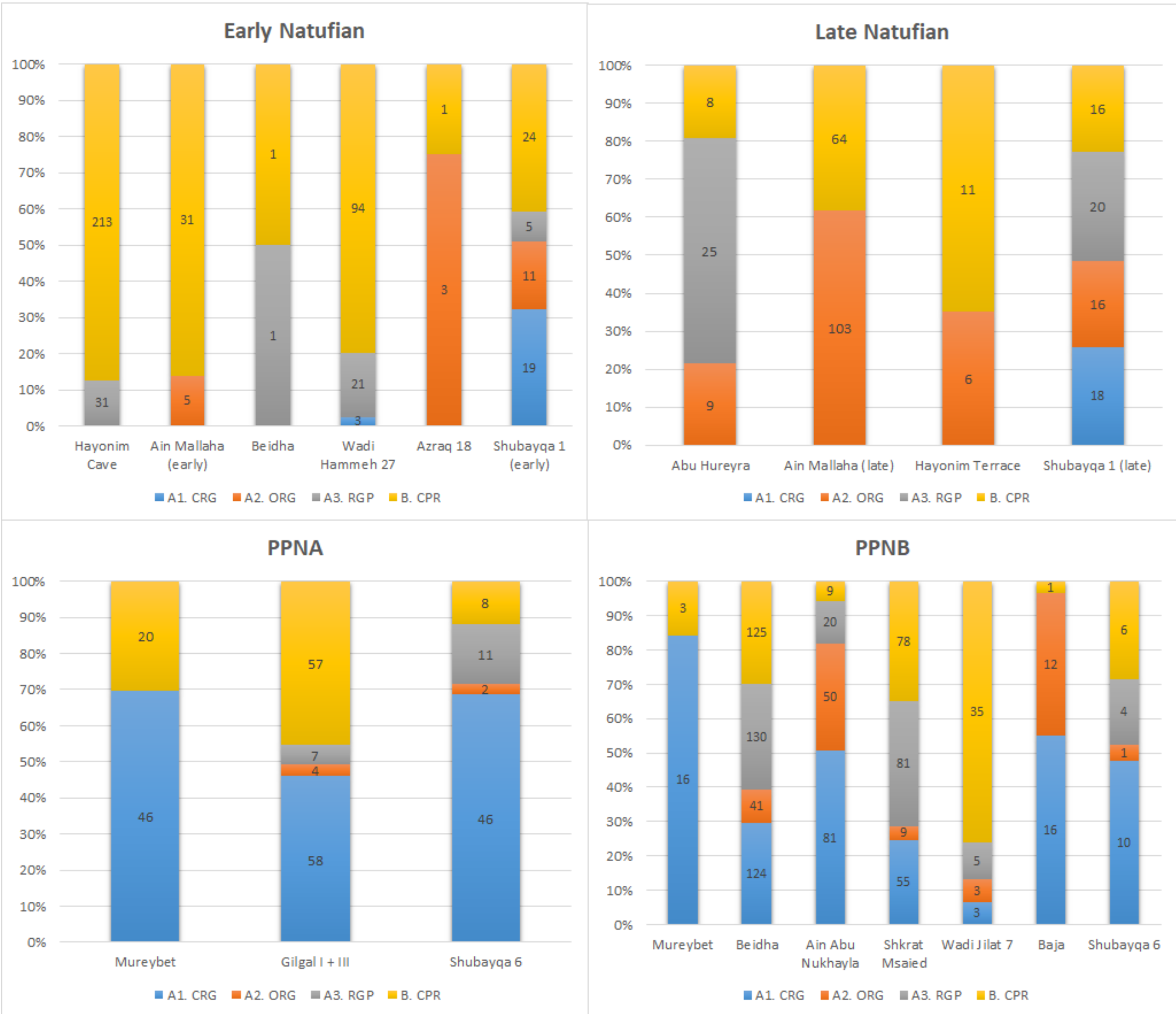

Figure 20: Processing strategies in the Levant. Including only discernible tools. In the case of the assemblages from Shubayqa 1 and 6 counting "complete" tools only. Early Natufian: Hayonim Cave (Dubreuil 2004), Ain Mallaha (early) (Dubreuil and Plisson 2010), Beidha (Natufian) (Wright 1992b), Wadi Hammeh 27 (Edwards and Webb 2013), Azraq 18 (Wright 1992b), Shubayqa 1 (early) (Pedersen 2021). Late Natufian: Abu Hureyra (Moore 2000), Ain Mallaha (late) (Dubreuil and Plisson 2010), Hayonim Terrace (Dubreuil 2004), Shubayqa 1 (late) (Pedersen 2021). PPNA: Mureybet

(early) (Nierle 2008), Gilgal I & III (Rosenberg and Gopher 2010), Shubayqa 6 (early) (Pedersen 2021). PPNB: Mureybet (Nierle 2008), Beidha (Wright 1992b), Ayn Abu Nukhayla (Kadowaki 2014), Shrat Msaied (Harpelund 2011), Wadi Jilat 7 (Wright 1992b), Ba'ja (Wright 1992b), Shubayqa 6 (late) (Pedersen 2021).

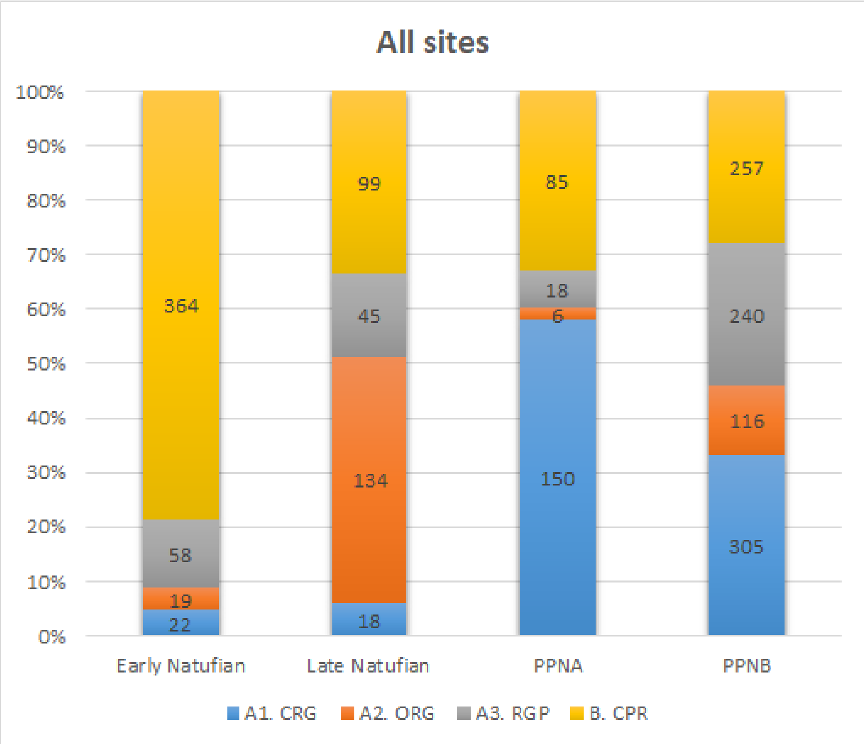

Figure 21: Aggregate processing strategies inferred from tool data from all of the above sites. (references same as above).

The above figures (Figure 20 and 21) are based on sites with published ground stone assemblages. The relative frequencies of processing strategies at each site shows interesting similarities as well as divergences.

The Early Natufian appears heavily dominated by pounding tools (CPR), but with geographically "close" sites of Azraq 18 and Shubayqa 1, having more grinding strategies present. Grinding in circular querns or elongated basins, with discoidal- and ovate-type seem relatively prevalent (see Figure 20 e.g. Hayonim Cave, Wadi Hammeh 27 and Shubayqa 1). It would appear the further to the west towards the Jordan and the Mediterranean the sites are located the more frequent pounding tools are. This may have something to due with woodland resources like acorns (Rosenberg 2008; Olszewski 2004), but pounding strategies would presumably have been used in multiple tasks, e.g. tuber processing (Wollstonecroft et al. 2008; A. Arranz-Otaegui et al. *submitted*) as well as and/or bone and meat pounding as we noted above.

By the Late Natufian grinding strategies become much more common, e.g. at Ain Mallaha flat grinding implements (ORG-strategy) proliferate (Dubreuil 2004; Dubreuil and Plisson 2010), while at Abu Hureyra 1 and Shubayqa 1 (Phase 2 and 3) there is a mix of different both circular grinding (RGP) and reciprocal grinding techniques (CRG and ORG).

Pounding continues to be common however, and may even increase in some cases by the Early Pre-Pottery Neolithic (see Figure 20).

The sites belonging to the PPNA seem to confirm the trend towards confined grinding (CRG) by the Earliest Neolithic, as observed at EPPNA-LPPNA Shubayqa 6 (Pedersen 2021), with Mureybet (phases I-III) featuring a very similar assemblage, both in terms of the applied processing strategies (CRG and CPR) and in the frequent re-use of basin grinding slabs as mortars (see in Nierle 2008).
Looking at the PPNB (Figure 20), numbers there also show a great variety in strategies. Four sites, Mureybet (phases IVA-IVB), Shubayqa 6, Ba'ja and Ayn Abu Nukhayla (see details in (Kadowaki 2014) continue the PPNA trend of processing through CRG modes. This seems also to be the case with the MPPNB food processing GST at Göbekli Tepe (see Dietrich et al. 2019; Dietrich 2021). Conversely, it would seem that people at Wadi Jilat 7 preferred to pound whereas at Shkrat Msaied circular grinding (RGP-style) dominates. A mix of various strategies appear to be used at Beidha during the MPPNB.

The divergence and diversity seen in the PPNB (see Figure 20 and 21) probably has to do with more sites and data being available and from more regions characterised by different ecological settings, but also diachronic diversity, being a period of *c.* 2000 years. For example, Wadi Jilat 7 and Beidha are quite different sites, which is also reflected in their ground stone assemblages. What this data shows, overall, is that even during the PPNB when cultivated and domestic cereals and legumes became more important than gathered and wild plants at many sites (Arranz-Otaegui 2018b), GST were still quite diverse and were not always - and not at all sites - geared towards the grinding of cereal flour.
In our brief comparison the PPNA is only represented by two sites in Transjordan and one in Syria. Whereas seven sites, one from Syria and six from modern day Jordan, belong to the PPNB, and all of these have relatively well-published (or easily accessible) data (see the references in Figure 20). The earlier PPNA, would probably show a similar pattern if we had more reports and data to work with. In any case, further functional analysis of the material from those sites, applying use-wear and residue analysis, would illuminate the similarities and differences.

The differences in the PPNB assemblages for example, may reflect different resources being available or being exploited, different or new practises and preferences for how to process certain ressources, and personal and or intra-communal preferences and differences. Conversely, one could argue the changes in applied processing strategies and their diversity, more grinding and more diverse strategies seen in the Late Natufian compared to the Early Natufian, may be more a result of actions and adaptations happening during this period, rather than slightly skewed image from incomplete reports and data.
Here, however, we are concerned with the Shubayqa material and let us now turn to the functional analysis of these ground stone tools.

Thus we can conclude that based on the comparison discussed above that there appears to be no single clear pattern across Southwest Asia for the Late Natufian to PPNB time frame. A general trend is however, that there appears to be an increasing reliance on grinding, often reciprocally from the Epipalaeolithic and into the PPN, as also noted by both K. Wright, L. Dubreuil and others (Dubreuil 2004; Wright 1994; Pedersen 2021; Pedersen et al. 2016). However, PPNB sites like Shkarat Msaied, Wadi Jilat 7 and Beidha all diverge somewhat from this general trend (see Figure 20 and 21). There also appears to be quite a diversity in the strategies applied within each site, e.g. EPPNA - Shubayqa 6 and MPPNB - Beidha. Though this may be down to reporting or slight chronological variations, it may also reasonably be assumed to be caused by a combination of factors, e.g. local ecology, local traditions and practises, i.e. variable ways of processing things and/or differences in what materials are being processed.

It can therefore be argued that the changes we observe on GST, may either be a result of processing “new” plants and animals (other materials?) or processing them in new ways or more intensely or all of the above. At the Shubayqa sites, and in the Southern Levant more broadly, it does not seem to be the case that “new” resources are introduced. A diet of gazelle, wild sheep/goat, fowl, wild grasses and cereals, tubers and legumes, though in differing frequencies, appears to span the Epipalaeolithic to Neolithic transition (Arranz-Otaegui et al. 2016; Arranz-Otaegui et al. *submitted*; Yeomans et al. 2017; Yeomans 2018; Yeomans and Richter 2020).

The changes may rather be the result of new recipes and trends in preparing, cooking and eating foods. As noted below the contact material does change it would appear, but there is also considerable continuity and overlap, so at Shubayqa 1 and 6 at least, it is mainly a change to how materials are processed.

Furthermore, these changes are not necessarily fast. Changes we observe happen over a period that spans over 4000 years (*c.* 14,800 to 10,600 cal. BP). Over time, at Shubayqa, we do see grinding becoming more important, specific types of grinding appear and make way for others as new practises take over. However, most of the practises, most ways of using the body to change materials, coincide. Strategies and thus gestures and movements exist simultaneously, presumably supplementing each other in processing different things or the same things differently.

So changing foodways are not simply linear, moving from one form of processing, one set of gestures to the next. Rather it flows movements turning from pounding and grinding (CPR) to circular grinding (e.g. RGP) to reciprocal confined grinding (e.g. CRG) (see Figures 19 and 20 above). No one strategy fully replaces another, at least at the Shubayqa sites, and this seems to be the case with a lot of the other sites presented in the comparison (see Figure 19 and 20).

Changing resource exploitation - changing contact materials?

The Shubayqa use-wear analysis also suggests that no single resource replaces all the others. As noted by Dubreuil there was considerable variety in uses and contact materials throughout the Natufian (Dubreuil 2004, 2008; Dubreuil and Plisson 2010; Dubreuil and Grosman 2009; see also Wright 1994), something we can now also attest to at Natufian Shubayqa 1, in spite of a limited sample size (see Figure 17, 11 and 9 above). The same appears to be true for the EPPNA at Shubayqa 6, variety and diversity prevail but by the LPPNA cereal/seed use-wear

traces do begin to dominate. This is, however, from a limited sample of only CRG/ORG grinding tools.
Furthermore, again we should not assume or overstate the importance of cereals, not even by the Early Neolithic. Cereals would no doubt have been important, both in the Natufian and the Neolithic, but together with a wide range of other plants and animals. At the Shubayqa sites cereals played an overall moderate role it seems, although cereal processing appears to become more important by the Early Neolithic from EPPNA and into the LPPNA(-EPPNB) at Shubayqa 6. And by this phase we may be able to (tentatively) associate confined reciprocal grinding (the CRG strategy) with cereal processing. But, importantly this strategy is not only used in cereal/seed processing. A heavy or "exclusive" reliance on cereals is somewhat questionable. This applies to both the Natufian and the PPNA. Though this reliance has been repeatedly suggested elsewhere (e.g. (Dietrich and Haibt 2020; Dietrich et al. 2019; Eitam 2016; Hayden et al. 2016), we caution against overemphasising the role of cereals in diets.
Several other resources like tubers/USO's, oily seeds/legumes, meat and animal matter and mineral (pigment) traces are abundant in all the phases and also still appear frequently in the use-wear of the PPN tools from Shubayqa 6.
The use of tubers/USO's as food has often been overlooked, as focus has tended to be on the emergence cereal processing in Natufian and Early Neolithic (Arranz-Otaegui et al. 2016, 2018a, 2018b, *submitted*). However, as has been suggested by Hillman and Wollstonecroft (Wollstonecroft et al. 2008, 2011) is that these plant organs potentially were an important food source while also providing other material like reeds. The GST use-wear evidence presented here indicates that tuber (or soft plants) make up 15-20 % of the wear traces, from the Early Natufian, into the Late Natufian and EPPNA, suggesting that this was indeed an important resource.
The use-wear thus tentatively confirms that GST were used in processing these tubers, thus they were both pounded and ground, using the CPR and RGP strategies in the Early to Late Natufian and the CRG and CPR strategies in the EPPNA.

These preliminary use-wear results however, need to be corroborated by future residue analysis of microbotanical remains, which is on-going. With results from this residue analysis in hand we may further elucidate whether the attested contact materials and the uses we have suggested above are correct.
The results of residue analysis of plant microremains may tell a slightly different story. This is something that has been noted elsewhere. For example, from the Late Neolithic further north at the site Catal Höyük, a site assumed to rely on cereals, there is now evidence from botanical microremains that tubers also played a very significant role (Santiago-Marrero et al. 2021). This is also the case in Early Neolithic Europe where a similar study has shown a much wider range of plants being processed than expected (Hamon et al. 2021; see also Hayes et al. 2021 for similar observations from Early Holocene Australia).
This recent evidence is upsetting the simplistic linear view of increasing cereal processing (grinding) over time that was previously put forward for Southwest Asia. Though this is no doubt a real trend in SWA in the later Neolithic periods (e.g. (M. Portillo et al. 2013), and

possibly at some sites (e.g. (Dietrich et al. 2019) we should attempt not to simply project this backwards into the earlier periods.

We may suggest that, at Shubayqa 1 and 6 at least, this was a period of "playing" and "experimenting" with cereals, along with other important plants and animals, rather than relying on them, a prospect similar to the one recently suggested by Graeber and Wengrow (2021: 237-241). Diversity, both in strategies used and in food sources may have been an advantage, in not relying too much on one resource. An "exclusive" reliance on cereals for example may have led to the demise of the Central European Early Neolithic (see in (Graeber and Wengrow 2021). Comparatively, the use-wear from ground stone tools of Western European Early Neolithic also suggest a heavy reliance on cereals (e.g. Hamon 2008) however, also here recent studies have shown that the botanical microremains tell a much more complex story (see again Hamon et al. 2021).
In any case one should take the evidence for cereal processing and suggestions of its sudden arrival and dominance with a grain (of salt).

What our results also seem to suggest is that more resources were exploited in the Late Natufian and EPPNA, i.e. a greater variety of plant and animal matter, than in the Early Natufian and the LPPNA (see Figures 17 above), and possibly also that some resources were exploited more intensely, e.g. cereals, seeds/legumes. This intensification of exploitation may be mirrored by the faunal material from Shubayqa 6 (see Yeomans and Richter 2020). A general diversification and intensification of certain foodways perhaps related to population pressure, environmental factors and/or internal adaptations.
The results suggest that in the time spanning the Late Natufian to the EPPNA the exploitation of resources became more varied and diverse and so did the tools used in processing compared to the preceding Early Natufian and succeeding LPPNA. By the EPPNA though the processing strategies begin to become less diverse again, e.g. because more CRG processing took place (Pedersen 2021), but it still appears to be involved in processing a wide range of materials. The CRG, reliance in the PPN could be a result of more flour and porridge production, as suggested by (Dietrich et al. 2019; Dietrich and Haibt 2020) for PPNB site Göbekli Tepe. We have evidence at Shubayqa going all the way back to the Early Natufian of the production of bread/bread-like foods (Arranz-Otaegui et al. 2018a). However, such flour/porridge production need not to be reflective of entirely cereal-based foodways, tubers, other seeds and legumes etc. many other resources appear to be important still, and may also be ground into flour, meal, oil or porridge. As our previous research has shown, tuber flour also seems to have been a part of "bread" production (Arranz-Otaegui et al. 2018a; Arranz-Otaegui et al. *submitted*). So, again, though we may trace a beginning trend of increasing cereals, that by the LPPNA becomes more pronounced, further investigations of the Shubayqa 6 LPPNA tools are needed.

In any case, these foodways, including making flour and cooking "bread" (and presumably gruel/porridge etc.), already existed in the Natufian, and here again we see clear continuities. The knowledge of how to process and cook certain foods already existed, what changed was the material technology, the tools. This in part coincides, it would appear, by the PPNA with an increase in cereals/seeds as contact material on reciprocal grinding tools (see above). End-products produced in these later phases, Late Natufian, EPPNA and LPPNA likely (still) included bread-like foods made from cereal and composite flours. But, could also have included other composite products of cereals, meat, herbs, like soup/stew-like foods or *köfte*- or *pemmican*-like foods, along with herbs, leafs, legumes and tubers, roasted in fires or boiled in water.

Our results thus hint at complexity, variation and diversity in the changing foodways at Shubayqa, during the shift from the Early Natufian to the EPPNA and beyond. Diversity in both strategies and contact materials increased in the Late Natufian and continued (with a slight drop) into the EPPNA. There is also quite a bit of continuity.
The most continuity is seen in the Late Natufian at Shubayqa 1 and the transitional period Late Natufian/EPPNA at Shubayqa 6. This period features quite similar contact materials (see Figure 17 above), as deduced from use-wear, as well as a continuity in the use of floor spaces to install lower pouding/grinding tools, e.g. the querns, slabs and mortars seen in the floor of Structure 2 at Shubayqa 1 and Space 4 at Shubayqa 6. These floor features are absent in the Early Natufian for example. But there are also significant, if subtle, changes to tools and strategies between the Late Natufian and EPPNA. In this transition between the Late Natufian at Shubayqa 1 to the EPPNA at Shubayqa 6, we see a clear shift (a discontinuity) in strategies, from a mix of circular grinding (RGP-strategy) and open reciprocal grinding (ORG-strategy) to confined reciprocal grinding (CRG) respectively (see Figure 19 above). It may be that there is a "convergence" happening of two strategies from the Late Natufian, i.e. circular confined grinding (RGP-strategy) and open reciprocal grinding (ORG-strategy), into a "single" confined reciprocal grinding (CRG) strategy. We should note however, that these other strategies do not entirely disappear. But this does highlight a change of movements, bodies adapting gestures and consequently tool morphology, but with similar processed (contact) materials. It reflects the way bodily actions are expressed or "trapped" in the tools (see Pedersen *forthcoming* a, *forthcoming* b). This returns to our initial point, that ways of use, and changes to how the body is applied and labour is performed is just as important as the materials transformed (see Figure 22 below). Here is where we may (also) see changing foodways.

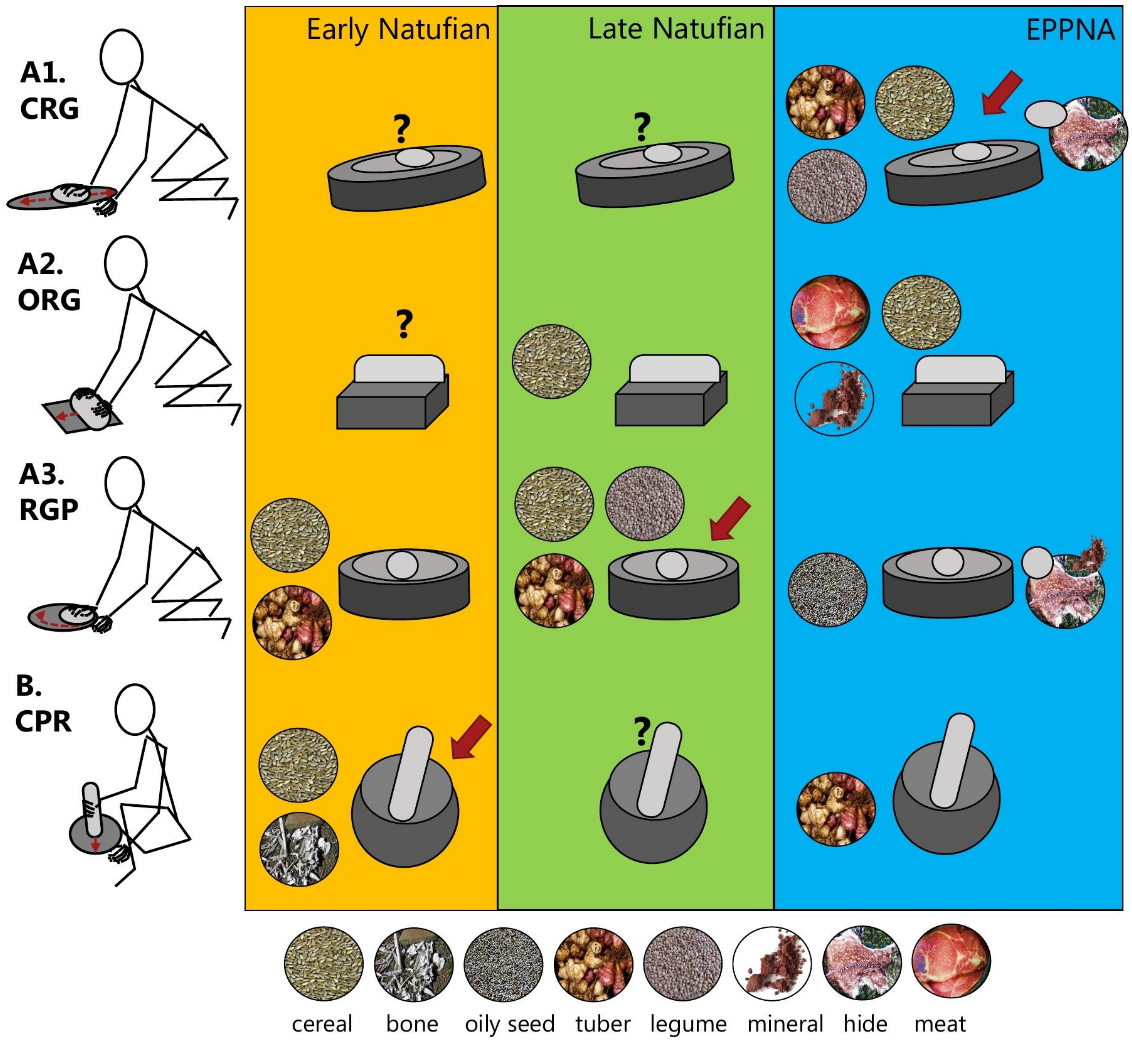

Figure 22: Illustration of the changing foodways of Shubayqa 1 and 6, based on the GST low-power use-wear. From the Early Natufian to the EPPNA. Including up to the three most commonly suggested contact material for each strategy in each phase. Question mark indicates no data or inconclusive data. Red arrow indicates the most common food processing strategy in each phase.

5. Some conclusions

These stone tools were used in specific forms of pre-consumption preparation of food. Ground stone tools are used to process foraged resources, turning larger animal and plant parts into smaller fragments and particles, more easily cooked, baked, consumed or stored. They allow new nutrients to be accessed, make food elements more palatable and easier to combine with others. They were (and are) a crucial part of foodways. However, other than their obvious ability to change material properties, e.g. crushing and grinding of plant and animal matter, what these exact activities were, i.e. the specific function and use of the food processing GST, are a difficult question to answer.

Our research allows us to posit a few suggestions of what contact materials were processed and how they were processed, by what gestures, as part of broad strategies of food

preparation. Part of labour processes, geared at processing acquired foodstuff securing sustenance for people inhabiting the Qa' Shubayqa 14,800-10,600 years ago.
Our work suggests that producing plant foods appears to be the main activity associated with these tools, both in the Early Natufian, Late Natufian, EPPNA and LPPNA.
Wild cereals/seeds were the plants most commonly processed, with tubers (or some sort of "soft plant") close behind, especially until the LPPNA, where cereals truly begin to dominate. Processing of these tubers (presumably *Bolboschoenus glaucus*, i.e. club-rush) in the Early and Late Natufian is achieved through pounding and rotary grinding (CPR and RGP strategies) and by the EPPNA, pounding and reciprocal grinding (CPR and CRG respectively) (see Figures 13, 17 and 18). Our experiments (see Arranz-Otaegui et al. *submitted*) also suggested that pounding and rotary grinding (CPR and RGP strategies) worked quite well to process tubers. Both as a means to "peel" roasted tubers (i.e. remove scales and rhizomes) through "light" grinding, as well as to pulverise tubers, turning them into flour. The use of tubers/USO's as food has often been overlook somewhat, as focus tends to be on the emergence, spread and proliferation of cereal processing in Natufian and PPN e.g. (Dietrich and Haibt 2020; Hayden et al. 2013; Liu et al. 2018; Terradas et al. 2013). However, what our own research and that of our colleagues has shown is that these plant underground organs were indeed an important resource (Arranz-Otaegui et al. 2018a, 2018b, *submitted*). The use-wear presented here serves to corroborate other evidence for the important role these plants played in the diet and daily life of Late Epipalaeolithic and Early Neolithic communities in the Levant.
Other plants, like seeds/pulses (possibly common poppy seeds) may also have been ground from the Late Natufian onwards using the same gestures and techniques (RGP and CRG) the use-wear analysis suggests (see Figure 17 and 11). This concurs with observations made Dubrueil about Late Natufian sites further west (Dubreuil 2004, Duberuil and Plissson 2010). Our observations from Shubayqa however, need to be confirmed through residue analysis of these tools surfaces to see what microremains were present, and to substantiate these use-wear results.[8]

We note that the proliferation of plant processing does not mean that the tools were only used for plants, all phases also suggest use on animal matter and minerals. In the Early Natufian, we see hints of bone and mineral pounding, by the EPPNA meat grinding as well as some animal by-product processing. This may have to do with processing ungulate carcasses (gazelle) as well as abundant avian fauna (Yeomans et al. 2017; Yeomans 2018; Yeomans and Richter 2020).
Diversity both in ways of processing and what is processed appear to be the order of things at Shubayqa 1 and 6. The changing foodways of Shuayqa during the Terminal Pleistocene and Early Holocene is as much a changing of the ways people processed materials, how they used their tools and bodies, as it was the materials, plants, animals and minerals themselves that changed. *Changing* what tools were involved in specific labour processes rather than the labour process itself. This is seen in the transition from the Late Natufian to EPPNA phases at

[8] The phytolith and starch samples that were taken from the tools before use-wear analysis are currently being analysed (by M. N. Ramsey) but were unfortunately not finished in time to be admitted into this paper. They will be included however, prior to official publication.

Shubayqa 1 and 6, that both feature a similar wide variety of materials (e.g. legumes, oily seeds, meat) and perhaps more intensive exploitation of already important resources (e.g. cereals, but also tubers). But while contact materials are similar, ways of use and tools change in this transitional period. We observe a shift from circular to reciprocal confined grinding (see also Pedersen 2021). The CRG processing strategy suddenly proliferates. Thus, we see bodies adapting and changing their movements, from circular to linear gestures, and the tools reflect this as the material expression of these changes.
Cereal processing does seem to become associated with reciprocal grinding, in particular the CRG-strategy, as seen during the EPPNA and into the LPPNA. This strategy is overall less diverse than the pounding and rotary grinding strategies (CPR and RGP respectively), while at the same time many show traces consistent with cereal processing. However, this strategy (CRG) still generally serves diverse functions, including being used (or re-used) in non-food activities such as hide/skin processing.
Finally, it is important for us to highlight the limitations to our study and our results.
The sample sizes are relatively small, especially the Early Natufian and LPNA, and these require further investigations. In addition use-wear interpretation are generally ambiguous (e.g. (Hamon and Plisson 2008; E. Hayes et al. 2017) and comparative data is sparse, relying heavily on a few studies (e.g. Dubreuil 2004; Dubreuil and Plisson 2010; Dietrich and Haibt 2020; Portillo et al. 2013) and in many areas additional analysis and work is needed.
This study however, provides an overview of the past changing foodways at Shubayqa basis for future analysis and comparison.

Our observations echo a quote from Marx: *"It is not the articles made, but how they are made, and by what instruments, that enables us to distinguish different economic epochs"* (Marx 1887: 128). Adapted for our results we may suggest that: *it is not only what is processed that is of importance to the changing foodways at the Qa Shubayqa sites, it is also how it is processed, using what gestures and tools*. How bodies operate tools changes in conjunction with the morphology of the tools, i.e. changes in processing strategies but this happens, to an extent at least, independently of the contact materials. This could mean that practises, techniques and technology, i.e. gestures, tools and ideas of how to process, are adapted to accommodate new recipes and/or new end-products and/or processing them more intensely and/or in ways that are then deemed more correct, appropriate or desirable. Likely, it could be a combination of all of these suggestions. Changing foodways are thus not just changing foods, but changing (labour) relationships to foods. This is the impression we are left with from the perspective of the Shubayqa ground stone tools.

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1. **Supplementary Table ST1**: Tools, tool subtypes *(italic),* and processing strategies (A1-A3. and B.) overview from Shubayqa 1 and 6. E.Nat. = Early Natufian at Shubayqa 1, L.Nat. = Late Natufian at Shuabyqa 1, L.Nat-EPPNA = Late Natufian to Early PPNA at Shubayqa 6, PPNA-EPPNB = Late PPNA to Early PPNB at Shubayqa 6.

Overview		**Upper tool** *type*			**Lower tool** *type*					
	A1. CRG	**Handstone** *ovate & rectilinear*			**Slab** *basin & trough*			**all**		
	Period	comp	frag	total	comp	frag	total	comp	frag	**total**
	E.Nat.	19	1	20	0	1	1	19	2	**21**
	L.Nat.	16	13	29	2	2	4	18	15	**33**
	L.Nat.-EPPNA	39	9	48	7	4	11	46	13	**59**
	LPPNA-EPPNB	10	1	11	0	2	2	10	3	**13**
Total		**84**	**24**	**108**	**9**	**9**	**18**	**93**	**33**	**126**
	A2. ORG	**Handstone** *loaf, loaf (tapered)*			**Slab** *block & saddle*			**all**		
	Period	comp	frag	total	comp	frag	total	comp	frag	**total**
	E.Nat.	6	55	61	5	2	7	11	57	**68**
	L.Nat.	13	191	204	3	7	10	16	198	**214**
	L.Nat.-EPPNA	0	11	11	2	7	9	2	18	**20**
	LPPNA-EPPNB	0	6	6	1	5	6	1	11	**12**
Total		**19**	**263**	**282**	**11**	**21**	**32**	**30**	**284**	**314**

	A3. RGP	**Handstone** *discoidal*			**Quern** *basin, block & boulder*			**all**		
	Period	comp	frag	total	comp	frag	total	comp	frag	**total**
	E.Nat.	2	1	3	3	3	6	5	4	**9**
	L.Nat.	12	9	21	8	14	22	20	23	**43**
	L.Nat.-EPPNA	7	3	10	4	3	7	11	6	**17**
	LPPNA-EPPNB	3	4	7	1	3	4	4	7	**11**
Total		**24**	**17**	**41**	**16**	**23**	**39**	**40**	**40**	**80**
	B. CPR	**Pestle** *all types*			**Mortar** *vessel, boulder and bowl*			**all**		
	Period	comp	frag	total	comp	frag	total	complete	frag	**total**
	E.Nat.	21	19	40	3	25	28	24	44	**68**
	L.Nat.	10	18	28	6	20	26	16	38	**54**
	L.Nat.-EPPNA	5	7	12	3	5	8	8	12	**20**
	LPPNA-EPPNB	3	7	10	3	4	7	6	11	**17**
Total		**39**	**51**	**90**	**15**	**54**	**69**	**54**	**105**	**159**
	All tools									**679**

2. **Supplementary table ST2. Experimental data on tuber processing.** Summary of low-power use-wear analysis of experimental tools overview table (pre-use see 4th column). Microscope used: GX Microscopes - GXMMZS0745

Activity (strategy)	**Grinding (RGP) GSX.5 & 6**	**Pounding (CPR) GSX.9 & 10**	**Grinding (ORG) GSX.7 & 8**	**Pecked surface before use (all)**
processed material	grain (2 h.) + roasted tubers (0,75 h)	dried and roasted tubers (0,65-0,83 h)	wet tubers (0,5)	N/A
(micro) topography	rounded	rounded	flat to rounded	uneven/ rugged
impaction pits	present	present	present	present
pit edges	rounded	rounded	rounded to rugged	rugged
orientation	concentric	concentric	longitudinal/ transverse	random
location	centre	centre	centre and proximal end (lower tool)	across
levelling	present	present (margins)	present	absent
groundmass/ phenocrysts	groundmass (at margins both)	both	groundmass (on distal and margins both)	absent
morphology/ texture	rounded/smooth	rounded/smooth (rounded/rough centre)	flat to rounded/ smooth (rounded/rough centre)	
distribution	covering	covering	covering	
location	across	margins	distal end and lateral margins	
phenocryst extraction	present	absent	absent	absent
phenocryst fractures	present	present	present	present
incidence	high and low (at	both	high	both

	margins only low)			
distribution	covering	covering	loose	covering (close)
location	across	centre	across	across
phenocryst rounding	present (only lower tool)	present	present	absent
incidence	low	high and low	high and low (HS only at margins low)	
location	across	margins (at centre some present in low)	across	
polish/sheen	present	absent	present	absent
relectivity	slight		slight	
distribution	loose		concentrated	
location	margins		distal ends	
Striations	none	none	none	none
tribological wear	centre = abrasive margins = tribochemical	centre = fatigue margins = abrasive	centre and lateral margins = abrasive distal end = tribochemical	fatigue

3. Supplementary table ST3. Tools subjected to residue sampling/use-wear

US# no.	Find Code	Raw material	Site code	Con-text	Phase	Basalt type	Tool type	Sub-type	Type of Area	Use-wear locations on tool	Ground stone residue sample (GSS#)
1	SHUB06-2016-1100	Olivine-plagioclase basalt	SHUB06	163	LNAT/EPPNA	III	HS	Ovate	UF	1 of 2	none
2	SHUB06-2016-1100	Olivine-plagioclase basalt	SHUB06	163	LNAT/EPPNA	III	HS	Ovate	UF	2 of 2	none
3	6,33	Olivine-pyroxene basalt	SHUB06	163	LNAT/EPPNA	IV	HS	Ovate	UF	1 of 1	GSS- 19 (WB) UF
4	SHUB06-2016-1097	Olivine-plagioclase basalt	SHUB06	163	LNAT/EPPNA	I	HS	Sub-circular	UF	1 of 2	GSS- 31 (PSP) UF
5	SHUB06-2016-1097	Olivine-plagioclase basalt	SHUB06	163	LNAT/EPPNA	I	HS	Sub-circular	WF	2 of 2	GSS- 32 (PSP) WF
6	SHUB06-2016-1087	Olivine-plagioclase -clinopyroxene basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-39 (PSP) UF1
7	SHUB06-2016-1087	Olivine-plagioclase -clinopyroxene basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	2 of 2	GSS-40 (PSP) UF2
8	SHUB06-2016-1089	Olivine-plagioclase basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-27 (PSP) UF1
9	SHUB06-2016-1089	Olivine-plagioclase basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	2 of 2	GSS-28 (PSP) UF1
10	SHUB06-2016-1094	Olivine basalt	SHUB06	163	LNAT/EPPNA	I	HS	Irregular	UF	1 of 1	GSS-36 (PSP) UF1

11	SHUB06-2016-1095	Olivine-pyroxene basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-37 (PSP) UF
12	SHUB06-2016-1095	Olivine-pyroxene basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	BR	2 of 2	GSS-38 (PSP) BR
13	SHUB06-2016-1093	Olivine-plagioclase -clinopyroxene basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	1 of 1	GSS-41 (PSP) UF1
14	SHUB06-2016-1109	Olivine-pyroxene basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	1 of 1	GSS-33 (PSP) UF1
15	SHUB06-2016-1088	Olivine-plagioclase -clinopyroxene basalt	SHUB06	163	LNAT/EPPNA	Un.	Ha	Rectangular	UF	1 of 2	GSS-35 (PSP) UF
16	SHUB06-2016-1088	Olivine-plagioclase -clinopyroxene basalt	SHUB06	163	LNAT/EPPNA	Un.	Ha	Rectangular	WF	2 of 2	none
17	SHUB06-2017-1863	Olivine-plagioclase -clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	HS	Ovate	UF	1 of 1	GSS-61 (PSP) UF1
18	SHUB06-2017-1508	Olivine-plagioclase basalt	SHUB06	256	LNAT/EPPNA	I	HS	Ovate	UF	1 of 1	GSS-30 (PSP) UF1
19	SHUB06-2017-1852	Olivine-plagioclase -clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	HS	Ovate	UF	1 of 1	GSS-58 (DB) UF1 + GSS-59 (PSP) UF1
20	SHUB06-2017-1167	Olivine-plagioclase -clinopyroxene basalt	SHUB06	220	LNAT/EPPNA	I	HS	Irregular	UF	1 of 1	GSS-60 (PSP) UF1
21	SHUB06-2017-1280	Olivine-plagioclase	SHUB06	245	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-45 (PSP) UF1

		basalt									
22	SHUB06-2017-1280	Olivine-plagioclase basalt	SHUB06	245	LNAT/EPPNA	I	HS	Ovate	UF	2 of 2	none
23	SHUB06-2017-1509	Olivine-plagioclase -clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-47 (PSP) UF1
24	SHUB06-2017-1509	Olivine-plagioclase -clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	HS	Ovate	BR	2 of 2	GSS-48 (PSP) BR
25	SHUB06-2017-1273	Olivine-plagioclase -clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-50 (DB) UF1
26	SHUB06-2017-1273	Olivine-plagioclase -clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	I	HS	Ovate	UF	2 of 2	GSS-51 (PSP) UF2
27	SHUB06-2018-492	Olivine basalt	SHUB06	276	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-52 (PSP) UF1
28	SHUB06-2018-492	Olivine basalt	SHUB06	276	LNAT/EPPNA	I	HS	Ovate	UF	2 of 2	GSS-53 (PSP) UF2
29	SHUB06-2017-1284	Olivine-plagioclase basalt	SHUB06	245	LNAT/EPPNA	III	HS	Rectangular	UF	1 of 1	GSS-46 (PSP) UF
30	SHUB06-2017-1855	Olivine-clinopyroxene basalt	SHUB06	256	LNAT/EPPNA	I	HS	Discoidal	UF	1 of 1	GSS-49 (PSP) UF
31	SHUB06-2017-1511	Olivine-plagioclase -clinopyroxene basalt	SHUB06	256	LNAT/EPPNA	II	HS	Ovate	UF	1 of 1	GSS-34 (PSP) UF1
32	SHUB06-2016-1092	Olivine-plagioclase -clinopyroxene	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-42 (PSP) UF

		basalt									
33	SHUB06-2016-1092	Olivine-plagioclase-clinopyroxene basalt	SHUB06	163	LNAT/EPPNA	I	HS	Ovate	WF	2 of 2	GSS-43 (DB) WF
34	SHUB06-2017-1520	Olivine-plagioclase-clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	III	P	Conical	WF	1 of 3	GSS-55 (PSP) WF
35	SHUB06-2017-1520	Olivine-plagioclase-clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	III	P	Conical	UF	2 of 3	GSS-56 (PSP) UF
35a	SHUB06-2017-1520	Olivine-plagioclase-clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	III	P	Conical	WF	3 of 3	GSS-54 (PSP) UF
36	SHUB06-2017-1001	Olivine basalt	SHUB06	220	LNAT/EPPNA	III	P	Conical	UF	1 of 1	GSS-64 (PSP) UF
37	SHUB06-2018-508	Olivine basalt	SHUB06	276	LNAT/EPPNA	IV	LGI	Basin slab	UF	1 of 1	GSS-66 (PSP) UF
38	SHUB06-2017-1525	Olivine-clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	M	Bowl	UF	1 of 1	GSS-71 (DB) UF, GSS-74 (PSP) UF
39	SHUB06-2017-1291	Olivine basalt	SHUB06	245	LNAT/EPPNA	IV	LGI	Basin slab	UF	1 of 2	GSS-72 (DB) BR
40	SHUB06-2017-1291	Olivine basalt	SHUB06	245	LNAT/EPPNA	IV	LGI	Basin slab	BR	2 of 2	GSS-68 (DB) WF
41	SHUB06-2017-1287	Olivine-clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	I	M	Boulder	WF	1 of 2	GSS-69 (DB) UF, GSS-70 (PSP) UF
42	SHUB06-2017-1287	Olivine-clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	I	M	Boulder	UF	2 of 2	GSS-82 (PSP) UF1
43	SHUB06-2017-1651	Olivine-clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	LGI	Basin slab	UF	1 of 4	GSS-83 (PSP) UF1

44	SHUB06-2017-1651	Olivine-clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	LGI	Basin slab	UF	2 of 4	GSS-81 (PSP) NA
44a	SHUB06-2017-1651	Olivine-clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	LGI	Basin slab	UF	3 of 4	GSS-89 (PSP) UF
45	SHUB06-2017-1651	Olivine-clinopyroxene basalt	SHUB06	258	LNAT/EPPNA	I	LGI	Basin slab	NA	4 of 4	GSS-89 (PSP) UF
46	SHUB06-2017-1650	Olivine basalt	SHUB06	258	LNAT/EPPNA	IV	LGI	Basin quern	UF	1 of 2	GSS-75 (DB) UF1, GSS-78 (PSP) UF1
47	SHUB06-2017-1650	Olivine basalt	SHUB06	258	LNAT/EPPNA	IV	LGI	Basin quern	UF	2 of 2	GSS-136 (PSP) UF1
48	SHUB06-2017-1286	Olivine-clinopyroxene basalt	SHUB06	245	LNAT/EPPNA	I	M	Boulder	UF	1	GSS-146 (PSP) UF1
49	SHUB01-2015-283	Olivine-plagioclase-clinopyroxene basalt	SHUB01	132	Early Natufian	I	HS	Ovate	UF	1 of 1	GSS-147 (PSP) UF2
50	SHUB01-2015-458	Olivine basalt	SHUB01	157	Early Natufian	I	Pou	Sub-sphere	UF	1 of 2	GSS-144 (PSP) UF1
51	SHUB01-2015-458	Olivine basalt	SHUB01	157	Early Natufian	I	Pou	Sub-sphere	UF	2 of 2	GSS-143 (PSP) UF
52	SHUB01-2015-462	Olivine-plagioclase basalt	SHUB01	157	Early Natufian	IV	P	Conical	UF	1 of 1	GSS-130 (PSP) UF
53	SHUB01-2015-490	Olivine-clinopyroxene basalt	SHUB01	157	Early Natufian	II	P	Conical	UF	1 of 1	GSS-128 (PSP) WF
54	SHUB01-2015-489	Olivine-plagioclase-clinopyroxene basalt	SHUB01	157	Early Natufian	I	M	Globular	UF	1 of 2	GSS-141 (PSP) UF
55	SHUB01-2015-489	Olivine-plagioclase-clinopyroxene	SHUB01	157	Early Natufian	I	M	Globular	WF	2 of 2	GSS-138 (PSP) UF1

		basalt									
56	SHUB01-2015-310	Olivine-clinopyroxene basalt	SHUB01	132	Early Natufian	IV	M	Bowl	UF	1 of 1	GSS-139 (PSP) UF2
57	SHUB01-2015-500	Olivine-clinopyroxene basalt	SHUB01	157	Early Natufian	III	LGI	Block quern	UF	1 of 2	GSS-133 (PSP) UF
58	SHUB01-2015-500	Olivine-clinopyroxene basalt	SHUB01	157	Early Natufian	III	M	Boulder	UF	2 of 2	GSS-127 (PSP) UF
59	SHUB01-2015-457	Olivine-clinopyroxene basalt	SHUB01	157	Early Natufian	III	M	Globular	UF	1 of 1	GSS-125 (PSP) WF
60	SHUB01-2015-494	Olivine-clinopyroxene basalt	SHUB01	157	Early Natufian	I	M	Goblet	UF	1 of 2	GSS-5 (WB)
61	SHUB01-2015-494	Olivine-clinopyroxene basalt	SHUB01	157	Early Natufian	I	M	Goblet	WF	2 of 2	GSS-112 (PSP) UF
62	SHUB01-12-312	Olivine-plagioclase basalt	SHUB01	20	Late Natufian	I	HS	Ovate	UF	1 of 1	GSS-108 (PSP) UF1
63	SHUB01-12-364	Olivine basalt	SHUB01	20	Late Natufian	Un.	HS	Discoidal	UF	1 of 1	GSS-6 (PSP) UF1
64	SHUB01-2013-262	Olivine-plagioclase-clinopyroxene basalt	SHUB01	70	Late Natufian	I	HS	Discoidal	UF	1 of 1	GSS-107 (PSP) UF2
65	SHUB01-12-382	Olivine basalt	SHUB01	20	Late Natufian	III	HS	Ovate	UF	1 of 2	GSS-7 (WB) NA?
66	SHUB01-12-382	Olivine basalt	SHUB01	20	Late Natufian	III	HS	Ovate	UF	2 of 2	GSS-119 (WB) UF1
67	SHUB01-12-311	Olivine-plagioclase-clinopyroxene basalt	SHUB01	20	Late Natufian	I			NA	1 of 1	GSS-4 (WB) UF1

68	SHUB01-12-307	Olivine-plagioclase -clinopyroxene basalt	SHUB01	20	Late Natufian	I	P	Cylindrical	UF	1 of 1	GSS-117 (PSP) UF
69	SHUB01-12-350	Olivine-plagioclase -clinopyroxene basalt	SHUB01	20	Late Natufian	III	P	Conical	UF	1 of 1	GSS-111 (PSP) UF
70	SHUB01-2013-293	Olivine basalt	SHUB01	70	Late Natufian	I	LGI	Block slab	UF	1 of 1	GSS-111 (PSP) UF
71	SHUB01-12-406	Olivine basalt	SHUB01	20	Late Natufian	I	LGI	Basin quern	UF	1 of 2	GSS-113 (PSP) UF
72	SHUB01-12-406	Olivine basalt	SHUB01	20	Late Natufian	I	LGI	Basin quern	UF	2 of 2	GSS-113 (PSP) UF
73	SHUB01-12-314	Olivine basalt	SHUB01	20	Late Natufian	III	LGI	Block quern	UF	1 of 2	GSS-114 (PSP) UF1
74	SHUB01-12-314	Olivine basalt	SHUB01	20	Late Natufian	III	LGI	Block quern	UF	2 of 2	GSS-115 (PSP) UF2
75	SHUB01-12-258	Olivine-plagioclase -clinopyroxene basalt	SHUB01	20	Late Natufian	I	Mu	Pestle-handstone	UF	1 of 2	GSS-122 (PSP) UF1
76	SHUB01-12-258	Olivine-plagioclase -clinopyroxene basalt	SHUB01	20	Late Natufian	I	Mu	Pestle-handstone	UF	2 of 2	GSS-123 (WB) UF2
77	SHUB01-2013-422	Olivine-clinopyroxene basalt	SHUB01	70	Late Natufian	I	Mu	Pestle-handstone	UF	1 of 2	GSS-3 (WB) UF1
78	SHUB01-2013-422	Olivine-clinopyroxene basalt	SHUB01	70	Late Natufian	I	Mu	Pestle-handstone	UF	2 of 2	none
79	SHUB1-2013-085	Olivine-plagioclase -clinopyroxene basalt	SHUB01	20	Late Natufian	I	LGI	Basin quern	UF	1 of 3	none

80	SHUB1-2013-085	Olivine-plagioclase -clinopyroxene basalt	SHUB01	20	Late Natufian	I	LGI	Basin quern	UF	2 of 3	GSS-90 (PSP) UF
81	SHUB1-2013-085	Olivine-plagioclase -clinopyroxene basalt	SHUB01	20	Late Natufian	I	LGI	Basin quern	WF	3 of 3	GSS-94 (PSP) UF1
82	SHUB06-2016-296	Olivine-clinopyroxene basalt	SHUB06	121	LPPNA-EPPNB	III	LGI	Trough slab	UF	1	GSS-97 (PSP) UF
83	SHUB06-2016-643	Olivine-plagioclase basalt	SHUB06	146	LPPNA-EPPNB	I	HS	Ovate	UF	1	GSS-106 (PSP) UF1
84	SHUB06-2016-297	Olivine-clinopyroxene basalt	SHUB06	121	LPPNA-EPPNB	I	HS	Discoidal	UF	1	GSS-105 (PSP) UF1
85	SHUB06-2016-299	Olivine-clinopyroxene basalt	SHUB06	114	LPPNA-EPPNB	I	HS	Ovate	UF	1	GSS- 102 (PSP) UF1, GSS-101 (PSP) UF1x
86	SHUB06-2017-774	Olivine basalt	SHUB06	228	LNAT/EPPNA	II	Ha	Discoidal	UF	1 of 1	GSS-98 (PSP) UF1
87	SHUB06-2016-646	Olivine-clinopyroxene basalt	SHUB06	146	LPPNA-EPPNB	I	HS	Discoidal	UF	1	GSS-99 (PSP) UF2
88	SHUB06-2017-1172	Olivine-plagioclase -clinopyroxene basalt	SHUB06	240	LPPNA-EPPNB	I	HS	Ovate	UF	1 of 2	GSS-100 (PSP) UF1
89	SHUB06-2017-1172	Olivine-plagioclase -clinopyroxene basalt	SHUB06	240	LPPNA-EPPNB	I	HS	Ovate	UF	2 of 2	GSS-92 (PSP) UF1
90	SHUB06-2016-642	Olivine-plagioclase -clinopyroxene basalt	SHUB06	146	LPPNA-EPPNB	I	HS	Ovate	UF	1	GSS-93 (PSP) UF2

91	SHUB06-2016-639	Olivine basalt	SHUB06	146	LPPNA-EPPNB	I	HS	Ovate	UF	1 of 2	GSS-91 (PSP) UF1
92	SHUB06-2016-639	Olivine basalt	SHUB06	146	LPPNA-EPPNB	I	HS	Ovate	UF	2 of 2	none
93	SHUB06-2017-998	Olivine-clinopyroxene basalt	SHUB06	204	LNAT/EPPNA	I	HS	Ovate	UF	1 of 2	GSS-85 (PSP) UF
94	SHUB06-2017-998	Olivine-clinopyroxene basalt	SHUB06	204	LNAT/EPPNA	I	HS	Ovate	UF	2 of 2	none
95	SHUB06-2017-283	Olivine-clinopyroxene basalt	SHUB06	224	LPPNA-EPPNB	III	LGI	Basin slab	UF	1 of 1	GSS-83 (PSP) UF1

4. Supplementary table ST4. Characteristic wear summary, used for interpretation

	Material																					
Gestures	Plant matter	topography	micro top.	pits	pit edges	levelling	groundmss/phenocryts?	lev. morph	lev. textu	grainextraction	extrac. inci	grainfractures	frac. inci	grainrounding	round inc.	sheen	sheen. inci.	reflect	striae	striae inci.	Raw. mat.	References
Grinding	USO’s																					

	Tuber	rounded	regular	present	rounded	present	groundmass (at margins both)	rounded	smooth	absent		present	high	present	low or both	present	high	slight	absent		basalt	P.N.Pedersen; Fullagar et al. 2016; Hayes et al. 2021; Liu et al. 2014; in line with "softer" materials in Delgado-Raack and Risch 2009, 2016
	Cereals																					
	Cereal	flat	regular	?		present	?	flat	smooth	present	high	present									basalt	Santiago-Marrero et al. 2021
	Cereals	flat	regular	present		present	groundmass? (at margins both)	flat	smooth	?		?		?		present	high	moderate	present	high	basalt	Dietrich and Haibt 2020
	Cereals	flat	regular	presen		presen	groundmass? (at margins both)	flat	smooth	?		?		?		presen	high	moderate	presen	high	basalt	Dietricht et al. 2019

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	Wheat (domestic)	flat	regular	present		present	groundmass	flat	smooth	?		present	high	present	high	present	high	slight	present	high	basalt	Dubreuil 2004
	Barley (wild)	flat	regular	present		present	groundmass	flat	smooth	?		present	high	present	high	present	high	highly	present	high	basalt	Dubreuil 2004
	Cereal	flat	regular	?		present	?	flat	smooth	?		?				present			present		basalt + limestone	Martinez et al. 2013
	Wheat/barley	flat	regular	present		present	both	flat	medium	?		?		?					present	high	basalt + limestone	Portillo et al. 2013

	Wheat	flat	regular	?		present	both	flat	smooth	present	high	present	high	absent		?			present	high	conglomerate + garnet bearing mica-schist	Delgado-Raack and Risch 2016
	Wheat (grilled)	flat	regular	absent		present	both	flat	smooth	?		present		absent		present	high	moderate	?		granite	Robitaille 2016
	Barley (wild)	flat	regular	?		present	both	flat	smooth	present	high	present	high	absent		?			present	high	sandstone	Delgado-Raack and Risch 2009
	Cereals	?	?	?	?	?	?	?	?	?	?	present	?	?	?	present	high	moderate	present		sandstone	van Gijn & Annemieke Verbaas 2007

	Wheat	flat	regular	?		present	both	flat	smooth	?		?		present	high	?			present	high	sandstone	Hayes et al. 2018
	Cereals	flat	regular	?		present	both	flat	rough	present	high	present	high	absent		?			present	high	sandstone	Zurro et al. 2005
	Cereals	flat	regular	?		present	both	flat	smooth	?				absent		present	high	moderate	?		sandstone	Hamon 2008
	Oat	flat	regular	?		present	both	flat	rounded	absent		?		present	high	?			absent		sandstone	Cristiani and Zupancich 2021; Zupancich and Cristiani 2020
	Cereals	flat	regular	prese		prese	both	flat	smooth	prese	high	?		prese	high	prese	high	slight to moderate	prese	high	schist, sandstone,	Chondrou et al. 2021

				nt		nt				nt				nt		nt			nt		gneiss, basalt	
	Other																					
	Wild grass	flat	regular	absent		present	both	flat	smooth	present	high	present	high	present	high	?			present	high	sandstone	Cristiani and Zupancich 2021; Zupancich and Cristiani 2020
	Wild grass	flat	regular	?		present	both	?		present	both	present	both	?		present	high	?	?		sandstone	Lucarini and Radini 2019
	Seeds	flat	regular	?		present	both	flat	smooth	?				?		present	high	highly	present	high	sandstone	Fullagar and Field 1997
	Oily seeds (e.g. mustard seeds)	flat	regular	?		prese	groundmass	flat	smooth	?		absen		prese	both	prese	high	slight	absen		basalt	Dubreuil 2004

						nt						t		nt		nt			t			
	Nuts																					
	Almond	rounded	?			present	groundmass	rounded	smooth			?		present	?				?		basalt	Martinez et al. 2013
	Acorn (fresh)	rounded	irregular	?		present	groundmass	rounded	?	?		?		present	both	present	both	highly	absent		basalt	Dubreuil 2004
	Acorn (dry)	rounded	irregular	?		present	groundmass	rounded	?	?		present	high	present	both	present	both	slight	absent		basalt	Dubreuil 2004
	Nut	rounded	irregular	?		present	groundmass	rounded	?	?		?		present	both	present	both	highly	absent		basalt	Dubreuil 2004

	Acorn	rounded	irregular	absent		?				absent		present	high	present	?	?			absent		sandstone	Cristiani and Zupancich 2021; Zupancich and Cristiani 2020
	Acorn	rounded	?	?						?		?		present	both	?			?		schist, sandstone, gneiss, basalt	Chondrou et al. 2021
	Legumes																					
	Legume (?)	flat	irregular	?		present	groundmass	flat	rough	?		present	?	absent		present	?	slight	absent		schist, sandstone, gneiss, basalt	Chondrou et al. 2021
	Fenugreek	flat	irregular	presen	sharp	presen	groundmass	flat	rough	?		presen	high	absent		presen	low	slight - dark metallic colour	absent		basalt	Dubreuil 2004

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	Fava	flat	?	present	sharp	present	groundmass	flat	rough	?		present	high	absent		present	both	slight-dark metallic colour	absent		basalt	Dubreuil 2004
	Animal matter																					
	Fish (dried)	flat	regular	present	sharp	present	both	flat	smooth	?		absent		present	low	present	high	moderate	present	high	basalt	Dubreuil 2004
	Meat (dried)	flat	regular	present	sharp	present	both	flat	smooth	present	high	absent		present	low	present	high	moderate	present	high	basalt	Dubreuil 2004
Abrading (one tool)	Hide (softening)	rounded	?	?		present	?	rounded	?	present	?	absent		present	?	?			absent		sandstone	Cristiani and Zupancich 2021

	Hide (softening)	rounded	regular	?		present	?	rounded	smooth	?		?		?		present	low	moderate	absent /present with ash/ochre		basalt + limestone	Martinez et al. 2013
	Hide (softening)	rounded	?	?		present	?	rounded	smooth	?		?		present	?	present	both	highly	absent /present with ochre-		sandstone	Hamon 2008
	Hide (softening)	rounded	regular	?		present	both	rounded	smooth	present	?	absent		present	both	present	both	highly	absent		sandstone + quartzitic sandstone	Adams 1988, 1989
	Hide processing	rounded	regular	?		?				?		?		present	both	present	both	highly	absent		basalt	Dubreuil and Grosman 2009
	Skin (dry)	rounded	regular	?		pres	both	rounded	smooth	pres	high	abse		?		pres	?	highly	some		basalt	Dubreuil 2004

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	Hide (defleshing)	rounded	regular	?		present	both	rounded	smooth	?		?		present	high	present	?	?	?		basalt	Bofill and Taha 2013
	Bone	rounded	irregular	?		present	grains	rounded	rough	absent		absent		present	?	?			absent		sandstone	Cristiani and Zupancich 2021
	Bone	rounded	?	?		absent				present	high	?		present	high	present	high	moderate	present		basalt	Dubreuil 2004
	Mineral																					
	Stone	flat	irregular	absent		present	both	flat	smooth	present	high	present	high	present	high	present	high	slight	present	high	basalt	Dubreuil 2004

	Ochre	flat	irregular	absent		present	both	flat	rough	present	both	present	both	absent		absent			present	both	basalt	Dubreuil 2004
	Plant matter																					
Pounding	USO																					
	USO (Tuber Cyperacae)	rounded	regular	present	rounded	present	groundmass (at margins both)	rounded	smooth	absent		present	both	present	low	absent			absent		basalt	P.N.Pedersen
	Nuts																					
	Acorn	rounded	regular	present	rounded		?			?		absent		present	both	absent			absent		sandstone	Buonasera 2013
	Hazel	rounded	irregular	pre	rugged	abs				pre	high	pre	high	pre	low	abs			abs		sandstone	Cristiani and Zupancich 2021

				sent		ent				sent		sent		sent		ent			ent			
	Nut (cracking)	rounded	irregular	present	rugged	absent				present	high	present	high	present	low	absent			absent		basalt, sandstone, quartzite	Kononenko et al. 2021
	Seeds																					
	Seeds	rounded	regular	present	rounded	present	?	rounded	smooth	?		?				absent			absent		sandstone	Hayes et al. 2018
	Animal matter																					
	Meat	rounded	regular	present	rugged	absent				present	both	present	high	absent		absent			absent		quartzite	de la Torre et al. 2013
	Bone	rounded	regular	abs		abs				abs		pre	high	pre	high	abs			abs		sandstone	Zupancich and Cristiani 2020

				ent		ent				ent		sent		sent		ent			ent			
	Tendon	rugged	irregular	absent		absent				present	both	present	both	absent		absent			absent		sandstone	Cristiani and Zupancich 2021
	Mineral																					
	Stone	rugged	irregular	present	rugged	present	both	rugged	rough	present	both	present	both	absent		absent			absent		sandstone, limestone, granite, basalt	Buonasera 2013; Hamon 2008; P.N.Pedersen; Roda Gilabert et al. 2016

5. Supplementary table ST5. Interpretation: Summary of wear traces and suggested uses from low-power use-wear analysis of the Shubayqa tools. Sorted by phase.

US#	phase	tool type	tool-code	location	Gestur	topography	microtop.	pits	pit edges	level	groundmass/phenocrysts?	lev. morph	lev. texture	extrac	extract. depth	fractu	Fract. incidence	grainr	rounding incidence	sheen	sheen incidence	reflectivity	striae	striae incidence	pigmen	suggested use	Wears

					e/Strat					ing				tion		res		ounding							t-y/n		tage
49	E .Nat	HS (ovate)	SHUB01-2015-283	UF1 - hs face	RGP	flat (levelled high top.)	regular	absent		present	both	flat	smooth	absent		absent		present	low	present	high	slight	absent			possibly cereal/grasses or legumes, but unclear	4
50	E .Nat	Pounder	SHUB01-2015-458	UF1 - pounding face	Pounding	uneven/rugged	regular	present	rounded	absent				absent		present	high	present	both	absent			absent		y	mineral (pigment) or bone (with stone anvil)	0
51	E. Nat	Pounder	SHUB01-2015-458	UF2 - handstone face/grinding face, black dot	abrading	sinuous/rounded	regular	present	rounded	present	both	rounded	rough	absent		absent		present	both	absent			absent			tuber	0

52	E. Nat	P (conical)	SHUB01-2015-462	UF1	CPR	sinuous/rounded	irregular	present	rounded	absent				absent		present	both	present	low	absent			absent			nuts or tuber (soft plant material)	0
53	E. Nat	P (conical)	SHUB01-2015-490	UF1	CPR	uneven/rugged	irregular	present	rugged	absent				absent		present	high	present	both	absent			absent			bone or stone	0
54	E. Nat	M (globular)	SHUB01-2015-489	UF	CPR	sinuous/rounded	irregular	present	rounded	present	groundmass	rounded	rough	absent		present	both	absent		absent			absent			seeds (harder material)	0
55	E. Nat	M (globular)	SHUB01-2015-489	WF	FNU	sinuous/rounded	irregular	present	rounded	present	both	rounded	smooth	absent		present	both	absent		absent			absent			stone	0
56	E. Nat	M (bowl)	SHUB01-2015-310	UF	CPR	sinuous/rounded	irregular	prese	rounded	absen				absen		prese	?	prese	both	absen			absen			Bone or unclear	0

								nt		t				t		nt		nt		t			t				
57	E. Nat	Block quern/mortar (multiple tool opposed faces)	SHUB01-2015-500	UF1-quern face	RGP	sinuous/rounded	regular	present	rounded	present	both	rounded	rough	absent		present	low	present	low	absent			absent			tuber	2
58	E. Nat	Block mortar/quern (multiple tool opposed faces)	SHUB01-2015-500	UF2-mortar face	CPR	uneven/rugged	irregular	present	rounded	absent				absent		present	both	absent		absent			absent			mineral or tendon (poss. with stone anvil)	2
59	E. Nat	M (globular)	SHUB01-2015-457	UF	CPR	sinuous/rounded	irregular	present	rounded	absent				absent		present	high	absent		absent			absent		y	nuts (or soft plant material)	3
60	E. Nat	M (goblet)	SHUB01-2015-494	UF	CPR	sinuous/rounded	irregular	present	rounded	present	both	rounded	smooth	absent		present	high	absent		absent			absent			seeds (harder plant material)	3
61	E. Nat	M (goblet)	SHUB01-	WF	FN	sinuous/ro	regular	pr	rounde	pr	groundmass	rounde	smooth	ab		pr	both	ab		ab			ab			stone/unclear	0

			2015-494		U	unded		esent	d	esent		d		sent		esent		sent		sent			sent				
62	L. Nat	HS (Oval)	SHUB01-12-312	UF	RGP	sinuous/rounded	regular	present	rounded	present	both	rounded	smooth	absent		absent		present	low	absent			absent			soft plant? (possibly tuber)	2
63	L. Nat	HS (Disc)	SHUB01-12-364	UF	RGP	flat	irregular	absent		present	both	flat	smooth	present	both/deep	present	high	absent		present	both	slight	absent			legumes?	2
64	L. Nat	HS (Disc)	SHUB01-2013-262	UF	Polisher	flat	irregular	absent		present	both	rounded	smooth	present	both/deep	present	low	absent		absent			absent			mineral	

65	L. Nat	HS (Oval)	SHUB01-12-382	UF1	RGP	flat	irregular	present	sharp	present	groundmass	flat	smooth	absent		present	both	present	both	absent			absent		y	seeds/cereal along with pigment (count as both), (or maybe legumes -possibly, somewhat unclear)	3
66	L. Nat	HS (Oval)	SHUB01-12-382	UF2	RGP	flat	regular	absent		present	both	flat	smooth	absent		present	low	absent		present	high	slight	absent			seeds/cereal	3
67	L. Nat	NA(tural)	SHUB01-12-311	NA	NA	sinuous/rounded	irregular	absent		present	both	rounded	rough			absent		absent		absent			absent			not used	0
68	L. Nat	P (cylindrical)	SHUB01-12-307	UF1	CPR	uneven/rugged	regular	present	rounded	absent				absent		present	both	absent		absent			absent			unclear (perhaps animal - meat)	2

69	L. Nat	P (conical)	SHU B01-12-350	UF	CPR	uneven/rugged	regular	present	rugged	present	groundmass	rounded	rough	absent		present	both	present	both	absent			absent			nuts	3
70	L. Nat	LGI (block slab)	SHU B01-2013-293	UF	ORG	flat	regular	absent		present	both	flat	smooth	absent		absent		present	low	present	high	slight	absent			seeds/cereal	2
71	L. Nat	LGI (basin quern)	SHU B01-12-406	UF1	RGP	flat	irregular	present	sharp	present	groundmass	flat	smooth	present	fine/shallow	present	high	absent		absent			absent		y	legumes?	0
72	L. Nat	LGI (basin quern)	SHU B01-12-406	UF2 - anvil	anvil	sinuous/rounded	irregular	present	rounded	absent				absent		present	both	absent		absent			absent			tendon or animal matter	0
73	L. Nat	LGI (block quern)	SHU B01-12-314	UF	RGP	rugged (Ce) to round	regular	prese	rounded	prese	Both (Ma), groundmass (Ce)	rounded	smooth (Ma), Rough	absen		prese	both	prese	low	absen			absen			tuber (or soft plant)	2

						ed (Ma)		nt		nt			(Ce)	t		nt		nt		t			t				
74	see above																										0
75	L. Nat	Mu(pestle-handstone)	SHUB01-12-258	UF1 - pestle face	CPR	sinuous/rounded	regular	present	rounded	present	both	rounded	rough	absent		absent		absent		absent			absent			unclear (perhaps animal matter - meat)	0
76	L. Nat	Mu(pestle-handstone)	SHUB01-12-258	UF2 - handstone face	ORG	flat	regular	absent		present	both	rounded	smooth	absent		absent		absent		absent			absent			unclear (perhaps mineral)	1
77	L. Nat	Mu(pestle-handstone)	SHUB01-2013-422	UF1 - handstone face	ORG	flat	regular	absent		present	both	rounded	smooth	absent		present	high	absent		absent			absent			seeds/cereal	2
78	L. Nat	Mu(pestle-handstone)	SHUB01-2013-422	UF2 - pestle face	CPR	uneven	regular	present	rounded	present	both	rounded	rough	absent		absent		absent		absent			absent			unclear (perhaps animal matter - meat)	0

79	L. Nat	LGI (basin quern)	SHUB1-2013-085	UF1 - smallest, newest	RGP	sinuous/rounded	regular	present	rounded	present	both	rounded	smooth	absent		absent		present	low	present	high	slight	absent		y	tuber and/or cereal	3
80	L. Nat	LGI (basin quern)	SHUB1-2013-085	UF2 - largest oldest	RGP	flat	regular	present	sharp	present	both	flat	smooth	absent		present	low	absent		absent			absent			seeds/cereal	2
81	L. Nat	LGI (basin quern)	SHUB1-2013-085	WF	FNU	flat	irregular	present	rugged	present	both	rounded	rough	absent		present	both	absent		absent			absent			stone	0
1	EPPNA	HS (Ovate)	SHUB06-2016-1100	UF1	CRG	flat	regular	present	sharp	present	both	flat	smooth	absent		present	low	absent		present	high	slight	absent		n	seeds/cereal	3
2	EPPNA	HS (Ovate)	SHUB06-2016-1100	UF2	CRG	flat	regular	prese	sharp	prese	both	flat	smooth	absen		prese	low	prese	low	absen			absen		n	seeds/cereal (less clear)	2

								nt		nt				t		nt		nt		t			t				
3	EPPNA	HS (Ovate)	Bag: 6,33	UF1	CRG	sinuous/rounded	regular	present	sharp	present	groundmass	rounded	smooth	absent		absent		present	both	absent			absent		n	tuber/soft plant	2
4	EPPNA	HS (Subcirc.)	SHUB06-2016-1097	UF	CRG	flat	regular	present	sharp	present	groundmass	rounded	smooth	absent		present	low	present	both	absent			absent		n	tuber/soft plant or nuts	3
5	EPPNA	HS (Subcirc.)	SHUB06-2016-1097	WF	?	flat	regular	e“dimple"	rugged	present	groundmass	rounded	smooth	absent		absent		present	both	absent			absent		n	handling and possibly tuber pounding	0
6	EPPNA	HS (Ovate)	SHUB06-2016-1087	UF1	CRG	flat	regular	few	sharp	present	both	flat	smooth	absent		absent		present	low	absent			absent		n	seeds/cereal (possibly some tuber)	2

7	EPPNA	HS (Ovate)	SHUB06-2016-1087	UF2	CRG	flat	regular	few	sharp	present	both	flat	smooth	present	superficial	present	low	absent		present	high	slight	present	high	n	seeds/cereal	3
8	EPPNA	HS (Ovate)	SHUB06-2016-1089	UF1	CRG	flat	irregular	present	sharp	present	groundmass	flat	smooth	absent		present	both	absent		absent			absent		n	legume	3
9	EPPNA	HS (Ovate)	SHUB06-2016-1089	UF2	CRG	flat	regular	present	sharp	present	groundmass	flat	smooth	absent		absent		present	low	absent			absent		n	meat or animal matter	3
10	EPPNA	HS (Irreg.)	SHUB06-2016-1094	UF	CRG	flat	regular	few	sharp	present	groundmass	flat	smooth	present	superficial	present	both	absent		present	high	moderate	present	high	n	seeds/cereals	3
11	EPPNA	HS (Ovate)	SHUB06-2016-1095	UF	CRG	sinuous/rounded	regular	few	rounded	prese	groundmass	rounded	smooth	prese	superficial	prese	both	absen		absen			prese	high	n	seeds/cereals	3

										nt				nt		nt		t		t			nt				
12	EPPNA	HS (Ovate)	SHUB06-2016-1095	Br(oken)	CRG	Ueven/rugged	irregular	breakage	rugged	absent				absent		absent		absent		absent			absent		n	breakage	0
13	EPPNA	HS (Ovate)	SHUB06-2016-1093	UF	CRG	sinuous/rounded	irregular	few	sharp	present	groundmass	rounded	smooth	absent		absent		absent		dark colouration?			absent		n	nuts? unclear (mixed perhaps animal matter)	3
14	EPPNA	HS (Ovate)	SHUB06-2016-1109	UF	CRG	flat (levelled high top.)	irregular	present	sharp	present	groundmass	flat	smooth	absent		present	high	absent		absent			absent		n	legume (unclear)	2
15	EPPNA	Ha (Rect.)	SHUB06-2016-1088	UF - impact face	Percussio	uneven/rugged	irregular	present	rounded	absent				absent		present	both	absent		absent			absent		n	stone	0

					n																						
16	EPPNA	Ha (Rect.)	SHUB06-2016-1088	WF	abrading	sinuous/rounded	regular	absent		present	groundmass	rounded	rough	absent		present	low	present	high	absent			absent		n	unclear (possbly mineral?)	0
17	EPPNA	HS (Ovate)	SHUB06-2017-1863	UF	CRG	flat (levelled high top.)	regular	present	rounded	present	both	flat	smooth	absent		present	low	absent		present	high	slight	absent		y (low)	seeds/cereal and pigment (mineral)	3
18	EPPNA	HS (Ovate)	SHUB06-2017-1508	UF	CRG	flat (levelled high top.)	regular	present	sharp	presentc	both	flat	smooth	absent		present	low	absent		present	high	moderate	absent		n	seeds/cereals	3
19	EPPNA	HS (Ovate)	SHUB06-2017-1852	UF	CRG	flat (levelled high top.)	regular	present	sharp	present	both	flat	smooth	absent		absent		present	high	absent			absent		n	dried meat but unclear	2

20	EPPNA	HS (irregular)	SHUB06-2017-1167	UF	ORG	flat (levelled high top.)	irregular	absent		present	groundmass	flat	rough	present	superficial	present	high	absent		absent			absent		n	mineral (pigment)	2
21	EPPNA	HS (Ovate)	SHUB06-2017-1280	UF1	ORG	flat (levelled high top.)	regular	present	sharp	present	both	flat	smooth	absent		present	low	absent		present	high	slight	absent		n	seeds/cereals	3
22	EPPNA	HS (Ovate)	SHUB06-2017-1280	UF2 - pigmented	ORG	flat (levelled high top.)	regular	present	sharp	present	both	flat	smooth	absent		absent		absent		present	high	moderate	present	high	y (both)	dried meat and mineral (pigment ?)	3
23	EPPNA	HS (Ovate)	SHUB06-2017-1509	UF	CRG	flat (levelled high top.)	irregular	present	sharp	present	both	flat	smooth	present	superficial	present	high	absent		present	high	slight	absent		n	legume	4
24	EPPNA	HS (Ovate)	SHUB06-2017-1509	BR		uneven/rugged	irregular	prese	rugged	absen				prese	both	prese	both	absen		absen			absen		n	breakage	0

								nt		t				nt		nt		t		t			t				
25	EPPNA	HS (Ovate)	SHUB06-2017-1273	UF1	CRG	flat (levelled high top.)	irregular	present	sharp	present	groundmass	flat	smooth	present	superficial	present	high	absent		absent			present	high	n	seeds/cereals	3
26	EPPNA	HS (Ovate)	SHUB06-2017-1273	UF2	CRG	flat (levelled high top.)	irregular	present	sharp	present	groundmass	flat	smooth	present	superficial	present	both	absent		absent			present	high	n	seeds/cereals	2
27	EPPNA	HS (Ovate)	SHUB06-2018-492	UF1	ORG	flat (levelled high top.)	irregular	present	sharp	present	groundmass	flat	smooth	absent		present	high	absent		present	high	moderate	present	high	y (both)	mineral (pigment)	2
28	EPPNA	HS (Ovate)	SHUB06-2018-492	UF2	ORG	flat (levelled high top.)	irregular	absent		present	groundmass	flat	smooth	absent		present	both	absent		absent			present	high	n	mineral	3

29	EPPNA	HS (Rect.)	SHUB06-2017-1284	UF	CRG-Abrading	flat (levelled high top.)	regular	present	sharp	present	both	flat	smooth	absent		absent		absent		present	high	moderate to highly	absent		n	skin/hide	2
30	EPPNA	HS (Disc.)	SHUB06-2017-1855	UF	RGP-Abrading	flat (levelled high top.)	regular	present	sharp	present)	both	flat	smooth	absent		absent		present	low	present	high	slight	absent		y(low)	skin/hide and mineral (pigment)	3
31	EPPNA	HS (Ovate)	SHUB06-2017-1511	UF1	CRG	flat (levelled high top.)	regular	present	sharp	present	both	flat	smooth	absent		present	low	absent		present	high	highly	present	high	n	oily seeds (mustard etc.)	4

32	EPPNA	HS (Ovate)	SHUB06-2016-1092	UF	CRG	flat (levelled high top.)	regular	present	sharp	present	both	flat	smooth	absent		absent		present	low	present	high	slight	absent		y (both)	seeds/cereals and pigment (mineral)	2
33	EPPNA	HS (Ovate)	SHUB06-2016-1092	WF	FNU	flat (levelled high top.)	regular	present	rounded	present	both	rounded	smooth	absent		absent		absent		present	both	slight	absent		n	handling/worked surface	2
34	EPPNA	P (Conical)	SHUB06-2017-1520	WF	FNU	sinuous/rounded	irregular	present	rounded	absent				absent		present	both	present	low	absent			absent		n	handling/worked surface	0
35	EPPNA	P (Conical)	SHUB06-2017-1520	UF	CPR	sinuous/rounded	regular	present	rounded	present	groundmass	rounded	rough	absent		present	both	present	low	absent			absent		n	tuber/soft plant	3
35a	EPPNA	P (Conical)	SHUB06-2017-1520	WF	FNU	flat (levelled high top.)	regular	prese	rounded	prese	groundmass	rounded	rough	absen		prese	low	prese	both	absen			absen		n	handling/worked surface	0

								nt		nt				t		nt		nt		t			t				
36	EPPNA	P (Conical)	SHUB06-2017-1001	UF	CPR	uneven/rugged	regular	present	rounded	present	groundmass	rounded	rough	absent		present	low	absent		absent			absent		n	unclear (possbly mineral?)	3
37	EPPNA	LGI (Basin slab)	SHUB06-2018-508	UF	CRG	sinuous/rounded	regular	present	rounded	present	groundmass	rounded	smooth	present	superficial	present	high	absent		absent			absent		n	tuber/soft plant	3
38	EPPNA	M (Bowl)	SHUB06-2017-1525	UF	CPR	uneven/rugged	regular	present	rugged	absent	groundmass	rounded	rough	absent		present	both	absent		absent			absent		n	seeds	0
39	EPPNA	LGI (Basin slab)	SHUB06-2017-1291	UF1	CRG	flat (levelled high top.)	regular	absent		present	both	flat	smooth	absent		present	high	present	both	present	high	moderate	absent		n	seeds/cereals	3

40	EPPNA	LGI (Basin slab)	SHUB06-2017-1291	BR	FNU	uneven/rugged	irregular	absent		absent				absent		present	both	absent		absent			absent		n	breakage	0
41	EPPNA	M (Boulder)	SHUB06-2017-1287	WF	FNU	sinuous/rounded	irregular	present	rounded	present	groundmass	rounded	rough	absent		absent		present	both	absent			absent		n	worked face	0
42	EPPNA	M (Boulder)	SHUB06-2017-1287	UF	CPR	sinuous/rounded	regular	present	rounded	present	groundmass	rounded	rough	absent		present	both	present	both	absent			absent		n	tuber/soft plant	2
43	EPPNA	LGI (Basin slab)	SHUB06-2017-1651	UF1 - proximal half	CRG	sinuous/rounded	regular	present	rounded	present	groundmass	rounded	smooth	absent		absent		present	both	absent			absent		n	tuber/soft plant	2
44	EPPNA	LGI (Basin slab)	SHUB06-2017-1651	UF1 - near centre but	CRG	sinuous/rounded	regular	prese	rounded	prese	groundmass	rounded	smooth	absen		absen		prese	both	absen			absen		n	see above	0

				distal on half of UF				nt		nt				t		t		nt		t			t				
44a	EPPNA	LGI (Basin slab)	SHUB06-2017-1651	UF1 - distal end	CRG	flat (levelled high top.)	regular	absent		present	both	flat	smooth	absent		present	low	absent		absent			absent		n	see above	0
45	EPPNA	LGI (Basin slab)	SHUB06-2017-1651	NA		flat (levelled high top.)	irregular	absent		present	groundmass	rounded	rough	absent		absent		present	low	absent			absent		n	natural face	0
46	v	LGI (Basin quern)	SHUB06-2017-1650	UF - Centre	RGP	flat (levelled high top.)	regular	absent		present	both	flat	smooth	absent		present	low	absent		present	high	highly	absent		n	oily seeds (mustard etc.)	4
47	EPPNA	LGI (Basin quern)	SHUB06-2017-1650	UF - side/margin	RGP	uneven/rugged	regular	present	rounded	present	groundmass	rounded	rough	absent		present	both	absent		absent			absent		n	see above	1

48	EPPNA	M (Boulder)	SHUB06-2017-1286	UF	CPR	uneven/rugged	regular	present	rugged	present	groundmass	rounded	rough	absent		present	both	present	low	absent			absent		n	tuber/soft plant	2
86	EPPNA	Ha (Disc.)	SHUB06-2017-774	UF	Percussion	sinuous/rounded	irregular	present	rugged	present	groundmass	rounded	rough	absent		absent		absent		absent			absent		n	stone	2
93	EPPNA	HS (Ovate)	SHUB06-2017-998	UF1	CRG-Abrading	sinuous/rounded	regular	present	rounded	present	both	rounded	smooth	absent		absent		present	low	present	both	highly	absent		n	skin/hide	2
94	EPPNA	HS (Ovate)	SHUB06-2017-998	UF2	CRG-A	flat	regular	prese	rounded	prese	both	rounded	smooth	absen		absen		prese	low	prese	both	highly	absen		n	skin/hide	3

					brading			nt		nt				t		t		nt		nt			t				
85	LPP NA	HS (Ovate)	SHU B06-2016 -299	UF1 dimple/groove	CRG	flat	regular	present	sharp	present	both	flat	smooth	absent		absent		present	low	absent			absent		n	seeds/cereals	3
84	LPP NA	HS (Disc.)	SHU B06-2016 -297	UF	CRG	flat	regular	present	sharp	present	groundmass	flat	smooth	absent		present	high	present	both	absent			absent		n	seeds/cereals	3
82	LPP NA	LGI (Trough slab)	SHU B06-2016 -296	UF	CRG	sinuous/rounded	irregular	present	rounded	present	groundmass	rounded	smooth	present	superficial	present	low	present	high	absent			absent		n	unclear (unused)	1
83	LPP NA	HS (Ovate)	SHU B06-2016 -643	UF1	CRG	flat	regular	prese	sharp	prese	both	flat	smooth	absen		absen		prese	both	prese	high	moderate	absen		n	seeds/cereals	3

								nt		nt				t		t		nt		nt			t				
87	LPPNA	HS (Disc.)	SHUB06-2016-646	UF1 dimple	CRG	flat	irregular	present	sharp	present	groundmass	flat	smooth	absent		present	both	absent		absent			absent		n	legume	3
90	LPPNA	HS (Ovate)	SHUB06-2016-642	UF1	CRG	flat	regular	absent		present	both	flat	smooth	absent		absent		present	low	present	high	slight	absent		n	meat (dried animal)	3
91	LPPNA	HS (Ovate)	SHUB06-2016-639	UF1	CRG	flat	regular	absent		present	both	flat	smooth	absent		present	low	present	low	present	high	slight	absent		n	seeds/cereals	3
92	LPPNA	HS (Ovate)	SHUB06-2016-639	UF2	CRG	flat	regular	absent		present	both	flat	smooth	absent		present	low	present	low	present	high	slight	absent		n	seeds/cereals	3
95	LPPNA	LGI (Basin	SHUB06-	UF	CR	flat	regular	ab		pr	both	rounde	smooth	ab		ab		pr	low	ab			ab		n	tuber/soft plant	3

		slab)	2017-283		G			sent		esent		d		sent		sent		esent		sent			sent				
88	LPPNA	HS (Ovate)	SHUB06-2017-1172	UF1	CRG	flat	regular	present	sharp	present	both	flat	smooth	absent		absent		absent		present	high	moderate	absent		n	seeds/cereals	3
89	LPPNA	HS (Ovate)	SHUB06-2017-1172	UF2	ORG	flat	regular	present	sharp	present	both	flat	smooth	absent		absent		present	low	present	high	slight	absent		n	seeds/cereals	2

Co-author statement

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Date of birth	29-11-1988
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"Attribution of authorship should in general be based on criteria a-d adopted from the Vancouver guidelines , and all individuals who meet these criteria should be recognized as authors:

A. Substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work, and
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*Title	From Stone to Food: Foodways and processing during the Natufian and Early Neolithic of Eastern Jordan - A Ground stone perspective
*Author(s)	Patrick Nørskov Pedersen, Monica Ramsey, Amaia Arranz-Otaegui, Tobias Richter
Journal	?
Volume (no)	?
Start page	?
End page	?

Co-author statement

PhD student Patrick Nørskov Pedersen

Date of birth 29-11-1988

Contributions to the paper/manuscript made by the PhD student

What was the role of the PhD student in designing the study?

The study was designed and carried out on the initiative of me, the PhD-student, with assistance and guidance from my supervisor T. Richter as well as input from the co-authors A. Arranz-Otaegui and M. N. Ramsey. Study was also part of the overall project “Changing footways” project under the direction of T. Richter and tied to the overall project goals of “reconstructing past ways of procuring and processing food” during the Late Epipaleoltihic and Early Neolithic.

How did the PhD student participate in data collection and/or development of theory?

Ground stone data was collected by the PhD-student, including travelling to Jordan to conduct low-power use-wear analysis and residue sampling of the Shubayqa ground stone.

Which part of the manuscript did the PhD student write or contribute to?

The Introduction (section 1.), ground stone background (2.1.2.) analysis (2.2.), including low-power use-wear analysis was conducted by me. The results section (3.), the comparisons, discussion and conclusions (sections 4. and 5.) were also authored by the PhD-student. The brief section (3.2.1.1.) on the residue sampling method for the ground stone tools was authored by the PhD-student based on a protocol provided by M.N. Ramsey.

Did the PhD student read and comment on the final manuscript?

Yes.

Signatures

If an article/ paper/chapter/manuscript is written in collaboration with three or less researchers (including the PhD student), all researchers must sign the statement. However, if an article has more than three authors the statement may be signed by a representative sample, cf. article 12, section 4 and 5 of the Ministerial Order No. 1039, 27 August 2013. A representative sample consists of minimum three authors, which is comprised of the first author, the corresponding author, the senior author, and 1-2 authors (preferably international/non-supervisor authors).

Co-author statement

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By their signature, the authors agree that the article/paper/chapter/manuscript will be included as a part of the PhD thesis made by the PhD student mentioned above.

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Date	10-01-2022	Name	Amaia Arranz-Otaegui	Signature	Amaia Arranz
Date	17/1/22	Name	Tobias Richter	Signature	

C.

Appendices for the PhD:

“Approaching Past and Changing Foodways Through Ground Stone“

By

Patrick Nørskov Pedersen

University of Copenhagen, Department of Cross-Cultural and Regional Studies,
Centre for the Study of Early Agricultural Societies

Contents:

Appendix Ia:
Ground stone sampling and use-wear protocol

1. Selecting tools for analysis Use-wear and Residues - by PP[1]

1.1. Criteria for selection

There were four main criteria selecting tools for sampling/use-wear:

1. They should be either complete or large enough to facilitate a large enough sample to be extracted
2. Tools with known and detailed provenance from "good" archaeological contexts. Confidently dated and phased within the site. → Avoiding tools with no clear provenance beyond site and contexts with mixed material, affected by bioturbation, or otherwise contaminated. Finds the topsoil and surface
3. Finds exposed to as little contamination as possible during recovery, handling, storage. Ideally tools that were swiftly recovered, recorded and bagged in individual new clean plastic zip-lock bags. Some come from bulk find bags, not individual bags, but bagged nonetheless. Some larger tools were not bagged, but stored in a locked storage room.
4. Specific tool types were selected for the sampling. Handstones, querns/slabs, pestles and mortars, polishers, pounders and hammerstones. All of these types come from the larger "processing" tool groups while the three latter come from tools mainly involved in stone to stone contact . These are tools used to pulverize/abrade intermediate material through abrasion or impaction between two stones (pairs). Grinding pairs: lower grinding implements (Querns, Slabs) and handstones. Pounding pairs: lower tool being mortars, upper tools pestles. Furthermore subtypes representative and common to the phases where selected. For example: ovate handstone and basin slabs for the PPNA.

1.2.2. "Background" sampling (phytolith)

Two types of stones may be interesting to test as a reference to "background" phytolith and starch residues left on stone.

1. A number of unused stones from the surface of the surrounding area should also be collected for sampling.
2. Ideally a few also unused stones from archaeological contexts may also be selected for sampling. These could come from the same context as some of the tools, they do not necessarily need to come from the same spit/level (though this is preferable) or close by as long as it is the same context. However again a sample from within 1 meter (horizontally) / 20cm (vertically) is prioritised/preferable

This can then be used as a reference of the "background". This should be done if possible!

[1] This author, PhD.-fellow, Patrick Nørskov Pedersen

2. Sampling for residues - by MR[2]

2.1. Methods

Sampling artefact (M. Ramsey 2019)

a. **Dry Brush:** remove adhering sediments from tool with clean toothbrush. Brush tool gently, collect sediment and transfer into a new 50 ml test tube.
b. **Wet Brush:** using the same toothbrush, scrub the tool with distilled water. Collect all of the aqueous material, and transfer to a new 50 ml test tube.
c. **Point sample with pipette.** Using distilled water take several samples from the clean working surface, and clean non-working surface of the ground stone. Drop several drops of distilled water on surface, use the tip of the pipette (use new pipette for every sample) ‘worry’ the surface, then pipette up the sample. Transfer sample to new 10 ml test tube. Focus on cracks or crevasses, as well as any visible residues on the working surface. Samples should also be taken from broken surfaces (i.e. post-depositional breaks so we know the surface was not used for processing). Photos and sketches should be used to record sample placement.
d. ***Sonocated:*** *(not conducted for this study) place tool into container adding enough distilled water to cover the artifact/surface of interest. Sonocate for 10 min. Transfer aqueous material to a new 50 ml test tube.*
e. **Sediment:** Sieve dry sediment through 0.25 mm sieve. Weigh out up to 10 gm of sediment. Record the weight of the sub-sample in mg using an analytical balance. Transfer sub-sample into 50 ml centrifuge tube. Sediment sample from area surrounding tools collected in field - was sub-sampled in lab in Copenhagen, further processing conducted by M. Ramsey (at Cambridge U.)

Further notes:

- Point sampling with pipette should be prioritised over other sample types (personal comment Ramsey 2019)
- Unused water in separate sample for each session of sampling. As control sample
- Tag/info accompanying the sample should only include ground stone sample number (GSS) and sample type, date and initials. This is to ensure the least amount of bias in sample processing
- All information will be recorded in detail in an excel database and in notebook (sketches etc.)

2.2. Sample recording - by PP

2.2.1. Ground stone sample register (excel sheet)

Used to record complete information about sample type, sample area, number of samples and tool type, provenance, corresponding sediment sample and date/initials of sampler.

[2] Dr Monica Nicolaides Ramsey, Department of Archaeology, University of Cambridge

Fill out these fields

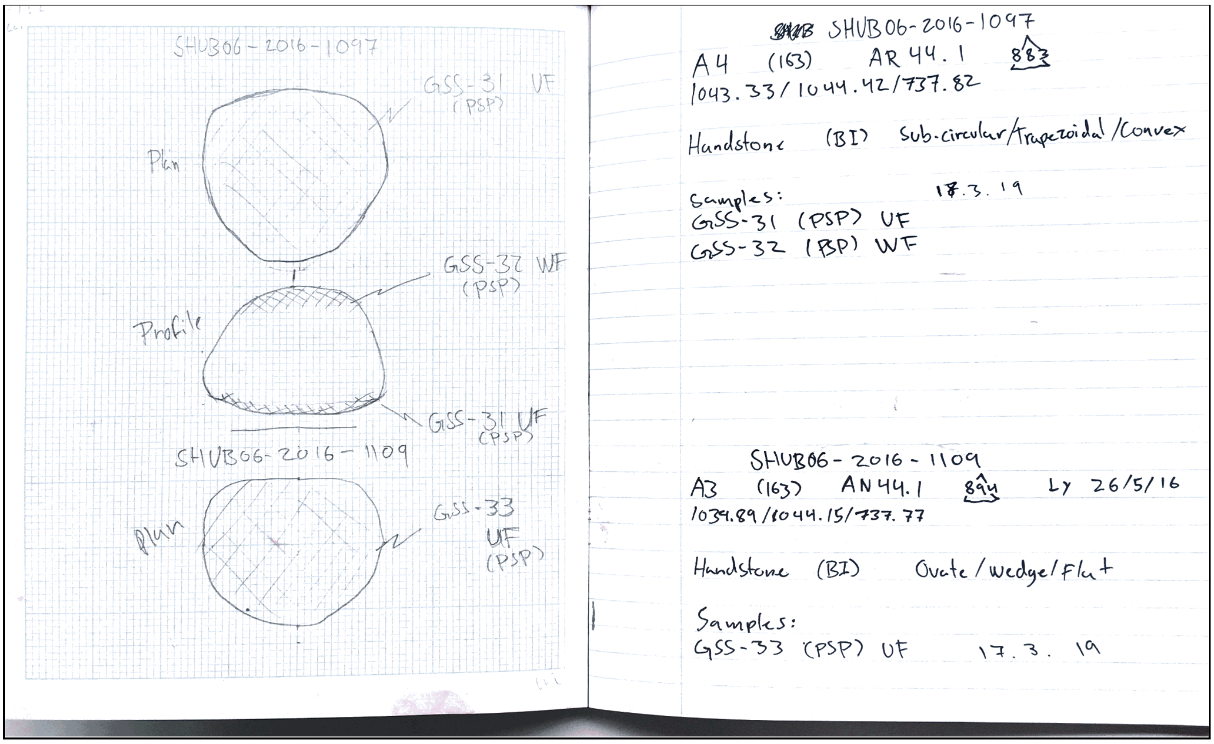
A. **Ground Stone Sample (GSS):** Sequential number given to each individual sample
B. **Sample type:** One area may be sampled up to three times: dry brush (DB), wet brush (WB) and point sample with pipette (PSP). Each get a seperate sample number. (RF) is for reference sample of distilled water
C. **Area sampled:** In addition, there are four types of "areas" of a stone where sampled can be taken: a used face (UF), broken (BR), or worked but unused face (WF) - for example the exterior face of a mortar etc. - and natural (NA), un-worked and unused. This area can be used as reference.
D. **Notes on sampled area:** If more than one UF, BR, WF or NA area is sampled from the same tool, which area is represented by what sample is noted in column D: "Notes on sampled area" for example: UF1, BR2 etc. Each takes up a seperate sample number and all is documented as above. Again a sketch should note the areas where the samples are extracted from and will be labelled with the above information as any other sample. If only one of two used faces is sample a small black sharpie dot indicates which
E. **No. of samples on this tool:** The number of samples from the same tool is noted (if applicable)
F. **Site code:** Shubayqa 1 (SHUB1) or Shubayqa 6 (SHUB6)
G. **Find Code:** If part of the Small Finds database
H. **Bag ID:** If bulk find record bag ID
I. **Context:** Provenance
J. **Square:** Provenance
K. **Level:** Provenance
L. **East Coordinate:** Provenance - serves as provenance of ground stone sample in relation to sediment sample
M. **North Coordinate:** Provenance - serves as provenance of ground stone sample in relation to sediment sample
N. **Height:** Provenance - serves as provenance of ground stone sample in relation to sediment sample
O. **Corresponding sediment ph/pl sample:** A sample of sediment is used as reference for the tool. This is to demonstrate that phytolith/starch residues are the result of activities during use-life and not merely a result of deposition in the sediment. This sample should come from the same context (fill, layer, midden etc.), or in the case of tools set in floors (floor installations) from the context immediately above or between the stones. The sediment sample should come from within 100cm (planar) of the tool - preferably 50cm - and no more than 20cm - preferably 10cm - above the tool.
P. **Type Detailed:** Type of tool (e.g. handstone, mortar)
Q. **Implement sub-type:** e.g. discoidal handstone, boulder mortar
R. **Phase:** Phase from the matrix of the site, if applicable
S. **Sampled by:** Initials
T. **Date:** Date of sampling

2.2.2. Notebook

Record information on two pages (graph page and a note page)

Graph page:
Here it should be documented, through illustration/sketch what face/area of that face was sampled, what type of sample and area it is.
A sketch is drawn of the tool in plan or profile and areas to be sampled are marked (dashed or hashed lines with legend).
On sketch is noted:
- Tool findcode
- Angle of sketch - i.e. plan or profile (trans. or long.)
- Approximate scale (usually 1:1, 1:2, 1:4, 1:5)
- What kind of sample it is
- What kind of face it is
- Sample numbers

Note page:
Here is the recording of provenance, find information and sample information:
- All the information from the original tag is noted
- A list of the information recorded on the sketch of is provided below tag information



x. Example of notebook recording

2.2.3. Writing tags
Only GSS number, sample type, date and initials. To ensure no sampling bias during processing. Should use *Tyvex* tags, or write on tube.

2.3. Step by step guide to sampling of tool/area (PP, based on MR 2019 protocol)

1. Check if the tool is in general ground stone database
- If not record it there first

2. Give the first sample number and enter all information from tag in to the GS sample database and into the notebook
3. Decide what sample types and areas to do, start with the sample number just given and take out numbers sequentially for desired samples
4. Sketch in sample areas, record sample type and number in notebook
5. Do the individual samples
- **a.** Dry brush with clean toothbrush (if possible)
- **b.** Wet brush with <u>same</u> toothbrush and some distilled water (if possible)
- **c.** Point sample with pipette with few drops of distilled water → **priority!**

6. Write tag for each sample with: ground stone sample number, date and initials (no more)
7. Record all information for each individual sample in the recording sheet and check all information is also in the notebook
8. Add all sample numbers to the back of the tools tag (or make a tag for it if it does not have tag)
9. Move on to next sample area or tool (change nitrile gloves and discard pipette)
10. When a session is over make one sample of unused distilled water for reference

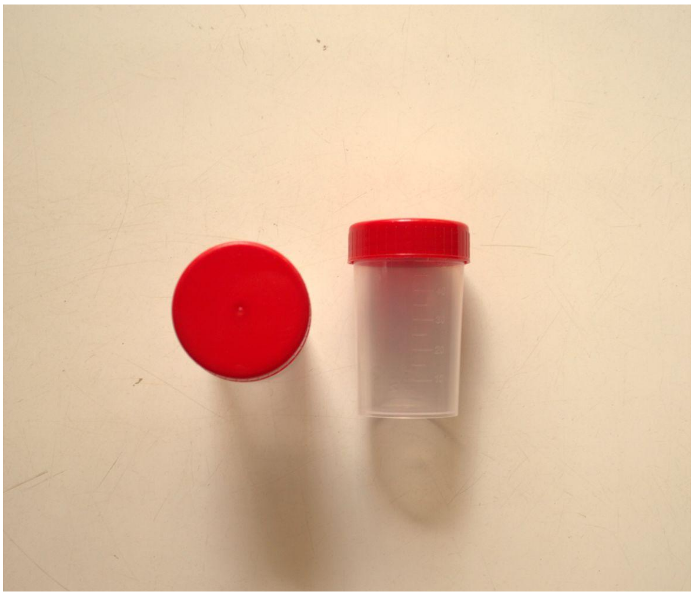
2.4. List of tools/supplies used in sampling (w. pictures)

a. Carrefour, medium hardness Toothbrushes used for sampling.

b. SUPERCARE Nitrile medical examination gloves, powder free (L), worn (double) while sampling.

c. Surgical face masks, non-woven, 3-ply face masks, worn while sampling

d. Max-protect, 3 ml transfer pipette, used for point sampling



e. 50 ml plastic "Pee-pot", for collected wet and dry samples

f. Distilled water, used for extracting wet samples

3. Use-wear protocol 2019-2021 (PP)

Before use-wear analysis was conducted tools were sampled (see above). Tools were washed thoroughly with tap water and generic washing-up liquid.

3.1. Use-wear protocol

Protocol generally follows Adams et al. 2009 (but see also Dubreuil et al. 2015, as well as inspiration drawn from: Dubreuil and Savage 2014; Dubreuil 2004; Adams 2002).

3.1.1. Workflow and recording fields (for Excel/Access)

US# (Use-wear no.): A running number of analyses, one tool may have multiple at different location on the tool, or with different methods/microscopes etc.

Artefact description

Archaeological (y/n): y= from site; n= experimental

Find Code: SHUB-code

Bag ID/Sf. No: Bag; small finds number

Site code: SHUB1; SHUB6
Context: Number
Square/Level: Letter/number
Phase: If applicable
Raw mat. (AOB - generic): Variations being, O*livine-plagioclase basalt; Olivine-pyroxene basalt; Olivine basalt; Olivine-plagioclase-clinopyroxene basalt*. Qualitative estimation of dominant phenocrysts by PP.

Raw mat. (notes): Cryptocrystalline; Microcrystalline. Presence of iddingsite; amygdules

Basalt type: I-IV =

I **Vesicular Basalt** Grey to dark grey, dense, very small (less than 1 mm) and very few vesicles (3 or less per 5x5mm area)

II **Non-vesicular basalt** Blackish grey, extremely dense with no visible vesicles

III **Vesicular Basalt** Grey to dark grey, dense, small (1-2mm) but numerous vesicles (at least 4 per 5x5 mm area)

IV **Vesicular Basalt** Grey to dark grey, lightweight, numerous large vesicles (2 to 5mm in diameter)

Un **Undetermined** Vesicular basalt that could not be categorized as either I, II or IV

Type Detailed: HS= Handstone; P= Pestle; LGI= Lower grinding implement i.e. slab/quern; M= Mortar; Pounder; Mu= Multiple tool; Ha= hammerstone
Implement sub-type: **HS:** Rectangular; Discoidal; Ovate; Loaf; Loaf(tapered); Irregular; **P:** Conical; Cylindrical; **LGI:** Basin quern; Basin slab; Saddle slab; Trough slab; Block quern; Block slab; **M:** Bowl; Globular; Goblet; Boulder; **Pounder:** Sub-circular; Sub-spherical; **Mu:** Mu(pestle-handstone)
Weight
Type of Area: a used face (**UF**), broken (**BR**), or worked but unused face (**WF**) - for example the exterior face of a mortar etc. - and natural (**NA**) un-worked and unused - this area can be used as reference.
Notes on analysed area: for example= UF1 black dot (1st use-wear face marked with black dot)
Use-wear notes: Initial thoughts for example= Maybe not so extensively used?
No. of use wear locations on this tool: # of #
Overall Surface type (transverse-upper/plan shape -lower). **HS:** Oval; Wedge; Rectangular; Lens; Trapezoidal; Tapered; Plano-convex; Plano-irregular; **LGI + M**: Triangular; Circular; Sub-circular; Eliptical, Rectangular
Used face Profile shape (trans.): HS + P: Flat; Convex; Concave **LGI:** Flat; Shallow; Convex; Concave; Conical **M:** Concave; Conical; Shallow **All:** N/A
Used face Profile shape (long.): HS + P: Flat; Convex; Concave **LGI:** Flat; Shallow; Convex; Concave; Conical; Sloped; Curved; **M:** Concave; Conical; Shallow **All:** N/A

Suggested use/strategy:
Diffuse resting percussion

A1. Confined Reciprocal Grinding (CRG)

A2. Open Reciprocal Grinding (ORG)

A3. Rotary Grinding w. some pounding (RGP)

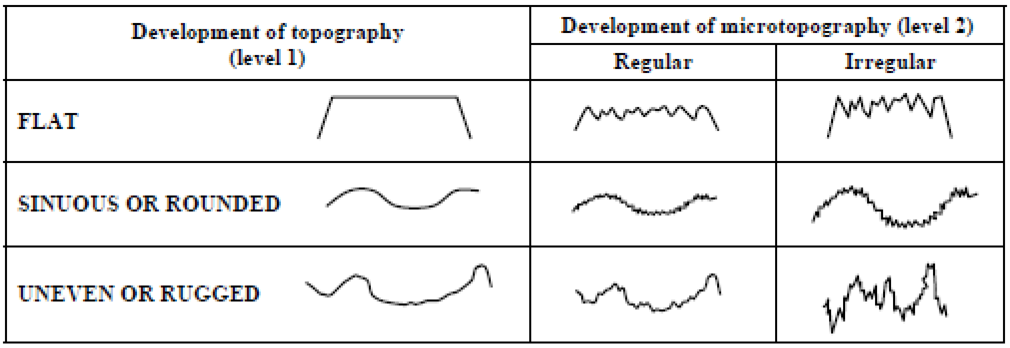
Diffuse thrusting percussion

B1. Open pounding (OPO)

B2. Confined Pounding (w. some rotary grinding) (CPR)

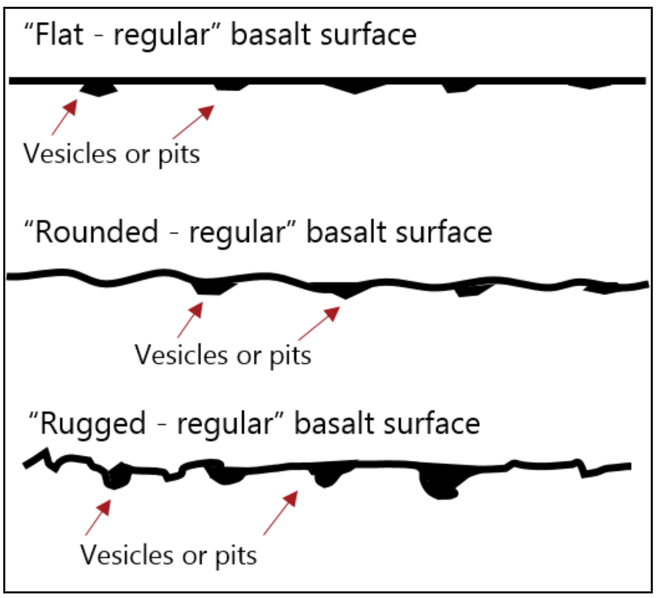
Use-wear description (UWD)

UWD 1a. Topography (Level 1) (5-10x): uneven/rugged; flat; sinuous/rounded (see Figure from Adams et al. 2009 below)



x. Topography (from Adams et al. 2009)

UWD 1aI. Microtopography of high topography (Level 2) - i.e. roughness (10-40x): See above. I.e. Topography and microtopography combined. for example: rounded/regular etc:



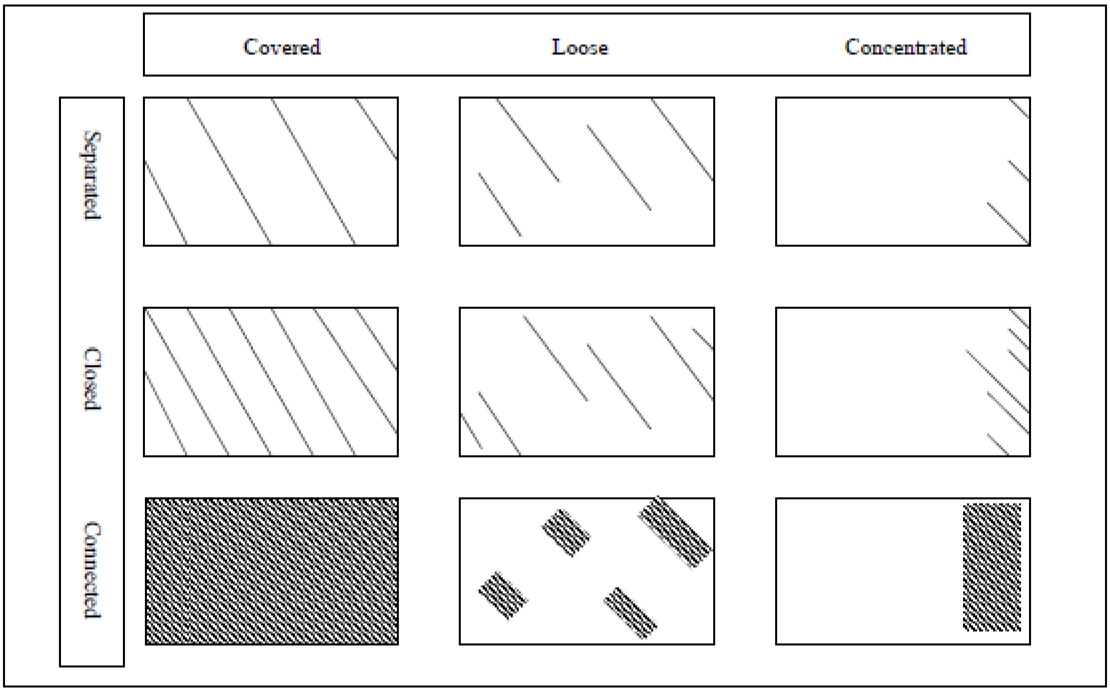
x. PP's amended version of topography

UWD 1b. Features of overall topography - Impactions traces (Level 1[3]) (less than 20x): Present; Absent

UWD 1bI. Suggested type: Pecking pits; Percussion pits (example: pestle terminus); Flaking (flake scar); Breaking (break surface). - Based on Naked eye observation

UWD 1bI. Distribution: loose; covering; concentrated; single (dimple) (see below also). "dimple"= a small area, circular/sub-circular (less than 5mm in diameter, between 1-5mm in depth), covered with pecking pits or percussion pits. Observed on several tools. Used as hammer/pounder? Or remains of pecked surface?

UWD 1bI. Density: seperated; close; connected (see Figure from Adams et al. 2009 below)



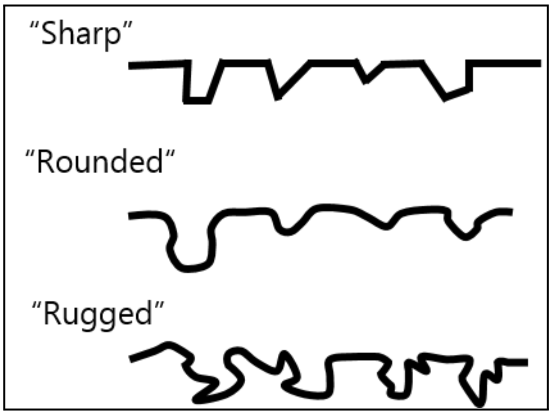
x. Distribution and density (from Adams et al. 2009)

UWD 1bI. Orientation/direction: In relation to estimated or apparent directionality of tool (if applicable): transverse;longitudinal;oblique;concentric;random

UWD 1bI. Depth Level 2: Relative to surrounding matrix/groundmass: shallow (fine); deep (wide); intermediate; mixed

UWD 1bI. Pit edges: Level 2: Edge of pits (morphology) in relation to rest of plane: sharp; rounded,; rugged

[3] Level 1 unless stated otherwise



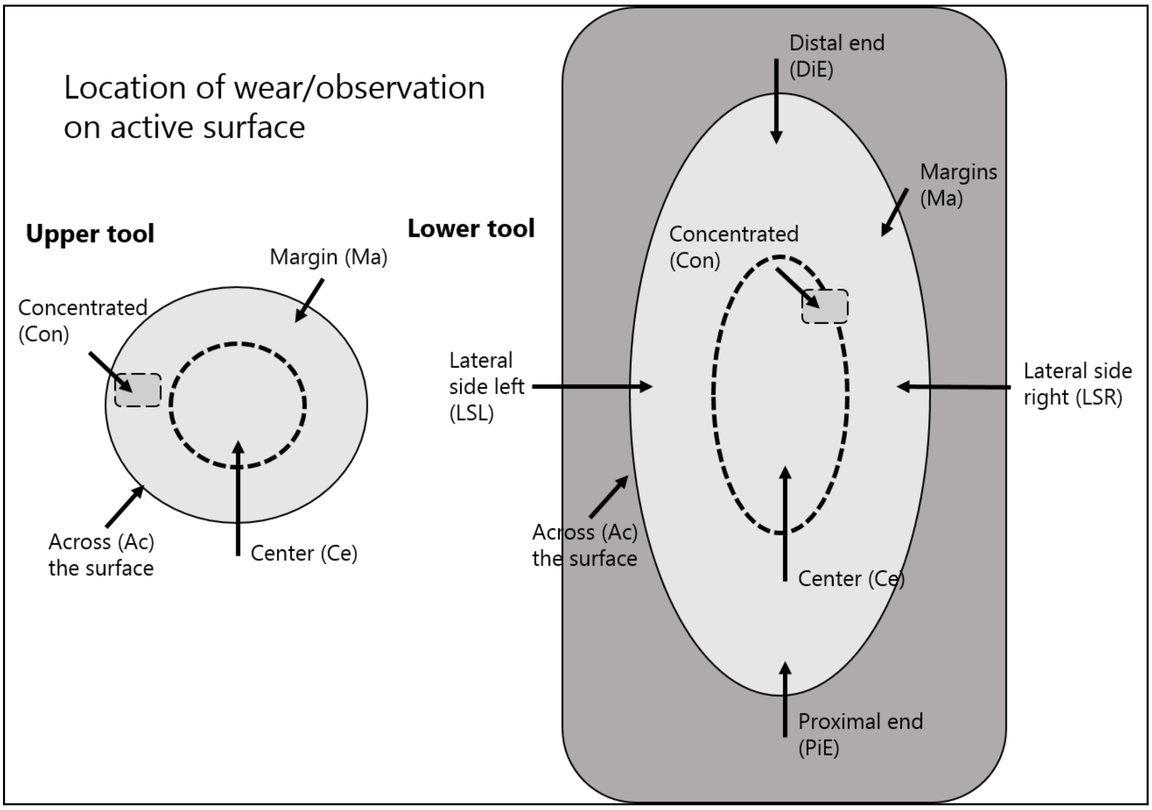
x. PP's version of pit/interstice edges

UWD 1bI. Shape plan: circular;oval;triangular;square;irregular

UWD 1bI. Shape section: U;V; Both

UWD 1bI. Size: small; large; mixed

UWD 1bI. Location on face: Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side "left"; LR= lateral side "right"; LB= both lateral sides; Be = between (specify). In relation to estimated or apparent directionality of tool (if applicable). See figure below:



x. PP's schematic view of the location of traces and/or observation

UWD 1c. Pigment? Present; absent

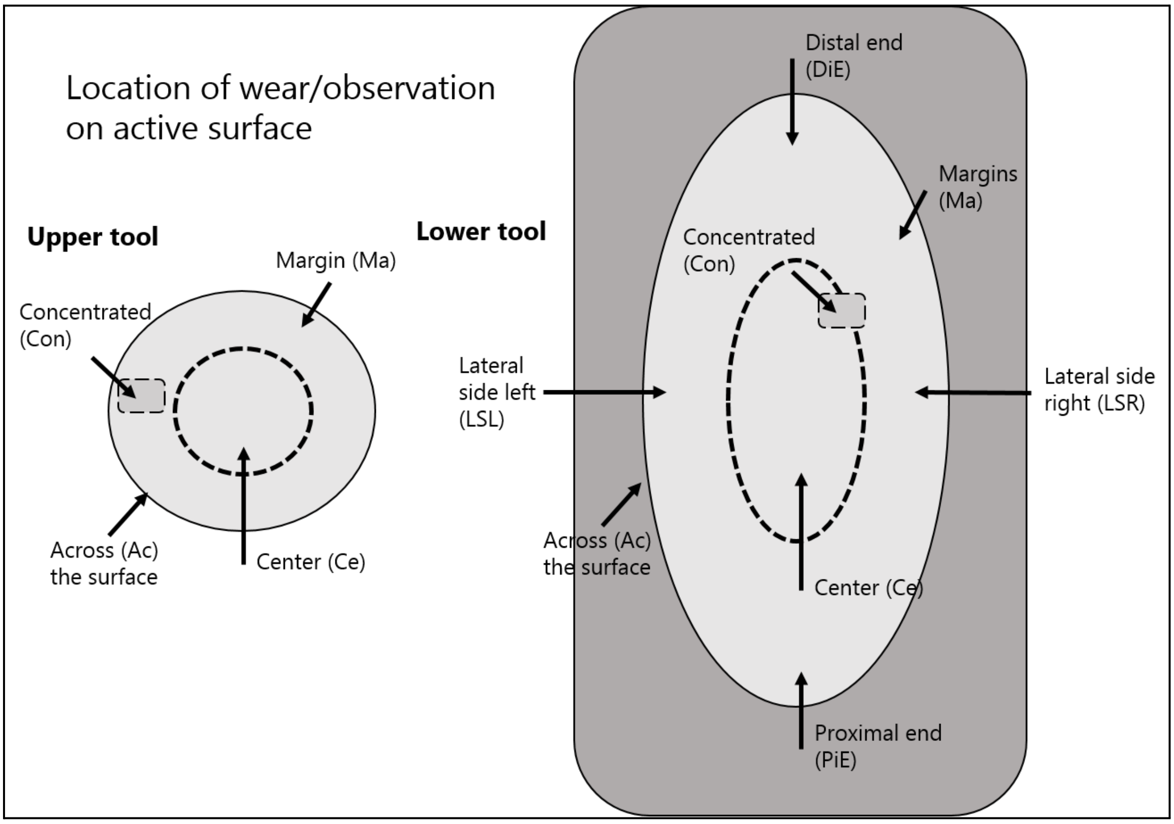
UWD 1cI. Pigment incidence (Level 1 + 2): High; Low; Both - I.e. present in high/low topography of surface

UWD 1cI. Pigment location (Level 1): Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side “left”; LR= lateral side “right”; LB= both lateral sides; Be = between (specify). Again all In relation to estimated or apparent directionality of tool (if applicable).

UWD 2a. Wear on Microtopography (Level 1-2)

UWD 2a. Wear on Microtopography - Summary (10-40x): A brief summary of observed wear

UWD 2a(x). Location of observation on face of micro. analysis: Description of the area on where use-wear analysis is based: Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side “left”; LR= lateral side “right”; LB= both lateral sides; Be = between (specify). Again all In relation to estimated or apparent directionality of tool (if applicable). See figure below:



x. PP’s schematic view of the location of traces and/or observation

UWD 2aI. Levelling (Level 1-2): present; absent

UWD 2aI. Of groundmass (Level 2): present; absent

UWD 2aI. Of phenocrysts (Level 2): present; absent

UWD 2aI. Distribution (Level 1): loose; covering; concentrated

UWD 2aI. Density (Level 1): seperated; close; connected

UWD 2aI. Incidence (Level 1): High; Low; Both - I.e. present on high/low topography of surface

UWD 2aI. Morphology (Level 2): Flat; rounded

UWD 2aI. Texture (Level 2): Smooth; Rough

UWD 2aI. Locations (Level 1): Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side "left"; LR= lateral side "right"; LB= both lateral sides; Be = between (specify). Again all In relation to estimated or apparent directionality of tool (if applicable).

UWD 2aII. Grain extraction desc. (Level 2) (10-40x): present; absent. The extraction of grains and description of area vacated (may be different from impact pits or an elaboration on **UWD 1b.**)[4]. For example: If area has pits **UWD 1b** but little to no extraction **UWD 2aII** ***it*** may be a hammered surface and <u>not</u> a surface <u>used for hammering</u> (J. Adams et al. 2009)

UWD 2aII. Distribution (Level 1): loose; covering; concentrated

UWD 2aII. Density (Level 1): separated;close;connected

UWD 2aII. Orientation/ direction (Level 1): In relation to estimated or apparent directionality of tool (if applicable): transverse;longitudinal;oblique;concentric;random

UWD 2aII. Depth (Level 2): Relative to surrounding matrix/groundmass: shallow (fine); deep (wide); intermediate; mixed

UWD 2aII. Shape plan (Level 2): circular;triangular;irregular;starlike;comet

UWD 2aII. Shape section (Level 2): U; V

UWD 2aII. Location on face (Level 1): Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side "left"; LR= lateral side "right"; LB= both lateral sides; Be = between (specify). Again all In relation to estimated or apparent directionality of tool (if applicable).

UWD 2aIII. (Micro)Fractures desc. (10-40x): present; absent

UWD 2aIII. On groundmass (Level 2): present; absent

UWD 2aIII. On phenocrysts (Level 2): present; absent

UWD 2aIII. Distribution (Level 1): loose; covering; concentrated

UWD 2aIII. Density (Level 1): separated;close;connected

UWD 2aIII. Incidence (Level 2): High; Low; Both - I.e. present on high/low topography of surface

UWD 2aIII. Orientation (Level 1): In relation to estimated or apparent directionality of tool (if applicable): transverse;longitudinal;oblique;concentric;random

UWD 2aIII. Depth (Level 2): Relative to surrounding matrix/groundmass: shallow (fine); deep (wide); intermediate; mixed

UWD 2aIII. Locations (Level 1): Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side "left"; LR= lateral side "right"; LB= both lateral sides; Be = between (specify). Again all In relation to estimated or apparent directionality of tool (if applicable).

[4] Not used as consistently as UWD 1b.

UWD 2aIV. Edge rounding (10-40x) (Level 2): **present; absent**

UWD 2aIV. Edge rounding incidence: high; low; both

UWD 2aIV. Locations (Level 1):

Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side “left”; LR= lateral side “right”; LB= both lateral sides; Be = between (specify). In relation to estimated or apparent directionality of tool (if applicable).

UWD 3. Linear traces (less 20x) (Level 1[5]): present; absent

UWD 3. Striations <0,5mm or Scratches >0,5mm

UWD 3. Distribution loose; covering; concentrated

UWD 3. Density separated; close; connected

UWD 3. Disposition random; concentric; parallel; oblique; perpendicular

UWD 3. Orientation/ direction In relation to estimated or apparent directionality of tool (if applicable): transversal;longitudinal;oblique;circular

UWD 3. Length short;long

UWD 3. Long. Morph: continuous;intermittent

UWD 3. Trans. Morph (Level 2): U;V

UWD 3. Location on face: Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side “left”; LR= lateral side “right”; LB= both lateral sides; Be = between (specify). In relation to estimated or apparent directionality of tool (if applicable).

UWD 4. Polish/sheen (NE-60x) (Level 1, 2, 3): present; absent

UWD 4. Distribution loose; covering; concentrated

UWD 4. Density separated;close;connected

UWD 4. Reflectivity slight;moderate;highly

UWD 4. Incidence High; Low; Both - I.e. present on high/low topography of surface

UWD 4. Location on face Ce= center; Ma= margins; Ac= across; DIE= distal end; PIE= proximal end; PDE= proximal and distal ends; LL= lateral side “left”; LR= lateral side “right”; LB= both lateral sides; Be = between (specify). Again all In relation to estimated or apparent directionality of tool (if applicable).

UWD 5. Main type of wear: Suggested main type of tribological wear: Adhesive; Fatigue; Abrasive; Tribochemical; N/A

Corresponding (GSS-?) - Ground Stone Sample no.: any samples (phyto/starch) taken of the same area or tool. Note **by** who and **Date**

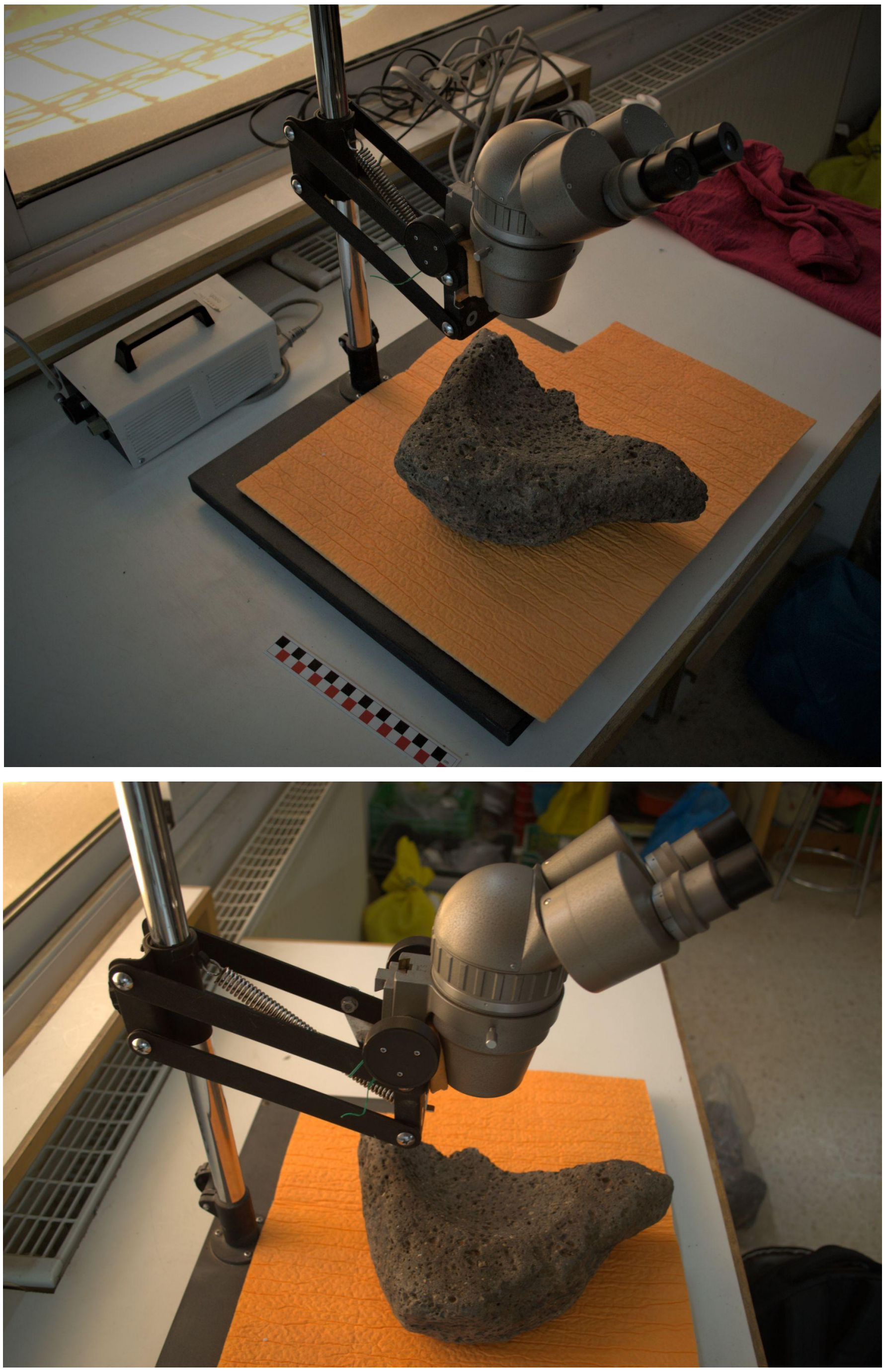
[5] Level 1 unless stated otherwise

Photo ref. Note tools to be photographed (by A. Pantos). Selected tools with wear are chosen by the following criteria: exemplary/representative of specific types use-wear also use-wear most commonly observed. Add priority

3.1.2. Microscope(s)

Main microscope: OLYMPUS SZ-III/SZ-Tr - Zoom-Stereo microscope

a. Photo of the CBRL, OLYMPUS SZ-III/SZ-Tr - Zoom-Stereo microscope set-up

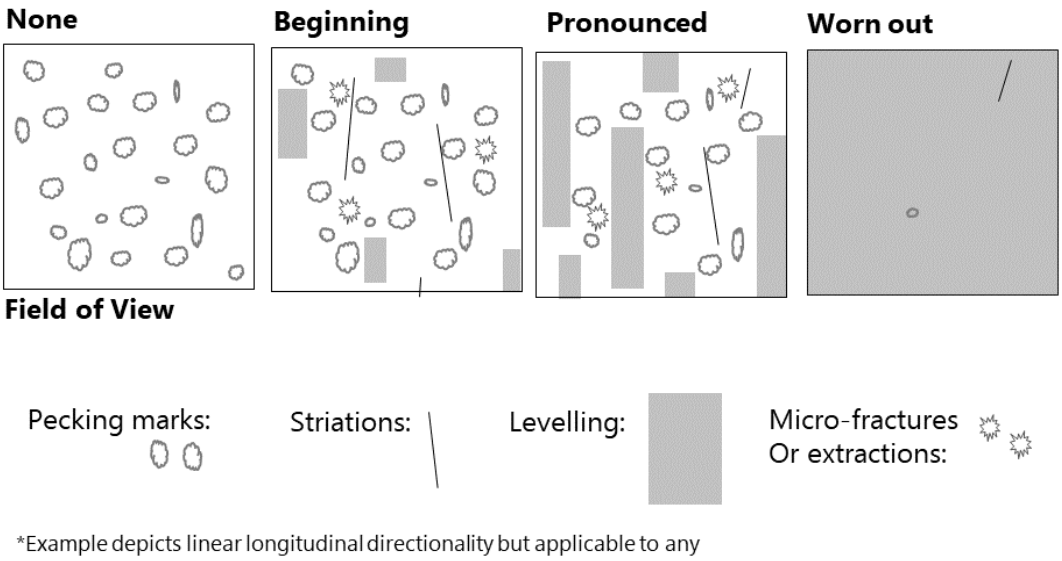


b. Two pictures of the alternative set up, still using the Olympus stereo-microscope, but here attached to a photography-station, a solution for larger artefacts that did not fit underneath the normal microscope set-up.

Other microscope: GX Microscopes - GXMMZS0745 (model)
Microscope for experimental tools in Copenhagen at the CSEAS/SWAP lab, at the University of Copenhagen, Denmark

4. Macroscopic-wear (see also in Appendix II)

Macro/Microscopic wear morphology (Level 0-2) directionality:



a. Macro/microscopic features used in determining strategy and state of discernible wear, see Appendix II: *Processing strategies and idealised use and wear progression*.

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Adams, J., S. Delgado, L. Dubreuil, C. Hamon, H. Plisson, and R. Risch. 2009. "FUNCTIONAL ANALYSIS OF MACRO-LITHIC ARTEFACTS: A FOCUS ON WORKING SURFACES." In *Non-Flint Raw Material Use in Prehistory Old Prejudices and New Directions - PROCEEDINGS OF THE XV WORLD CONGRESS (LISBON, 4-9 SEPTEMBER 2006)*, edited by F. {Sternke, L. Eigeland, and L-J }. Costa, 43–66. BAR International Series 1939. Archaeopress.

Adams, Jenny L. 2002. *Ground Stone Analysis: A Technological Approach*. University of Utah Press.

Dubreuil, Laure. 2004. "Long-Term Trends in Natufian Subsistence: A Use-Wear Analysis of Ground Stone Tools." *Journal of Archaeological Science* 31 (11): 1613–29.

Dubreuil, Laure, and Daniel Savage. 2014. "Ground Stones: A Synthesis of the Use-Wear Approach." *Journal of Archaeological Science* 48 (August): 139–53.

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Appendix Ib:
Raw material notes for Ground Stone use-wear

1. Initial petrographic description - by PP[6]

1.1. the Harrat-ash-Sham(ah).
The basalt the tools analysed in this study is made of comes from the area around Qa' Shubayqa. The analysed assemblage is from the to sites Shubayqa 1 and Shubayqa 6 which are situated on the edge of a mudflat (a *Qa'*) in what Bender refers to as *"[t]he Northern Plateau Basalt province"* (Bender, F 1975) of Jordan: the *Harrat-ash-Shams* desert a basalt desert that spreads from modern day Southeast Syria and the extinct volcano Jebel Druze, through eastern Jordan and into Northwestern Saudi Arabia. *"The [harra] mainly consists of massive lava flows, which are often separated by sedimentary horizons and red lateritic weathering crusts…"* (Krienitz et al. 2007). It was formed through volcanic activity from late Tertiary and into the Quaternary (Pliocene-Pleistocene) c. 8.9 to 0.1 million years ago (Allison et al. 2000).

1.2. The Harrat-ash-Sham basalts
This description of the local *Harrat-ash-Sham* basalt (henceforth referred to simply as the *harra*) is currently based on the work of other researchers, i.e. geologists working on the basalt flows of the local region principally: (Allison et al. 2000; Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006; Odat 2015; Shaw et al. 2003) and not on a specific analysis of our assemblage as such. More detailed analysis of our own specimens are pending. Chemically the basalt of the *harra* can be defined as mafic alkali to sub-alkali basalt or basanite (Ibrahim and Al-Malabeh 2006; Krienitz et al. 2007; Shaw et al. 2003)(Allison et al. 2000; Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006; Odat 2015; Shaw et al. 2003); (Ibrahim and Al-Malabeh 2006; Krienitz et al. 2007; Shaw et al. 2003). It often features vesicles and generally a porphyritic texture, fine to medium grained, holocrystalline with phenocrysts primirally of olivine, plagioclase and clinopyroxene, situated within an microcrystalline to cryptocrystalline groundmass (Al-Malabah et al. 2002; Odat 2015; Shaw et al. 2003). The groundmass also consists of plagioclase, olivine and clinopyroxene, as well as glass and Fe–Ti oxides (Al-Malabah et al. 2002; Krienitz et al. 2007; Odat 2015). *I.e.* the main minerals of both phenocrysts and groundmass is plagioclase, olivine and clinopyroxene (Al-Malabah et al. 2002; Odat 2015; Shaw et al. 2003). Rocks modally contains anywhere between 5 to 20% of phenocrysts of all types (Shaw et al. 2003).

1.2.1. Phenocrysts and Groundmass
Olivine are the most common phenocrysts (Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006; Shaw et al. 2003). These can be anywhere between 0.5 to 2-3 mm in size, crystals vary in shape between euhedral, subhedral and are tabular (Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006; Shaw et al. 2003). The olivine phenocrysts are in some cases partly or completely turned turned into iddingsite as Shaw et al. (2003) also note. Plagioclase

[6] This author, PhD.-fellow, Patrick Nørskov Pedersen

phenocrysts are the second most common, and these are euhedral, equant-tabular in shape, cluster twinned zoned and are between 0.4 and 3.8 mm in size (Al-Malabah et al. 2002; Odat 2015)(Ibrahim and Al-Malabeh 2006);(Al-Malabah et al. 2002; Odat 2015).
Clinopyroxene phenocryst crystals are mostly anhedral, equant in shape with size up to 1,5-2.0 mm ((Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006).

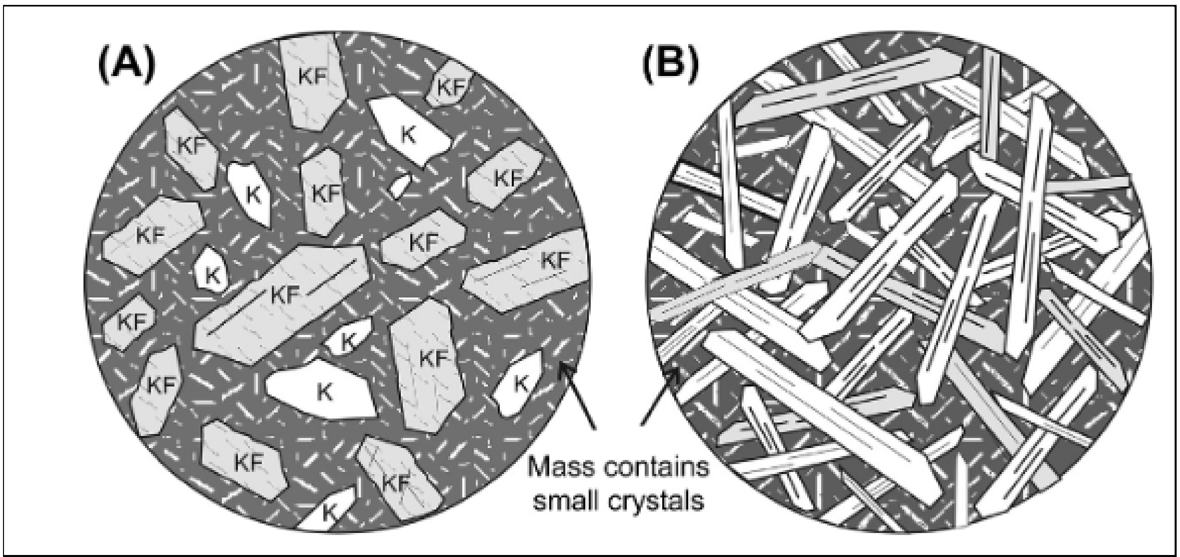

Figure 1: Phenocrysts and groundmass, from (Haldar and Tišljar 2014 - Introduction to Mineralogy and Petrology).

Plagioclase is the most abundant mineral making up to 60 vol% of the rock (Al-Malabah et al. 2002; Odat 2015)(Ibrahim and Al-Malabeh 2006)). In the groundmass plagioclase is fine-grained, acicular laths with intergranular and trachytic textures ((Ibrahim and Al-Malabeh 2006).
Clinopyroxene (augite) make up around 20 vol% of the rock and is the second most common mineral (Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006). Clinopyroxene crystals in the groundmass are anhedral, equant, also fine to very fine-grained and intergranular ((Ibrahim and Al-Malabeh 2006). In the groundmass olivine crystals are anhedral, equant, also fine to very fine-grained and intergranular ((Ibrahim and Al-Malabeh 2006). Modally clinopyroxene forms 20–24% of the total groundmass, olivine 15-20% and the remaining 55-60% is then plagioclase ((Ibrahim and Al-Malabeh 2006)

1.2.2. Summary

The texture, an important aspect in use-wear analysis. The texture of the *harra* basalt is porphyritic with phenocrysts most commonly of olivine between 0.5 to 2 mm in size, between euhedral, subhedral in shape, followed by plagioclase phenocrysts, these are euhedral, equant-tabular in shape, cluster twinned zoned and are between 0.4 and 3.8 mm in size, and finally are clinopyroxene phenocrysts up to 1.5-2.0 mm in size and anhedral, equant-tabular in shape (Al-Malabah et al. 2002; Ibrahim and Al-Malabeh 2006; Shaw et al. 2003).

In the microcrystalline to cryptocrystalline groundmass (Al-Malabah et al. 2002; Odat 2015; Shaw et al. 2003), plagioclase is most common, grains are fine-grained acicular laths, with intergranular and trachytic textures, whereas olivine and clinopyroxene crystals, the remaining 1520% and 20-24% respectively are anhedral, equant, but also fine to very fine-grained and intergranular ((Ibrahim and Al-Malabeh 2006). They are often vesicular though not exclusively (see below). Some of these vesicles feature amygdules, probably of calcite. Variations in the exact amounts of these individual minerals, that is their modal composition, means three petro-types from the *harra* can be recognized: *olivine-plagioclase basalt*, *olivine-pyroxene basalt* and *olivine basalt* (Ibrahim and Al-Malabeh 2006). Following (Ibrahim and Al-Malabeh 2006) we refer to these collectively as: *alkali olivine basalt* (AOB).

1.2.3. Subdividing basalt

Below is presented a table originally devised for on-site initial analysis of the ground stone tool. This was done as a way to subdivide an assemblage which is more or less exclusively made of basalt. These sub subdivisions do not necessarily conform to the above petrographic description of the *harra* basalts, but do not, or should not, conflict with it either. Instead these basalt types are based on macroscopic (naked-eye) observations of the number of vesicles, colour and density of hand specimens. These observations are ones that must have been observable for ancient tool makers as well, and may indicate certain attributes that they deemed desirable.

Basalt (AOB)	**Type Description**	**Qualitative description**
I	Vesicular Basalt	Grey to dark grey, heavy/dense, very small (less than 1 mm) and very few vesicles (3 or less per 5x5 mm area)
II	Non-vesicular Basalt	Blackish grey, extremely dense/heavy with no visible vesicles
III	Vesicular Basalt	Grey to dark grey, dense, small (1-2 mm) but numerous vesicles (at least 4 per 5x5 mm area)
IV	Vesicular Basalt	Grey to dark grey, lightweight, numerous large vesicles (2 to 10mm in diameter)
Un.	Vesicular Basalt	Vesicular basalt that could not be categorized as either I, III or IV

Table: Naked-eye observations, in field divisions of basalt (PP)

1.2.4. A brief note on rock durability

By some modern groups engaged in traditional food processing ground stone tools are used for generations (Hayden and Nelson 1981; Searcy 2011). The rocks used for ground stone tools are generally very durable, at least compared to chipped stone, though this is of course related to what rock type (Delgado-Raack, Gómez-Gras, and Risch 2009). This means that, potentially, they are not only shaped by each individual person grinding/pounding, but in these cases by generations of people processing.

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Appendix II:

Processing strategies, idealised use and wear progression - by PP

A1. Confined Reciprocal Grinding (CRG)

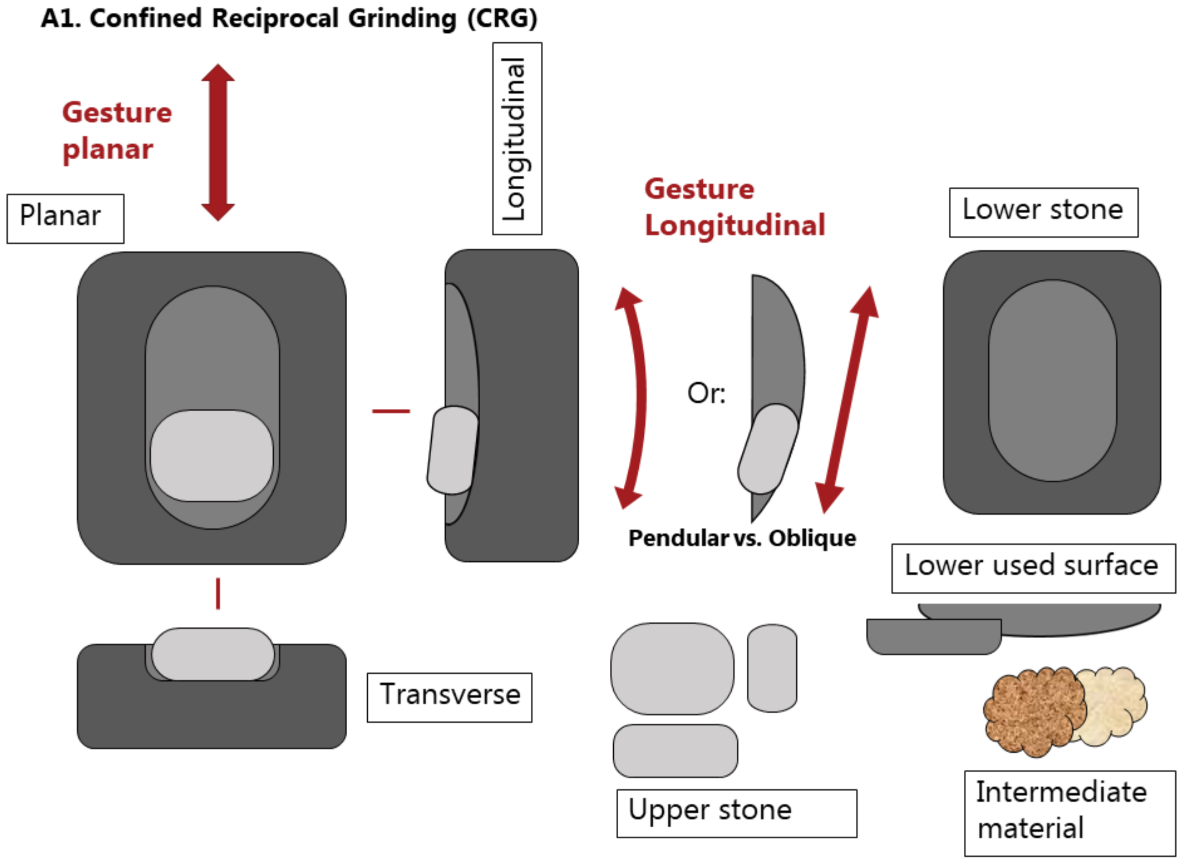

Figure 1: A1. CRG Overall idealised processing strategy and tools: Ovate/rectilinear handstone (Oval/flat profile), basin slab (oval surface with concave profile[s]).

1. **Before use**
   a. Lower tool (Level 0): The use surface of the lower tool is at maximum width and length (planar) = MWL(L) and at minimum depth = mD(L) and minimum longitudinal and transverse concavity = mLCA(L) and mTCA(L)
      i. **Macro/micro** (Level 1-2): pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
   b. Upper tool (Level 0): : is at maximum width and length (planar) = MWL(U), minimum longitudinal and transverse convexity = mLCX(U) and mTCX(U), as well as maximum thickness MT(U)
      i. **Macro/micro** (Level 1-2): Pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged.

Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass

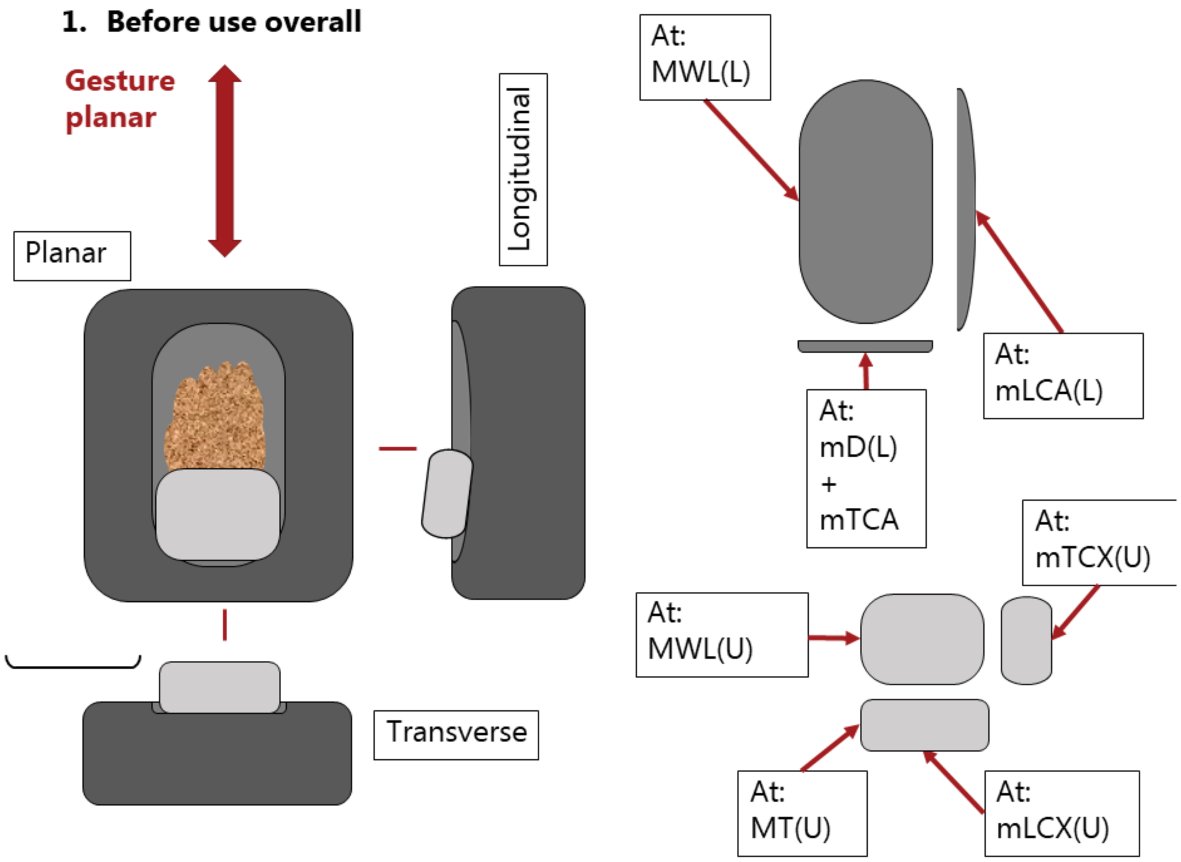

Figure 2: Idealised Stage 1 - before use overall view

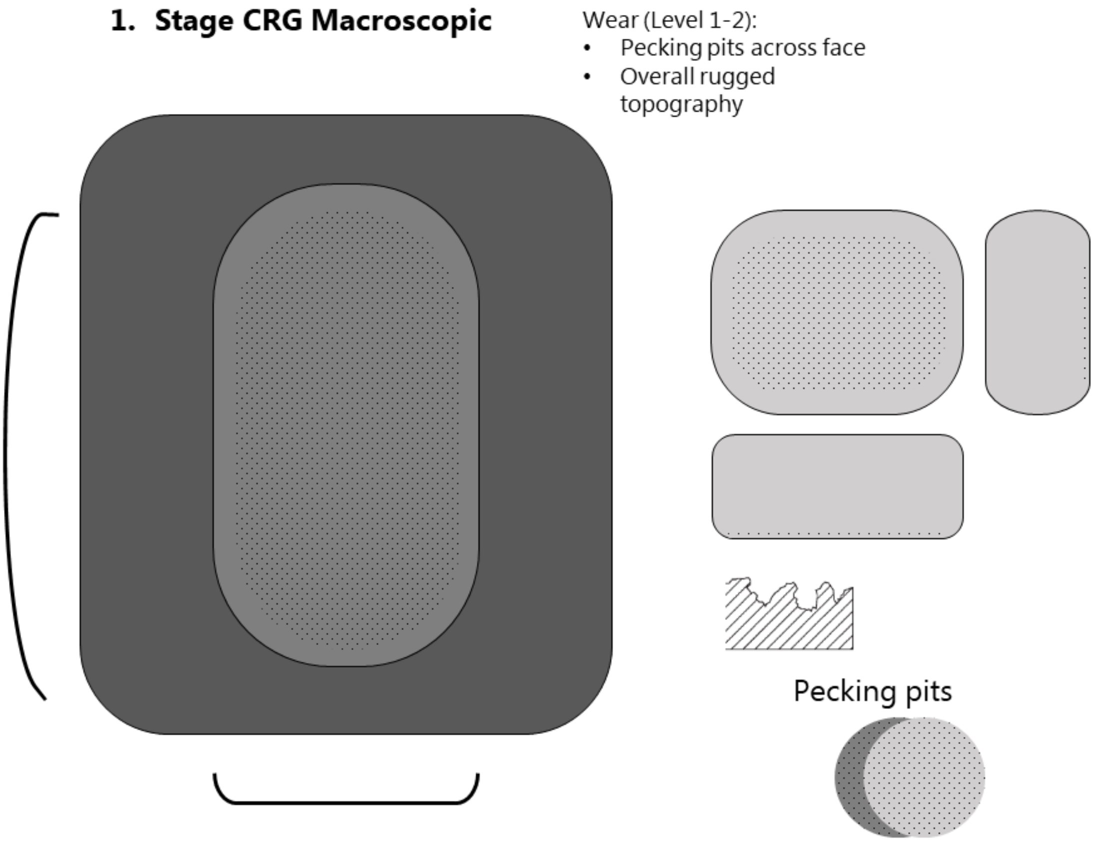

Figure 3: Idealised Stage 1 - before use macroscopic view.[7]

2. **Initial use phase**

As the two stones (upper & lower) engage each other and the intermediate material the following happens:

a. Lower tool (Level 0): depth D(L) and longitudinal and transverse concavity LCA(L) + TCA(L) will begin to increase as the tool loses mass: mD(L) → xD(L), and mLCA(L) and mTCA(L) → yLCA(L) and yTCA(L) respectively. The used surface's maximum width (planar) will at the same time decrease with this process, but the length stay more or less the same from MWL(L) → ML(L) and xW(L)

    i. **Macro/micro** (Level 1-2): Overall levelling begins at distal and proximal margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at these margins (possibly a result of most stone/stone contact). The lateral margins are also affected, but less and more slowly than the others. Some striations and/or sheen may also appear along these margins.
    Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be most intense at

[7] Figure by P.N. Pedersen, but note that the topography profiles used in the figures are borrowed from Adams et. al. 2009. This is the case for all following figures.

the distal and proximal margins as these receive more pressure. A beginning linear longitudinal distribution/patterning of the of wear

b. Upper tool (Level 0): MT(U) will begin to decrease as tool loses mass MT(U) → xT(U). The used surface's maximum length (planar) will decrease with this process, but the width stays more or less the same from MWL(U) → MW(U) and xL(U). Minimum longitudinal and transverse convexity mLCX(U) and mTCX(U) will increase to yLCX(U) and yTCX(U). However, see *Surface wear management upper* further below. Upper stone may also become more ovate and less rectangular as the corners of the stone wear.

    i. **Macro/micro** (Level 1-2): Overall levelling begins at the margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense outside of the centre and at margins as these receive more pressure. A beginning linear, transverse patterning in the distribution of wear

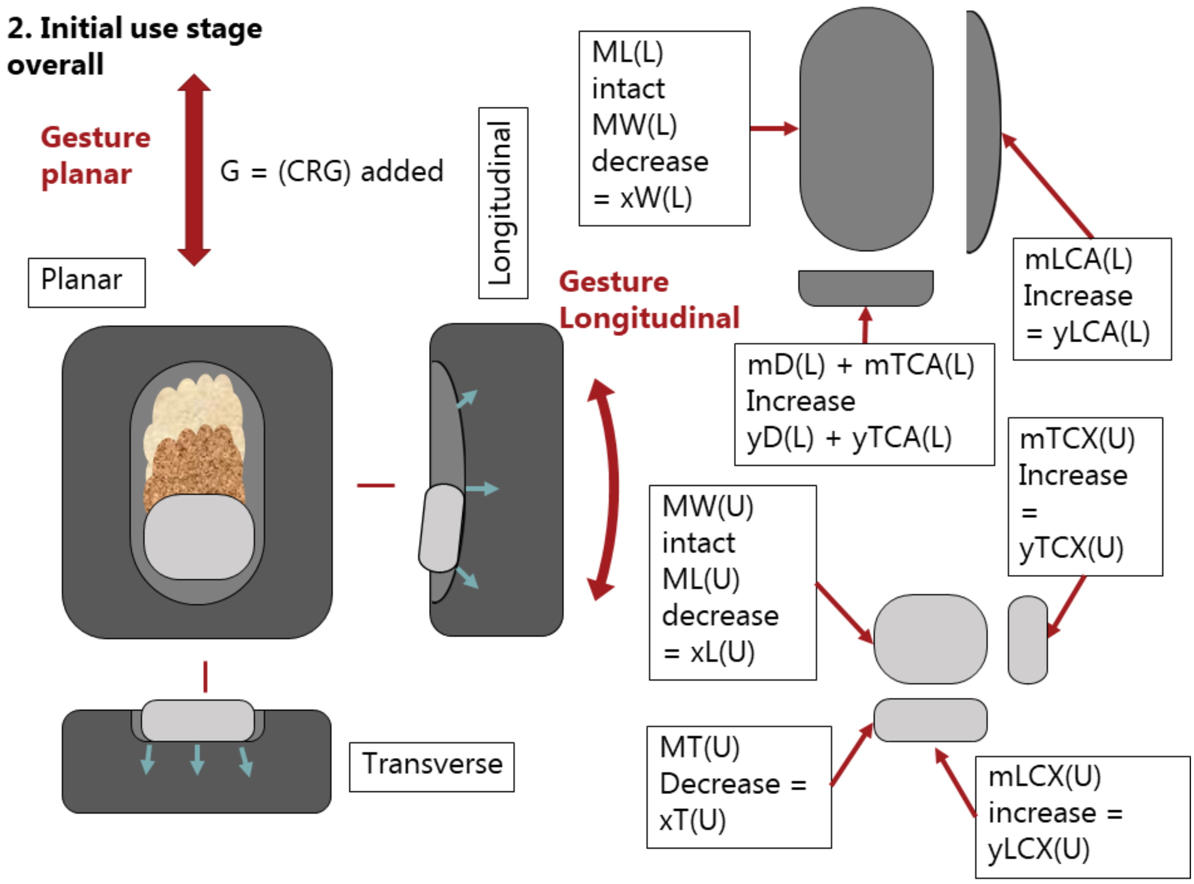

Figure 4: Idealised Stage 2 - initial use, overall view

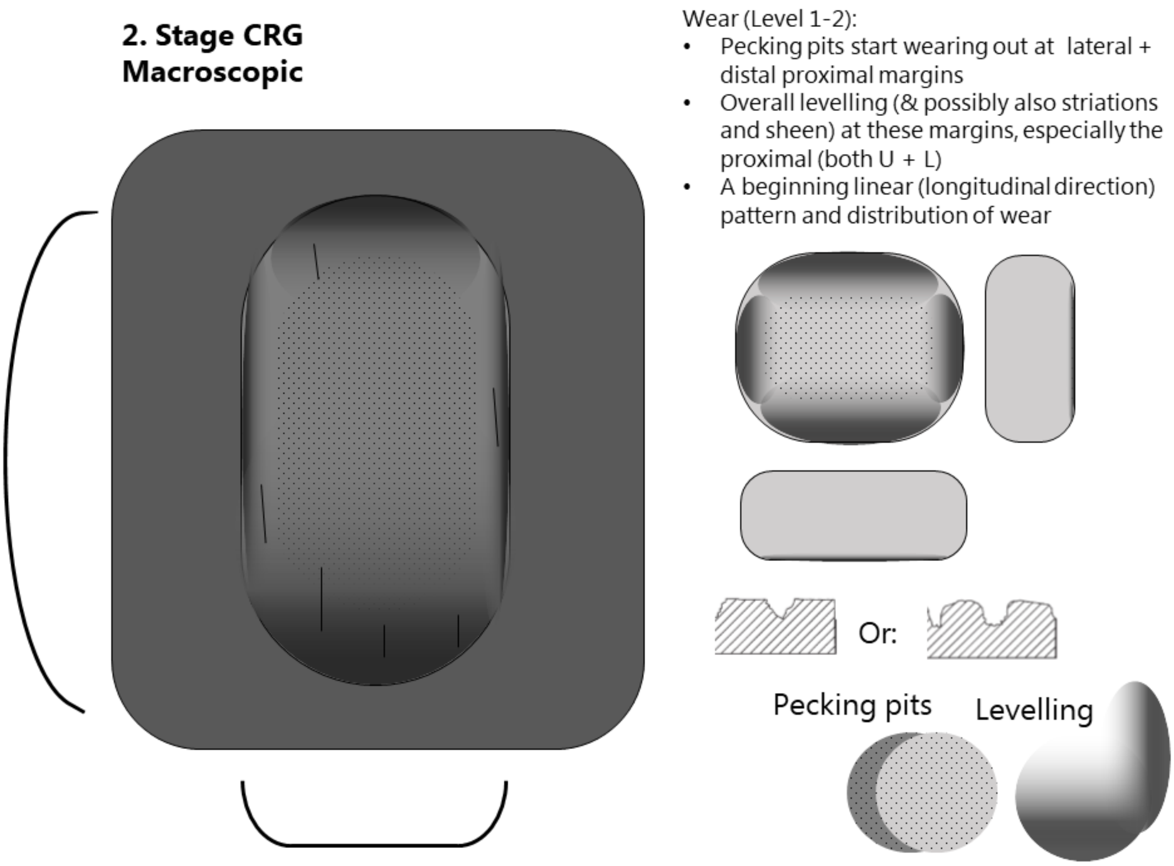

Figure 5: Idealised Stage 2 - initial use, macroscopic view.[8]

3. **Continued use phase**

As use continues through cycles of processing with the tools and re-pecking of both upper and the lower tools, both lose mass. However as the lower face becomes deeper (a new upper tool can always be introduced), a technological choice is faced to continue use on the same face or to open up a new face somewhere else on the tool. Here I have assumed use continues on the same face, in a smaller area (but see a more detailed explanation below in *Surface wear management*). Either way on the new face, the previous process repeats itself. The following happens:

a. Lower tool (Level 0): depth yD(L) and concavity yT-LCA(L) and of the original face stop increasing as a smaller area is used and a "new" face starts, set through the old. This has a new minimum depth, longitudinal and transverse concavity and maximum planar size $m^2D(L)$, $m^2TCA(L)$ and $m^2LCA(L)$, $M^2WL(L)$. These through use then become → $y^2D(L)$, $y^2TCA(L)$ and $y^2LCA(L)$ and $x^2W(L)$
   i. **Macro/micro** (Level 1-2): previous process repeats on this new face, erasing older wear. First of overall levelling again begins at the proximal and distal margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at all margins (possibly a

[8] Figure by P.N. Pedersen, but note that the topography profiles used in the figures are borrowed from Adams et. al. 2009. This is the case for all following figures.

result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense around the centre and at margins as these receive more pressure. More pronounced linear, longitudinal patterning in the distribution of wear. Possibly intensifies on this new face

b. Upper tool (Level 0): L(U) and T(U) continue to decrease as the tool loses mass, also erasing older wear. Goeas from xL(U) / xT(U) → zWL(U) / zT(U). Convexity, especially transverse will continue increase to zTCX(U) and zLCX(U), but again see *Surface wear management upper*

    i. **Macro/micro** (Level 1-2): Overall levelling continues at the margins along with a wearing out of pecking pits, only a few now left at centre. Striations and/or sheen may also appear at margins, possibly moving further in (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense outside of the centre and margins as these receive more pressure. More pronounced linear, transverse patterning in the distribution of wear. Upper stone may also become more oval to discoidal rather than ovate as the corners of the stone continue to wear.

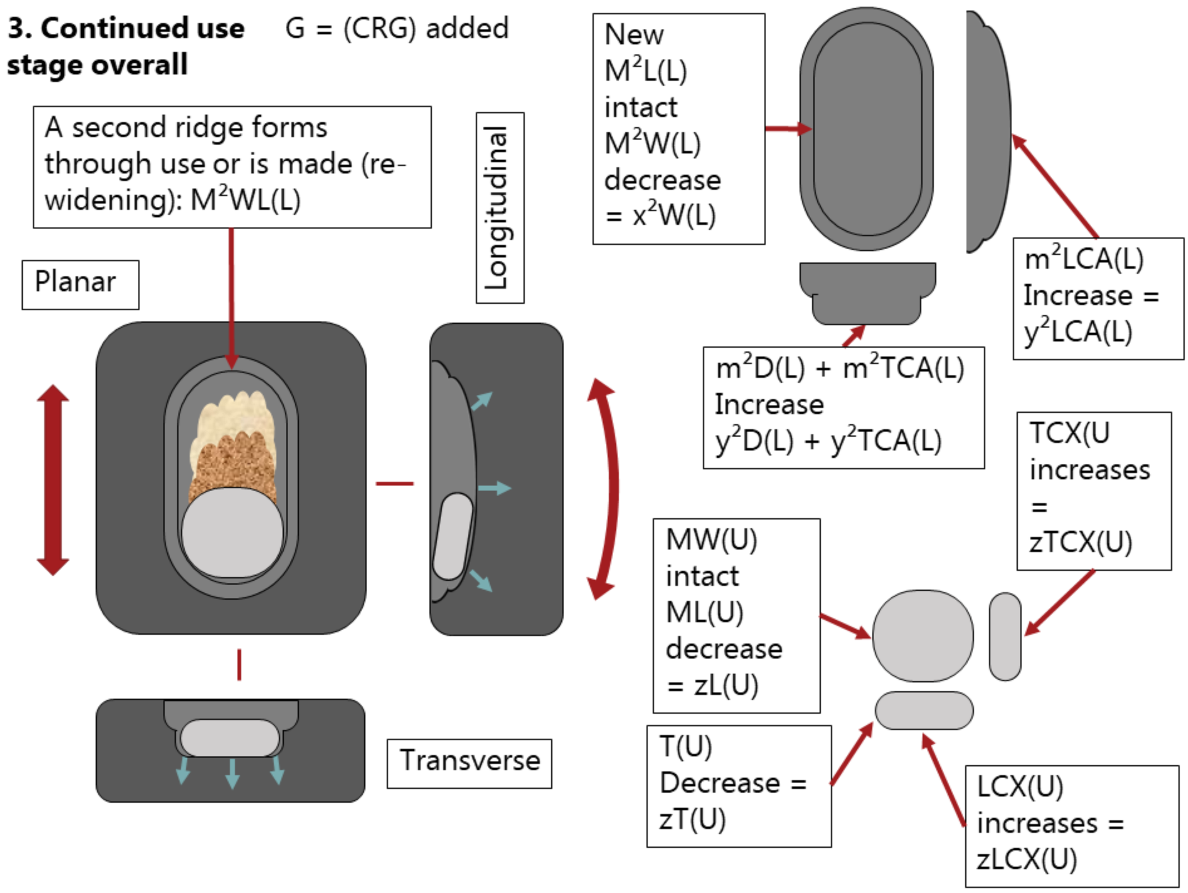

Figure 6: Idealised Stage 3 - Continued use, overall view

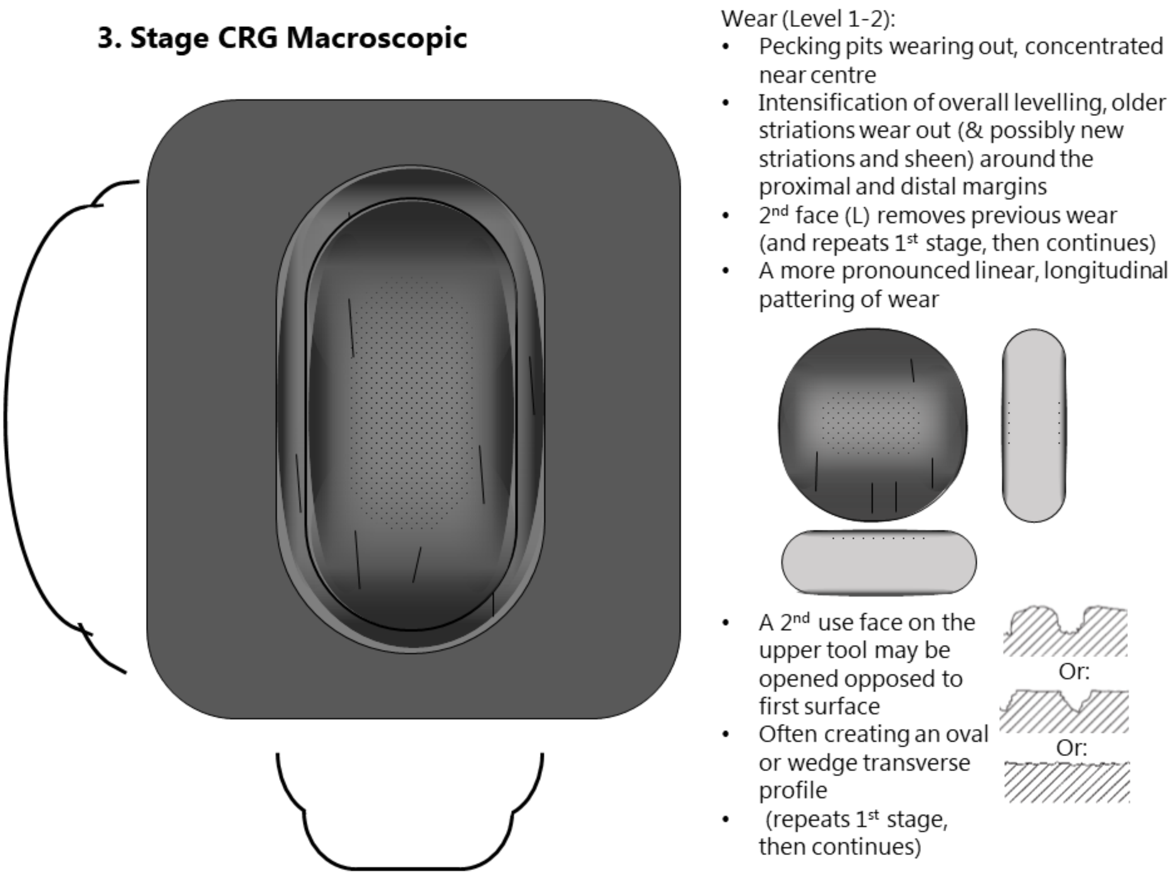

Figure 7: Idealised Stage 3 - continued use, macroscopic view

4. **Worn out phase**

The final stage, i.e. before a new round of pecking or breakage (unintentional and/or intentional), discard, abandonment. Pits all worn out. Intense overall levelling across the face. Depending on contact material a microtopography of covering: micro fractures, grain rounding or levelling, a sheen seen across face.Rarely found complete archaeologically (? examp.) possibly because of intentional breakage(?) or immediate re-pecking/re-use.

Surface wear management upper (individual wear)

The type of wear management and technological choices of the operator will have an effect on the morphology of the upper stone. For example, if wear is managed by exploiting both sides (faces) of the handstone. This will then decrease the thickness faster as both faces lose mass and slow down (or negate) the increase in the convexity. Continued use on two faces will probably continue to decrease thickness and increase convexity steadily. If on the other hand the same face is used constantly, mainly the margins of the tool will lose mass, but thickness decreases slower, while convexity increases faster. (example shubayqa 6). presence of pecking pits at center and levelling at proximal and distal margins (see below), as well as some on the edges of lateral sides may be a result of the least stone/stone contact happening at centre (see Martinez et al. 2013) or rather more contact with the intermediate material there. Most of the grinding happens at the margins as the upper stone is moved, pressing forwards and backwards by the operator (Dietrich et al. 2019; Dietrich and Haibt 2020), material being pressed down with the proximal and distal margins.

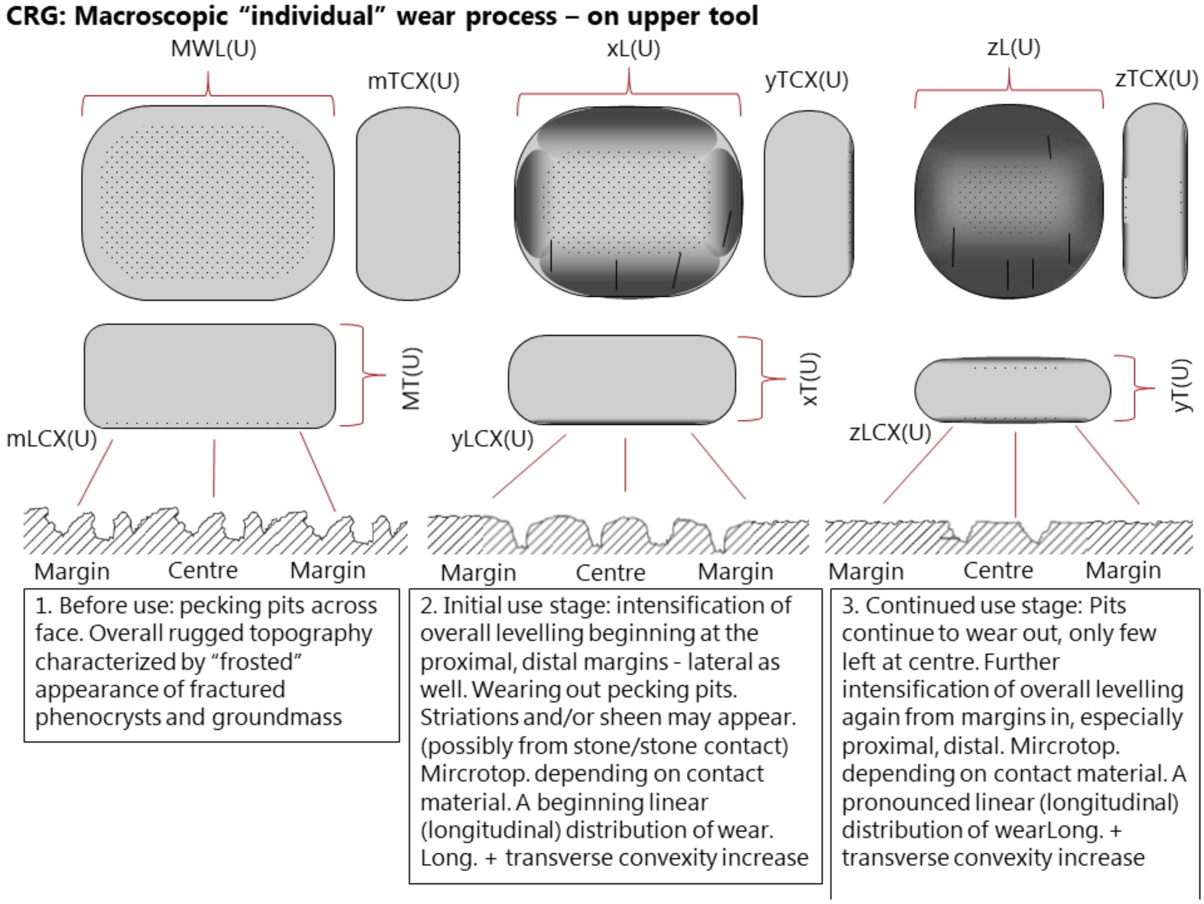

Figure 8: Idealised stages - upper tool individual wear, overall/macroscopic view

Surface wear management lower (individual wear)

Again we may note that the type of wear management will have an effect on the lower stone, if wear is managed by using a smaller area on the same surface or by opening a new surface (for example on the opposite side). As the first lower face gets deeper it the active surface either by choice or naturally gets narrower (smaller), the ridges/edges/ rim become higher and more concave , and grinding is possibly more comfortable (or easily) achieved in the center within a narrower/smaller face a new but smaller area than previous face. These choices and limitations, thus creates a stepped face as we see here (Figure 9). A more confined face, restarting the first stages of wear. Most of the grinding happens at the margins, (as with the upper stone) as the material is moved, pressing forwards and backwards by the operator causing the material to be pressed against the lateral sides (walls) of the lower face as well as against the proximal and distal margins.

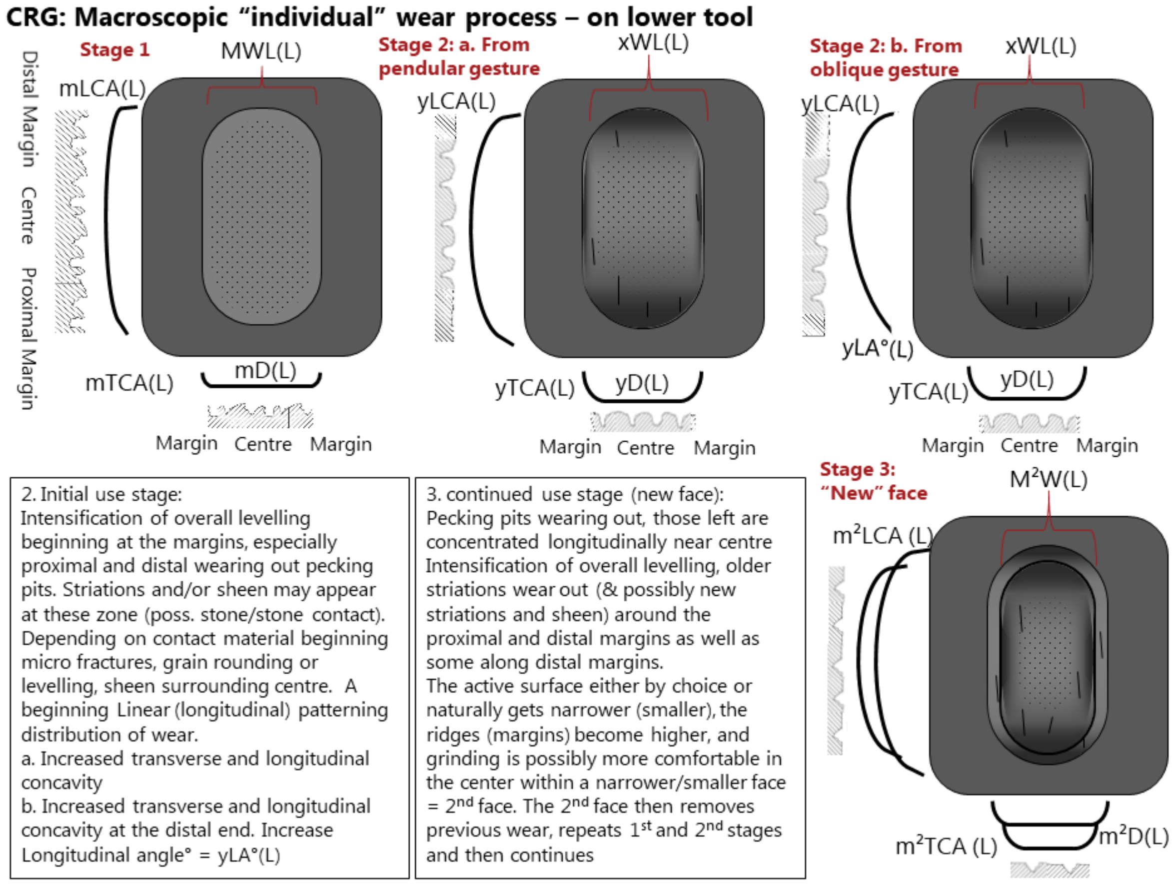

Figure 9: Idealised stages - lower tool individual wear, overall/macroscopic view. Note difference in Stage 2a and 2b according to gestures. (Stage 1 - description similar to other stage 1 descriptions elsewhere left out here because of limited space).

Two different longitudinal wear trajectories

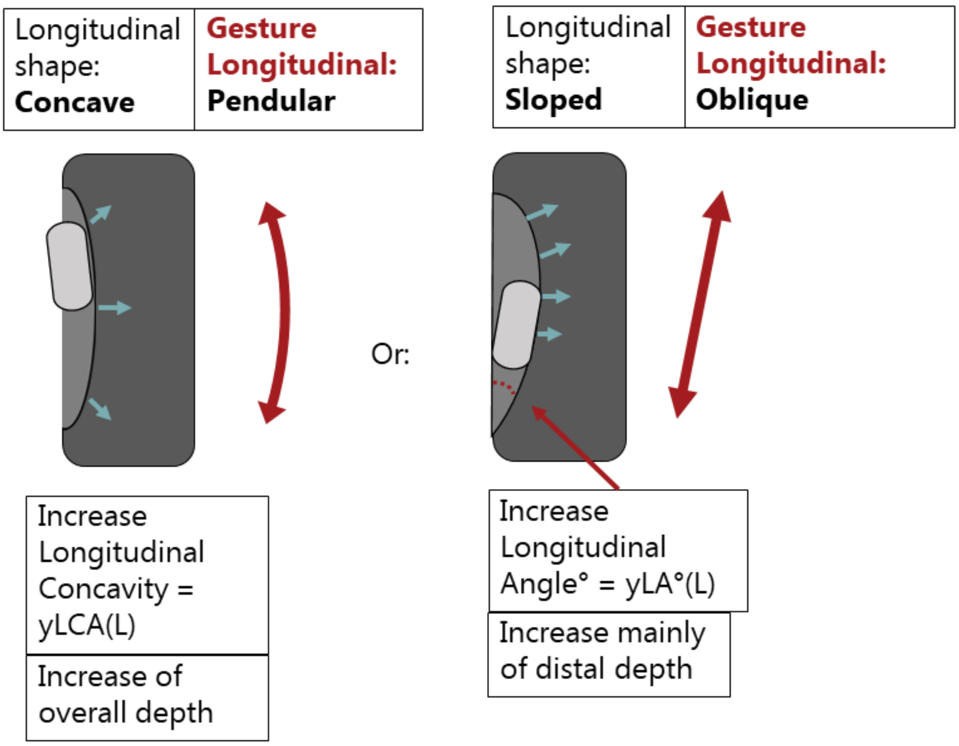

Figure 10: Idealised trajectories of lower tool individual wear, overall view. Note difference in pendular vs. oblique gesture. The main gesture: a reciprocal resting percussion fall within the CRG strategy.

Summary:

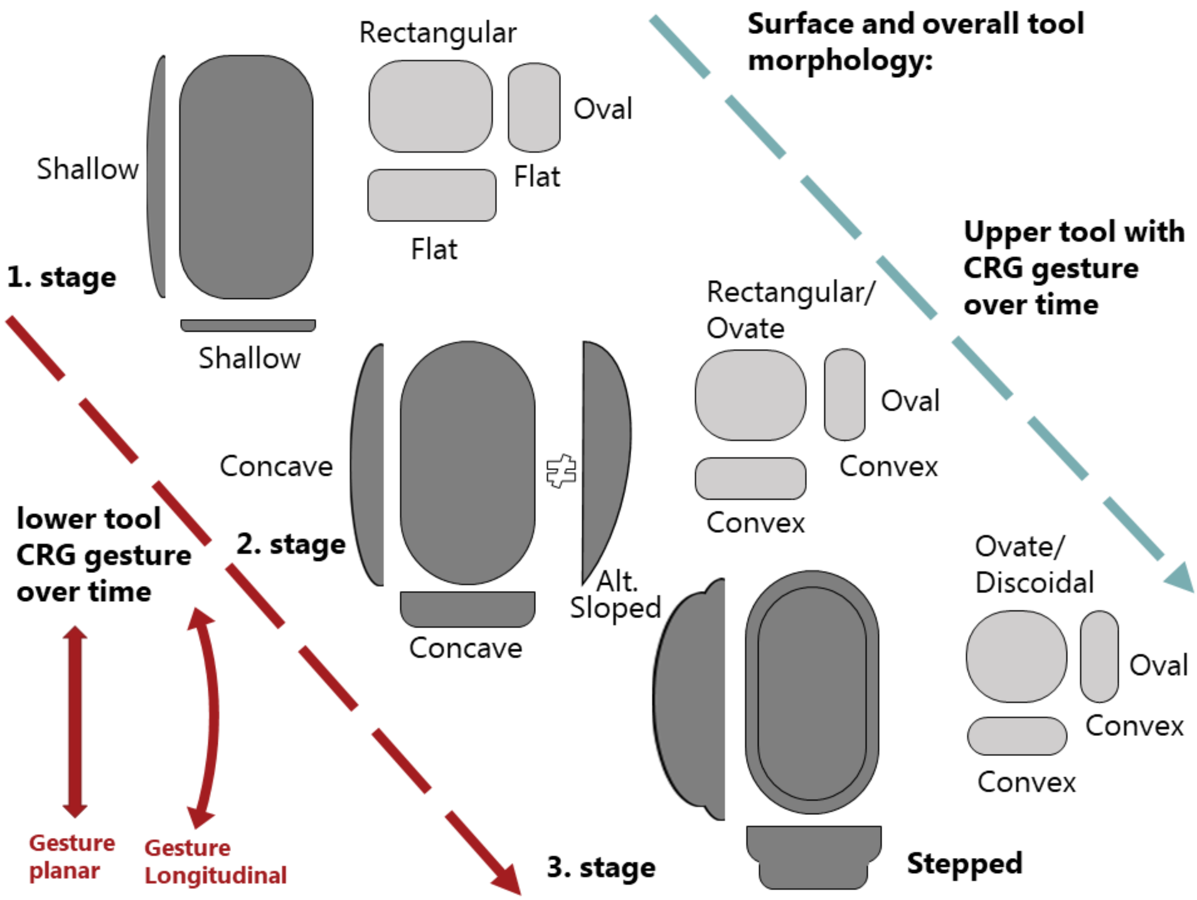

Figure 11: Idealised trajectories of both upper and lower tools individual wear, in an overall view. Again note the difference in pendular vs. oblique gesture, i,e. Concave vs. sloped longitudinal profiles. Note also the opening of the second face within the previous surface. All fall within the CRG strategy.

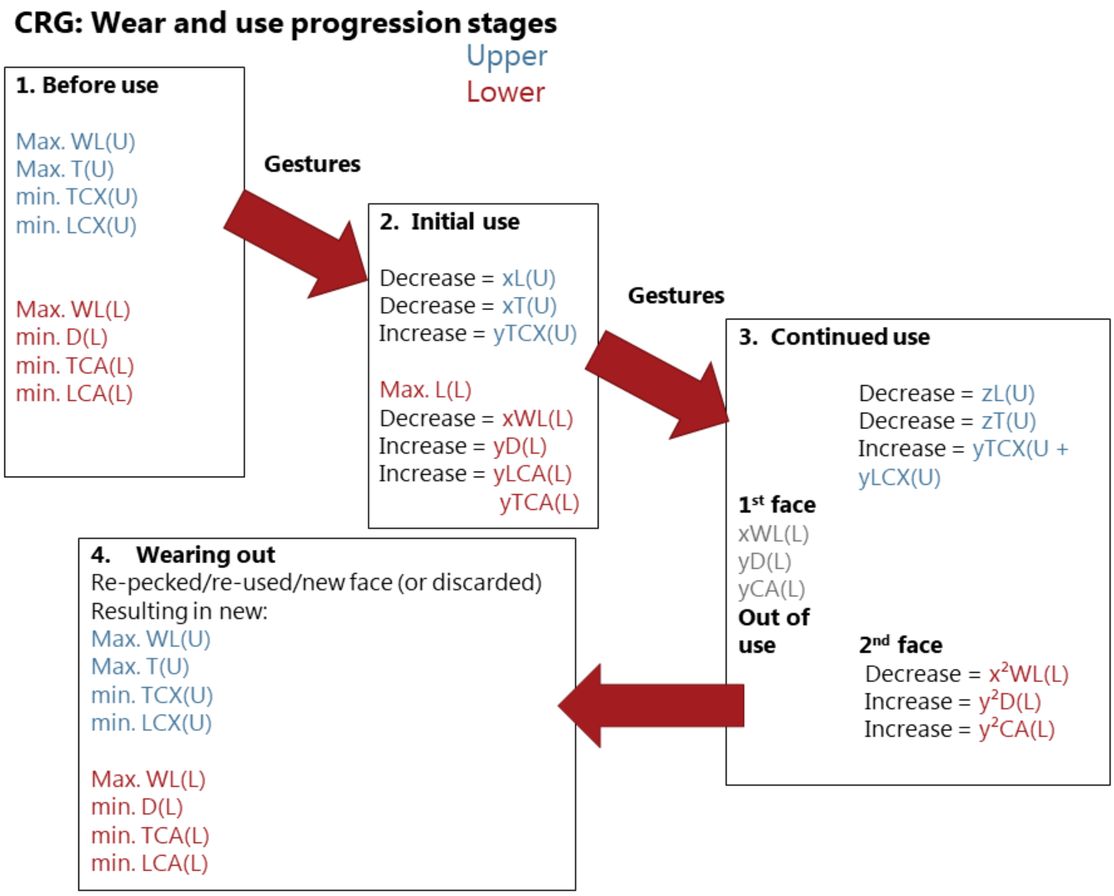

Figure 12: Generic "measurements" of the idealised morphology and how these change through use.

A1. Body positions and examples:

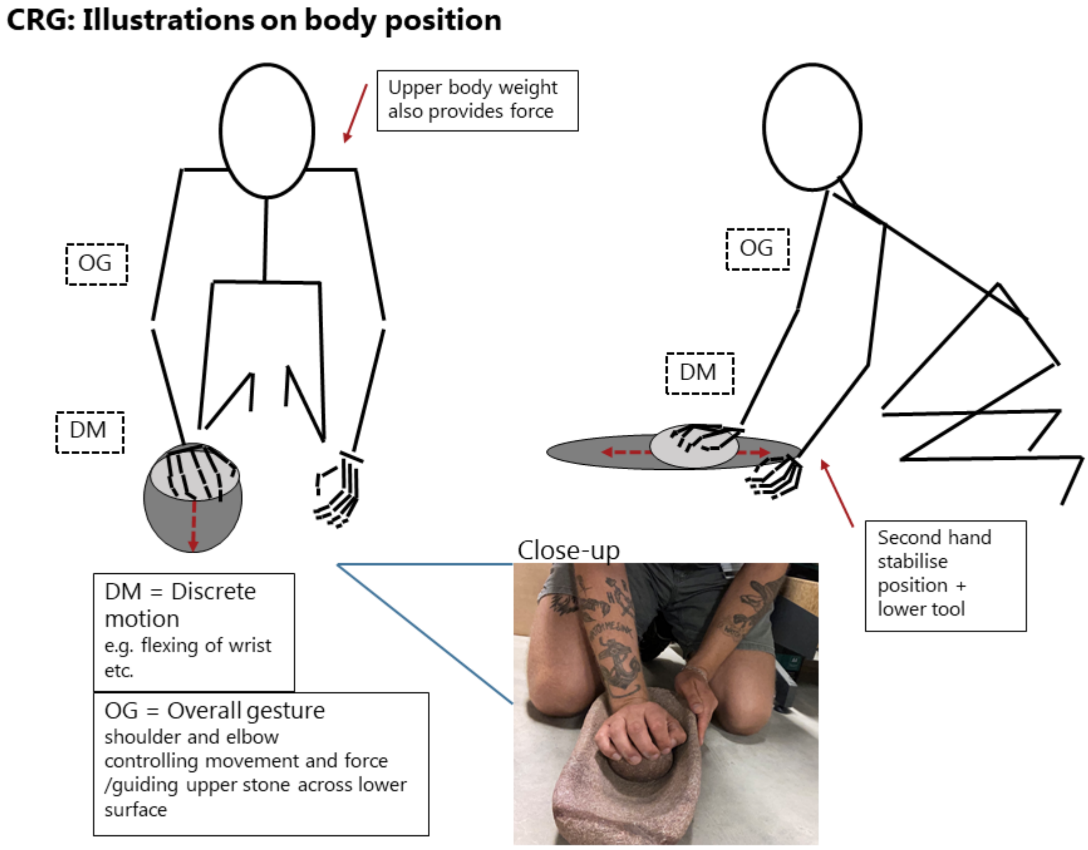

Figure 13: A1. CRG Body positions, gesture

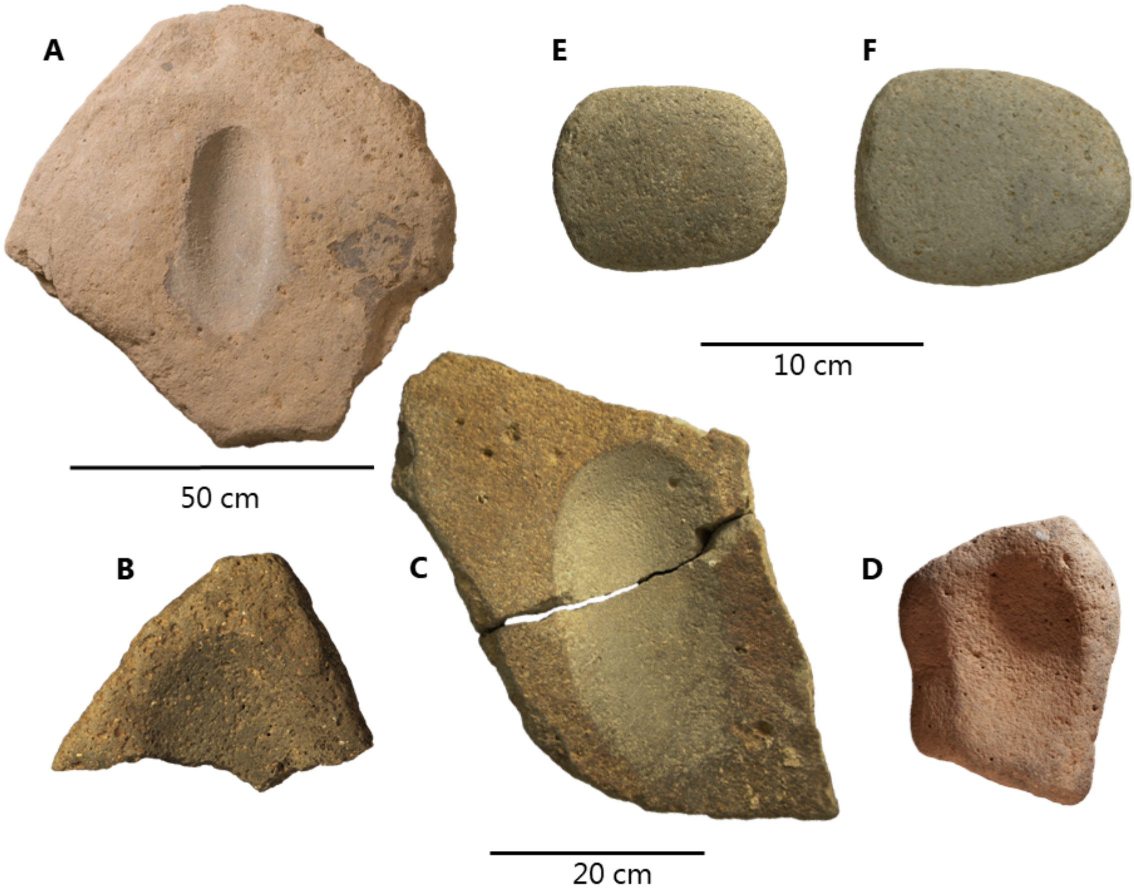

Figure 14: Archaeological examples of A1. CRG basalt tools from Shubayqa 1 and 6: A-C + E-F PPNA-early PPNB examples, D Late Natufian phase. A-D lower tools, basin slabs E-F Upper tools, ovate/rectilinear handstones.

The general size of the upper tools for this strategy. from Ovate, rectangular, handstone sizes (n=84). Length is: max. 150 mm, min. 46 mm, avg. 103,1 mm. Width: max. 120 mm, min. 36 mm, avg. 82,7 mm. Thickness: max. 99 mm, min. 18 mm, avg. 49,5 mm Face size (calculated as ellipse: a x b x π): a 65,05 mm x b 41,35 mm x π = avg. 84,50 cm²

The general size of the lower tools for this strategy from Basin and Trough slabs with oval, sub-rectangular, elliptically shaped active surface face sizes (n=9). Length: max. 400 mm, min. 305 mm, avg. 354,4 mm. Width: max. 252 mm, min. 140 mm, avg. 178,3 mm. Depth: max. 70 mm, min. 13 mm, avg. 39,2 mm. Face size (as ellipse: a x b x π): a 177,20 mm x b 89,15 mm x π = avg. 496,28 cm²

Shape	Overall plan	#	%	Face trans. profile*	#	%	Face longitudinal profile	#	%
	ovate	93	**86**	*lens*	10	**9**	*concave*	4	**4**
	rectangular	11	**10**	*oval*	31	**29**	*convex*	27	**25**
	square	4	**4**	*plano-convex*	18	**17**	*flat*	39	**36**
				plano-irregular	5	**5**	*unidentified*	38	**35**
				triangular	9	**8**			
				wedge	15	**14**			
				various	12	**11**			
				unidentified	8	**7**			

Table 1: CRG upper tools shapes: handstone plan and transverse and longitudinal profiles of active surfaces.

Shape	Plan	Face trans. profile	#	%	Face longitudinal profile	#	%
	All elliptical/oval	*concave*	8	**44**	*concave*	2	**11**
	n=18	*shallow*	5	**28**	*shallow*	4	**22**
		flat	1	**6**	*sloped*	7	**39**
		unidentified	4	**22**	*unidentified*	5	**28**

Table 2: CRG lower tool shapes: All elliptically or oval-shaped basins, and their transverse and longitudinal profiles of active surfaces.

A2. ORG (Open Reciprocal Grinding)

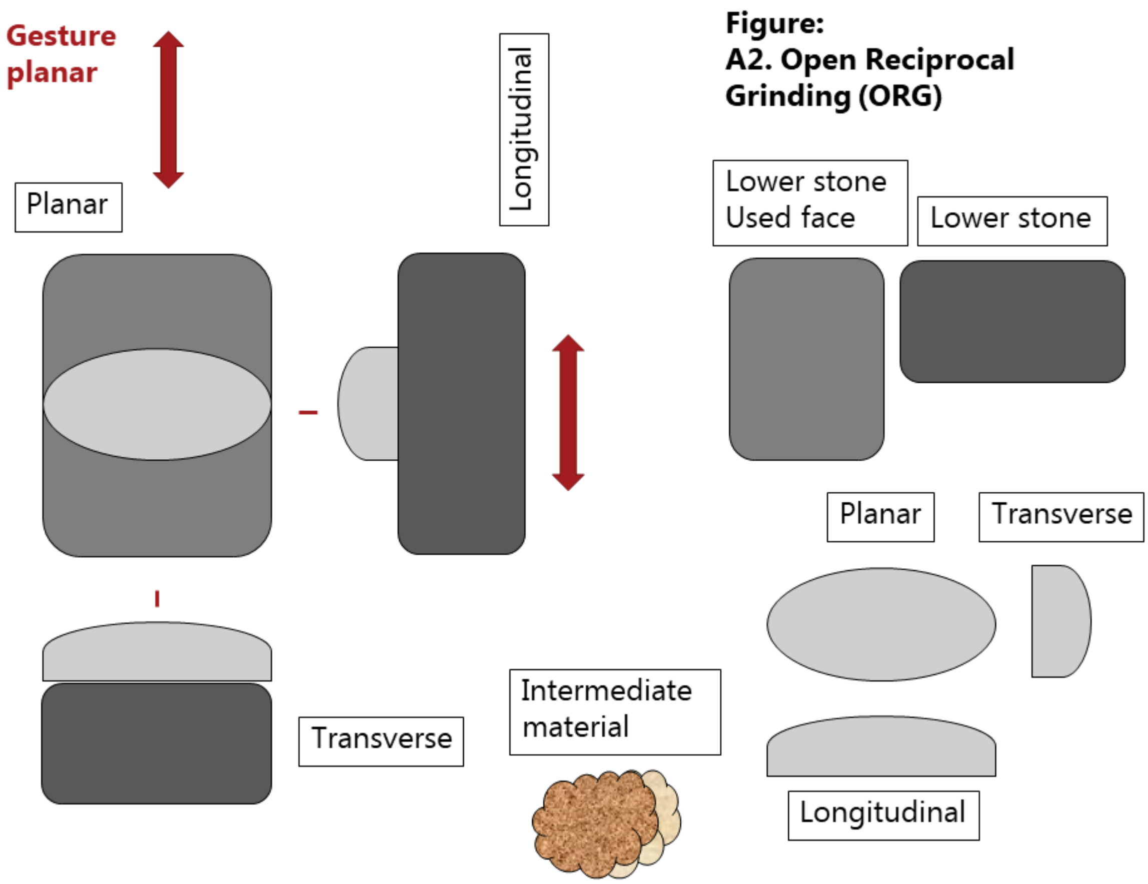

Figure 15: A2. CRG Overall idealised processing strategy and tools. Block slab and loaf shaped handstone (plano-convex/flat profile[s]).

1. **Before use (equal handstone)**
    a. **Lower tool** (Level 0): The use surface of the lower tool is at maximum width and length (planar) = MWL(L) minimum transverse convexity = mTCx (L) and at maximum thickness = MT(L)
        i. **Macro/micro** (Level 1-2): pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
    b. **Upper tool** (Level 0): : is at maximum width and length (planar) = MWL(U), minimum longitudinal convexity mLCx(U), maximum thickness MT(U)
        i. **Macro/micro** (Level 1-2): Pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass

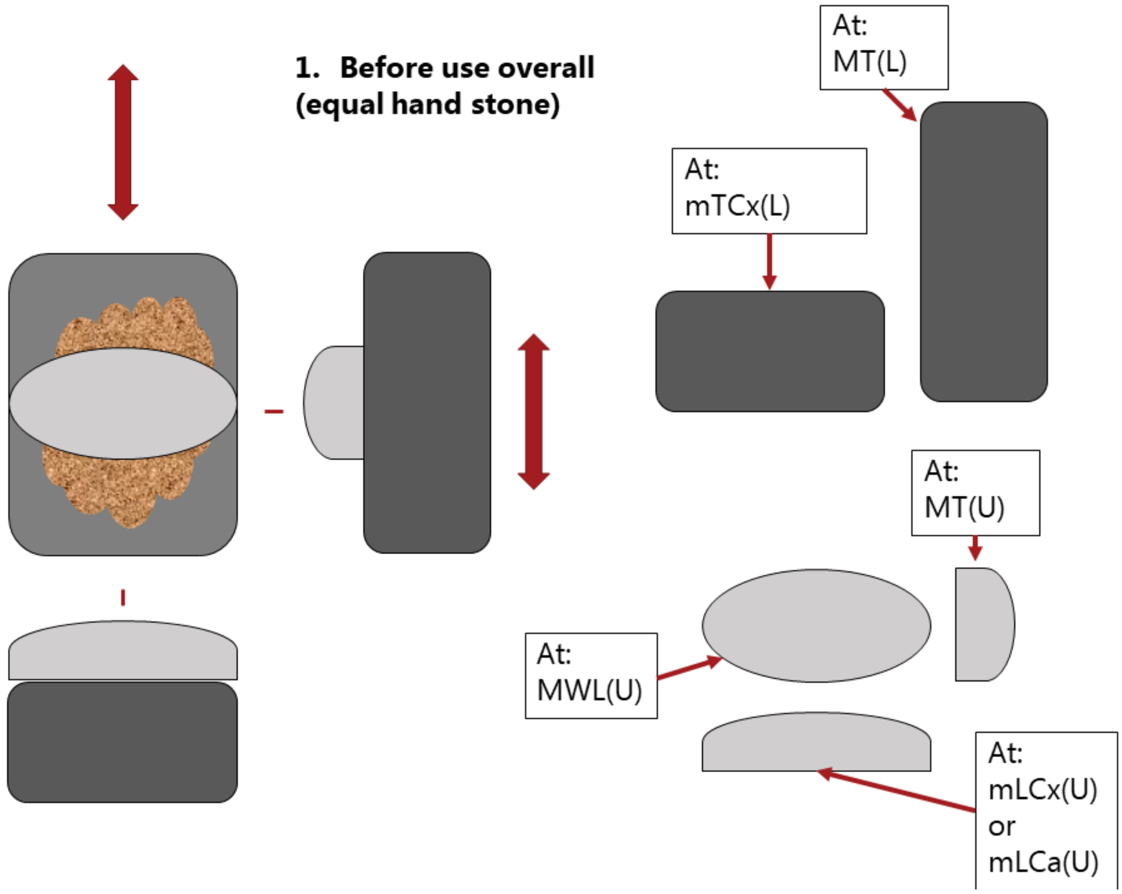

Figure 16: Idealised Stage 1 - before use overall view

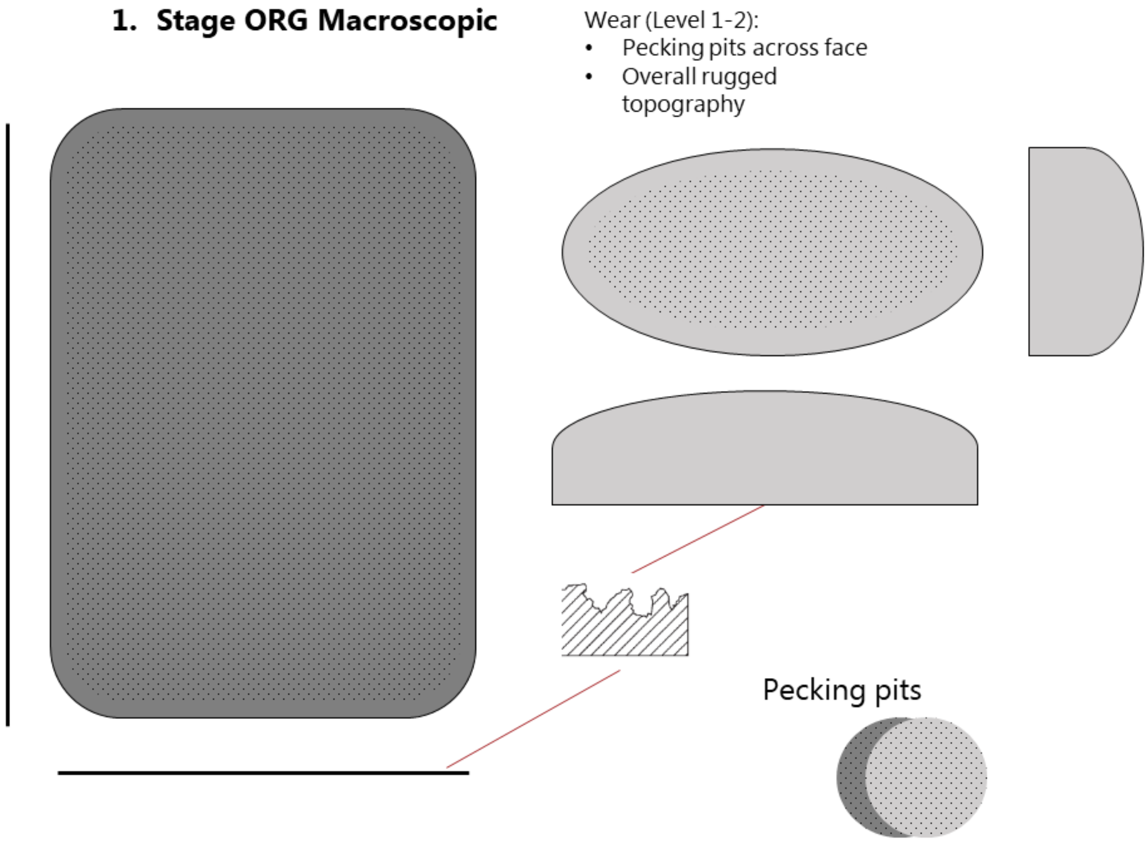

Figure 17: Idealised Stage 1 - before use macroscopic view

2. **Initial use phase**

As the two stones (upper & lower) engage each other and the intermediate material the following happens:

a. **Lower tool** (Level 0): The use surface of the lower tool is at maximum width and length (planar) is more or less unchanged = MWL(L). Maximum thickness decreases MT(L) → xT(L). Beginning of a slight increase in transverse convexity of lower tool mTCX(L) → yTCX(L).
   i. **Macro/micro** (Level 1-2): Pecking pits start wearing out at distal and proximal margins. Overall levelling (and possibly also striations and sheen) at these margins, especially the proximal. A beginning linear (longitudinal direction) pattern and distribution of wear
b. **Upper tool** (Level 0): The use surface of the upper tool is at maximum width and length (planar) is more or less unchanged = MWL(U). Beginning of a slight increase in transverse concavity of the upper tool mTCA→ yTCA(U). Maximum thickness decreases MT(U) → xT(U).
   i. **Macro/micro** (Level 1-2): Pecking pits start wearing out at distal and proximal margins. Overall levelling (and possibly also striations and sheen) at these margins, especially the proximal. A beginning linear (transverse direction) pattern and distribution of wear

2. Initial use stage overall

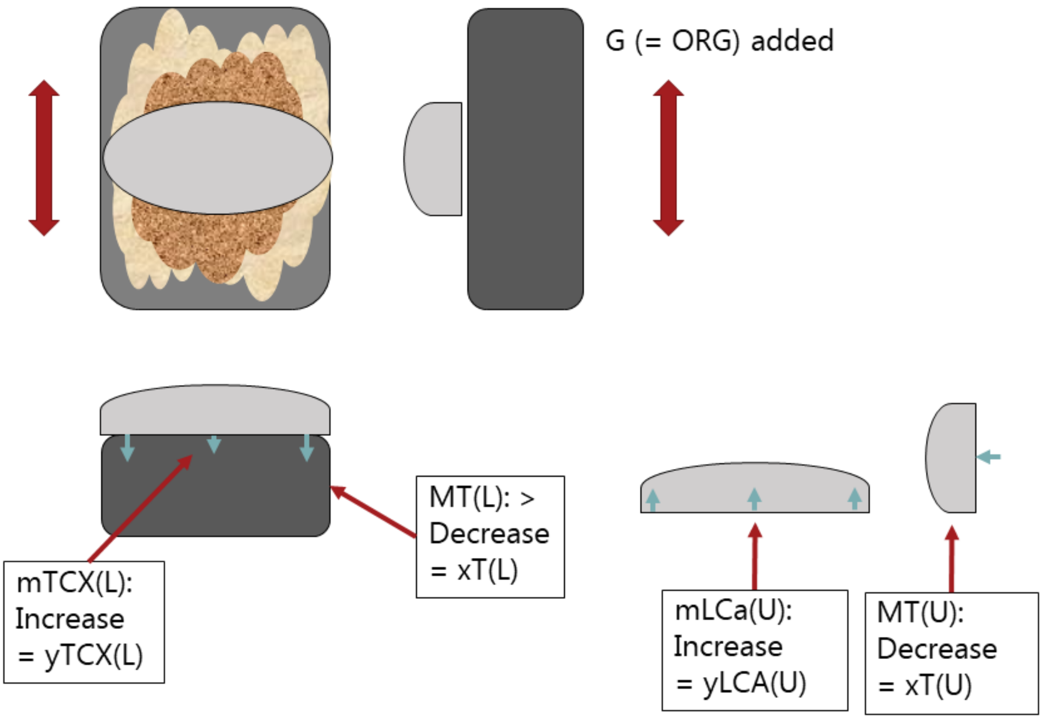

Figure 18: Idealised Stage 2 - initial use, overall view

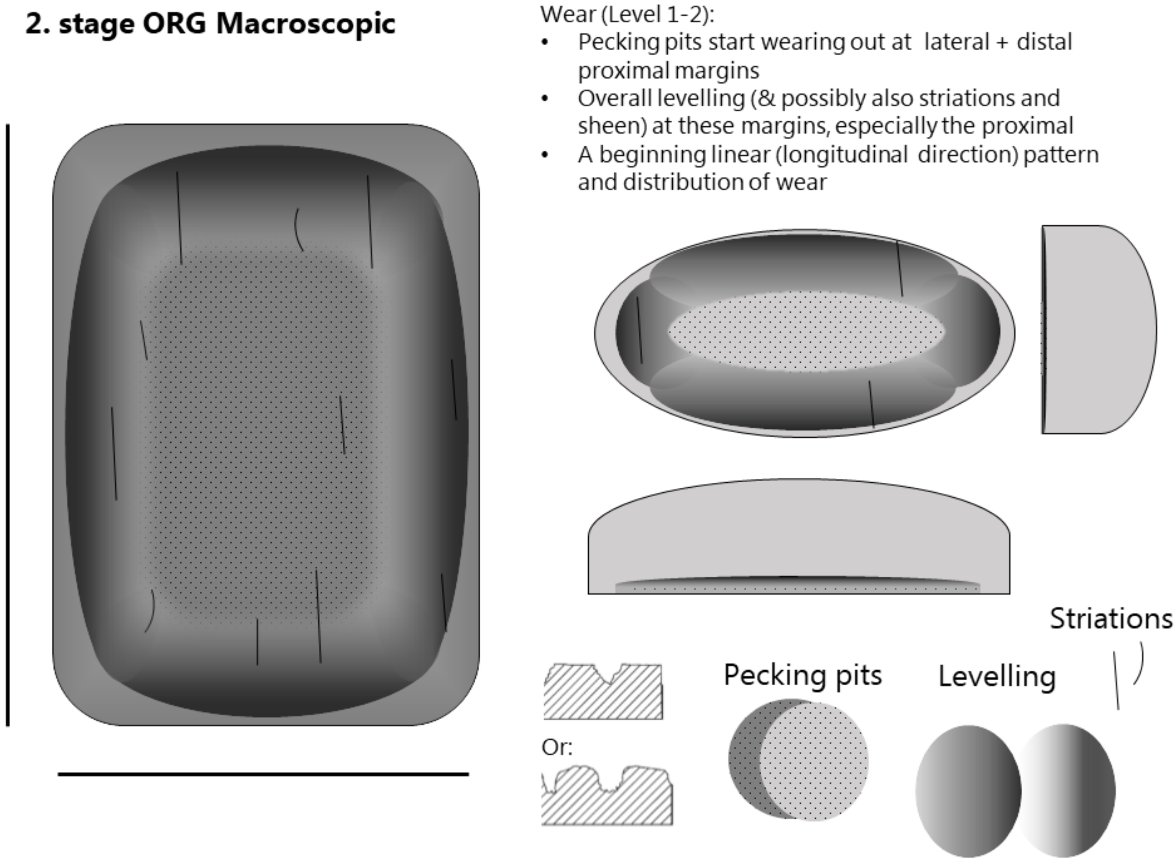

Figure 19: Idealised Stage 2 - initial use, macroscopic view

3. **Continued use phase**

As use continues through cycles of processing with the tools and re-pecking of both upper and the lower tools, both lose mass.

a. **Lower tool** (Level 0): The use surface of the lower tool is at maximum width and length (planar) is more or less unchanged = MWL(L). Thickness continues to decrease xT(L) → zT(L). Possibly a continued slight increase in transverse convexity of lower tool yTCX(L) → zTCX(L).
    i. **Macro/micro** (Level 1-2): Pecking pits continue wearing out at distal and proximal margins, as well as lateral margins (if transverse convexity increased). Overall levelling (and possibly also striations and sheen) continues to be more pronounced at these margins, especially the proximal. Also more pronounced linear (longitudinal direction) pattern and distribution of wear
b. **Upper tool** (Level 0): Either use continues and thickness decreases → zT(U), plano-convex transverse profile intact. Or a new face on the opposite (or elsewhere) may also be opened here. Either way the use surface of the upper tool is at maximum width and length (planar) is more or less unchanged = MWL(U). And = M^2WL(U) for the second use face as well as second minimum transverse concavity of the upper tool = m^2TCa(U)

i. **Macro/micro** (Level 1-2): Pecking pits wearing out, mostly gone at proximal and distal ends and lateral margins, distributed near center longitudinally interrupted by more and more pronounced transversely distributed overall levelleled and homogeneous zones and possibly striations, polish and sheen. Striations and sheen may be especially pronounced proximally. I.e. a generally pronounced linear (transverse direction) pattern and distribution of wear.

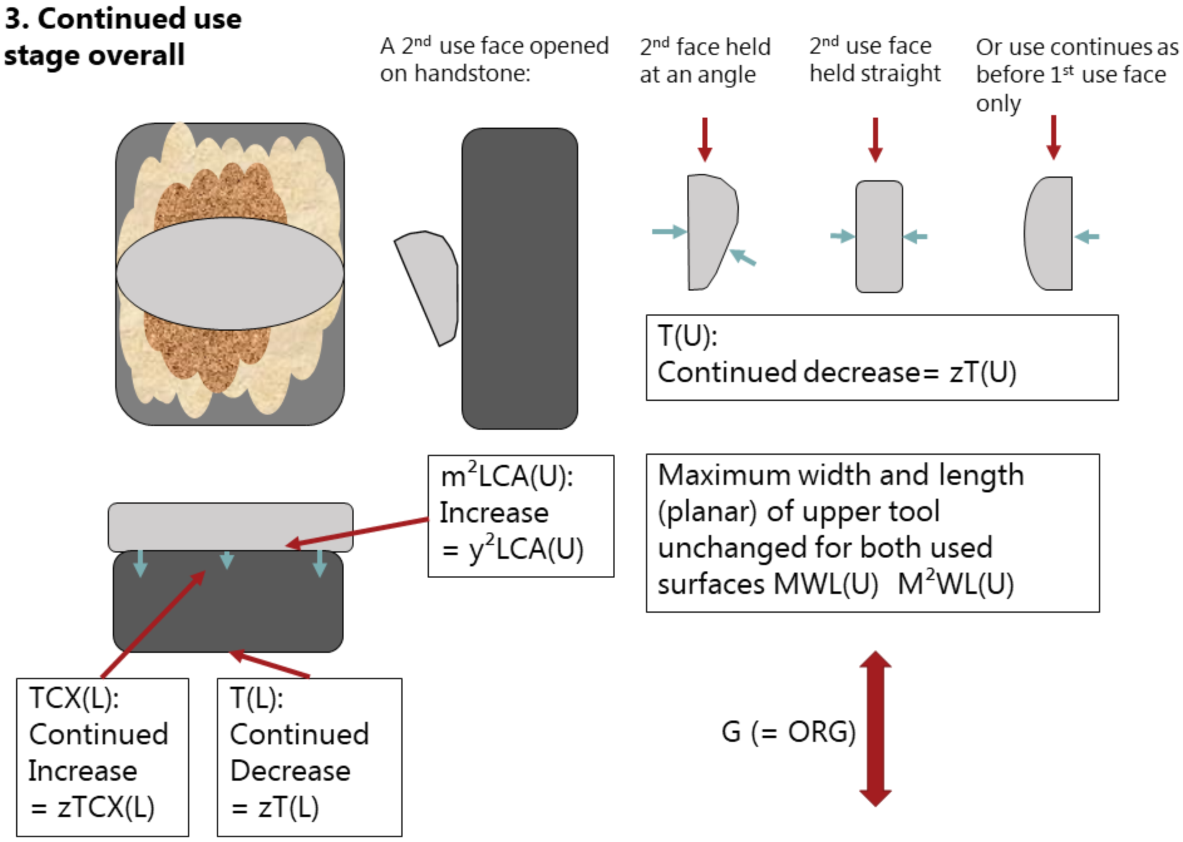

Figure 20: Idealised Stage 3 - initial use, overall view

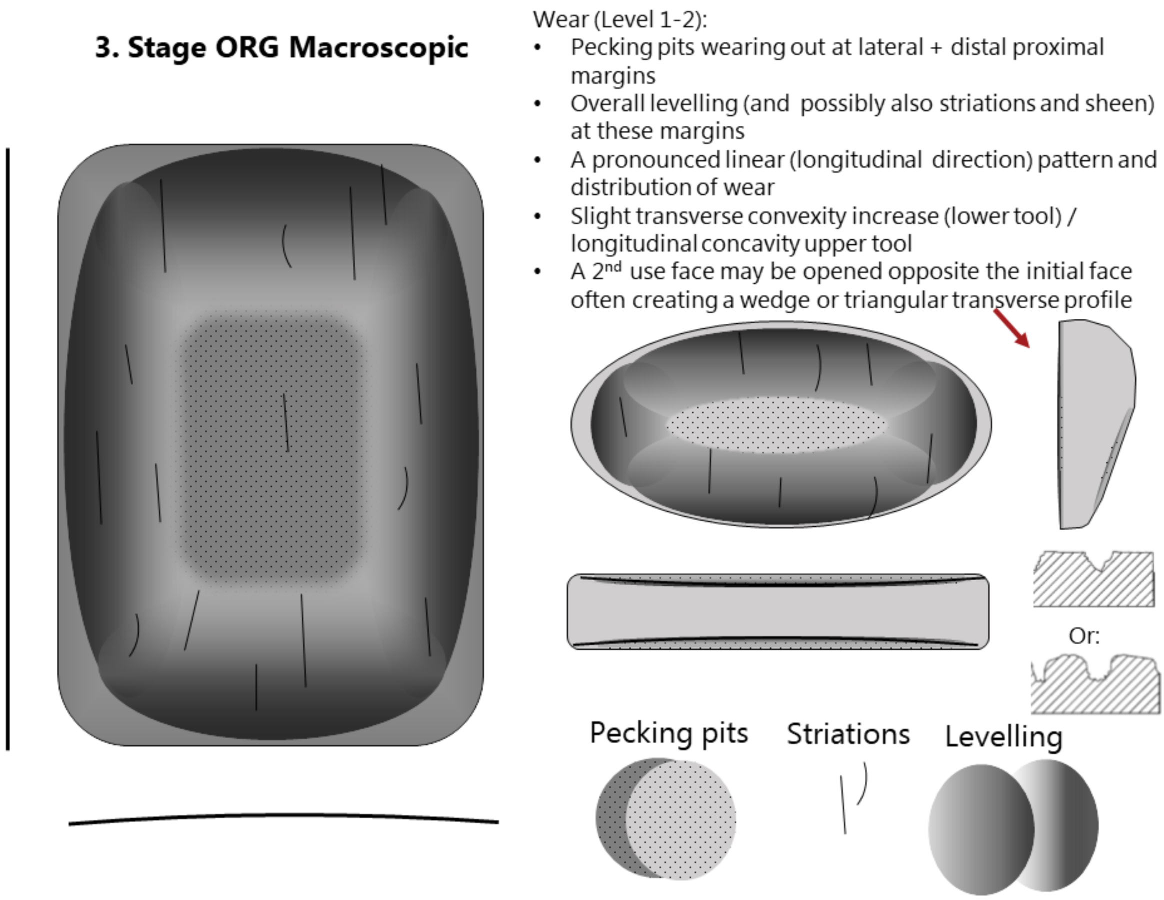

Figure 21: Idealised Stage 3 - initial use, macroscopic view

4. **Worn out phase**

The final stage, i.e. before a new round of pecking or breakage (unintentional and/or intentional), discard, abandonment. Pits all worn out. Intense overall levelling across face. Depending on contact material a microtopography of covering: micro fractures, grain rounding or levelling, a sheen seen across face.Rarely found complete archaeologically (? examp.) possibly because of intentional breakage(?) or immediate re-pecking/re-use

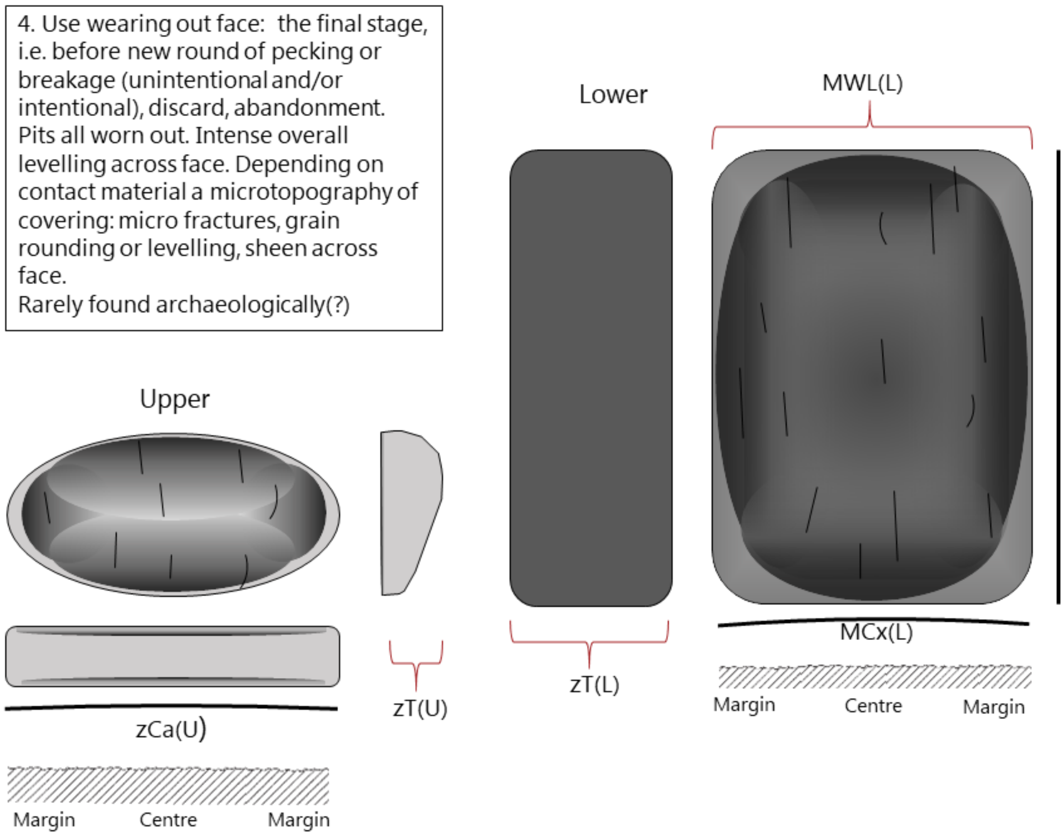

Figure 22: Idealised Stage 4 - or worn out, macroscopic view

Wear management (individual wear) upper ***and*** *lower*

Dependent on size of the used upper stone (Delgado-Raack and Risch 2009, 2016; Lidström Holmberg 2004; Stroulia et al. 2017). For example movements with a upper stone that is longer than the width of the lower tool will create a convex (transversal) lower used surface and a concave (longitudinal) handstone. Movements with an upper stone that is equal the width of the lower will enforce a flat or concave (longitudinal) surface and a flat (transversal) used surface of the lower tool and a flat (longitudinal) to slightly convex (transverse) use profiles of the upper tool.

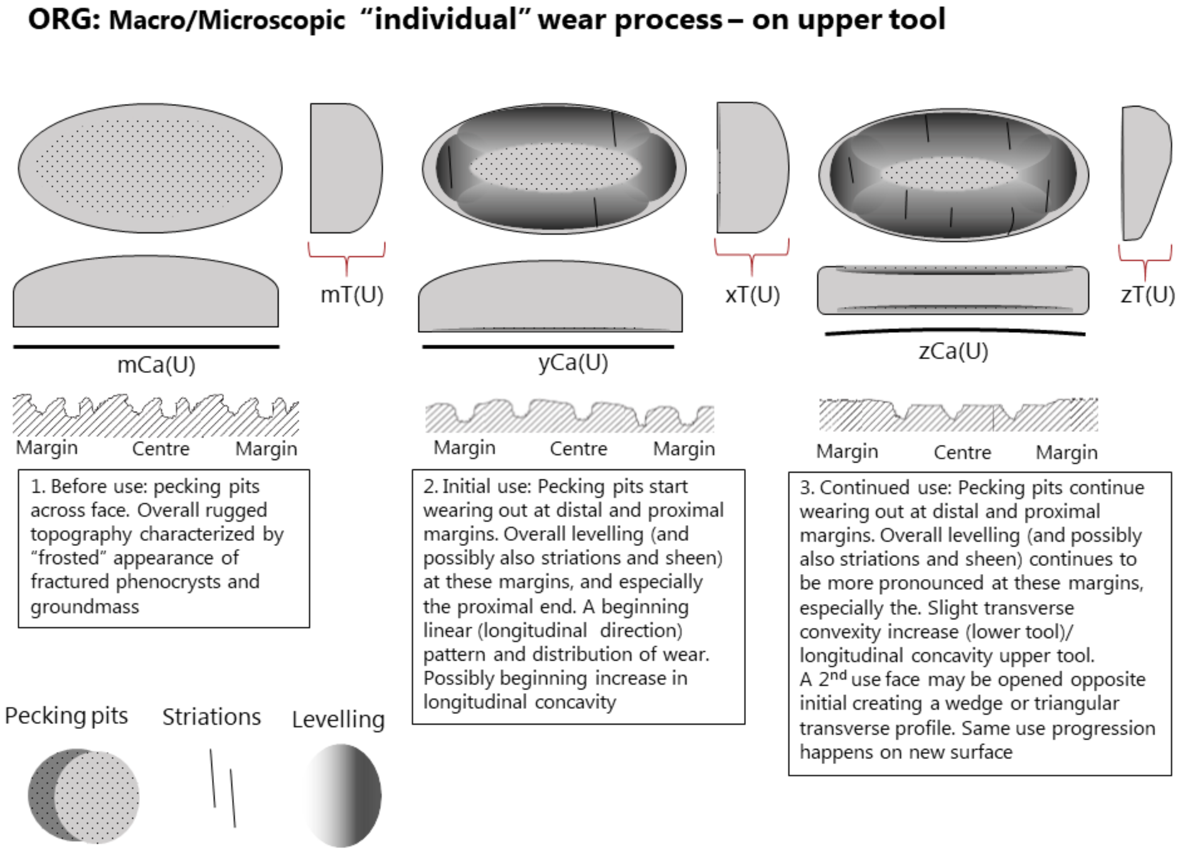

Figure 23: Idealised stages - upper tool individual wear, overall/macroscopic view

Movements with an upper stone that is shorter than the width of the lower tool will promote a concave (longitudinal) and concave (transversal) surface of the lower tool, with ridges on edges of the used surface, creating a "basin" over time. Upper tool profile will be convex both longitudinally and transversely (*e.g.* oval or lens shaped). Here I chose to engage only with a trajectory of wear based on a handstone of equal length, for the sake of brevity and as this is the type that seems to appear at Shubayqa, but see (Delgado-Raack and Risch 2009, 2016; Stroulia et al. 2017) for details on these other types. Opening of a second face on the upper stone seems to be very common among the handstone at Shubayqa 1 (Pedersen, Richter, and Arranz-Otaegui 2016). This causes the transverse profile to change to triangular (see Fig.), if held at an angle or: oval/lens with two directly opposing used surfaces if held "straight" (See also Adams 2002, Fig.5.12).

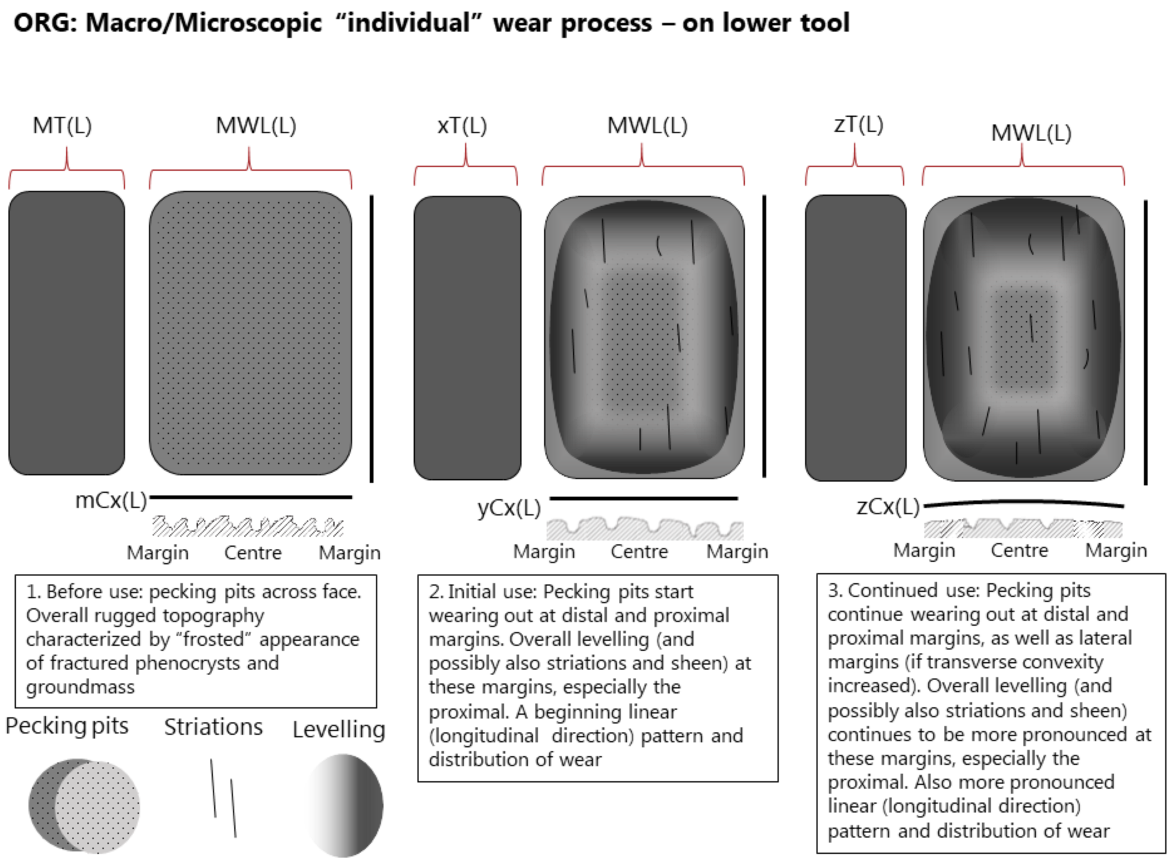

Figure 24: Idealised stages - lower tool individual wear, overall/macroscopic view

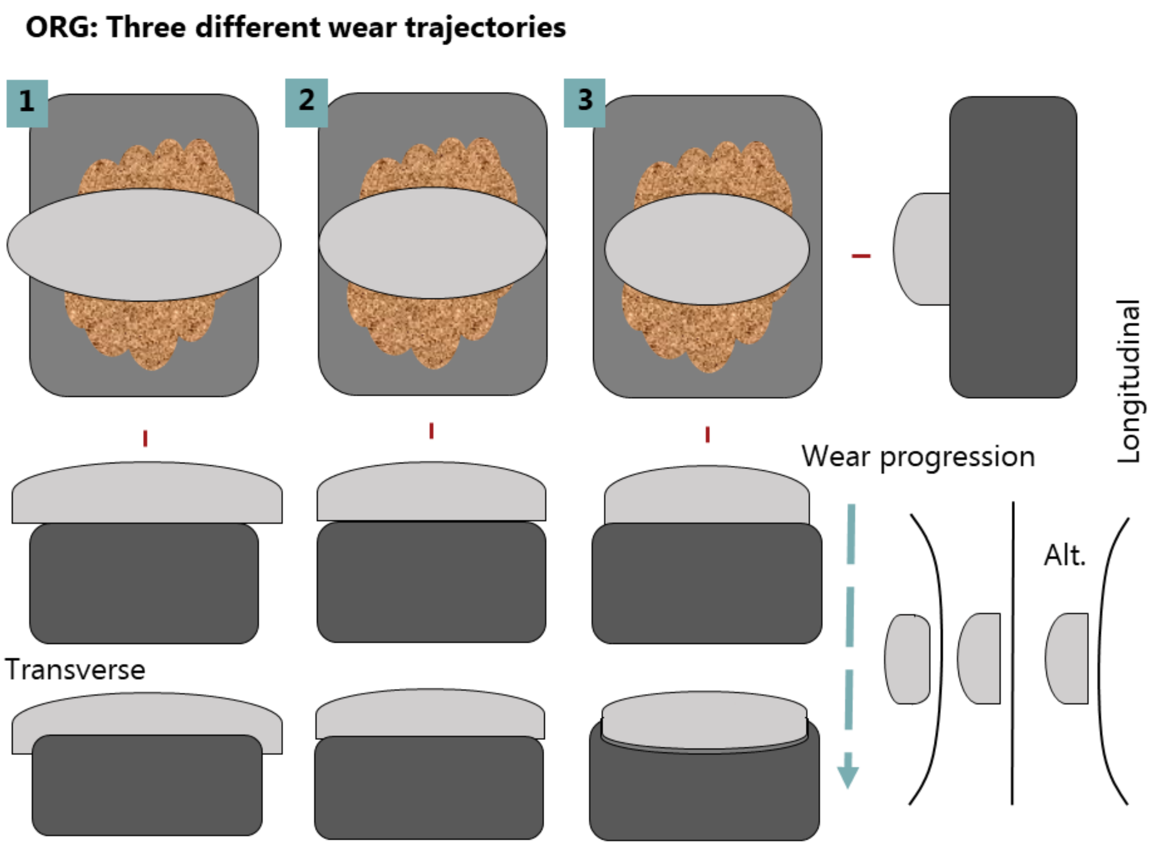

Figure 25: Idealised trajectories of lower tool individual wear, overall view. ORG. Note difference between 1, 2 and 3. The main gesture: a reciprocal resting percussion is the same (processing strategy), but length of upper stone influences trajectory.

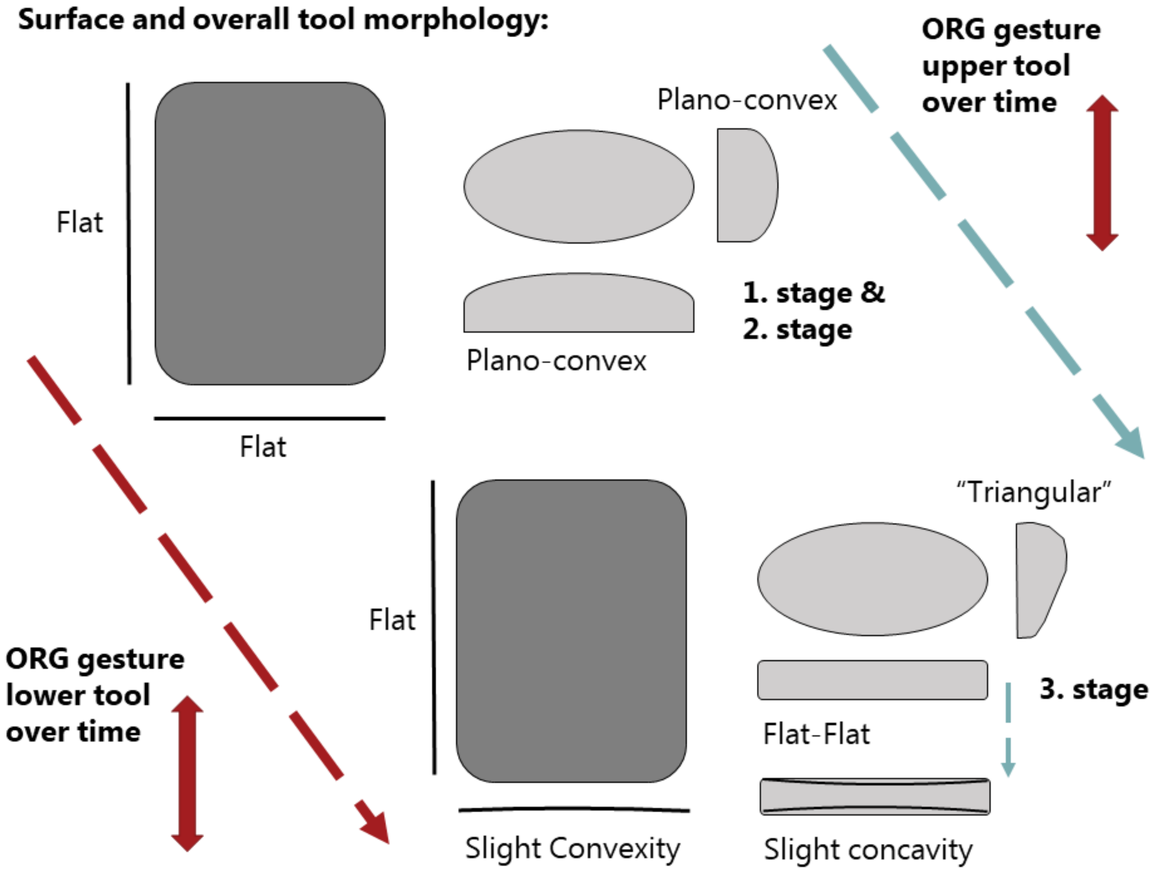

Figure 26: Idealised trajectories of both upper and lower tools individual wear, in an overall view.

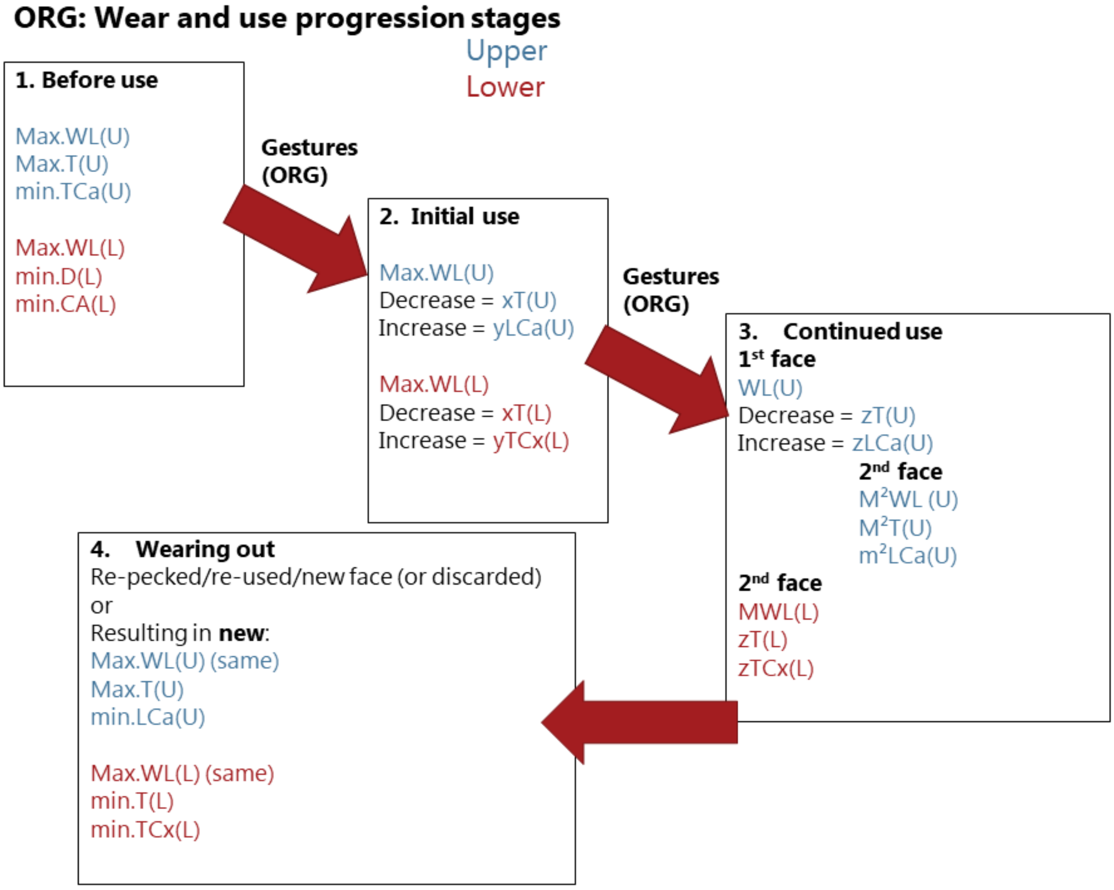

Figure 27: Generic "measurements" of the idealised morphology and how these change through use.

A2. ORG Body positions and examples:

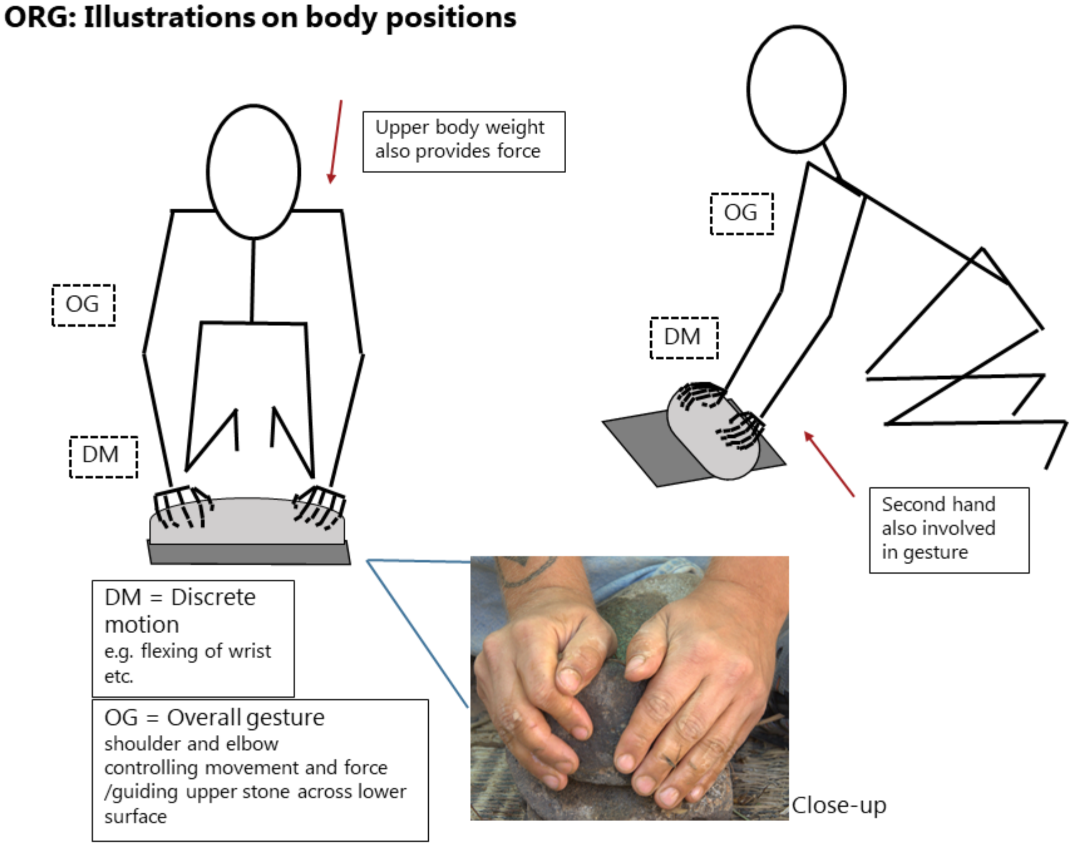

Figure 28: A2. ORG Body positions, gesture

Figure 29: Large “Saddle” slab and large“loaf” handstone, probably later Neolithic to early Iron age in date.

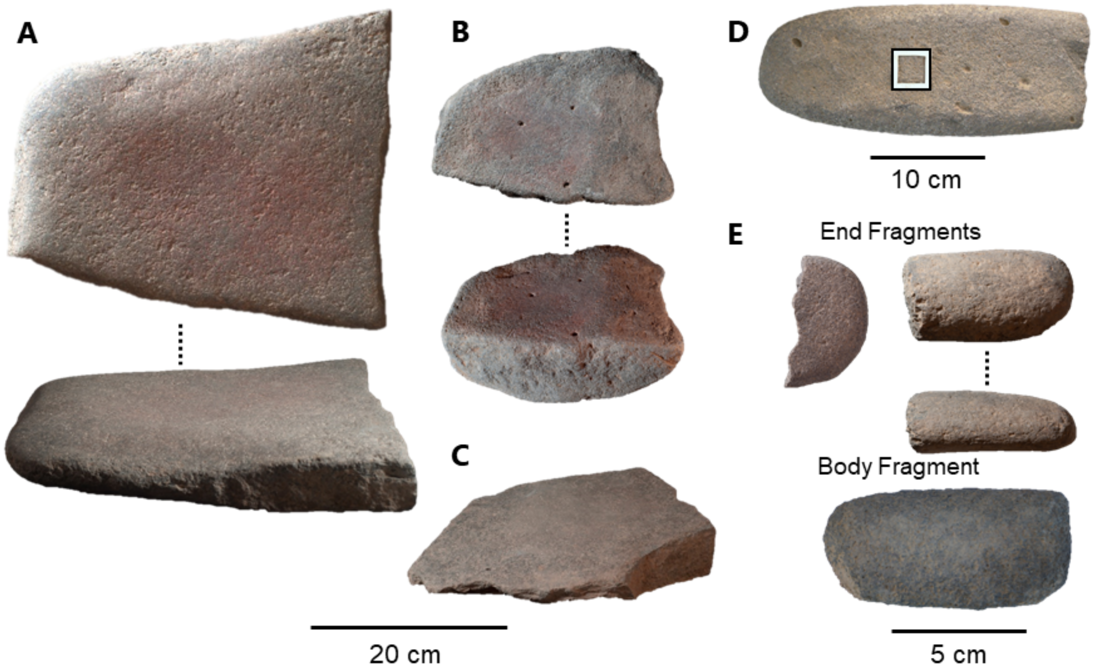

Figure 30: Archaeological examples of A2. ORG basalt tools from Shubayqa 1: All Late Natufian phase. A-C lower tools. D a large multiple upper stone both used for grinding and pounding (the square indicates use-wear analysis location) Note the end and body fragments E, frequently retrieved from the Late Natufian phase.

The general size of the upper tools for this strategy from Loaf, loaf tapered, and triangular plan handstone sizes (n=24). Length: max. 200 mm, min. 57 mm, avg. 117,9 mm. Width: max. 87 mm, min. 33 mm, avg. 55,7 mm. Thickness max. 48 mm, min. 20 mm, avg. 33 mm Face size (as rectangle: a x b): a 117,9 mm x b 55,7 mm = avg. 65,67 cm²

The general size of the lower tools for this strategy15 from Block, saddle slab size (n=11). Length: max. 370 mm, min. 147 mm, avg. 249,6 mm. Width: max. 320 mm, min. 87 mm, avg. 189,1 mm.
Face size (as rectangle: a x b): a 249,6 mm x b 189,1 mm = avg. 471,19 cm²

Shape	Overall plan	#	%	Face trans. profile	#	%	Face longitudinal profile*	#	%
	loaf	170	**60**	*irregular*	6	**2**	*concave*	7	**26**
	loaf (tapered)	112	**39**	*lens*	7	**2**	*convex*	5	**18**
	triangular	3	**1**	*oval*	30	**11**	*flat*	15	**56**

plano-convex	63	**22**
plano-irregular	10	**3**
tapered	14	**5**
trapezoidal	10	**4**
triangular	105	**37**
wedge	19	**7**
varia	10	**4**
unidentified	8	**3**

Table 3: ORG upper tools: handstone, transverse and longitudinal profiles of active surfaces. **Face longitudinal profile***unidentified* **(**not included *n*= 254)

Shape	**Overall shape**	**#**	**%**	**Face trans. profile**	**#**	**%**	**Face longitudinal profile**	**#**	**%**
	block	24	**75**	*concave*	1	**3**	*concave*	0	**0**
	boulder	1	**3**	*convex*	8	**20**	*convex*	3	**8**
	saddle	7	**22**	*shallow*	14	**36**	*shallow*	6	**15**
				flat	9	**23**	*flat*	13	**33**
				unidentified	7	**18**	*unidentified*	17	**44**

Table 4: ORG lower tools: slabs, overall shape transverse and longitudinal profiles of active surfaces.

A3. RGP (Rotary/circular Grinding with some Pounding)

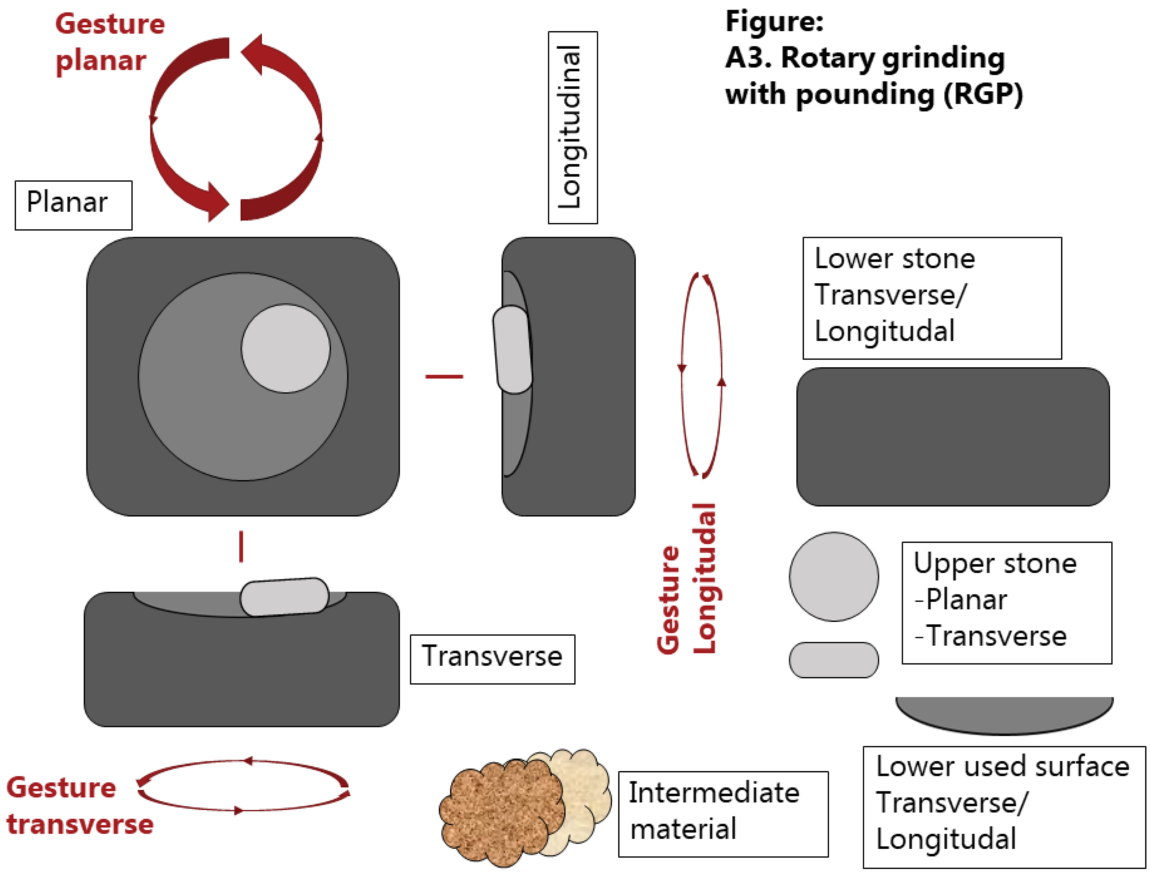

Figure 31: A3. RGP Overall idealised processing strategy and tools: discoidal/circular) handstone (oval/flat profile), basin quern (circular/oval surface with concave profile).

Wear progression:

1. **Before use**
   a. **Lower tool** (Level 0): The use surface of the lower tool is at maximum width and length (planar) = MWL(L) and at minimum depth = mD(L) and minimum concavity = mCA(L).
      i. **Macro/micro** (Level 1-2): pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass
   b. Upper tool (Level 0): : is at maximum width and length (planar) = MWL(U), minimum convexity = mCX(U), maximum thickness MT(U)
      i. **Macro/micro** (Level 1-2): Pecking pits across what will become the active surface. Pits have no apparent directionality, pit edges rugged. Overall topography characterised by "frosted" appearance of fractured phenocrysts and groundmass

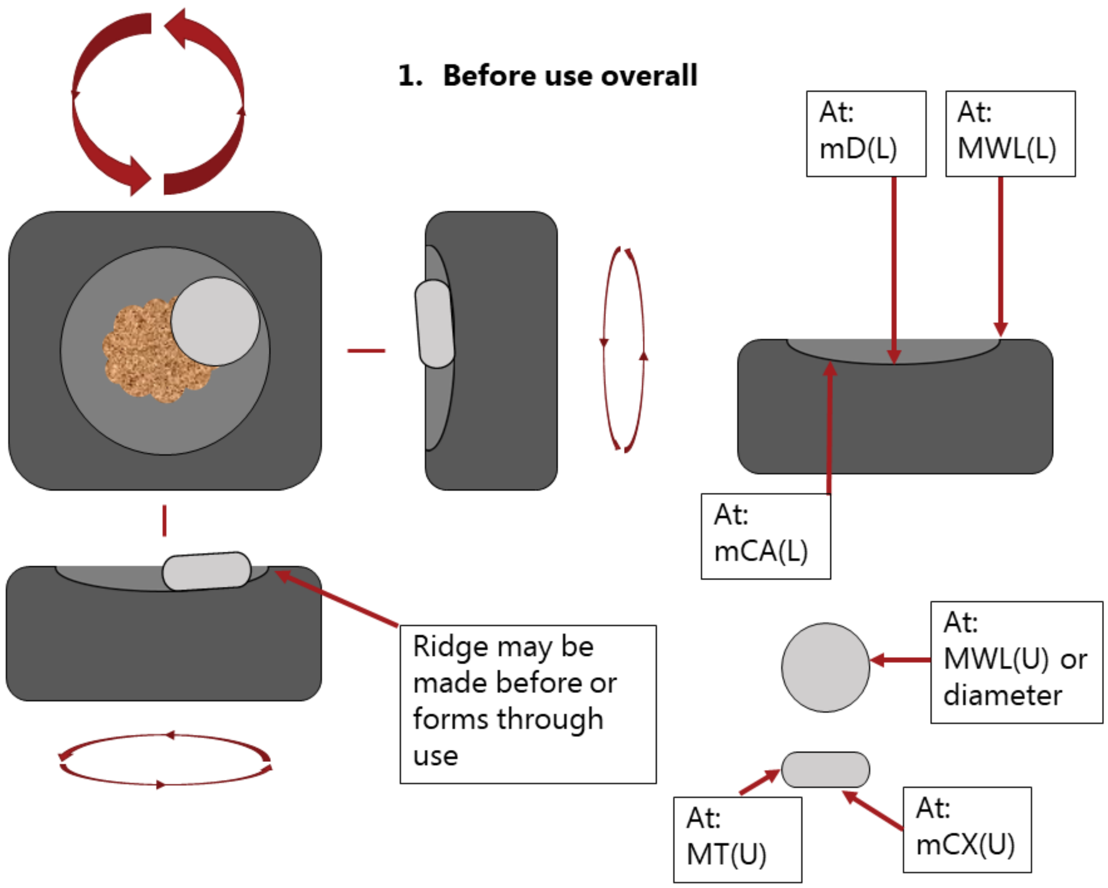

Figure 32: Idealised Stage 1 - before use overall view

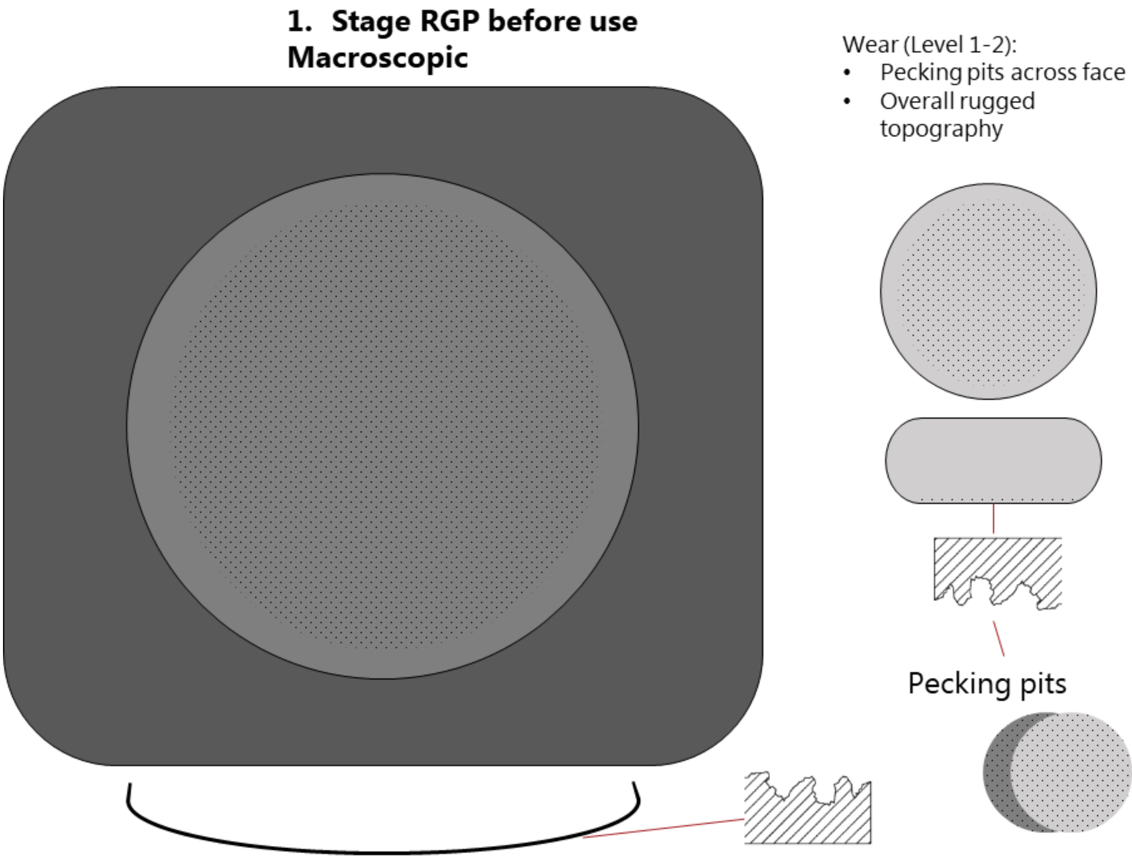

Figure 33: Idealised Stage 1 - before use macroscopic view

2. **Initial use phase**

As the two stones (upper & lower) engage each other and the intermediate material the following happens:

a. Lower tool (Level 0): depth D(L) and concavity CA(L) will begin to increase as the tool loses mass. From mD(L) / mCA(L) → yD(L) / yCA(L). The use surface maximum width and length (planar) will at the same time decrease with this process from MWL(L) → xWL(L).
    i. **Macro/micro** (Level 1-2): Overall levelling begins at the margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense around the centre and margins as these receive more pressure. A beginning circular/concentric (patterning) in the distribution of wear
b. Upper tool (Level 0): MWL(U) and MT(U) will begin to decrease as tool loses mass, from MWL(U) / MT(U) → xWL(U) / xT(U). Minimum convexity mCX(U), will increase to yCX(U). However, see *Surface wear management upper* further below.
    i. **Macro/micro** (Level 1-2): Overall levelling begins at the margins along with a wearing out of pecking pits. Striations and/or sheen may

also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense outside of the centre and at margins as these receive more pressure. A beginning circular/concentric (patterning) in the distribution of wear

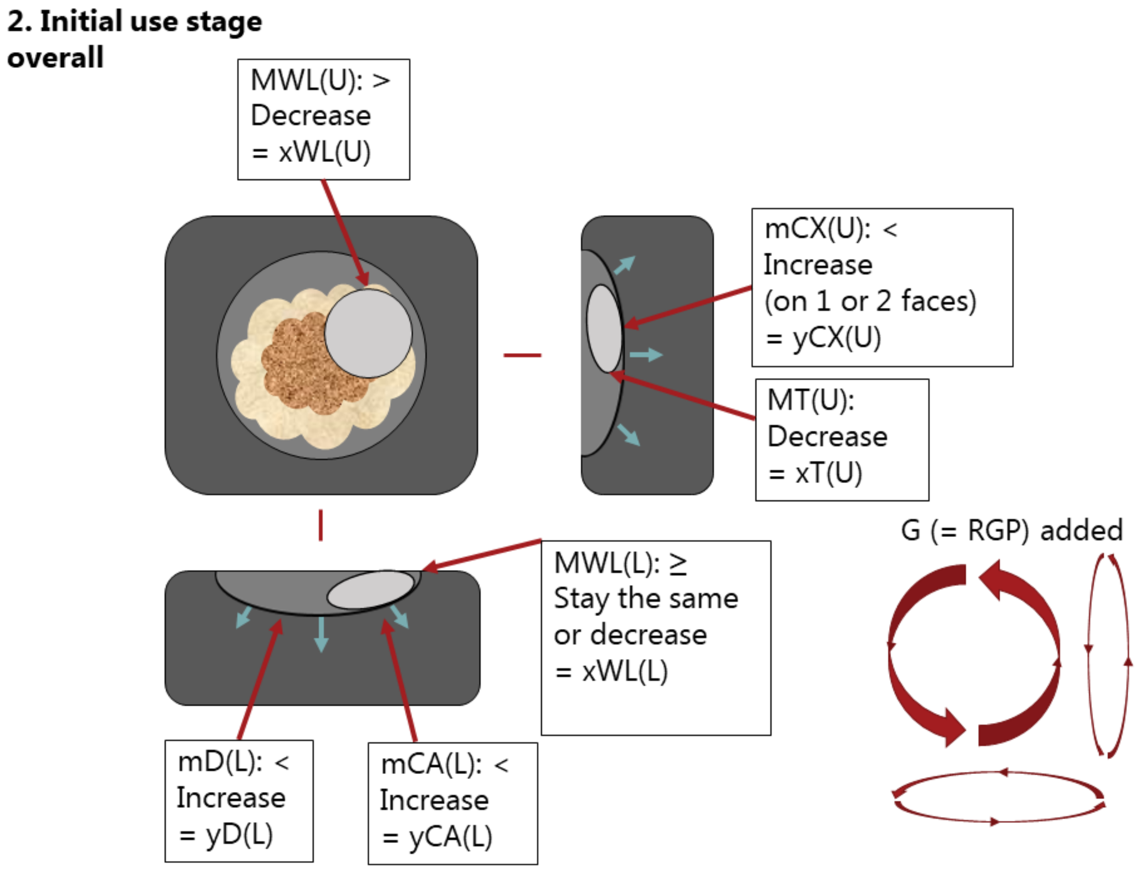

Figure 34: Idealised Stage 2 - initial use overall view

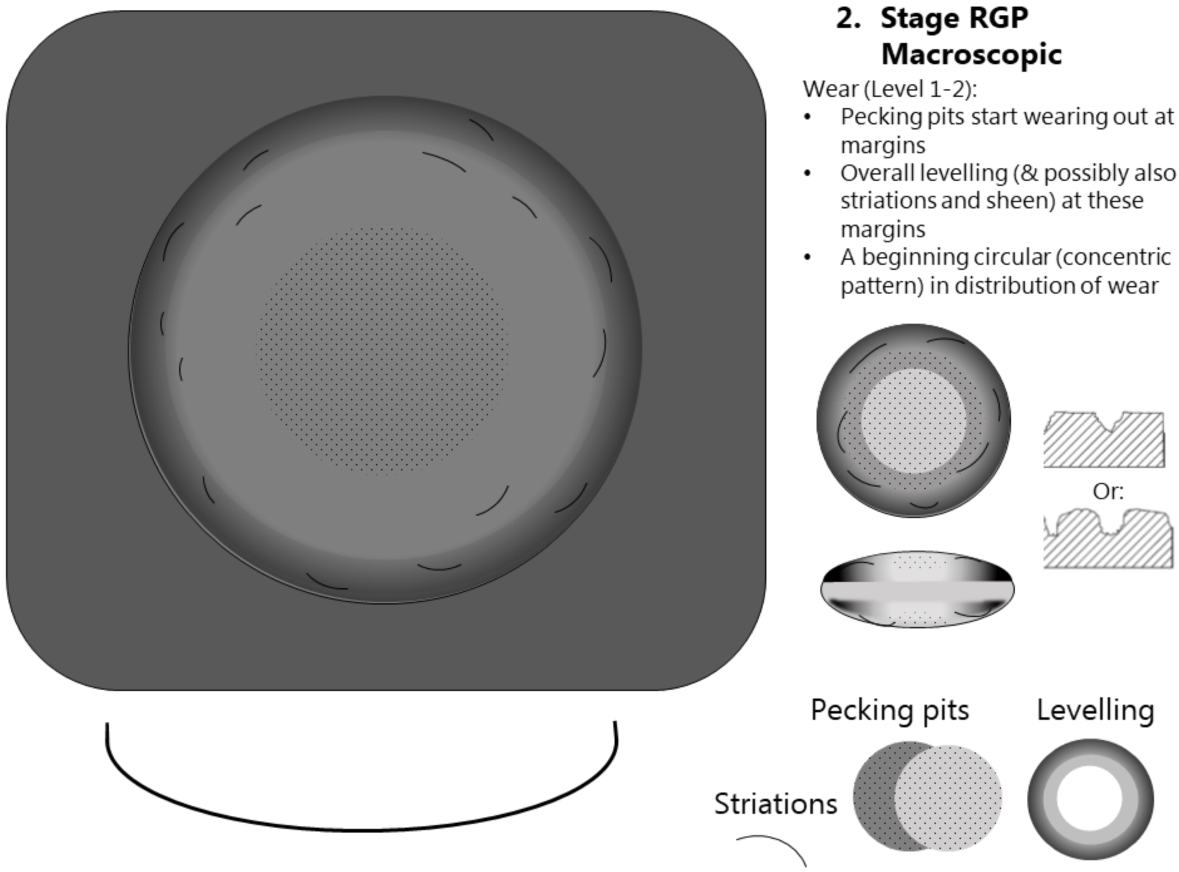

Figure 35: Idealised Stage 2 - initial use, macroscopic view

3. **Continued use phase**

As use continues through cycles of processing with the tools and re-pecking of both upper and the lower tools, both lose mass as was explained above. However as the lower face becomes deeper (a new upper tool can always be introduced), a technological choice is faced to continue use on the same face or to open up a new face somewhere else on the tool. Here I have assumed use continues on the same face, in a smaller area (but see a more detailed explanation below in *Surface wear management*). Either way on the new face the previous process repeats itself. The following happens:

a. Lower tool (Level 0): depth yD(L) and concavity yCA(L) of the original face stop increasing as a smaller area is used and a "new" face starts. This has a new minimum depth and concavity and maximum planar size $m^2D(L)$ / $m^2CA(L)$ / $M^2WL(L)$. These through use then become → $y^2D(L)$ / $y^2CA(L)$ / $x^2WL(L)$
    i. **Macro/micro** (Level 1-2): previous process repeats on this new face, erasing older wear. First of overall levelling begins at the margins along with a wearing out of pecking pits. Striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense around the centre and at margins as these receive more pressure.

Circular/concentric (patterning) in the distribution of wear. Possibly intensifies on this new face

b. Upper tool (Level 0): WL(U) and T(U) continue to decrease as tool loses mass, also erasing older wear. Goeas from xWL(U) / xT(U) → zWL(U) / zT(U). Convexity yCX(U), will increase to zCX(U), but again see *Surface wear management upper*

    i. **Macro/micro** (Level 1-2): Overall levelling continues at the margins along with a wearing out of pecking pits, only a few now left at centre. Striations and/or sheen may also appear at margins, possibly moving further in (possibly a result of stone/stone contact). Depending on contact material beginning micro fractures, grain rounding and/or levelling across the surface. May be more intense outside of the centre and margins as these receive more pressure. Circular/concentric (patterning) in the distribution of wear.

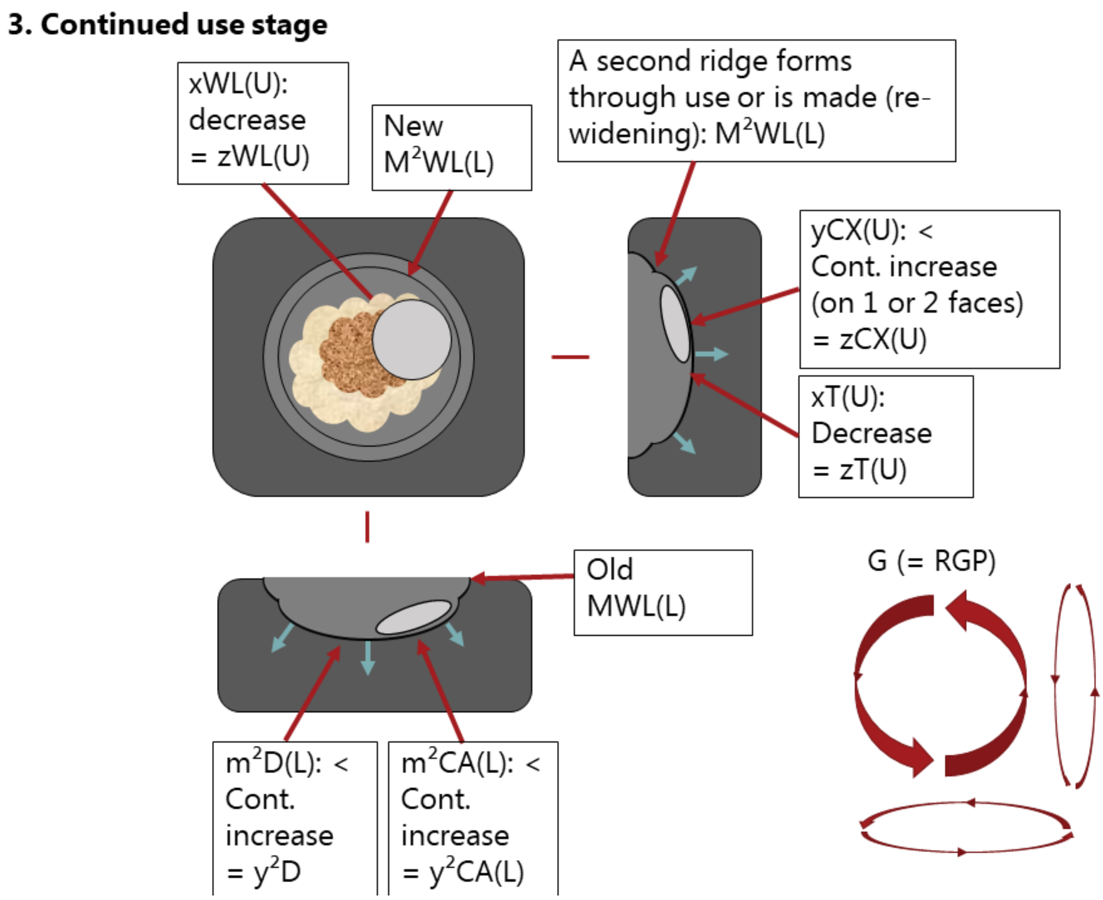

Figure 36: Idealised Stage 3 - continued use, overall view

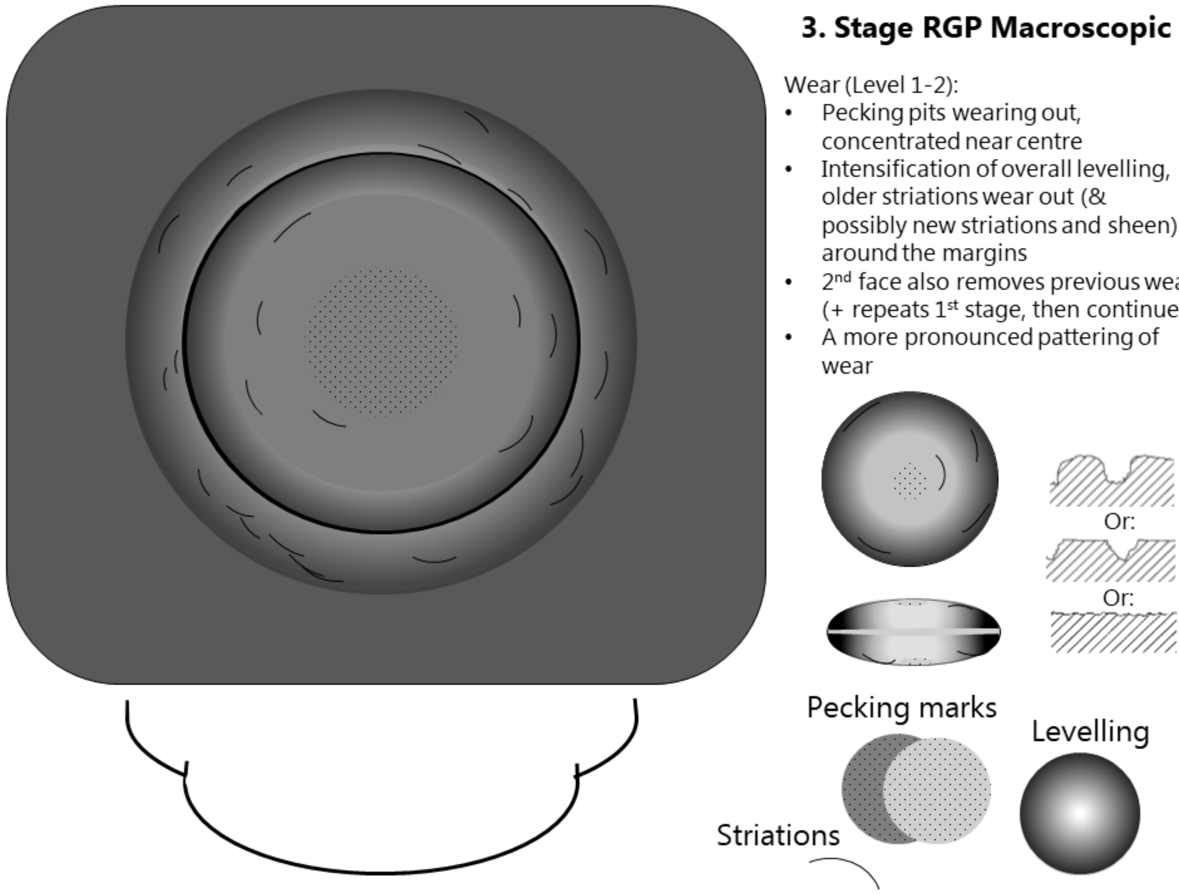

Figure 37: Idealised Stage 3 - continued use, macroscopic view

4. **Worn out phase**

The final stage, i.e. before new round of pecking or breakage (unintentional and/or intentional), discard, abandonment. Pits all worn out. Intense overall levelling across face. Depending on contact material a microtopography of covering: micro fractures, grain rounding or levelling, a sheen seen across face.Rarely found complete archaeologically (? examp.) possibly because of intentional breakage(?) or immediate re-pecking/re-use

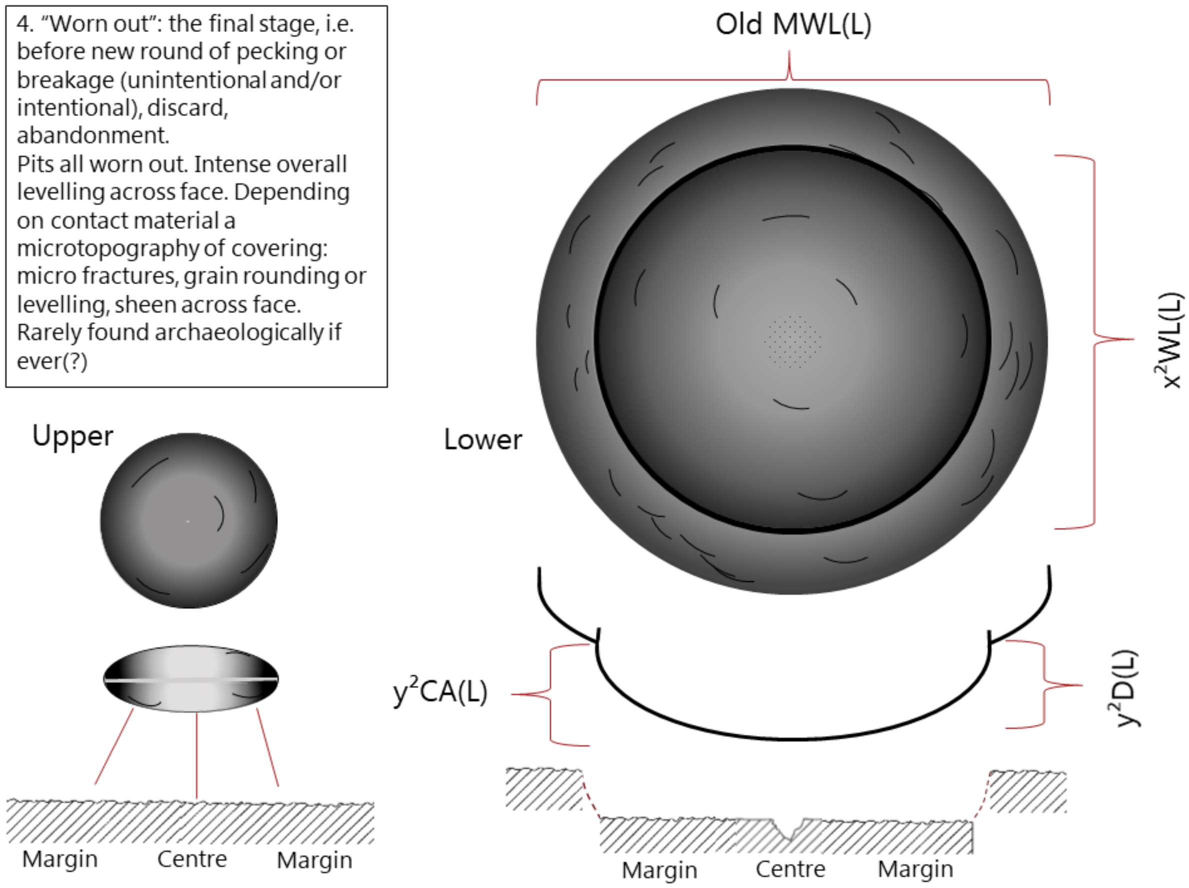

Figure 38: Idealised Stage 4 - or worn out, macroscopic view

Surface wear management upper (individual wear)

The type of wear management and technological choices of the operator will have an effect on the morphology of the upper stone. For example, if wear is managed by exploiting both sides (faces) of the handstone. This will decrease the thickness faster as both faces lose mass and slow down (or negate) the increase in the convexity. Continued use on two faces will probably continue to decrease thickness and increase convexity steadily. If on the other hand the same face is used constantly mainly the margins of the tool will lose mass, but thickness decrease slower, while convexity increases faster. (example shubayqa 6). Presence of pecking pits at center and levelling at proximal and distal margins (see below), as well as some on the edges of lateral sides may be a result of the least stone/stone contact happening at centre (see (Martinez et al. 2013) or rather more contact with the intermediate material there. Most of the grinding happens at the center as stone is moved, pressing outwards by the operator (Dietrich et al. 2019; Dietrich and Haibt 2020). Potentially, the center is being used to pound as well.

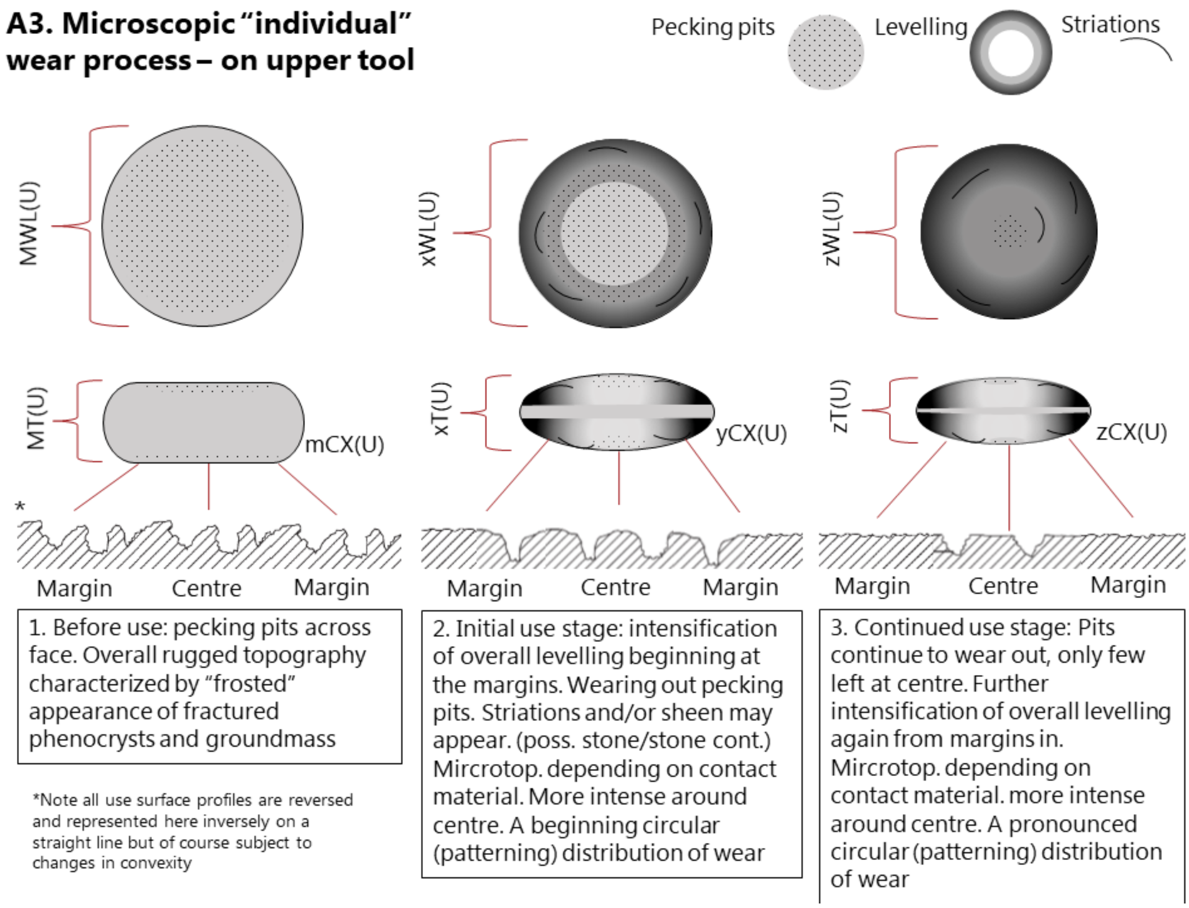

Figure 39: Idealised stages - upper tool individual wear, overall/macroscopic view

Surface wear management lower (individual wear)

Again we may note that the type of wear management will have an effect on the lower stone, if wear is managed by using a smaller area on the same surface or by opening a new surface (for example on the opposite side). As the first lower face gets deeper it the active surface either by choice or naturally gets narrower (smaller), the ridges/edges/ rim become higher and more concave , and grinding is possibly more comfortable (or easily) achieved in the center within a narrower/smaller face a new but smaller area than previous face. This thus creates a stepped face as we see here (Fig. + arch ex. Shub1 stepp). Alternatively a second face on the opposite side may start (see Fig. and arch. Examples shub1 Opposed face) restarting the first stage of wear but potentially at equal size as the first. In this case no step is formed (initially at least) and the wear on the two surfaces develop independently of each other.

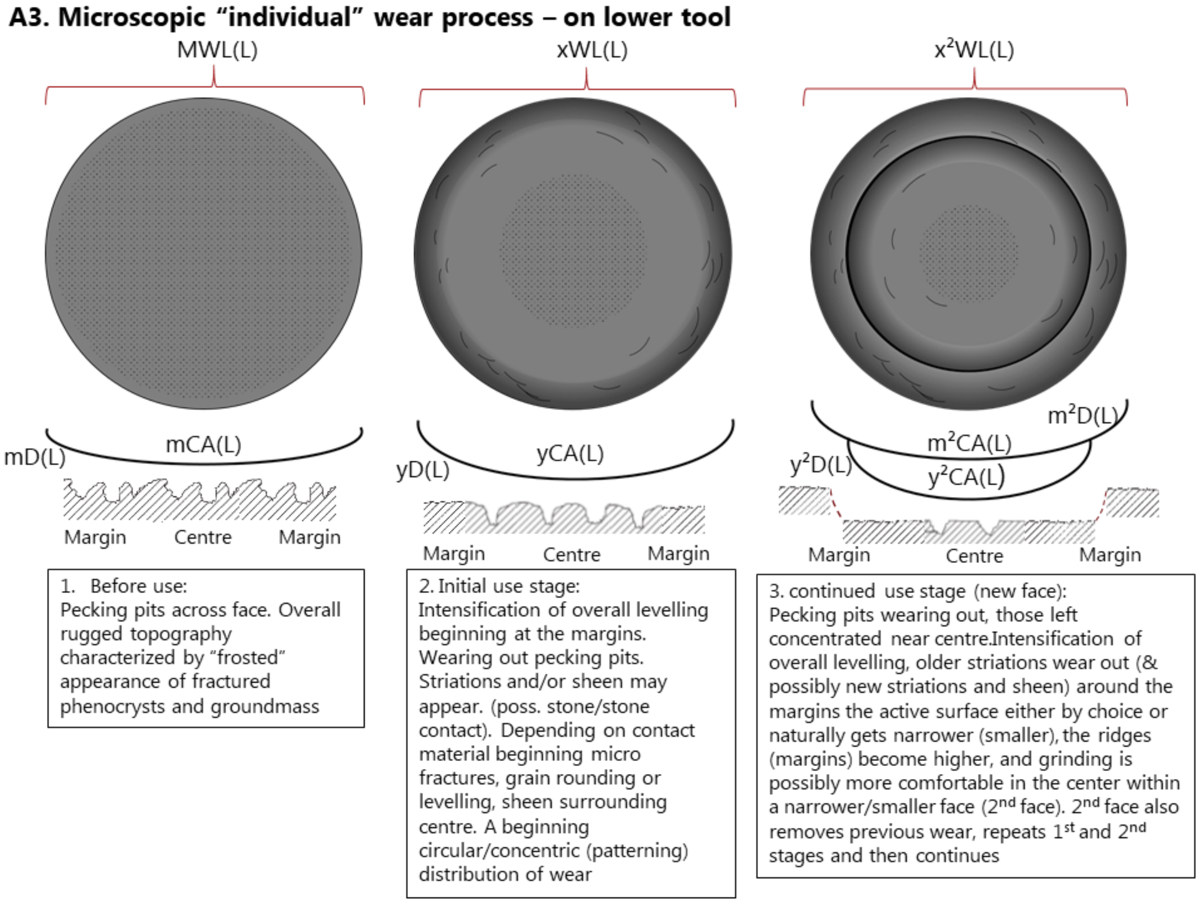

Figure 40: Idealised stages - lower tool individual wear, overall/macroscopic view

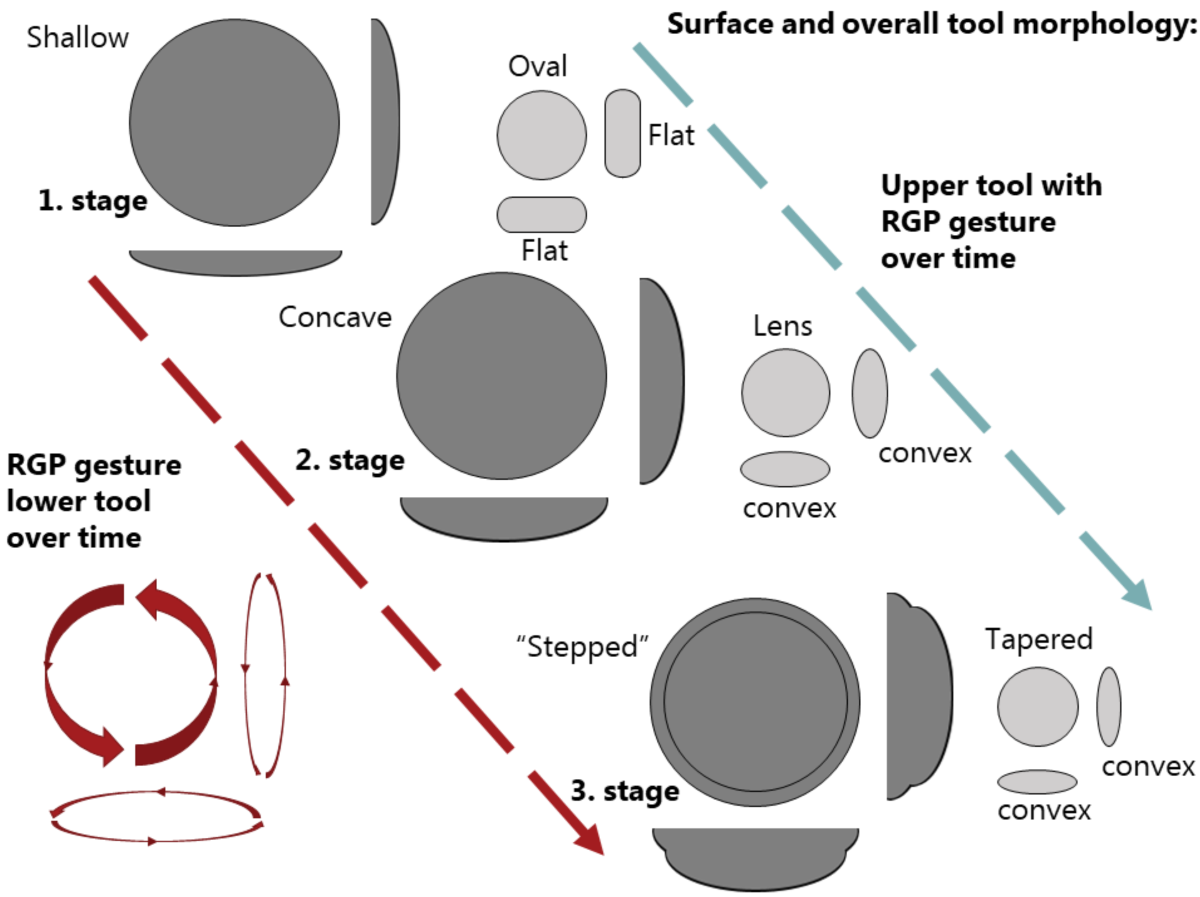

Figure 41: Idealised trajectories of both upper and lower tools individual wear, in an overall view. Note the opening of the second face within the previous surface. All fall within the RGP strategy.

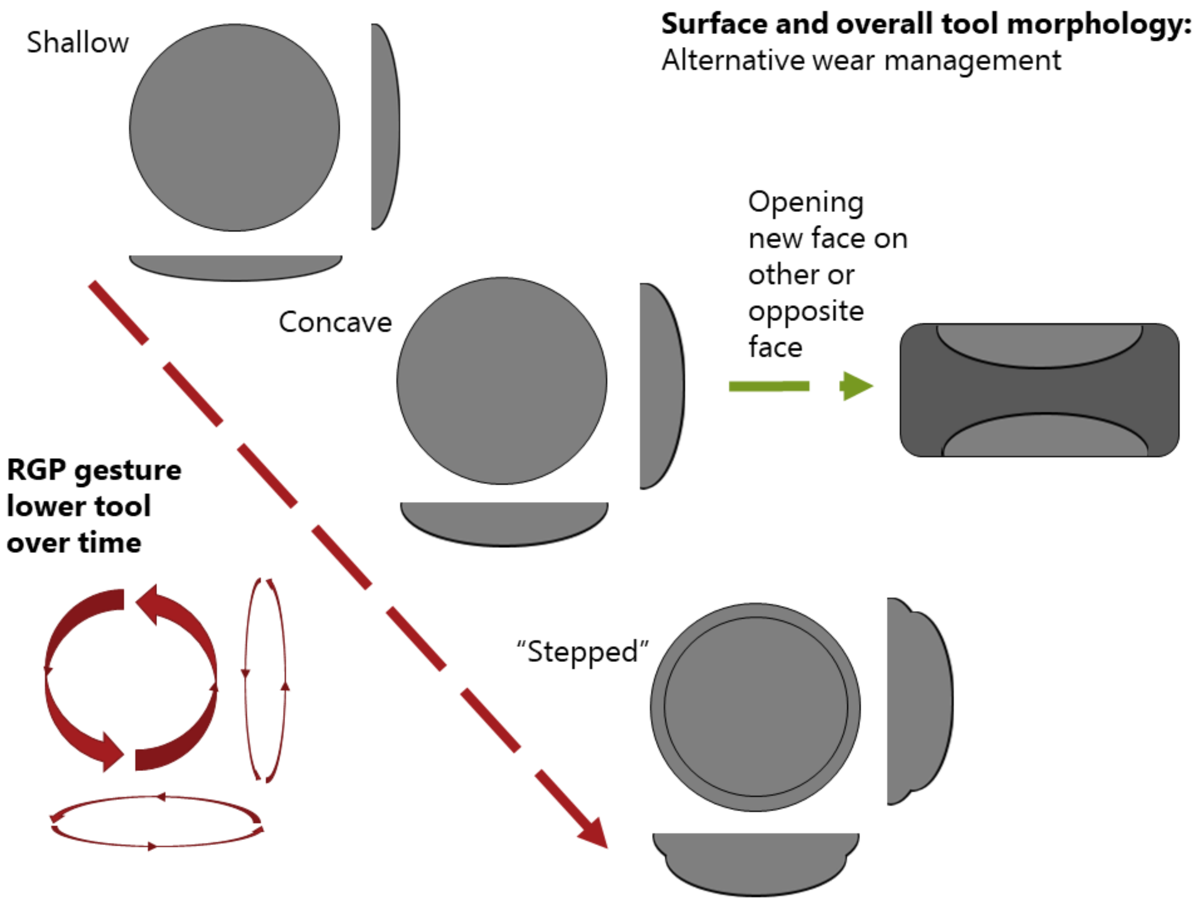

Figure 42: Idealised trajectories of both lower tools individual wear, in an overall view. Note the opening of the second face opposed to the original surface. Opposed faced quern. All fall within the RGP strategy.

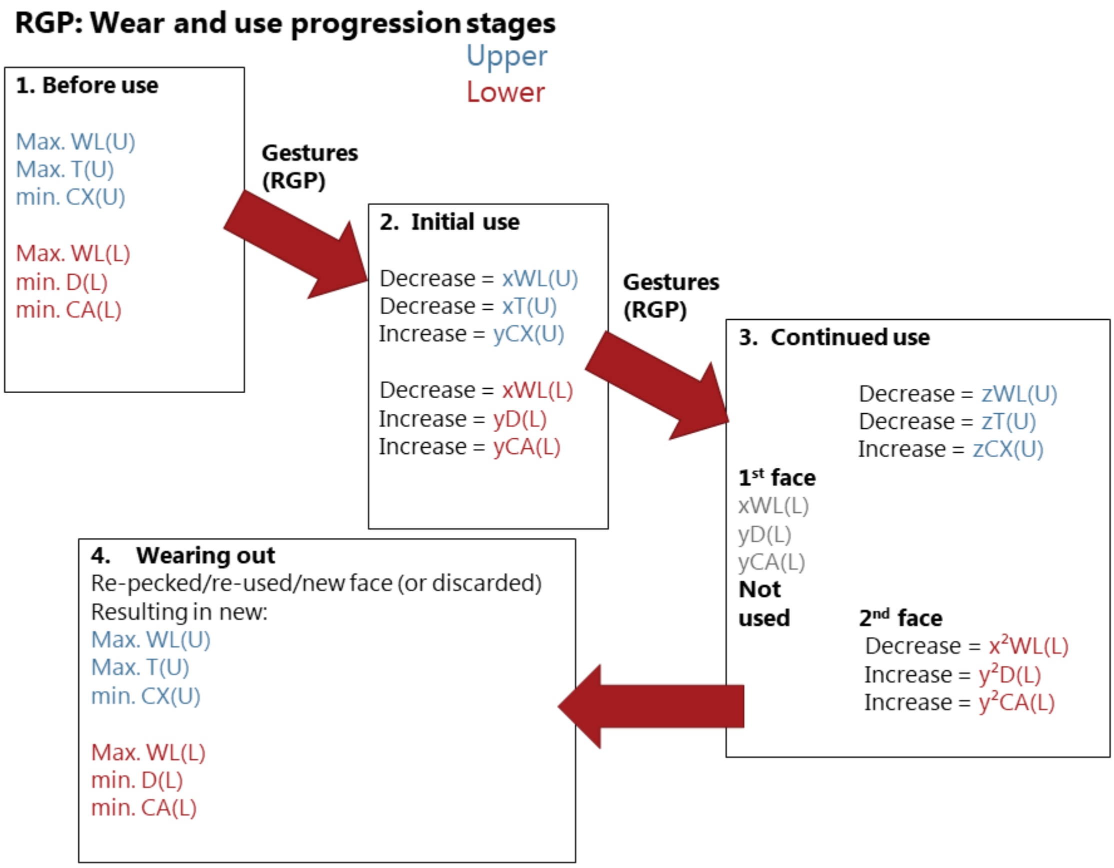

Figure 43: Generic "measurements" of the idealised morphology and how these change through use.

A3. Body positions and examples:

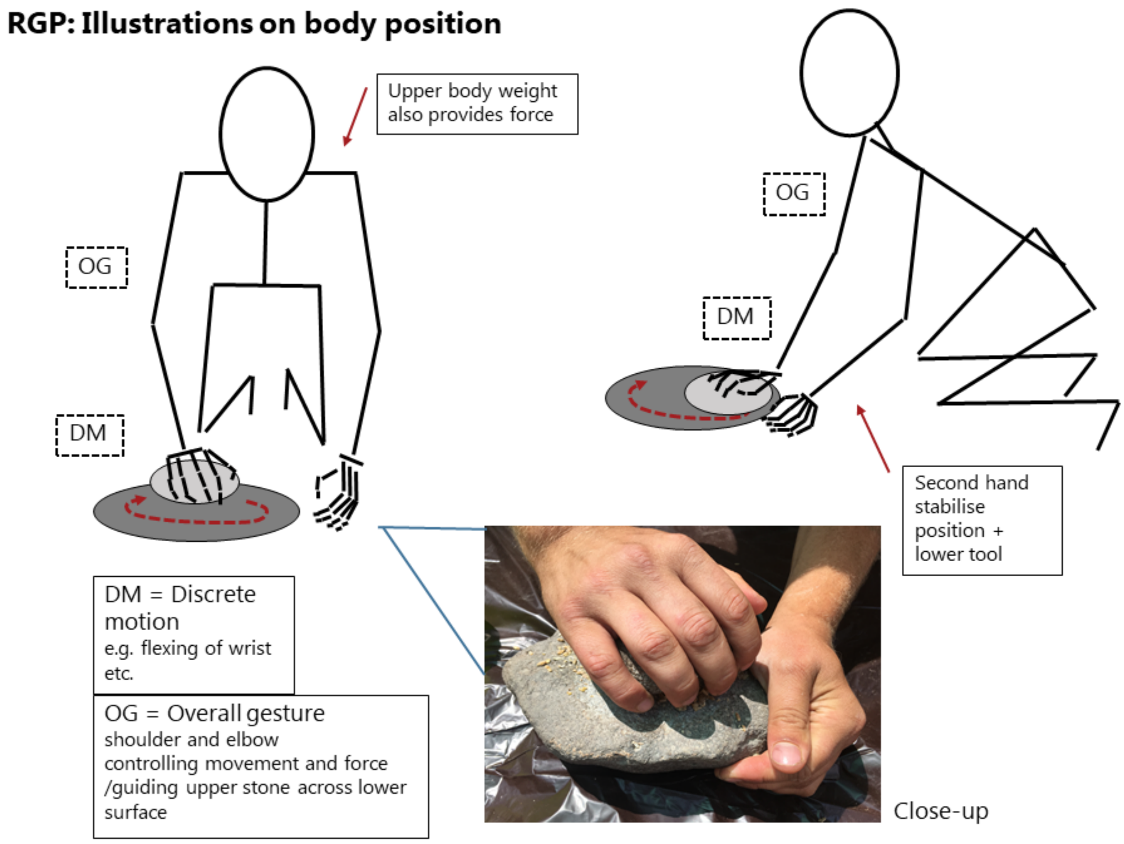

Figure 44: A3. RGP - Body positions, gesture

Figure 45: A3. RGP - Body positions, gesture, experimental example

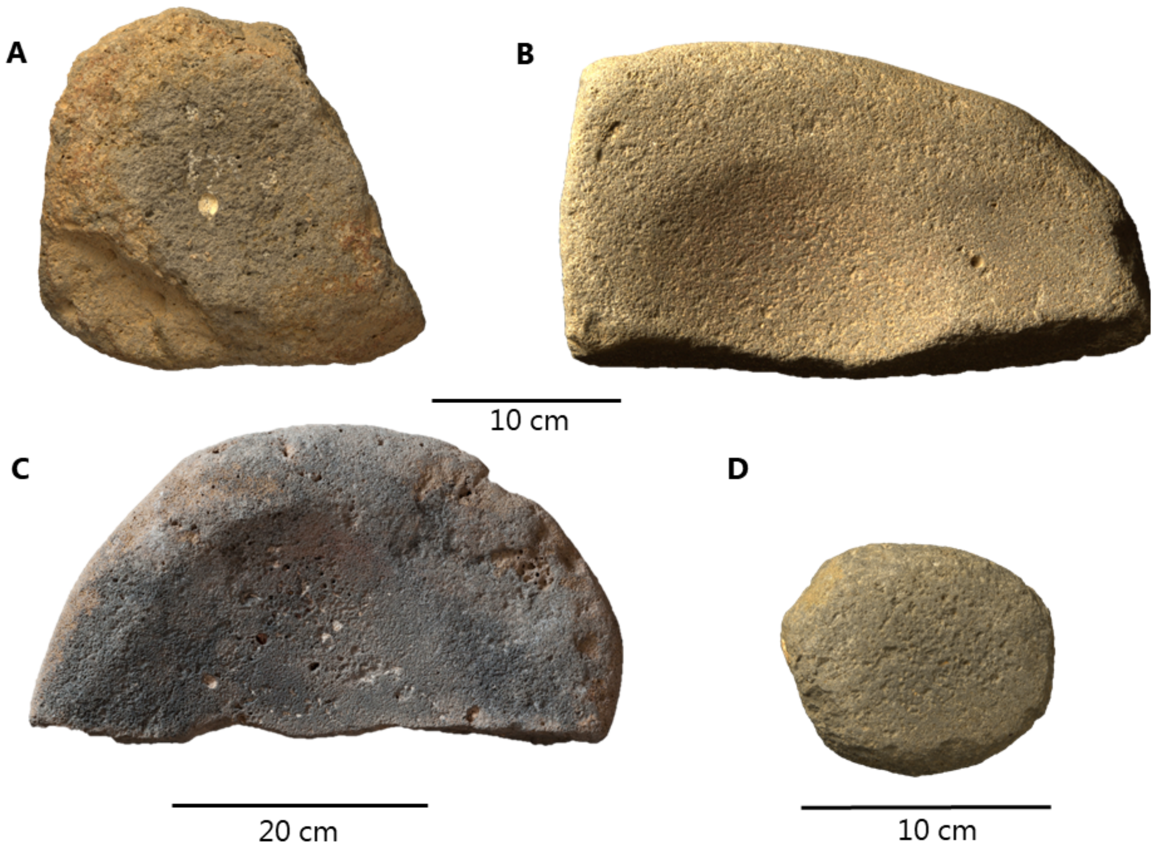

Figure 46: Archaeological examples of A3. RGP tools from Shubayqa 1: A Early Natufian phase, B-D Late Natufian phase. Note the smaller and deeper surface, that is set a previous grinding surface. A has a second face on opposite side, a so-called opposed-faced quern.

The general size of the upper tools for this strategy from the Shubayqa assemblages are:
Based on complete Discoidal-type handstone sizes (n=24). Length/width/diameter: max. 170 mm, min. 38 mm, avg. 79,1 mm thickness max. 70 mm,
min. 37 mm, avg. 41 mm
Face size (as ellipse: a x b x π): a 39,55 mm x b 39,55 mm x π = avg. 49,14 cm²

The general size of the active surface of lower tools of this strategy from the Shubayqa assemblages are:
From complete Quern faces (n= 20). Length/width/diameter: max. 396 mm, min. 28 mm, avg. 158,5 mm depth max. 36 mm, min.
3 mm, avg. 13,4 mm. Face size (as ellipse: a x b x π): a 79,25 mm x b 79,25 mm x π = avg. 197,3 cm²

Shape *ALL Discoidal*	**Face(s)** (circular)	**#**	**%**	**Face overall trans. profile**	**#**	**%**	**Face longitudinal profile**	**#**	**%**
	unifacial	14	**34**	flat	3	**7**	concave	0	**0**
	bifacial	21	**51**	lens	2	**5**	convex	12	**29**
	unidentified	6	**15**	oval	17	**42**	flat	10	**25**
				plano-convex	5	**12**	unidentified	19	**46**
				plano-irregular	2	**5**			
				wedge	6	**15**			
				varia	1	**2**			
				unidentified	5	**12**			

Table 5: RGP upper tools: discoidal handstone, number of used faces and profiles of active surfaces

Shape	**Overall plan**	**#**	**%**	**Face trans. profile**	**#**	**%**	**Face longitudinal profile**	**#**	**%**
	circular	10	**59**	*concave*	10	**26**	*concave*	3	**15**
	oval	7	**41**	*convex*	0	**0**	*convex*	0	**0**
				shallow	10	**42**	*shallow*	6	**30**
				flat	1	**2**	*flat*	0	**0**
				unidentified	18	**46**	*unidentified*	11	**55**

Table 6: RGP lower tools: querns, shape overall, plan and profiles of active surface

B. Confined Pounding with some Rotary grinding (CPR)

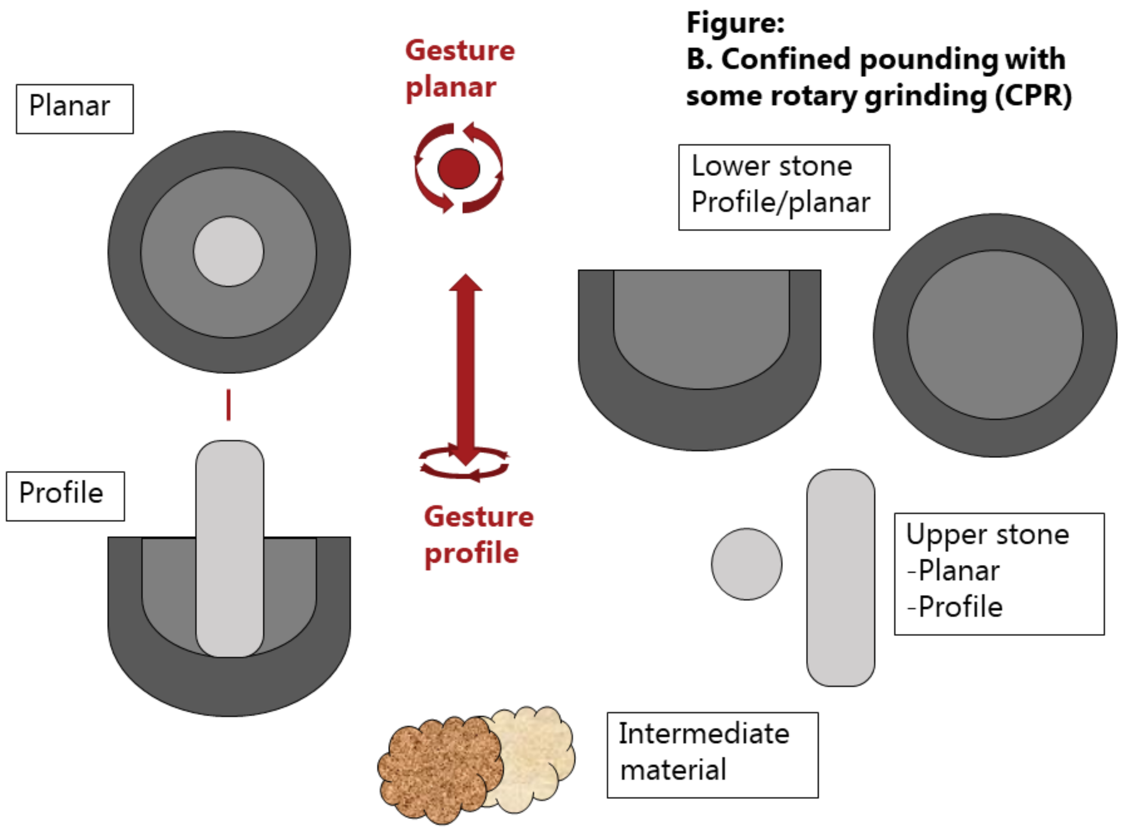

Figure 47: B. CPR, Overall idealised processing strategy and tools: cylindrical pestle handstone (circular profile, flat to convex terminus), vessel mortar (circular surface with a concave profile).

CPR - wear progression summary

1. **Before use**
    a. Lower tool (Level 0): The use surface of the lower tool is at minimum depth mD(L) and minimum concavity mCA(L) and the bottom of the face is at maximum diameter bottom MDI(L), top of hole is at maximum top diameter top MDI(L).
        i. **Macro/micro** (Level 1-2): Either levelled from smoothening finish (both interior + exterior) or pecking pits across surface. Here example is assumed "finished". A few pits with no apparent directionality may remain, pit edges rugged: i.e. no wear from contact with intermediate material only production traces.
    b. Upper tool (Level 0): : is at maximum length ML(U), minimum convexity mCX(U) and maximum diameter MDI(U)

i. **Macro/micro** (Level 1-2): Either levelled from smoothening finish (both interior + exterior) or pecking pits across what will become the active surface. Here the example is assumed "finished". A few pits with no apparent directionality may remain, pit edges rugged: i.e. no wear from contact with intermediate material only production traces.

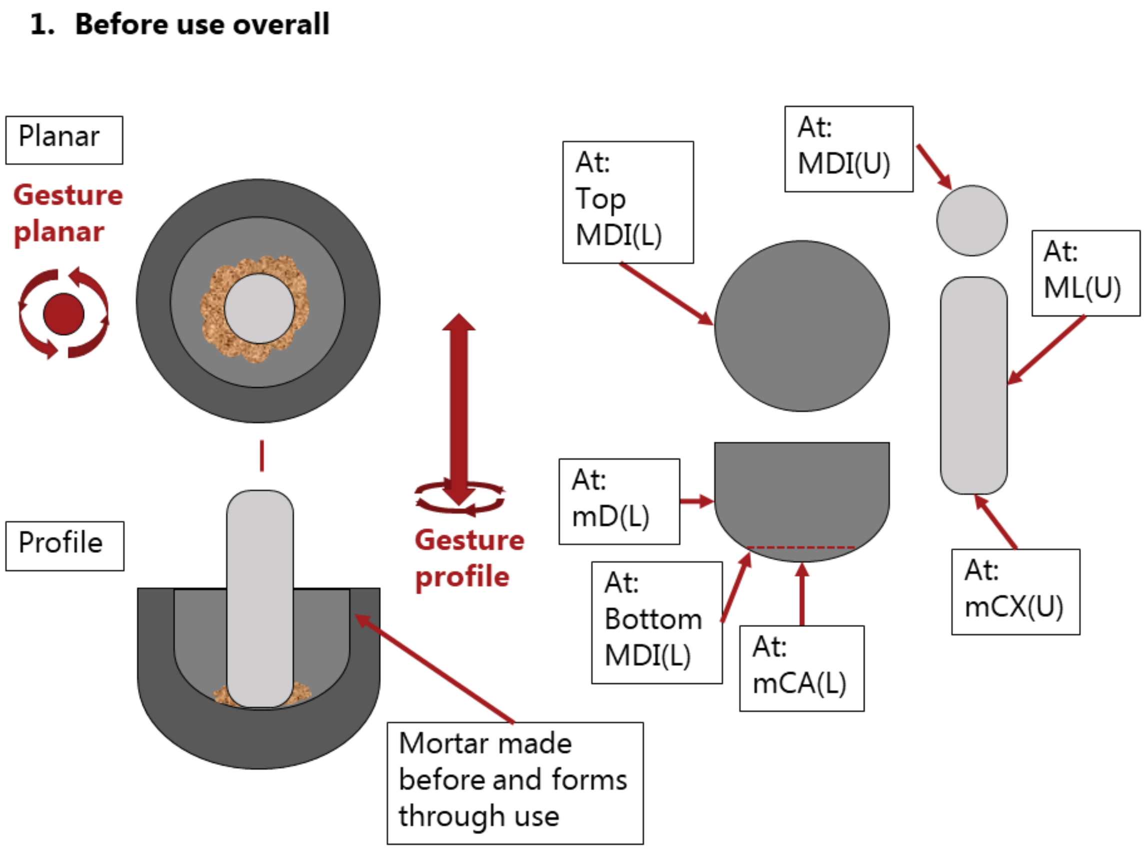

Figure 48: Idealised Stage 1 - before use overall view

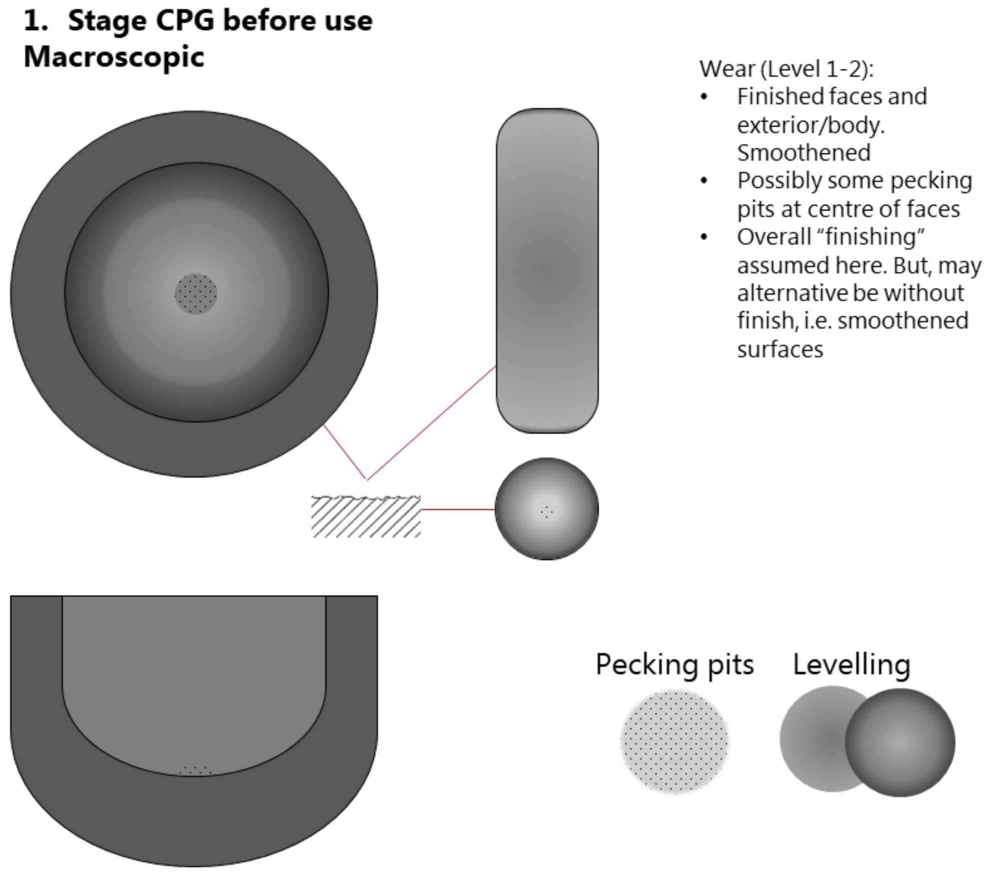

Figure 49: Idealised Stage 1 - before use, macroscopic view

2. **Initial use phase**

As the two stones (upper & lower) engage each other and the intermediate material the following happens:

a. Lower tool (Level 0): depth and concavity will begin to increase as the tool loses mass: mD(L) → yD(L), mCA(L) → yCA(L) respectively. The bottom diameter will at the same time decrease with this process bottom MDI(L) → xDI(L). Maximum top diameter unchanged, top MDI(L)
    i. **Macro/micro** (Level 1-2): Expansion of percussion pits, starting with few at the center to several spreading concentrically from the center. Levelling begins at the margins along with possibly striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A beginning circular/concentric (patterning) in the distribution of wear
b. Upper tool (Level 0): Length will very slowly begin to decrease as the tool from ML(U) → xL(U). As it loses mass from flaking, percussion (mainly center) and abrasion (mainly margins) convexity of terminus will increase,

from mCx(U) → yCX(U). However, see *Surface wear management* further below. Maximum diameter MDI(U) overall unchanged.

i. **Macro/micro** (Level 1-2): Expansion of percussion pits, starting with few at the center, then to several spreading concentrically from the center. Levelling begins at the margins along with possibly striations and/or sheen may also appear at margins (possibly a result of stone/stone contact). Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A beginning circular/concentric (patterning) in the distribution of wear.

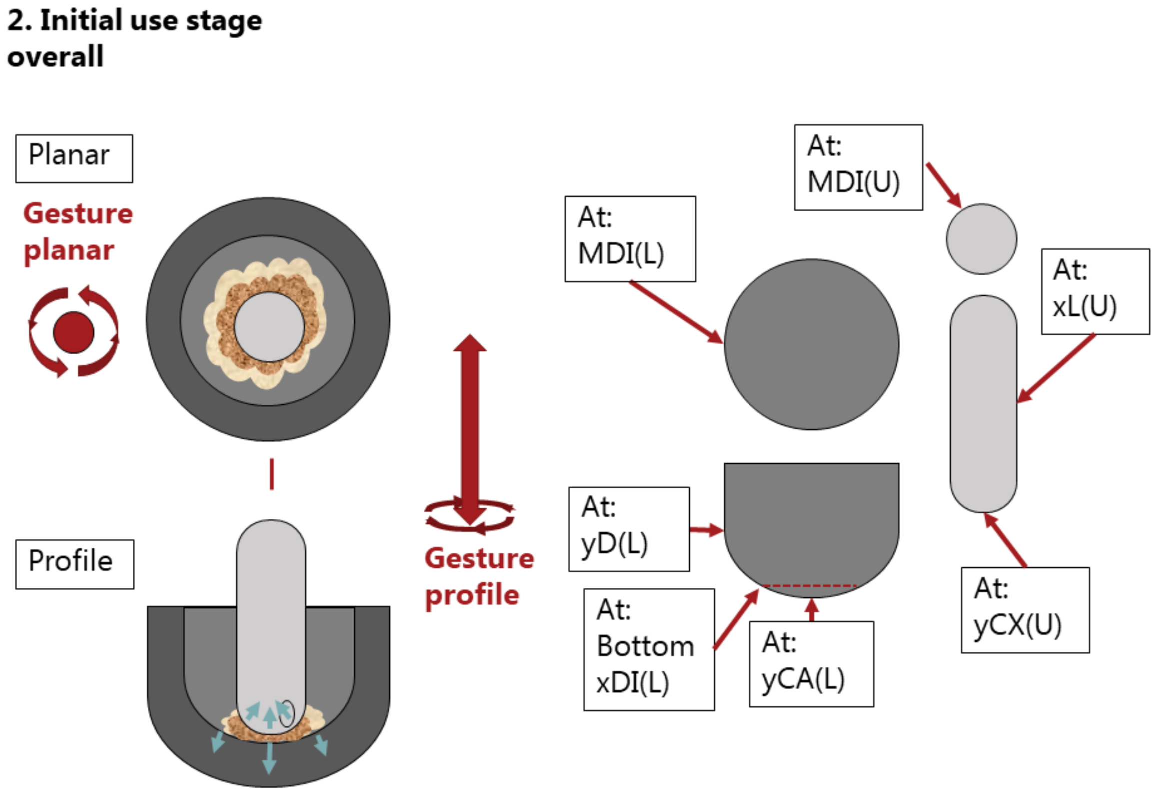

Figure 51: Idealised Stage 2 - initial use, overall view

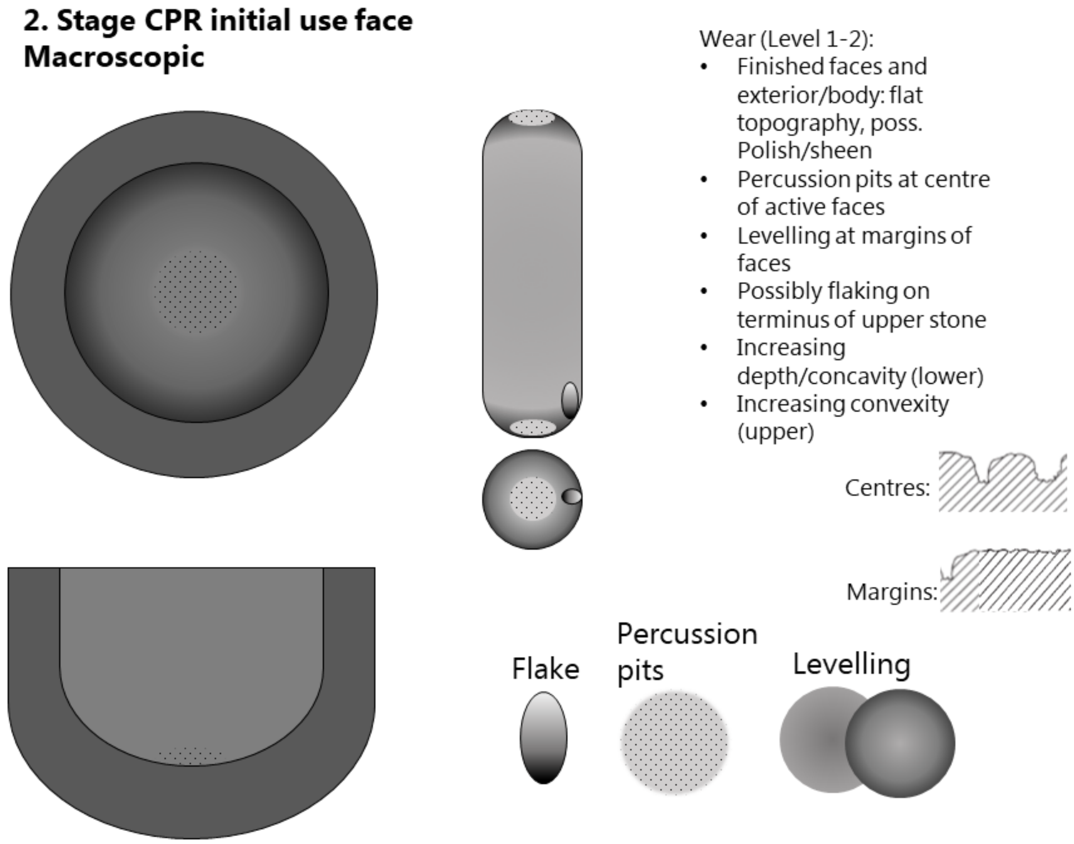

Figure 52: Idealised Stage 2 - initial use, macroscopic view

3. **Continued use phase**

As the lower face becomes deeper, use continues but on a smaller area).

a. Lower tool (Level 0): depth continues increasing yD(L) → zD(L), and concurrently pounding happens in a smaller area reducing bottom diameter bottom xDI(L) → zDI(L). Here if mainly involved in pounding the face becomes more conical and less concave, if both used in pounding and grinding (as assumed here) concavity continues to increase yCA(L) → zCA(L)(see a more detailed explanation below in *Surface wear management*). depth and concavity will begin to increase as the tool loses mass: respectively. Maximum top diameter unchanged, top MDI(L)

  i. **Macro/micro** (Level 1-2): Reduction of area with percussion pits: still several near the center, but levelling (potentially also sheen) at the margins(possibly a result of stone/stone contact), increasing concavity and decreases the area of percussion pits. Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A pronounced and concentrated circular/concentric (patterning) in the distribution of wear

b. Upper tool (Level 0): Length continues to slightly decrease as the tool loses mass xL(U) → zL(U). Again as it loses mass from flaking, percussion (mainly center) and abrasion (mainly margins) convexity of the terminus continues to increase, from yCx(U) → zCX(U). However, see *Surface wear management* further below. Maximum diameter MDI(U) overall unchanged.
    i. **Macro/micro** (Level 1-2): Reduction of area with percussion pits, still several near the center, but levelling at the margins along with micro and macro flaking (possibly a result of stone/stone contact) here increasing convexity, decreases the area of percussion pits. Depending on contact material beginning frosted appearance micro fractures, grain rounding and/or rounded levelling across the surface. May be more intense around the centre, especially pits and fractures from pounding gestures and margins, mainly levelling and rounding as these receive more pressure from rotary grinding. A pronounced and concentrated circular/concentric (patterning) in the distribution of wear

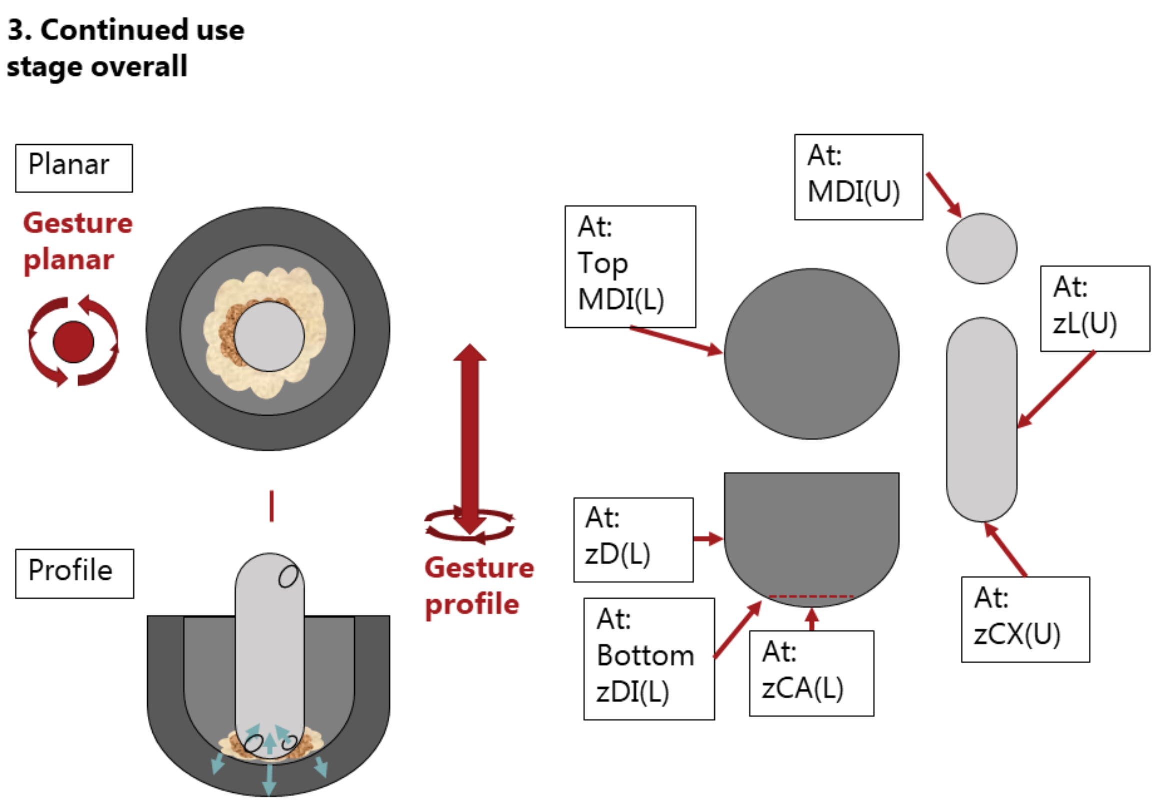

Figure 53: Idealised Stage 3 - continued use, overall view

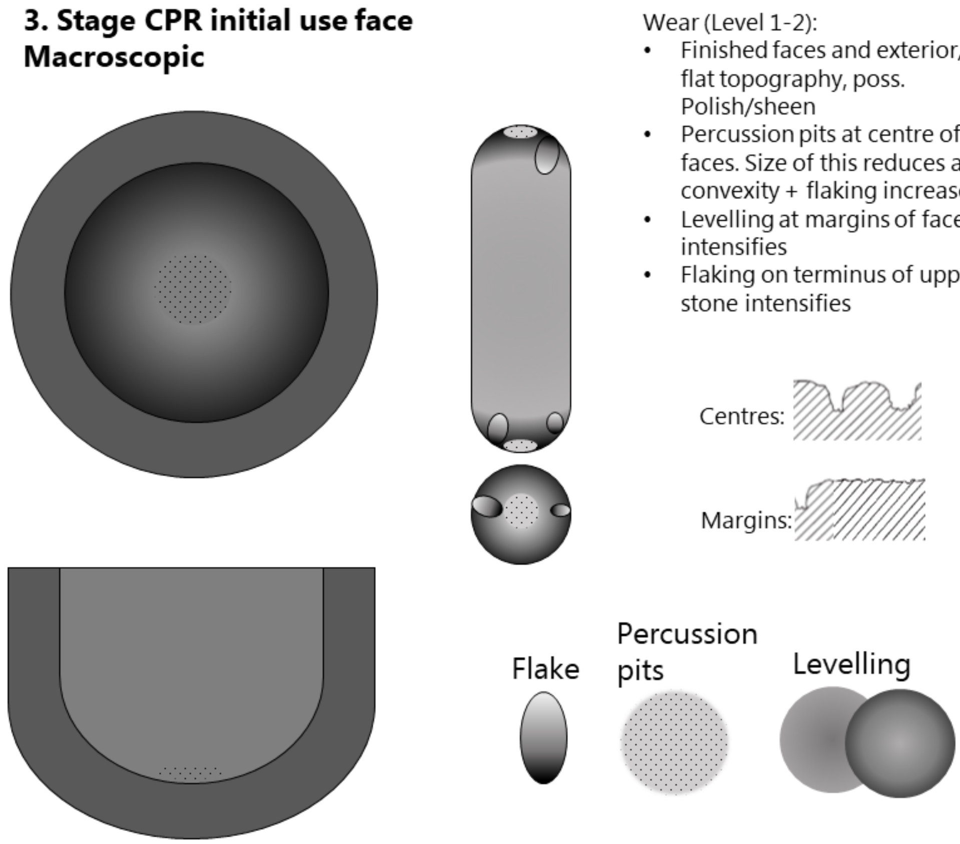

Figure 54: Idealised Stage 3 - continued use, macroscopic view

4. **Worn out phase**

The final stage, i.e. before a new round of pecking or breakage (unintentional and/or intentional), discard, abandonment. Heavily pitted and flaked. Intense levelling/sheen at margins on lower tool face. Depending on contact material a microtopography of covering: micro fractures, grain rounding or levelling, a sheen seen across face. Rarely found complete archaeologically (? examp.) possibly because of intentional breakage(?) or immediate re-pecking/re-use.

The confined pounding strategies and individual wear management

Here we may again argue that there are the same dialectical relationships at play: shaping before use and shaping through use. Repeated cycles of abrading margins of the face and crushing fractures etc at Center reducing length and promotion of convexity (Buonasera 2013) 199:"*pestles that exhibited fractured and crushed grains in the central portion of the distal end, but showed levelling and polish around the margins. This pattern indicates that both pounding and a rotary grinding motion with substantial rock-on-rock contact may have been employed.*" Pestles only used for pounding equals flat terminus (to concave), less round terminus (planar? crushing fractures etc at Center reducing length but not promoting convexity, little or no levelling along margins of the Center. Flaking of terminus present in both situations. Area with percussion marks first expands, stage 2, then subsides: stage 3 as convexity increases and levelling and flaking around terminus reduces most protruding part. Then the process repeats itself. Potentially on both upper and lower.

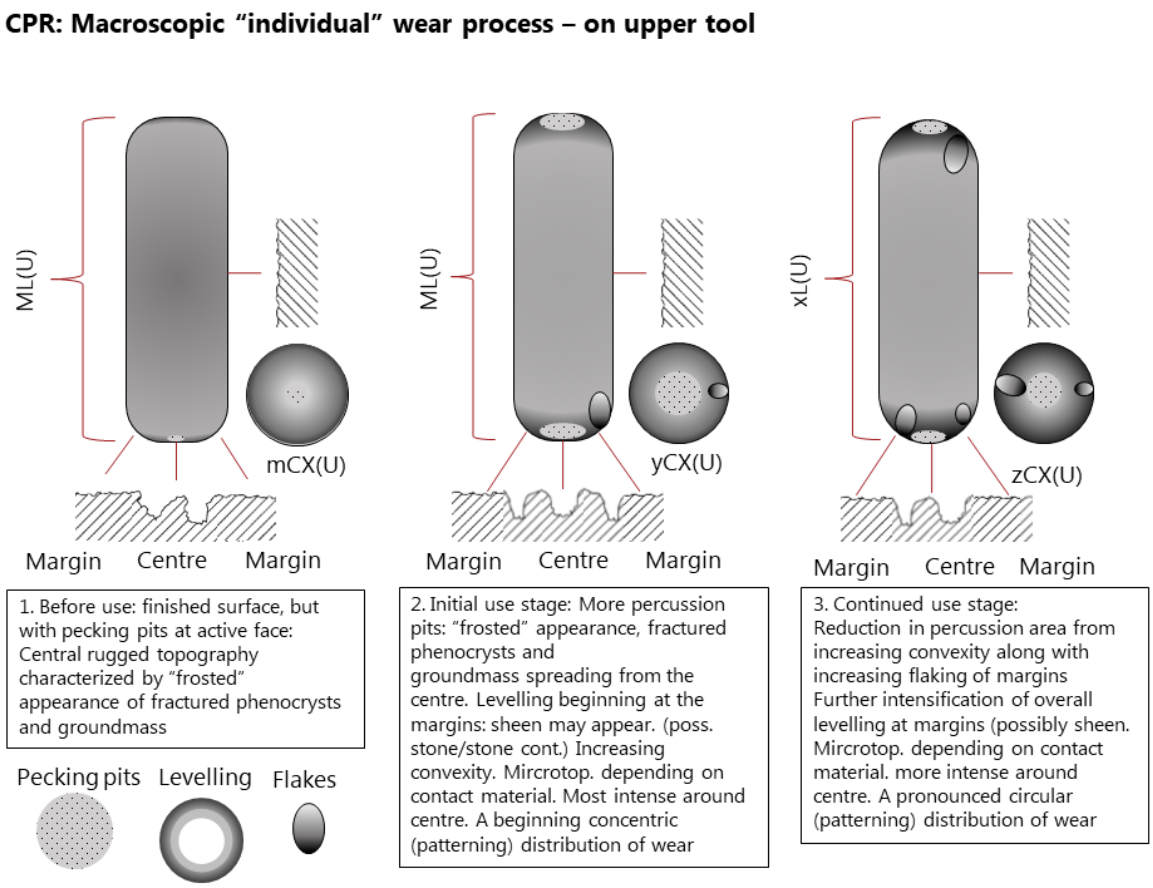

Figure 55: Idealised stages - upper tool individual wear, overall/macroscopic view

It could be that conical mortars, may be concave mortars that became deeper (Buonasera 2013), losing their concave/bowl profile and becoming more conical. Also a linear relationship between diameter and depth within an assemblage, may suggest that depth is a result of use (Wright 1991), and not necessarily prepared beforehand (at least in the case of immoblie bedrock features). Again these two poles, use and manufacture, are of course linked, manufacture is a prerequisite for use and use manufactures certain shapes. What it does tell us, is again a confirmation of this dialectical relationship found within the grinding tools (and tools in general). So changes within the confined pounding strategy are pertinent and related to conscious choices, though they may be external modifications or changes in size rather than the gesture itself, they are still determined by material conditions of wear.

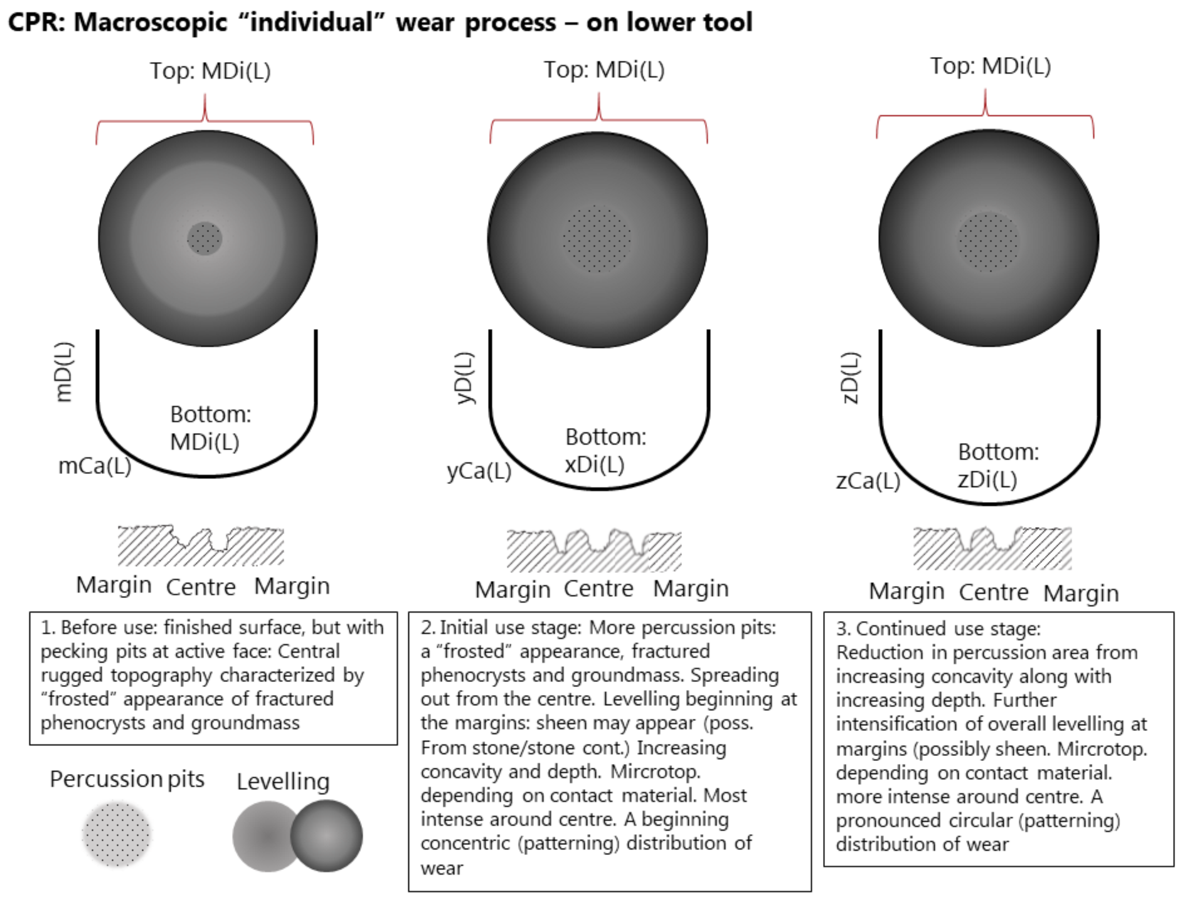

Figure 56: Idealised stages - lower tool individual wear, overall/macroscopic view

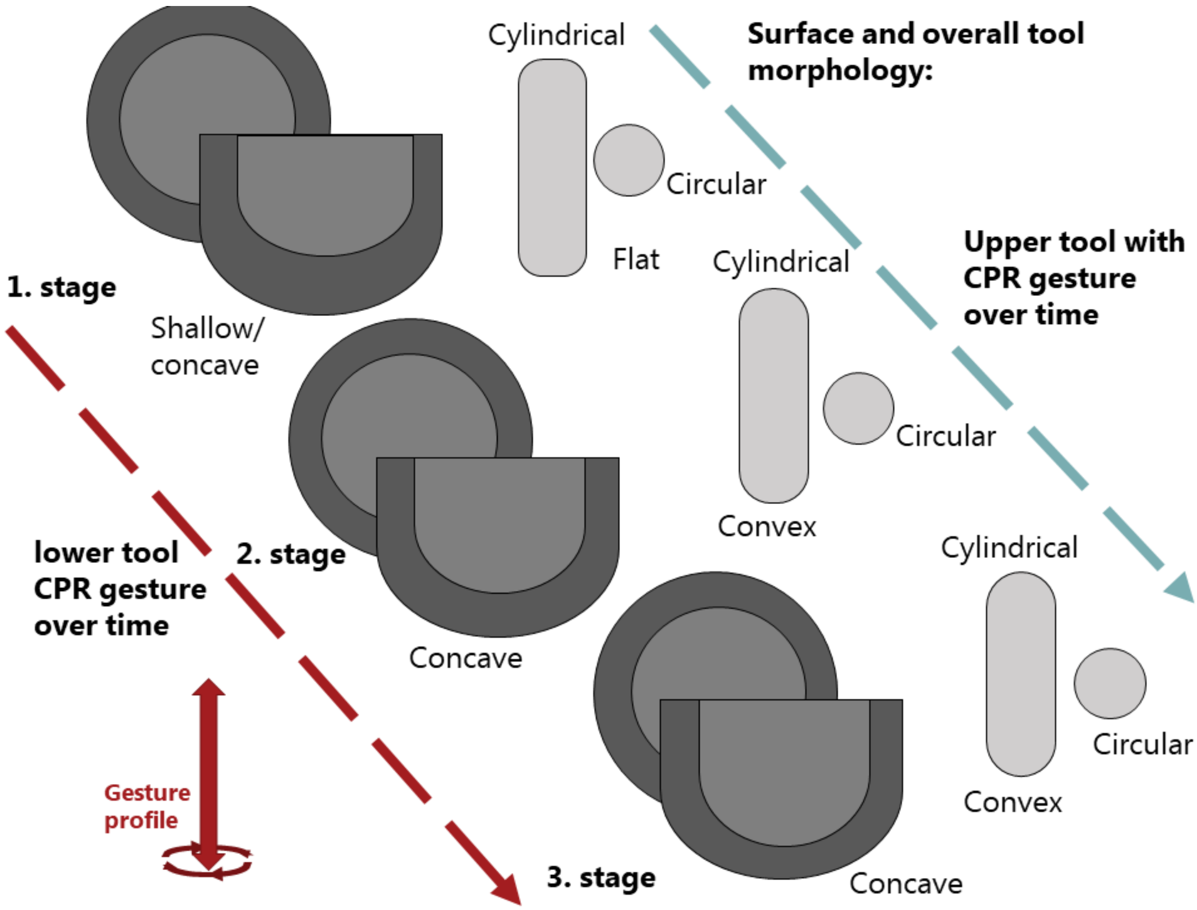

Figure 57: Idealised trajectories of both upper and lower tools individual wear, in an overall view.

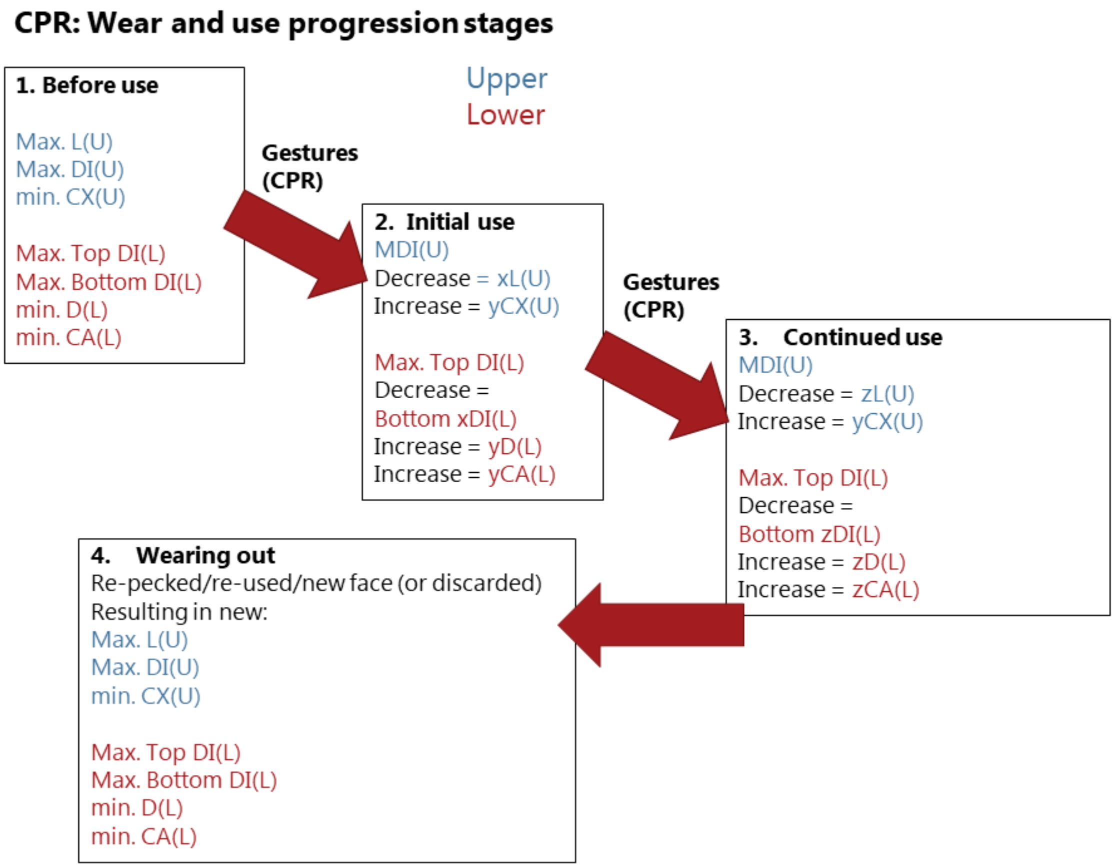

Figure 58: Generic "measurements" of the idealised morphology and how these change through use.

B. CPR Body positions and examples:

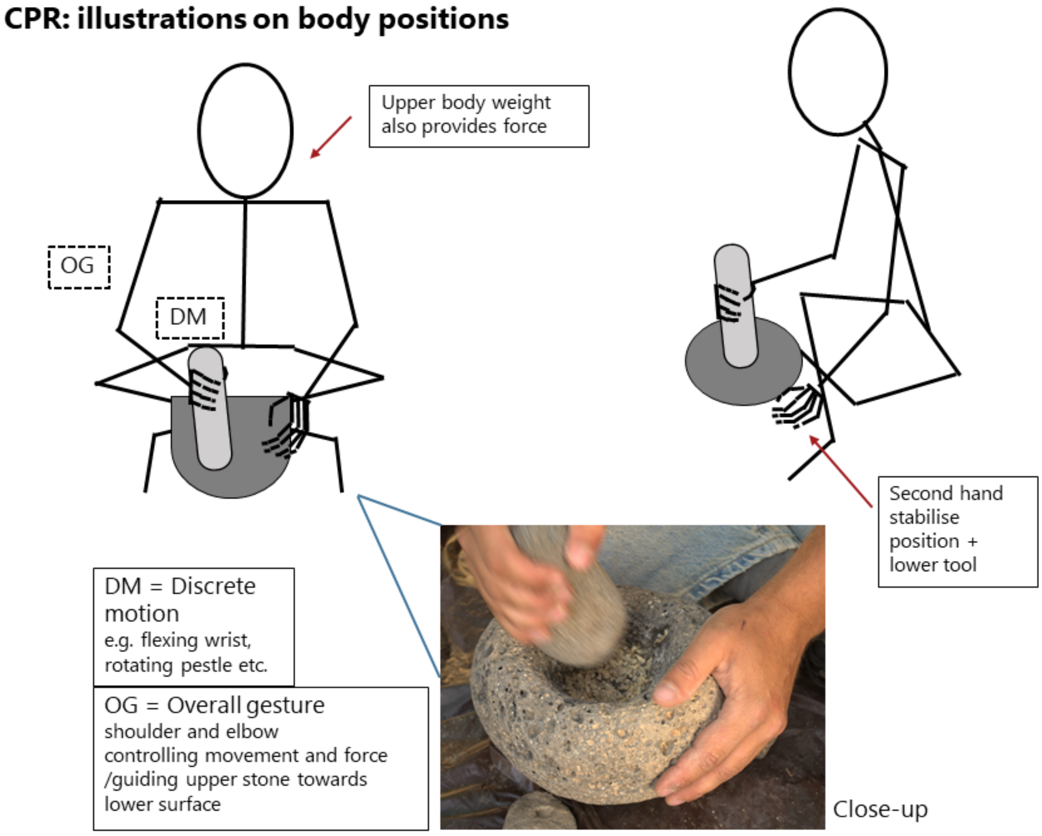

Figure 59: B. CPR - Body positions, gesture

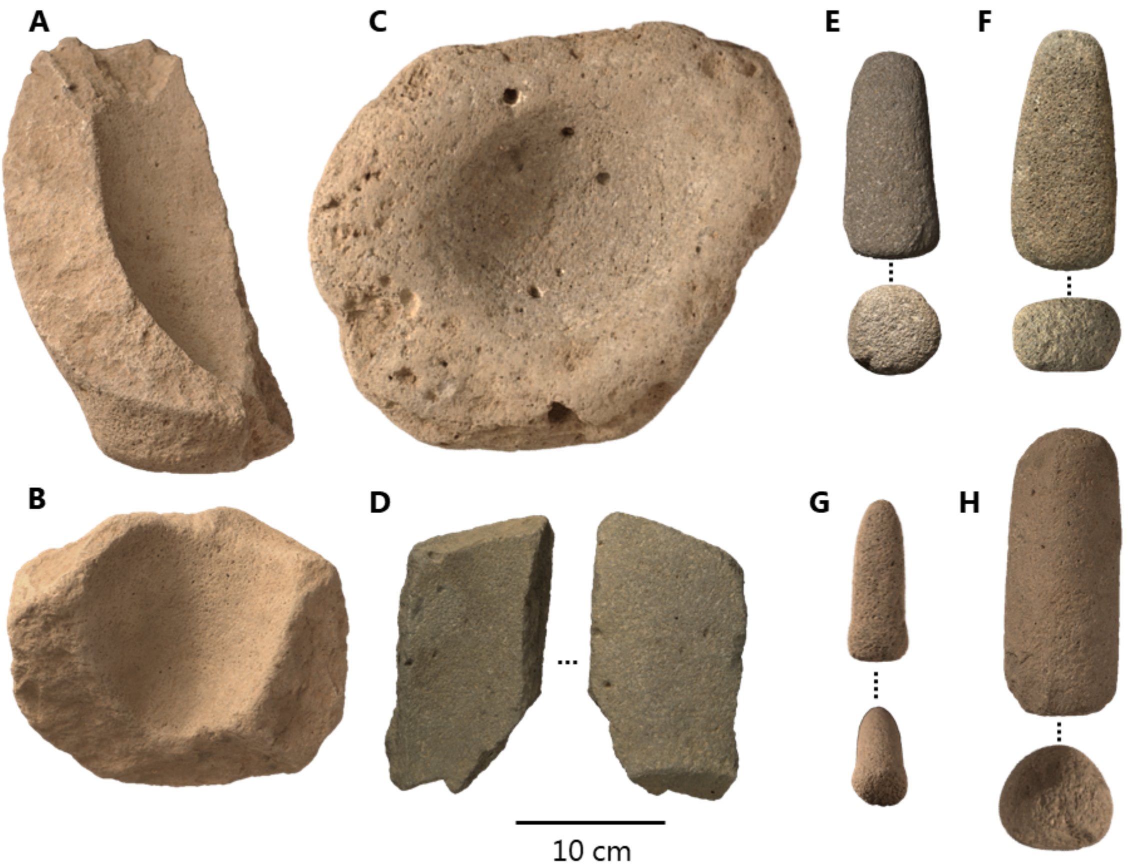

Figure 60: Archaeological examples of B. CPR. Basalt tools from Shubayqa 1 and 6: A-D lower tools, mortars E-H upper tools, pestles. A, C and D Early Natufian examples. B, F, H, Late Natufian. E and G from PPN, Shubayqa 6.

The general size of the upper tools for this strategy from Pestles size (n= 39). Length: max. 230 mm, min. 51 mm, Avg. 124,5 mm. Width: 125 mm, min. 35 mm, Avg. 67,8 mm. Face size (as ellipse: a x b x π): a 33,9 mm x b 27,9 mm x π = 31,84 cm².

The general size of the active surface of the lower tools for this strategy21 from Mortar/vessel face size (n= 22). Length/width/diameter: max. 310 mm min. 40 mm avg. 188,3 mm. Depth: max. 346 mm min. 6 mm avg. 148,5 mm. Volume too few to calculate.

Shape	**Overall**	#	**%**	**Face plan**	#	**%**	**Face profile**	#	**%**
	conical	29	**32**	*circular*	11	**12**	*concave*	8	**9**

	cylindrical	35	**39**	*sub-circular*	27	**30**	*convex*	20	**22**
	irregular	11	**12**	*oval*	19	**21**	*flat*	8	**9**
	rectangular	2	**2**	*irregular*	7	**8**	*unidentified*	54	**60**
	varia	2	**3**	*rectangular*	7	**8**			
	unidentified	11	**12**	*square*	5	**5**			
				triangular	8	**8**			
				unidentified	6	**7**			

Table 7: CPR upper tools: pestles, shape overall, plan and profile of active surface

Shape	**Overall**	**#**	**%**	**Face plan**	**#**	**%**	**Face profile**	**#**	**%**
	block	7	**10**	*circular*	51	**74**	*concave*	27	**39**
	boulder	15	**22**	*sub-circular*	2	**3**	*conical*	16	**23**
	bowl	10	**15**	*oval*	4	**6**	*shallow*	2	**3**
	globular	25	**36**	*square*	1	**1**	*unidentified*	24	**35**
	goblet	9	**13**	*unidentified*	11	**16**			
	varia	1	**1**						
	unidentified	2	**3**						

Table 8: CPR lower tools: mortars, shape overall, plan and profile of active surface

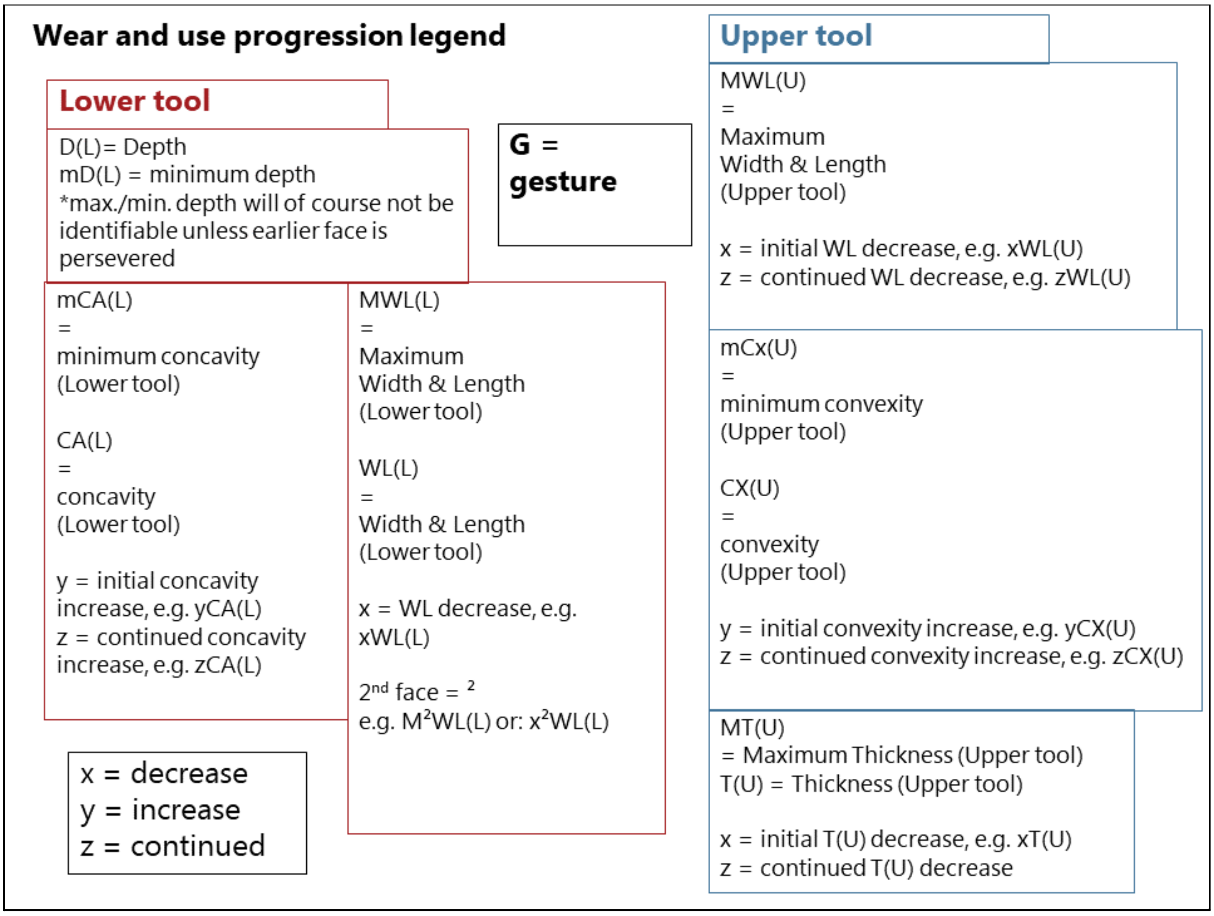

Figure 61: Legend for schematic overview of use progression

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Appendix III:
Experiments conducted in the field in Jordan May-June 2019 and preliminary microscopic use-wear analysis 2021*

*All Experiments conducted in Jordan May-June 2019 - a write up from field notebook of Patrick N. Pedersen (PP). Use-wear analysis of experimental tools conducted in Copenhagen 2021 by PP

1. Experimental tool production - by PP

1.1. Grinding tools

Quern (GSX.5)

Blank: was made on an angular, relatively flat basalt block. The naturally stable and flat side designated the dorsal surface. (Type I basalt)

Dimensions: 210 mm in length, 16 cm in width and c. 50 mm in thickness and a weight of 3134 gr.

Active face: a circular depression, quern face. Shallow-shallow profiles.

Face.Dimensions: diameter of 96 mm and a depth of 6 mm

Production description: The quern use face was fashioned with basalt hammerstones. One fist-sized cobble with angular "sharp" edge ("chopper" type I basalt) hammerstone for delineating and starting the depression and one slightly smaller (palm-sized) "pointed" hammerstone for more discrete pecking. In addition to pecking, and alternating with this, a third sub-angular stone (type IV basalt) was used together with water, a little dirt and sand to abrade the depression. Both techniques were effective (though pecking was more fruitful in deepening) in manufacturing the depression and worked well in unison. The exterior and sides of the quern was not modified.

Work time: The manufacture of this small quern took roughly 2 hours.

Handstone (GSX.6)

Blank: was made on a sub-circular basalt cobble, (Type I basalt)

Dimensions: length of 110 mm, width of 90 mm and thickness of 35 mm, weight of 732 gr

Active face: Whole "ventral face", flat/convex shape

Production description: basalt cobble, chosen for its suitable shape, as this then required less modification. A strategy that was possibly also followed by the people of the Natufian at Shubayqa, where a lot of suitably sized and shaped cobbles can found across the *harra* desert, making up its basalt fields. Indeed one may observe sparsely used handstone from the assemblage feature weathered, unmodified surfaces, suggesting a semi ad hoc approach, modifying mainly the face to be used. This was the approach we used and quickly, in about an hour, we manufactured a sub-circular handstone with a length of 110 mm, width of 90 mm and thickness of 35 mm, with only a single modified surface, roughened by pecking, using the same pecking hammerstones as above.

Work time: about an hour, probably slightly less

Figure 1: Finished quern and handstone pair, with harvested cereals

Figure 2: three examples of "pointed" hammerstones (PA.1-3) used for experimental GST production

1.1.1. Ad-hoc slab and handstone

Slab (GSX.7)

Blank: was made on an elongated sub-angular basalt cobble, (Type I basalt)

Dimensions:

Blank: length of 240 mm, width 160-150 mm and thickness 65 mm

Active face: Flat

Production description: basalt cobble, chosen for its suitable shape, little modification. Fashioned quickly, ad-hoc, only one face pecked (roughened).

Work time: less than an hour

Handstone (GSX.8)

Blank: was made on an elongated angular basalt cobble, (Type I basalt)

Dimensions:

Blank: length of 120 mm, width 90 mm and thickness 65 mm

Active face: Flat

Production description: basalt cobble, chosen for its suitable elongated shape, little modification. Fashioned quickly, ad-hoc, only one face pecked (roughened) and some flaking of the margin 5-7 flakes

Work time: less than an hour

1.2. Pounding tools

Mortar (GSX.9)

Blank: sub-angular basalt boulder, (Type IV basalt)
Dimensions:
Finished tool: length and width 190 mm and 220 mm, 12 cm in height, *c.* 5800 gr.
Blank: length and width 220 and 220 mm, 150 mm in height, *c.* 9000 gr.
Active face: circular mortar hole, concave profile
F.Dimensions: diameter 125 mm, depth 55 mm, volume 265 ml
Production description
Spread over 2 days.:
Day 1
10.00-10.45 = 0,75
12.15-12.45 = 0,50
13.30-15.30 = 2,0
Day 2
08.00-09.10 = 1,2
09.30-10.15 = 0,75
11.00-12.50 = 1,8

Detailed description:

Initial flaking along margins with a large (13x11x 8 cm and 1600 gr.) basalt hammerstone (HA.4). 10.15 - Switched to steel hammer and chisel, to save time. 14.30 - switch from steel to to HA.2. (hole 120 mm diameter, 39 mm deep). Only stone from then. 08.00 - (day 2) HA.2-.4 used. HA.2 breaks in half, because of calcite penetration. HA.2 still used though.
09.45 - PA.2 used on hole and rim, then PA.1. 11.15 - HA.3 for rim, PA.2 for rim and Ha.2 as well. 12.10 FA.3 for smoothening (abrading) exterior, rim and base. Done at 12.50 (day 2). See excel and pics for details of hammerstones.
Work time: 7 h. (3,5 on exterior + finishing)

Figure 3: Progress in mortar production with steel tools, before removing central "plug" and switching back to stone tools

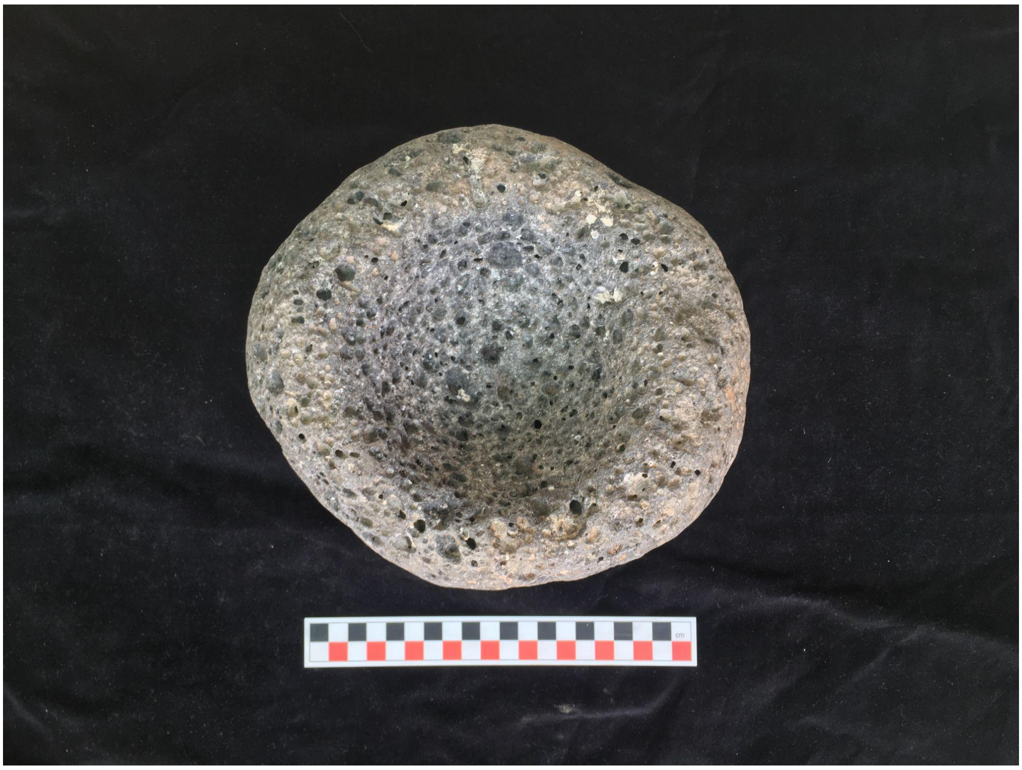

Figure 4: finished mortar

Pestle (GSX.10)

Blank: was made on an elongated sub-angular basalt cobble, (Type I basalt)

Dimensions:

Finished tool: 140 mm, 65-55 mm thickness/width, weight of 900 gr.

Blank: length of 160 mm, width/thickness 60-70 mm and weight of 1100 gr

Active face: Convex (to flat)

Production description: basalt cobble, chosen for its suitable elongated shape, as this then required less modification. One day only

07.50-10.15 = 2,6

11.00-12.15 = 1,25

Detailed description:

07.50 - flaking margins with FA.1 + HA.2. FA.1 discarded, too fragile. HA.2 exhausted, left alone. From 08.30 and 09.00 FA.2 and FA.3 used. 09.45 - pecking stops and a flat slab is used as a whetstone with water and sand + mud to abrade the body of the pestle. 11.00 - start pecking again with HA.2 used again, still works well. End, i.e. use face worked on. 11.45 - HA.2 used for abrading the body, with no water. Works better than whetstone! HA.2 and FA.2 + 3 retired after this.

Work time: 3,85 hours effective work

1.2.1. Wooden pestle

Blank: A fig-tree branch

Dimensions:

Finished tool: 610 mm long, 52 mm diameter/width, weight of 900 gr.

Active face: Flat (to convex)

Production description: none

Figure 4: Wooden pestle in use, 2019

1.3. Experimental tool use

1.3.1. Flour experiments

Activity: Grinding grain
Date: 12.06.2019
Location: Jordan, Safawi, Khaled's house
People: PP and AFS (Frida)
Tool(s): GSX.5 (LGI), GSX.6 (HS)
Surface shape upper + lower (planar/trans./long.):
Sub-circular/flat to slightly-convex
Circular/shallow/shallow
Gesture/strategy: diffuse resting percussion/RGP - rotary grinding (with some pounding)
Notes on movements: PP: Kneeling, flexing both knees. right-handed, moving right-hand in circular, counter-clockwise motion counter-clockwise most comfortable. When tired, shift to left-hand, clockwise or alternatively two-handed counter-clockwise left hand on top of right.
AFS: Two-handed in circular clockwise motion, left hand on top of right, the most comfortable. The right hand leading, left mainly simply providing pressure from above.
Time(s):
10:45-11:30 (PP),
11:30-12:20 (AFS)

12:30-12:55 (PP)
= 2 hours (0,75 + 0,80 + 0,45)
Start product (gr.): 100 gr. Bread wheat grains (harvested in the Qa' Shubayqa)
End product (gr.):
10:45-12:20 = 84 gr. of both coarse/cracked and fine flour (34 gr. Fine, 50 gr. coarse)
12.30-12:55 (continued with the coarse) = 54 gr. Fine, 30 gr. coarse
Pictures (no#): SHB_PP19_8753.JPG → SHB_PP19_8786.JPG
Tool location (or discarded?): in Copenhagen

Figure 5: Harvesting cereals with microlithic sickle in the Qa' Shubayqa 2019

Figure 6: Grinding cereals with experimental quern and handstone set (GSX.5 + 6), 2019.

Activity: Making tuber flour (grinding)
Date: 12.06.2019
Location: Jordan, Safawi, Khaled's house
People: PP and AA
Tool(s): GSX.5 (LGI), GSX.6 (HS)
Surface shape upper + lower (planar/trans./long.):
Sub-circular/flat to slightly-convex
Circular/shallow/shallow
Gesture/strategy: diffuse resting percussion/RGP - rotary grinding (with some pounding)
Notes on movements: PP: Kneeling, flexing both knees, right-handed, moving right-hand in circular, counter-clockwise motion counter-clockwise most comfortable. Also some pounding with the handstone's margins. When tired, shift to left-hand, clockwise or alternatively two-handed counter-clockwise left hand on top of right.
AA: right-handed, same as PP, but clockwise and squatting
Time(s):
17:40-17:50
17:50-18:00 - re-roughening (pecking w. FA.5)
18:00-18:10 PP
18.10-18:20 AA
Start product (gr.): hand-peeled dried rhizome tubers: 15 gr.
End product (gr.): 10 gr. Coarse flour
Pictures (no#): SHB_C19_5487.JPG → SHB_C19_5518.JPG

Tool location (or discarded?): in Copenhagen

Activity: Making tuber flour (pounding)
Date: 12.06.2019
Location: Jordan, Safawi, Khaled's house
People: PP and AA
Tool(s): GSX.9 (mortar), GSX.10 (pestle)
Surface shape upper + lower (planar/trans./long.) Upper: Convex (to flat) **lower:** circular mortar hole, concave profile
Gesture/strategy: Diffuse thrusting percussion: CPR - confined pounding with rotary grinding
Notes on movements: Sitting or squatting only using one hand, as the stone pestle was small, but heavy weight (900 gr.). Upper arm and elbow as the motive force behind, and a hand firmly grasping the pestle during the forceful downward stroke. The upper body produces additional weight behind the thrust.
Notes on experiment: Was much faster than grinding, fine flour as well
Time(s): 18:30-18:45
Start product (gr.): hand-peeled dried rhizome tubers: 15 gr.
End product (gr.): 11 gr. "fine" tuber flour
Pictures (no#): SHB_C19_5520.JPG → SHB_C19_5542.JPG
Tool location (or discarded?): in Copenhagen

Figure 7: Making tuber flour through pounding in experimental mortar and pestle set (GSX.9 + 10).

1.3.2. "Peeling" experiments

Activity: Peeling tubers (pounding) 1 (ash-roasted)
Date: 13.06.2019
Location: Jordan, Safawi, Khaled's house
People: PP and AA
Tool(s): GSX.9 (mortar), GSX.10 (pestle)

Surface shape upper + lower (planar/trans./long.) Upper: Convex (to flat) **lower:** circular mortar hole, concave profile
Gesture/strategy: Diffuse thrusting percussion: CPR - confined pounding with rotary grinding
Notes on movements: Sitting or squatting only using one hand, as the stone pestle was small, but heavy weight (900 gr.). Upper arm and elbow as the motive force behind, and a hand firmly grasping the pestle during the forceful downward stroke. The upper body producing additional weight behind the thrust.
Notes on experiment: Stopped quickly. It didn't work
Time(s): 07:30-07:45
Start product (gr.): 26 gr. Ash roasted tubers
End product (gr.): did not work, only cracked/crushed tubers left
Pictures (no#): N/A
Tool location (or discarded?): in Copenhagen

Activity: Peeling tubers (pounding) 2 (pit-roasted)
Date: 13.06.2019
Location: Jordan, Safawi, Khaled's house
People: PP and AA
Tool(s): GSX.9 (mortar), GSX.10 (pestle)
Surface shape upper + lower (planar/trans./long.) Upper: Convex (to flat) **lower:** circular mortar hole, concave profile
Gesture/strategy: Diffuse thrusting percussion: CPR - confined pounding with rotary grinding
Notes on movements: Sitting or squatting only using one hand, as the stone pestle was small, but heavy weight (900 gr.). Upper arm and elbow as the motive force behind, and a hand firmly grasping the pestle during the forceful downward stroke. The upper body produces additional weight behind the thrust.
Time(s): 07:55-08:01
Start product (gr.): 10 gr. pit-roasted tubers
End product (gr.): mainly cracked/crushed tubers
Pictures (no#): N/A
Tool location (or discarded?): in Copenhagen

Activity: Peeling tubers (grinding) - pit roasted
Date: 13.06.2019
Location: Jordan, Safawi, Khaled's house
People: PP and AA
Tool(s): GSX.5 (LGI), GSX.6 (HS)
Surface shape upper + lower (planar/trans./long.):
Sub-circular/flat to slightly-convex
Circular/shallow/shallow
Gesture/strategy: diffuse resting percussion/RGP - rotary grinding (with some pounding)
Notes on movements: PP: Kneeling, flexing both knees, right-handed, moving right-hand in circular, counter-clockwise motion counter-clockwise most comfortable. Without exerting pressure. Little to no pressure applied! AA: right-handed, same as PP, but clockwise and squatting.
Notes on experiment: Worked well! "rolled" the tubers between the grinding pair, the abrasion peeling them. Not so much pulverizing!
Time(s):

08:04-08:15 PP
08:25-08:29 AA
= 0,25 h
Start product (gr.): 10 gr. pit-roasted tubers
End product (gr.): 4 gr nicely peeled tubers
Pictures (no#): SHB_C19_5562.JPG → SHB_C19_5583.JPG
Tool location (or discarded?): in Copenhagen

Figure 8: Grinding tubers to "peel" them, getting rid of scale leafs etc. in experimental Quern and handstone set (GSX.5 + 6).

1.3.3. Making mash

Activity: Making tuber mash (pounding)
Date: 14.06.2019
Location: Jordan, Safawi, Khaled's house
People: PP and AA
Tool(s): GSX.9 (mortar), GSX.10 (pestle)
Surface shape upper + lower (planar/trans./long.) **Upper:** Convex (to flat) **lower:** circular mortar hole, concave profile
Gesture/strategy: Diffuse thrusting percussion: CPR - confined pounding with rotary grinding
Notes on movements: Sitting or squatting only using one hand, as the stone pestle was small, but heavy weight (900 gr.). Upper arm and elbow as the motive force behind, and a hand firmly grasping the pestle during the forceful downward stroke. The upper body produces additional weight behind the thrust. Both pounding and rotary grinding.
Notes on experiment: To crush tubers with water and make a mash. Worked alright
Time(s):
08:58 start
09:01 added 10 ml of water
09:04 added 10 ml more (water)
09:08 finished

Start product (gr.): 12 gr. pit-roasted tubers (pit#3 a little water was added to the stems to "steam" the tubers) + water
End product (gr.): 18 gr. of mash/gruel
Pictures (no#): N/A
Tool location (or discarded?): in Copenhagen

2. Experimental use-wear

2.1. Introduction

Three different experimental ground stone processing tool pairs were tried in the experiments to process tubers (USO's). These where: rotary or circular grinding (what I term RGP) with a quern and discoidal handstone, open reciprocal back-and-forth grinding (ORG in my terminology) on a flat slab and pounding in a mortar, a confined hole, with both stone and wooden pestle (CPR). The experimental tools were based on archaeological examples retrieved from the Natufian layers of the Shubayqa 1 occupation. (For detailed description of the technologies and processing strategies see Pedersen *forthcoming* AGSTR, Pedersen *forthcoming*). GST use for processing tubers/USO's is also attested ethnographically: both the grinding of tubers (e.g. Schroth 1996; Stewart 1942; Shoemaker, Davies, and Moore 2017) and pounding of tubers (e.g. Shoemaker, Davies, and Moore 2017; Gott 1982, 62), which inform our studies as well.

2.1 Below write up of result of initial use-wear analysis June 2021

Indicators of tuber processing (see table below): Overall the topography of the tools used in tuber processing through grinding, in all states (wet, dry and roasted), is rounded/sinuous and smooth. Levelling present on all, and is rounded and smooth. Edge rounding is prevalent, especially in the low topography, same goes for microfractures on the phenocrysts, this however mostly in high topography. For the tools used to process by pounding use-wear is slightly different. Here the center is rounded and rough while margins have rounded smooth levelling, and phenocryst fractures are most prevalent at the center in both high and low topography with some rounding in the low topography, while the margins display edge rounding in both high and low topography and few if any microfractures. See table (last column) for description of the pecked but otherwise unused surfaces.

All but two tools feature edge rounding, a rounding of the phenocrysts. The two without GSX.6 and 8, are upper tools, handstones. In both cases several pecked pits from production, or in the case of GSX.6 re-roughening/rejuvenation of the active surface remain in the central area. The edge rounding probably had not yet developed, on GSX.8 having only been used for 0,5 hours for grinding wet tubers and GSX.6 in 0,75 for grinding roasted tuber, but would potentially also develop through continued use in tuber processing. This is because wear happens progressively (e.g. (Hayes, Pardoe, and Fullagar 2018); Pedersen *forthcoming*), and not only a result of contact material but also the time the tool is used for. Both the lower stones the two handstones were used with quern GSX.5 and slab GSX.7 display edge rounding. This presence of rounding may be the result of the lower tools bearing more on the load and weight, thus the tubers being mashed down into these surfaces, more so than the upper tools and microscopic soft plant material then cover the high and extending into the interstices and low topography of the lower tools coursing the rounding there but not as quickly on the upper tools. As mentioned, when “peeling” the roasted tubers with GSX.5 and GSX.6 hardly any pressure was exerted on the upper stone, which may also factor into the rounding not developing.

GSX.6 had also been used in grain (wheat) grinding, and along with the quern GSX.5 the only other tool used in grain grinding, these are also the only to display phenocryst extraction. A combination of levelled grains and occasional sporadic extracted grains has been noted as possibly indicative of wild cereal grass processing (Cristiani and Zupancich 2021). And this may be a place where the tuber processing and cereal processing use-wear diverge. Interestingly no striations or linears traes were observed on the used surfaces. Something also often associated with cereal grinding especially with sandstone and quartzite tools (e.g. Adams 1989; Fullagar and Field 1997; Verbaas and van Gijn 2007; Zurro, Risch, and Conte 2005).

Polish/sheen was observed on only the grinding tools, suggesting that grinding gestures and strategies promote sheen to a greater extent than pounding, even though the same material (tubers) in the same states (wet, dry and roasted), was processed. This even though the pounding was used for more time than the one grinding ORG pair (GSX.7 + 8). However used for less time than the RGP grinding pair GSX.5 + 6. Specifically in the highest areas are affected and along the margins and distal end, suggesting this is a result of stone-stone contact in addition to contact with the intermediate material (see also(Adams 1989); (Verbaas and van Gijn 2007). In pounding the tool surfaces appear better protected by the intermediate material, see also (Cristiani and Zupancich 2021). Interestingly the sheen appeared on the tools used to “peel” the tubers: GSX.7 + 8 used to peel wet tubers with reciprocal grinding (unsuccessfully), and GSX.5 + 6 used to peel roasted tubers with circular grinding. GSX.7 + 8 were also used for the shortest time, less than an hour. However the combination of several high points of both upper and lower surfaces, contact along margins and ends (causing stone-stone contact), the reciprocal gesture and the water content of the tubers is suggested here to have caused the sheen to form. With GSX.5 + 6, used to peel roasted tubers, the sheen probably also had to do with the time they were used (2,75 h in all), in combination with the grinding processing strategy and contact with the tubers. This sheen is on the lower tools paired with a more intense, rounded (GSX.5) to flat (GSX.7) levelling of both groundmass and phenocrysts, like the sheen it also observed at the margins of GSX.5 and the distal part of grinding surface on GSX.7.

Activity (strategy)	**Grinding (RGP) GSX.5 & 6**	**Pounding (CPR) GSX.9 & 10**	**Grinding (ORG) GSX.7 & 8**	**Pecked surface**

				before use (all)
processed material	grain (2 h.) + roasted tubers (0,75 h)	dried and roasted tubers (0,65-0,83 h)	wet tubers (0,5)	N/A
(micro) topography	rounded	rounded	flat to rounded	uneven/ rugged
impaction pits	present	present	present	present
pit edges	rounded	rounded	rounded to rugged	rugged
orientation	concentric	concentric	longitudinal/ transverse	random
location	centre	centre	centre and proximal end (lower tool)	across
levelling	present	present	present	absent
groundmass/phenocrysts	groundmass (at margins both)	both	groundmass (on distal and margins both)	absent
morphology/texture	rounded/smooth	rounded/smooth (rounded/rough centre)	flat to rounded/ smooth (rounded/rough centre)	
distribution	covering	covering	covering	
location	across	margins	distal end and lateral margins	
phenocryst extraction	present	absent	absent	absent
phenocryst fractures	present	present	present	present
incidence	high and low (at margins only low)	both	high	both
distribution	covering	covering	loose	covering (close)
location	across	centre	across	across
phenocryst	present	present	present	absent

rounding	(lower tool)	(lower tool)		
incidence	low	high and low	high and low (at margins low)	
location	across	margins (at center present in low)	across	
polish/sheen	present	absent	present	absent
relectivity	slight		slight	
distribution	loose		concentrated	
location	margins		distal ends	
Striations	none	none	none	none
tribological wear	center = abrasive/margins = tribochemical	center = fatigue/margins = abrasive	center and lateral margins = abrasive/distal end = tribochemical	fatigue

Table 1: Use-wear analysis overview table (pre-use see 4th column). Microscope used: GXMicroscopes: GXMMZS0745

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