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Decoding changes: technological and statistical investigation of the Middle Stone Age-Later Stone Age transition in the Horn of Africa

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Abstract

The transition from the Middle Stone Age (MSA) to the Later Stone Age (LSA) in Eastern Africa is a highly complex topic that generates significant interest. Indeed, the archaeological record shows a technological shift characterised by the progressive decline of features typical of the MSA (such as the use of the Levallois method and the production of points) in favour of an increase in traits typical of the LSA (backed tools, increased production of blades and bladelets, frequent use of bipolar technique on anvil, and a rise in the presence of ornamental objects).

However, while these changes are evident in archaeological contexts of the MIS 4-3, the modes and tempos of these changes are not yet clear. In fact, while these aspects appear in some contexts at the beginning of the MIS 4, in others such as in Ethiopia, the appearance of the LSA is much more recent (late MIS 3). It is clear, therefore, that the dynamics related to this transition phenomenon vary at a regional level. Hence, this thesis focuses on the MSA-LSA transition in the Horn of Africa through a comparative analysis on two levels: a local examination consisting of the technological and statistical analysis of the lithic assemblages found in the Gotera area, dated to the MIS3 and located in southern Ethiopia; and a regional analysis, with the investigation of multiple contexts located in the Horn of Africa and parts of Kenya, aimed at evaluating this phenomenon at both small and large scales. The results of the archaeological analysis were then integrated with paleoclimatic and environmental data to assess the role of the environment in the MSA-LSA transition. From this study, the nuanced nature of the boundaries between the two techno-complexes MSA and LSA is confirmed, as well as the difficulty of developing a large-scale model with the available data. However, the correlation between lithic industries and paleoclimatic aspects has allowed for the formulation of new research hypotheses on adaptability to the environment and seasonal variations, as well as the behavioural response of our species at the end of the Pleistocene in Eastern Africa.

Although explanations for the MSA-LSA transition are still challenging to unravel, especially due to several weaknesses in available data, it is likely that environmental factors were critically influential and acted as drivers for the observed changes. It is essential to remain persistent in testing these hypotheses through quantitative analysis and data integration.

Introduction

General objective and research questions

This doctoral dissertation originates from a general research objective aimed at understanding the occupation and adaptative dynamics of *Homo sapiens* groups during the Marine Isotope Stages (MIS) 4-2 in the Horn of Africa region.

In the classification of African Prehistory, this period has been characterised by scholars as the transition between the MSA and the LSA. The MSA-LSA transition is generally described as a process in which technologies that had persisted in Africa for more than 200,000 years – such as the Levallois and discoid methods for core reduction and the production of retouched points typical of MSA – were replaced in favour of a progressive increase in the production of - depending on the regions -: microliths and backed tools (Leplongeon, 2014; Leplongeon et al. 2020; Pargeter & Shea, 2019); blades and bladelets using volumetric methods (Leplongeon et al. 2020a); reduction in size tools (Shipton et al. 2018; 2023), and the use of the bipolar on anvil technique (Eren et al. 2013; Grove and Blinkhorn 2020; Tryon, 2019). Furthermore, an increase in the use of ochre and evidence interpreted as ornamental objects (e.g. shell and ostrich eggshell beads) is observed in some contexts (d'Errico et al. 2020; Shipton et al. 2023; Tryon, 2019).

These elements are generally seen as chronological markers, respectively, for MSA and LSA techno-complexes, and comparisons have been drawn with the Middle to Upper Palaeolithic transition in Eurasian contexts, albeit with no apparent change/replacement of hominin species associated with the cultural changes seen in Africa (Grove & Blinkhorn, 2021; McBrearty and Brooks, 2000; Scerri and Will, 2023; Tryon, 2019). However, many scholars do not agree with the definition of this process as a transition, because even if it is true that the archaeological record of the MSA differs from the LSA, there are no clear-cut boundaries, that led to a complex classification (Brandt, 1986; Leplongeon et al. 2020; Tryon, 2019). In many Late Pleistocene African contexts for example, typical MSA elements coexist with LSA elements, just as they can also exist in Holocene contexts (Leplongeon et al. 2017), while LSA elements sometimes appeared earlier, in typical MSA assemblages (Ambrose, 1998; Shipton et al. 2023). This is likely due to multiple factors, especially the significant fragmentation of populations living in diverse environments across Africa, which is characterised by enormous bio-geographical variability. In these contexts, it is not difficult to imagine groups living in isolation due to specific environmental conditions or climatic events, habitat fragmentation, avoidance of encounters between groups, with resultant exchanges of technological innovations perhaps originating somewhat by chance.

Therefore, it is advisable not to view the MSA and the LSA as two monolithic entities, as it is highly likely that behind these technological changes, there are dynamics of interaction between groups that are much more complex (and also difficult to identify), making the development of a definitive model much more challenging.

There is still a strong interest in defining the modes and tempos that led to changes in human technical behaviours across MIS4 and 2, especially in eastern Africa. This is mainly due to several factors such as the evidence of the gradual replacement of technologies that persisted for more than 200000 years – with no species replacement as seen in Europe - the behavioural changes and possibly the population growth (rather than population interaction of replacement), and the old vision of the origin of modern humans, or behavioural modernity, and its dispersal out of Africa (Tryon and Faith, 2016; Tryon, 2019).

Behind this description the null hypothesis is that there is no causal or significant relationship between the various traits described of the LSA in eastern Africa. According to this, it can be said that the observed variations in the sizes of lithic artefacts, the use of certain techniques, the presence or absence of certain types of tools, such as retouched points for MSA and backed pieces for LSA, and a selection for particular finer grain raw materials are not correlated or driven by a single cause or process of cultural changes.

This null hypothesis suggests that the observed variations may be due to a variety of different factors, including environmental, social, demographic, or local changes, rather than to a single, universal model of cultural development. Furthermore, it suggests that the labels and categories used by researchers to classify and interpret these data may not fully represent the complexity and diversity of archaeological contexts.

To develop a valid model of synchronic and diachronic variability, what is needed is a set of reliable data to construct a narrative on both large and small scales. To achieve this, it is important to have well-dated archaeological contexts from the relevant period, with long stratigraphies corresponding to extended temporal spans. This will allow for the assessment of technological changes in lithic industries over time and space, at both inter-site and intra-site levels.

It would be ideal to integrate multiple data sources into this model, including archaeological, climatic, environmental, and genetic data (as done in North Africa, see Scerri et al. 2014). This comprehensive approach would provide a meaningful understanding of the affirmation, interaction, and spread of *Homo sapiens* within the Horn of Africa (and subsequently out of Africa).

However, mostly due to the scarcity of well-dated sites, it is still challenging to build a model that allows for the reasons behind these changes to be investigated while also building a solid narrative about human past behaviour. In general, this period in Africa is

still poorly documented and thus the mode and tempo behind this transition is still obscure (Tryon, 2019).

Going back to the null hypothesis, the main goal of this doctoral dissertation is to understand how is characterise the period between MIS 4 and 2 in the Horn of Africa from a technological point of view and if there are traditions in lithic technologies or specific changes in the region using quantitative methods to compare lithic technological attributes (Pargeter et al. 2023; Will et al. 2019). Therefore, to test the context of climatic and environmental changes in this period integrating paleoclimate reconstructions (Leonardi et al. 2023) as one of the potential factors that influenced changes in technology.

In recent years, there have been tentative attempts made to provide new data with which to understand of the MSA-LSA transition debate. Improved data has come from the systematic recovery of old archaeological excavations, and also from new remote research projects. The latter have attempted to clarify, from a quantitative point of view, the characteristics in MSA and LSA assemblages, and have analysed their similarities and differences based on the presence/absence of some categories (Grove & Blinkhorn, 2020; 2021; Tryon, 2019).

The primary goal of this research is to analyse archaeological contexts dated to MIS 4-2 in order to integrate the Horn of Africa in the broader debate about the causes and modalities of the MSA-LSA transition. The main context analysed in this thesis is the Gotera area in southern Ethiopia, which will provide novel evidence for the reconstruction of human behaviours during the MIS3 (Fusco et al. 2021; Spinapolice et al. 2017). This area is rich in Pleistocene evidence, as already reported by Jean Chavaillon in the 1970s (Chavaillon and Chavaillon, 1985). Since 2016, the Sapienza University of Rome has been investigating the human occupation dynamics at Gotera during the Pleistocene and has discovered an archaeological deposit dated to the MIS 3 (~43-42 ka). The analysis of the archaeological material from Gotera is crucial given the very limited knowledge of the late Pleistocene human occupation in the region. A comparative statistical analysis at a macro-regional level has been initiated.

Therefore, in this thesis, I will attempt to answer the following research questions:

- What are the technological characteristics of lithic assemblages in the region under study during the MSA-LSA transition?
- Additionally, how do the lithic assemblages of the Gotera area, characterized by human occupation dating to MIS 3, compare to other sites in the region? How the technological differences seen in the assemblages from the area (both in surface and stratigraphy) can be categorised according to the MSA and LSA definition?

- Lastly, since climate changes had a pivotal role in shaping human cultural diversity, what is their role in the technological changes characterising the transition from MSA to LSA?

This research will then consider the transition from the MSA to the LSA, taking into account the asynchrony of the phenomenon, and explore whether changes in technical and behavioural aspects have been influenced or guided by environmental factors, among others.

This hypothesis will be tested through a comparative statistical analysis of the archaeological record dated from MIS 4 to MIS 2. The analysis will be structured on two levels: one local and one regional (Figure 1):

1. At the local level, I will thoroughly examine the Gotera area in southern Ethiopia, where recent excavations have revealed a dense MSA occupation dating back to MIS 3. The goals are threefold:

   a) to understand the occupation dynamics and behavioural characteristics of human groups at Gotera during the MIS 3;

   b) to establish a tentative chronological timeline for the surface lithic material (by comparing lithics from dated layers with surface collections) in order to understand if the site of GOT-10 was characterised by multiple distinct occupations over time or if it is the evidence of one occupation episode, maybe characterised by different seasonal exploitation;

   c) to understand and quantify the degree of technological continuity or change within the assemblages from the whole Gotera area and attempt to provide a categorisation of technological traits from the Gotera assemblages according to the MSA and LSA definitions, in order to contribute with new data to the general knowledge of MIS 3 occupation dynamics in the Horn of Africa.

   To achieve this, the local analysis will be conducted through:

   a) an archaeological investigation of the GOT-10 site (though the excavation of the Mound1 archaeological deposit and the collection of surface material eroded from the mound) and an analysis of the lithic industry from both stratigraphic levels and from loose sediments formed by the eroded archaeological layers and defined here as clusters, as well as lithics from the scatters found on the surface of the GOT-10 site;

   b) Statistical comparative analysis at the intra-site level, in order to understand the technological relationships between lithics from the archaeological layers and lithics from clusters and scatters;

c) Statistical comparative analysis of lithic industries from GOT-10 and GOT1-S; a surface collection made in 2km² of the Gotera area (Fusco et al. 2021), and a sample of material from the Chavaillon excavations of the 1980s preserved at the Ethiopian Heritage Authority (EHA) in Addis Ababa (Chavaillon and Chavaillon, 1985). The latter was attributed to the late MSA by the authors, thus it may provide a good comparative term with the GOT-10 lithic industries in order to detect transitional traits in the area. More in detail, the analysis will allow for the characterisation of the lithic technological reduction systems at Gotera, as a basis to explore its relationships with other lithic assemblages across the Horn of Africa.

2. At a macro-regional level, a comparative statistical analysis will be conducted, followed by the integration of paleoenvironmental and climatic data. This analysis will help clarify how the variability observed in lithic industries between MIS 4 and MIS 2 may be linked to population dynamics, social structures, or adaptations to different environments.

   The regional analysis will involve the quantitative comparison of lithic assemblages, from Goda Buticha, Porc Epic, Deka Wede 4 in Ethiopia, and Enkapune ya Muto in Kenya. Subsequently, the collected data, both at the regional and local levels, will be integrated with paleoclimate data to evaluate the role of the environment in shaping cultural diversity.

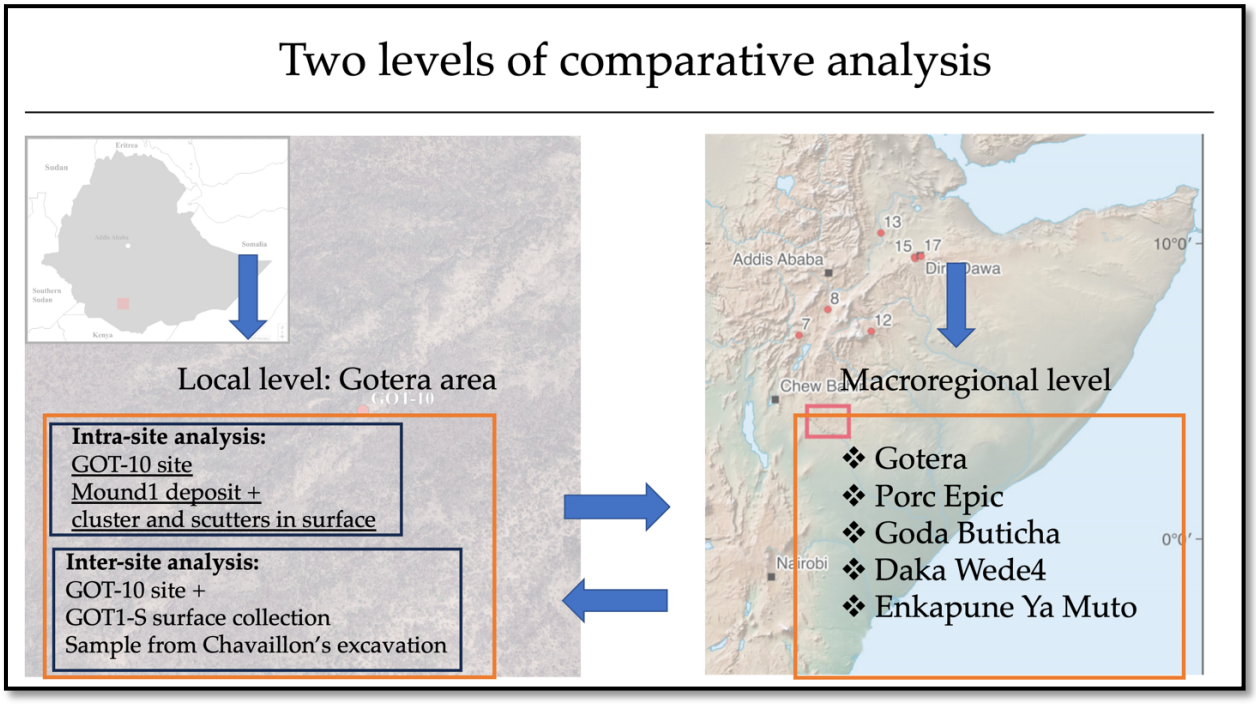


Figure 1: schematic explanation of the research methods and materials used for this doctoral thesis.

Outline of the dissertation

This doctoral thesis is organized into five chapters.

The first chapter presents an introduction to the research problems and is composed of four sections. The first section provides a detailed description of the overall objective and research questions that form the basis of this doctoral research. The second section constitutes a comprehensive summary of the current state of the art regarding the MSA-LSA transition in Eastern Africa. The third section offers a review of the MSA in Eastern Africa, while the fourth serves as a synthesis of contexts providing evidence of the MSA-LSA transition, to fully understand the nature of the issue under investigation (Figure 2).

Chapter 1 Introduction to the research problem	**1st section**: detailed description of objectives and research questions
	2nd section: summary of the current state of the art of the MSA-LSA transition in Eastern Africa.
	3rd section: review of the MSA sites in Eastern Africa
	4th section: review of the sites in Eastern Africa with transitional MSA-LSA occupation

Figure 2: schematic synthesis of the Chapter 1

The second chapter is entirely dedicated to the analysis of the Gotera area. This is the primary analytical tool drawn upon to achieve the main objective of the thesis, which is to reconstruct the settlement dynamics in the region during MIS 3. The second chapter is further divided into three sections.

The first provides a summary of the field activities conducted by Jean Chavaillon in the Gotera area. The secondo section provides information regarding the ongoing investigations since 2016 by the Sapienza University of Rome. Additionally, a detailed overview of the discovery and the archaeological sequence of the Mound1 at the GOT-10 site is provided. The materials and methods used for the archaeological investigations at Gotera, consisting of surveys and stratigraphic excavation, are then outlined (Figure 3).

Chapter 2 The Gotera area	**1st section**: detailed description of the Gotera area after Chavaillon's activities
	2nd section: descritpion of field activities conducted by Sapienza University of Rome since 2016
	3rd section: description of the GOT-10 site

Figure 3: schematic synthesis of the Chapter 2

The third chapter delves into the technological analysis of the lithic assemblage from the GOT-10 site, explaining the methods and presenting the results obtained, as well as a comparative analysis at intra-site level of the lithic assemblages collected at the GOT-10 site, both from stratigraphy and surface (Figure 4).

Chapter 3 Technological analysis of GOT-10 lithic assemblages and intra-site comparative analysis.	**1st section**: detailed description of materials and methods used for the technological analysis
	2nd section: results of the technological analysis of the lithic assemblages from the GOT-10 site
	3rd section: statistical analysis at intra-site level, comparing the lithic assemblages from the Mound1 stratigraphy, the clusters and the scutters in suface.

Figure 4: Schematic synthesis of the Chapter 3.

Chapter four will present the comparative analysis, including methods and results, of the lithic industries in the Gotera area (GOT-10, the surface assemblage of GOT1-S, and the artefact sample from the 1980s excavations by Jean Chavaillon). This will help clarify and reconstruct the occupational dynamics of human groups in the area of Gotera (Figure 5).

Chapter 4 Comparative statistical analysis at local level: the Gotera area.	**1st section**: materials and methods of the comparative statistical analysis of the Gotera lithic assemblages
	2nd section: results of the comparative statistical analysis at the local level
	3rd section: discussion and interpretation of the Gotera area occupation dynamics

Figure 5: Schematic synthesis of Chapter 4

The fifth chapter will present the results of the regional analysis of MSA-LSA sites. It is divided into four sections. The first section will provide a summary of the sites examined in this doctoral thesis, with detailed information regarding archaeological excavations, chronology, lithic assemblages, and the samples under consideration. The second and third sections will outline the methods and statistical analyses used to compare the data from the lithic industries and is followed by the presentation of the results in the fourth section.
The final part of the fourth chapter will explain the methods and results relating to the integration and analysis of climatic and environmental data with archaeological data. The section will focus on the role of the environment and climate changes during MIS 4-1 as a driving factor behind the technological changes visible in the archaeological record during the MSA-LSA transition (Figure 6).

Chapter 5 Comparative statistical analysis at macro regional level.	**1st section**: summary of the sites analysed for the comparison
	2nd section: methods of statistical comparative analysis of lithic assemblages
	3rd section: integration of paleoclimatic data into the analysis
	4th section: discussion and interpretation of the results obtained from the comparative analysis and the paleoclimate data integration

Figure 6: Schematic synthesis of Chapter 5

The thesis concludes with a final synthesis of this reasearch that discusses and summarise the obtained and analysed data. It provides an overall conclusion regarding the MSA-LSA transition, current methods of analysis, and, above all, future hypotheses to be tested. Additionally, the future perspectives of integrated quantitative analyses will be highlighted, emphasizing the importance of knowledge and the selection of the archaeological sample in order to develop valuable and solid models for the behavioural evolution of our species.

From this doctoral research, the following publications have been produced:

In press:

Fusco, M. Asrat, S., Aureli, C., Zerboni, A., Lemorini, C., Gallinaro, M. Spinapolice, E.E. in press. "The Gotera Archaeological Mission in Southern Ethiopia: A Preliminary Field Report on the ongoing research at the Middle Stone Age site of Gotera". *Annales d'Ethiopie, vol. 35*

In review:

Fusco, M. and Spinapolice, E.E., in review. "Technological analysis of new Middle Stone Age assemblage from the Gotera area, southern Ethiopia". *Rivista di Scienze Preistoriche.*

In submission:

Fusco, M.; Douze, K.; Habte, B.; Leplongeon, A.; Ménard, C.; Manica, A., Spinapolice, E.E., Leonardi, M. in submission. "Unveiling the Environmental Role during the MSA-LSA Transition of Eastern Africa: seasonality and resource predictability is the key". Scientific Reports

2022

Fusco, M. and Spinapolice, E.E., 2022. New evidence of bipolar technique use in the eastern Africa Middle Stone Age (MSA). *Intervento presentato al convegno: La tecnica bipolare. Produzione, prodotti e funzione dei manufatti litici tenutosi a Genova): 18-21.*

2021

Fusco, M., Carletti, E., Zerboni, A.; Gallinaro, M.; Spinapolice, E. E. 2021. Lithic Variability and Raw material exploitation at the Middle Stone Age (MSA) site of Gotera, Southern Ethiopia: a combined technological and quantitative approaches. *Journal of Lithic Studies*, 8(1): 1-29.

Chapter 1 – State of the art of the MSA-LSA transition in eastern Africa

1.1 Introduction

"Transition: the process of changing from one state to another."
Oxford English Dictionary

The theme of transitions, namely the shift from one piece of evidence to another, represents one of the most discussed, analysed, and studied topics in the field of human evolution and the reconstruction of past human behaviour. Transitions in the past are primarily detected (or attempted to be detected) by identifying changes in the archaeological record. However, it is necessary to evaluate their modes, tempos, and spatial dimensions for a comprehensive understanding. Archaeologists rely on robust chronological, stratigraphic, and terminological frameworks to scrutinize changes in human behavior evident in the material record.

In the global narrative on past human behaviours, the transition from the MSA to the LSA in Africa has gained considerable attention. This transition has been linked to changes in material culture, suggesting an increase in cultural complexity, and for a long time, the onset of LSA in Africa was chronologically associated with the beginning of behavioural modernity. This was mostly based on what was seen in the European archaeological record as an Upper Paleolithic 'revolution' linked to the transition from the Middle Palaeolithic and the distinction between "modern" humans from Neanderthals (Ambrose, 1998; Klein, 2000, but see also Mellars, 1989; 1996; 2005; Mellars and Stringer, 1989; White, 1992). However, current evidence demonstrates that the boundary between the MSA and the LSA is nuanced, and that this phenomenon cannot be seen as a revolution and it is now widely accepted that it is more the result of a gradual process that does not mark the passage to a more "complex" human behaviour (McBrearty and Brooks, 2002; Scerri and Will 2023), or a unique event. In fact, evidence of what is defined as "behavioural complexity" is present in Africa as far back as >100 ka (d'Errico et al. 2020; Martinón-Torres et al. 2021; Wilkins et al. 2021), in a fully "MSA environment", and even earlier (Brooks et al. 2018). The archaeological evidence shows an asynchronous presence and duration of innovations across the African continent (McBrearty and Brooks, 2000; Scerri and Will, 2023).

The MSA-LSA transition in eastern Africa occurred during the Late Pleistocene, with the earliest evidence in Kenya dating to ~67 ka (Shipton et al. 2018), while in Ethiopia what is believed to be the earliest LSA evidence is dated to ~27 ka at the Ziway Sahla basin area, near the Bulbula River (Brandt, 1986; Gasse et al. 1980; Leplongeon et al. 2020). However, the lack of knowledge regarding the origin and nature of the transition is also due to the

scarcity of long-stratified and well-dated sites that provide a comprehensive view of the events between ~80 and 17 ka in the region. Moreover, current large-scale models are built on local-scale evidence. Therefore, there is no agreement on a unique definition for the transition from the MSA to the LSA as well as a unique hypothesis for the changes observed. In addition, it is necessary to remember the problems related to the classification of periods. The use of labels such as MSA and LSA have been often questioned because of the absence of clear boundaries between these entities (reflected in the archaeological record). Therefore, it is true that there is no unique definition for the transition, but it is also true that the transition in itself may be a concept related more to our classification rather than a true changing event (Clark et al. 1966; Parkiton, 1948)

To illustrate the current data available for the MSA and LSA in Eastern Africa, I provide a review of the general knowledge on the topic. This is achieved by dividing the contexts with evidence of MSA occupations (starting from the beginning of the MSA) and those with evidence of both MSA and LSA occupations. It is worth noting that this review will principally focus on those sites with at least some chronological and stratigraphic control (see also Tryon and Faith, 2013). Moreover, for eastern Africa, I will refer to the modern countries of Ethiopia, Eritrea, Kenya, and Tanzania.

1.2 The Middle Stone Age in eastern Africa: an overview

The MSA covers the evolution, emergence, and dispersal of *Homo sapiens*. This term was introduced by Goodwin and van Riet Lowe (1929) and originally denoted the Palaeolithic record of Southern Africa (Clark, 1988). However, this classification poses challenges because the original definition of the term MSA essentially comprised cultural techno-complexes that do not include technologies from assemblages defined as Early Stone Age (ESA) (large cutting tools, large bifaces, handaxes) and LSA. It spans various temporal and regional subdivisions, and the definition does not account for the extensive variability of these cultural complexes. Therefore, the MSA label essentially refers to a broad classification of all the lithic industries present across the African continent over a period of more than 250,000 years (Basell, 2008; 2013; McBrearty and Brooks, 2002; Scerri and Will, 2023). The emergence of MSA lithic technologies is described by scholars as a gradual process (McBrearty and Brooks, 2000; Scerri and Will, 2023; Tryon and Faith, 2013). This process is characterised by a progressive reduction in Acheulean-like features within lithic assemblages, such as the occurrence of Large Cutting Tools (LCT), including handaxes, picks, and cleavers. This decrease is accompanied by an increasing presence of different technological patterns over time (i.e. a greater degree of complexity in lithic technology is

seen in younger ESA contexts, such as the Victoria West and 'proto'-Levallois cores) and includes the co-occurrence of ESA and MSA technologies in some archaeological contexts (McBrearty and Brooks, 2000; Scerri and Will, 2023; Tryon and McBrearty, 2002; Tryon et al. 2005, but see also Van Peer et al. 2003).

The MSA is seen by many scholars as the cultural manifestation of *Homo sapiens* in Africa. The pan-African model of our species' origin depicts a complex scenario for the emergence and spread of *Homo sapiens* across the African continent, and it is likely that MSA techno-complexes and the emergence of the *Homo sapiens* lineage occurred concurrently (Hublin et al. 2017; Richter et al. 2017; Scerri and Will, 2023; Scerri et al. 2018). Indeed, the chronological span of the MSA coalesces on the period ~300,000 to 30,000 years ago, with notable regional variability including both significantly older (Brooks et al. 2018; Wilkins et al. 2012) and more recent occurrences (Scerri et al. 2017; 2021).

1.2.1 A definition of MSA lithic technologies

According to Clark's classification of prehistoric lithic technologies into five modes, the MSA corresponds to Mode 3. In Clark's words, *"What indicates a new stage in technology is when the flint- or stone-worker appears to aim first and foremost at producing flake tools and, to achieve this, goes to particular lengths to prepare cores from which these tools could be struck in a finished state*" (Clark, 1969: 42) (Figure 7).

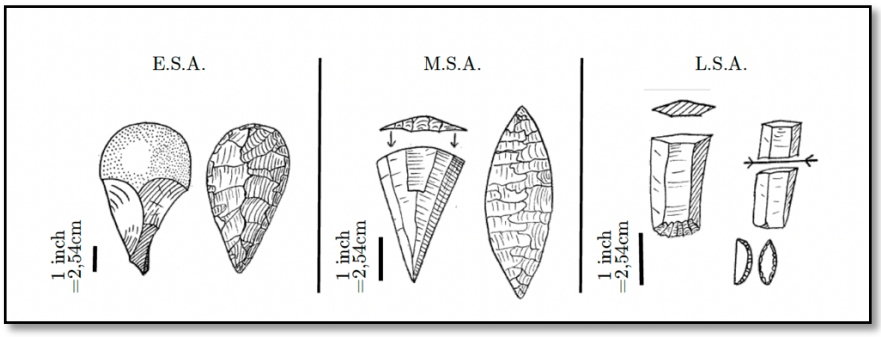


Figure 7: Schematic representation of the Early Stone Age, Middle Stone Age, and Later Stone Age key technological traits (Goodwin, 1946).

The MSA is generally defined by the widespread use of prepared core technologies (PCT), the production of points (both retouched and unretouched), blades, hafted tools, and the frequent use of the Levallois method for core reduction, along with discoid method and other PCT reduction strategies (McBrearty and Brooks, 2000; Scerri and Will, 2023; Spinapolice, 2020; Tryon, 2006; Tryon et al. 2005; Tryon and Faith, 2013).

The use of the Levallois method is a key feature to define an assemblage as MSA. The Levallois concept is defined by six techno-morphological criteria, developed by Eric Boëda (1986; 1992) who described the morphology of Levallois cores as being shaped to produce two asymmetric, intersecting convex surfaces. These two surfaces are hierarchical and have two different functions: one is used to produce predetermined flakes (flaking surface: from which the Levallois blanks are struck), while the other is used as a striking platform surface. The creation of lateral and distal convexities on the flaking surface allows the production of the Levallois blank(s) with controlled morphology. The Levallois removal surface on cores is shaped by the preparatory flakes previously struck from the core. From this Levallois flake removal surface, a single Levallois flake, blade, or point may be removed before re-preparing the core's convexities. This method is known as the Levallois preferential method. When multiple flakes, blades, or points are removed, the approach is referred to as a recurrent reduction strategy (Böeda, 1991; 1994; 1995). Various removal patterns within the Levallois reduction system mark the variability of this method. When a flake or preparatory flake is removed from one direction, the method is called Unipolar. When a flake or preparatory flake is removed from two opposite directions, it is termed Bipolar, and when they are removed around the circumference of the core, it is known as centripetal. Furthermore, these main thematic patterns can have variations (e.g., a unipolar convergent pattern for flake scars).

The variability of this method is also influenced by the combination of specific Levallois methods, such as recurrent or preferential, with particular flake removal patterns, such as Unipolar, Bipolar, or Centripetal (Böeda, 1991; 1994; 1995). This variation is observed at many African MSA sites, including Gademotta and Kulkuletti Formation, Porc Épic and Aduma in Ethiopia, Kapthurin Formation sites, and Rusinga Island in Kenya (Clark, 1984; Douze and Delagnes, 2016; Tryon and McBrearty, 2002; Yellen et al. 2005), among others.

However, it is worth noting here that some elements defined as Levallois in the African MSA do not exhibit all of the morphological criteria upon which the definition of this method is based (Boëda, 1994: 5-6). Therefore, it is important to acknowledge not only the known variability of this method based on the analysis of Mousterian lithic industries from Eurasia, but also differences in the definition of this method as seen in the African MSA (Boëda et al. 2013). While it is true that the concept underlying this method can be compared and contrasted between Mousterian and the MSA, it is equally true that the evidence of its use in the MSA creates some particular difficulties in definition and analytical applicability.

A specific Levallois variant used to produce points has also been identified within the MSA technological repertoire, and it has been defined as Nubian Levallois Technology. This specific method is characterised by the production of a Levallois point from the intersection

of two elongated preparatory flakes struck from the distal end of the core. Nubian cores are considered to have a distal platform for the striking of preparation removals, in opposition to the proximal platform, from where the preferential removals are struck. The distal part of the core is prepared by focusing on the distal ridge, with removals made from the distal platform and/or steep lateral preparation concentrated on the distal half to a third of the core. Nubian cores are said to have an overall pointed morphology, and the products are generally points (Hallinan et al. 2022: 230, but see also Oron et al. 2024). This Levallois variant was believed to be typical of North Africa and the Nile Valley, however, it is also found in the Arabian Peninsula (Crassard et al. 2013; Hilbert et al. 2017; Rose et al. 2011; Van Peer & Veermersch, 2000), as well as some Middle Paleolithic contexts in the Levant (Blinkhorn et al. 2021; Oron et al. 2024) and in India (Groucutt, 2020). These points have been discovered at Aduma and K'one in Ethiopia (Kurashina, 1978; Yellen et al. 2005).

Among the characteristics, the presence of various types of points has been considered another typical feature of MSA technological variability (Clark 1988; McBrearty and Brooks, 2000; Tryon and Faith, 2013). Pointed flakes and flake-blades have been recognised as a primary objective of MSA lithic repertoires, and retouched points resulting from a shaping conception applied to raw material reduction appear to be characteristic of some early MSA assemblages (Douze and Delagnes, 2016; Porraz et al. 2015). These points display significant variability and morphological diversity throughout the archaeological record of the African MSA (Douze et al. 2020).

The term "point" is associated with both morphological and technological characteristics, representing pointed artefacts and their functional use, such as tips for spears or other hafted elements used in hunting. The determination of whether points were hafted can potentially be inferred from the study of microwear patterns on their edges, as well as their morphology (Douze et al. 2020; Lombard, 2005; Lombard et al. 2010; McBrearty and Brooks, 2000; Rots et al. 2011; 2016; 2017; Villa et al. 2009). Despite numerous analyses on point function, it is still difficult to determine whether all, or even a majority, of points from African MSA sites were hafted or not, or if they were used exclusively for hunting (Plisson and Beyries, 1998; Scerri and Will, 2023). Stone points from Gademotta have revealed that they were used as cutting tools rather than hafted spear tools (Douze, 2014; Douze and Delagnes, 2016).

MSA lithic variability incorporates numerous non-Levallois flake reduction systems that nevertheless fall within the broader definition of PCT. One of these is the Discoidal core method, which is known for the presence of Discoidal cores and the products struck from them. Discoidal cores are defined as biconical and bifacially flaked, resulting from the alternate flaking of both sides of an oval cobble. Platform cores (single, double or multi-

platform) are produced by using one or more edges of the raw material block as a striking platform. These cores are commonly found at MSA sites and serve as the foundation for the sharp-edged flaking technology in LSA assemblages (Douze, 2013; Tryon, 2006; Tryon and Faith, 2013).

Among the formal tools, scrapers have been discovered at some MSA sites, as well as denticulates, and bifacially retouched tools (mostly points). The scrapers are characterised by infrequent and irregular retouch, and they differ significantly from the classical Mousterian scrapers described by Bordes (Bordes, 1961; Tryon and Faith, 2013) (Figure 8).

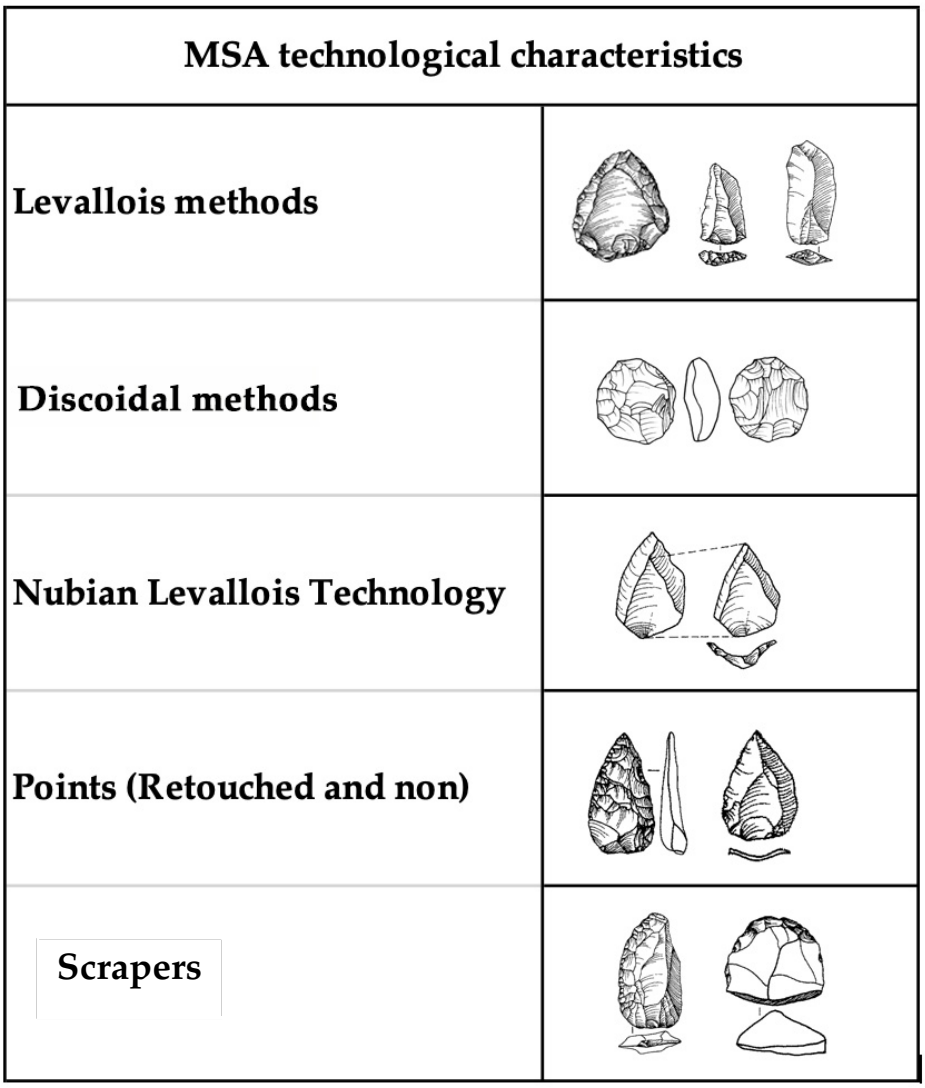


Figure 8: Schematic synthesis of the MSA technological characteristics (Modified after Clark, 1988 and Shea, 2008)

1.2.2 Regionalisation of the MSA

While the term MSA is still used to refer to lithic industries from Middle and Upper Pleistocene sites in Africa, the above-described variability in lithic production and products has led to questions over the utility of this nomenclature. The desire to understand the reasons behind the marked differences observed in Eastern African lithic technologies has led researchers to formulate various hypotheses. It was likely with Clark's (1988) seminal article that differences in the MSA began to be viewed as a reflection of specific (and diverse) identities, to the extent that regional cultural identities were considered characteristic of human populations (Clark, 1988; McBrearty and Brooks, 2000; Tryon and Faith, 2013) (Figure 9). Among the factors that may have driven the "regionalisation" of MSA groups, the environment has been seen as a key driving force (Blome et al. 2012). The heterogeneity of environments present in eastern Africa seems to have been a determining factor in the development of cultural diversity (Clark, 1988: Blinkhorn et al. 2022; Blinkhorn and Grove, 2018). However, paleoenvironmental records from eastern African lacustrine sources testify to several climatic changes through the Pleistocene, with episodic wet-dry periods during the Middle and Late Pleistocene (Foerster et al. 2022). The transition from arid to more humid climates in certain areas of eastern Africa would have allowed the contraction and subsequent spread of populations, leading to the development of technologies during isolation due to adaptation, which later spread with the opening of more favourable environments. MSA occupations occurred in a worldwide climate system shaped by a 100,000-year climatic cycle of Northern Hemisphere glacials and interglacials. Embedded within this cycle were shorter-term variations known as stadial and interstadials. These climatic shifts almost certainly played an important role in shaping the evolution of hominins, impacting both their geographical presence and movements. Concurrently, other faunal populations experienced shifts, contributing to distinct behavioural innovations and transformations (Basell, 2008; Timbrell et al. 2022). The evolution of *Homo sapiens* and its behavioural expression may have been shaped by environmental factors and climatic variability leading to population fragmentations, isolation, and coalescence. This hypothesis is particularly valid for eastern Africa, where ecological diversity may have contributed to generalist adaptations to different ecosystems and a range of both broad and specific cultural innovations.

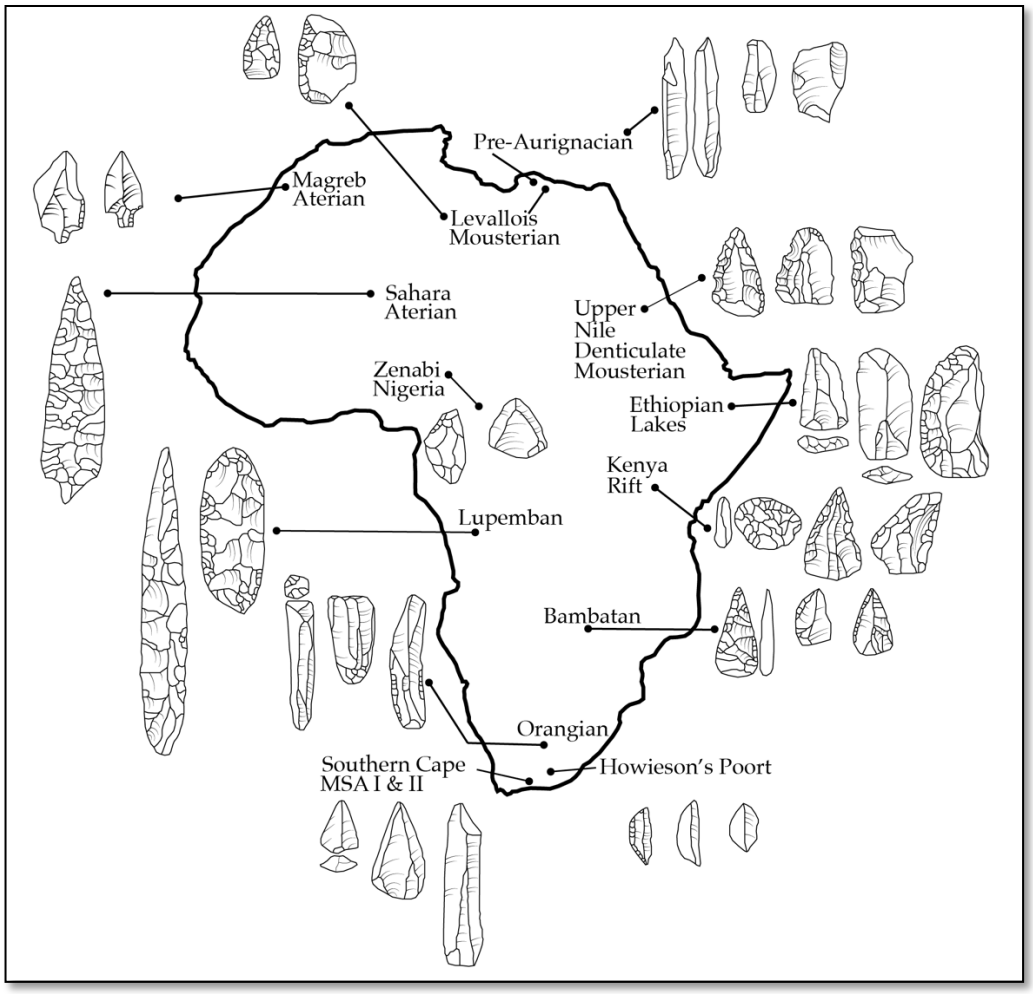


Figure 9: Map of the MSA regional variant and an indication of the region analysed (modified after Clark, 1993)

1.2.3 Temporal variation within MSA occupations

The MSA shows diversity in both spatial but also temporal dimensions. Lithic assemblages dating to the beginning of the MSA in eastern Africa seem to show greater variability compared to assemblages recovered from Late Pleistocene deposits. Probably the most notable temporal difference is the greater presence of Acheulean-like features in some old contexts (Douze and Delagnes, 2016; McBrearty and Tryon, 2006)

A difference in size between early MSA and later MSA points has also been noted (Brooks et al. 2006). Stone points from earlier contexts tend to be larger than those from later contexts, and this variation could be explained by a shift in functional use over time, including the emergence of projectile technology in the later Middle Stone Age (LMSA), dating between approximately 100 - 40 thousand years ago (Brooks et al. 2006; Shea, 2006). This characteristic is explored further below, when a list of MSA-LSA sites is provided.

The production of blades and bladelets occurs at early Middle Stone Age (EMSA) sites, such as Gademotta in Ethiopia, as well as at LMSA sites, like Aduma and Porc Épic in Ethiopia (Leplongeon, 2014). Blades are also found at ESA sites in eastern Africa and South Africa (Wilkins and Chazan, 2012; Wilkins et al. 2012; Wilkins et al. 2015).
Bipolar-on-anvil cores are sometimes used to produce small flakes and are commonly found at ESA sites as well as LSA sites, thus having a widespread chronological distribution. However, they are not very common at MSA sites in eastern Africa (Blinkhorn and Grove, 2018). Truncated-faceted pieces, which are common in some Levantine and European Middle Palaeolithic sites, are less frequently reported at African MSA sites. Nevertheless, there is some evidence of truncated-faceted pieces reported from sites in eastern Africa, including Gademotta, K'one locality in Ethiopia, as well as Lukenya Hill and Prolonged Drift in Kenya (Kusimba, 2001; Merrick et al. 1984; Pleurdeau et al. 2014).

1.2.4 Other behavioural evidence in MSA contexts

In the archaeological record of the MSA in eastern Africa, certain features have been identified as characteristics of 'modern behaviour' (Blinkhorn and Grove, 2018; Bouzouggar et al. 2007; McBrearty and Brooks, 2000; Scerri and Will, 2023; Trinkaus, 1989; Tryon and Faith, 2013). Among these characteristics, landscape knowledge linked to raw material procurement (McBrearty and Brooks, 2010; Brooks et al. 2018) and non-utilitarian evidence probably linked to what has been defined as symbolic traits, seem to reflect a diversity of modern human behaviours (d'Errico and Henshilwood, 2007; Henshilwood et al. 2001; Henshilwood et al. 2002; Henshilwood et al. 2004, Rosso et al. 2023).
Information about home range size and social interconnectedness is provided by the distance for stone material procurement. The site-to-source distance for raw materials offers valuable empirical insights into the extent of the physical and social landscapes exploited by hominin populations (Tryon and Faith, 2013).
The hominin groups that created MSA artefacts primarily used fine-grained rocks, with obsidian being the most common and basalt less frequent. Several studies focused on the geochemical characterisation of raw materials from the Rift Valley have revealed that site-to-source distances for eastern African MSA sites frequently exceeded 300 km (Brooks et al. 2018; Negesh and Shackley, 2006; Negesh et al. 2006; Shackley and Sahle, 2016; Tryon and Faith, 2013). These analyses, particularly XRF methods, have been conducted on obsidian artefacts, as this raw material is commonly found within Stone Age contexts (Brown et al. 2013) and is eminently traceable based on its precise geochemical origins.

The example from Porc Épic illustrates that MSA groups transported obsidian cores, flakes, and tools for more than 130 km, with finished tools found up to about 300 km from their source (Pleurdeau 2006). Additional evidence comes from Kenya and Tanzania, where the elemental and chemical composition of obsidian artefacts has been analysed. These studies have identified around a dozen distinct petrological groups among the obsidian flows in the central Kenya Rift Valley (Brown et al. 2013; Merrick and Brown, 1984; Merrick et al. 1994). Artefacts made of obsidian from these sources have been discovered at MSA sites in Kenya and Tanzania.

Raw material procurement is not the only key feature for understanding hominin movements over the landscape. It has been also suggested that some of the observed transportation could reflect the exchange of goods, and the development of trade networks (Scerri and Will, 2023 for a review, but see also Brooks et al. 2018; Henshilwood et al. 2004; d'Errico et al. 2009). However, evidence demonstrating any such inference is still currently lacking.

Other noteworthy aspects of behaviours including burials and special treatment of the dead are almost absent in the MSA. The skulls of the Herto Member, Bouri Formation in Ethiopia, dating back to ~160 ka, represent the only example of peri- or post-mortem treatment of the deceased. The evidence of cut and polished marks on the skulls has been interpreted as evidence of mortuary practices (Basell, 2008; Blome et al. 2012; McBrearty and Brooks, 2000; Tryon and Faith, 2013). However, despite the evidence from Panga ya Saidi representing the earliest known MSA burial, dated to ~78 ka (Martinón-Torres et al. 2021), given the limited evidence it is still challenging to interpret these behaviours at a broader scale.

Another characteristic of the MSA not present at a broader scale is the presence of beads made of shell and ostrich eggshell, that are believed to have been used as personal ornaments (d'Errico et al. 2009; McBrearty and Brooks, 2000). This evidence is likely linked to the tradition of body ornaments predating that of Europe by several thousand years. One example comes from Porc Épic cave, where perforated gastropod opercula of the terrestrial species *Revoilia guillainopsis* were discovered during excavations between 1976 and 1979. These opercula have a central perforation and were worn as beads. These artefacts were associated with MSA lithics and have been dated to a period between 43 and 33 ka (Assefa et al. 2008). Ostrich eggshell beads found at Mumba Rockshelter in Tanzania provide additional evidence of symbolic behaviours in the eastern African MSA, with dates ranging between 60 and 30 ka. However, ostrich eggshell beads from the archaeological layers at Mumba become much more abundant in the LSA (Prendergast et al. 2007).

Although evidence of bead use in eastern Africa is limited and appears only in the final phase of the MSA, it marks an important transition within the MSA record.

1.3 Archaeological contexts from the early to late MSA in eastern Africa

The context of dated MSA sites located in eastern Africa (Figure 10) is now described. Early MSA (EMSA) (Figure 11) and late MSA (LMSA) (Figure 12) evidence are listed above. Sites dated between ~300 and 80 ka are considered EMSA while sites dated between ~79 and 29 ka are considered LMSA.

Well-dated sites in the MIS 5-7 timeframe are not numerous in eastern Africa. However, the earliest assemblages, dating to ~300-280 ka show the coexistence of Acheulean and MSA-type traditions, and are relevant to understanding the origin of early MSA technologies (Lahr and Foley, 2016; McBrearty and Brooks, 2000; Tryon, 2006; Tryon and Brooks, 2002; Tryon and Faith, 2013). The following sections will first explore the evidence of early MSA contexts in eastern Africa, followed by late MSA contexts, and finally, archaeological sites with assemblages attributed to the MSA-LSA transition have been reported (Figure 13). In this synthesis, only contexts with some chronological and stratigraphic control are considered.

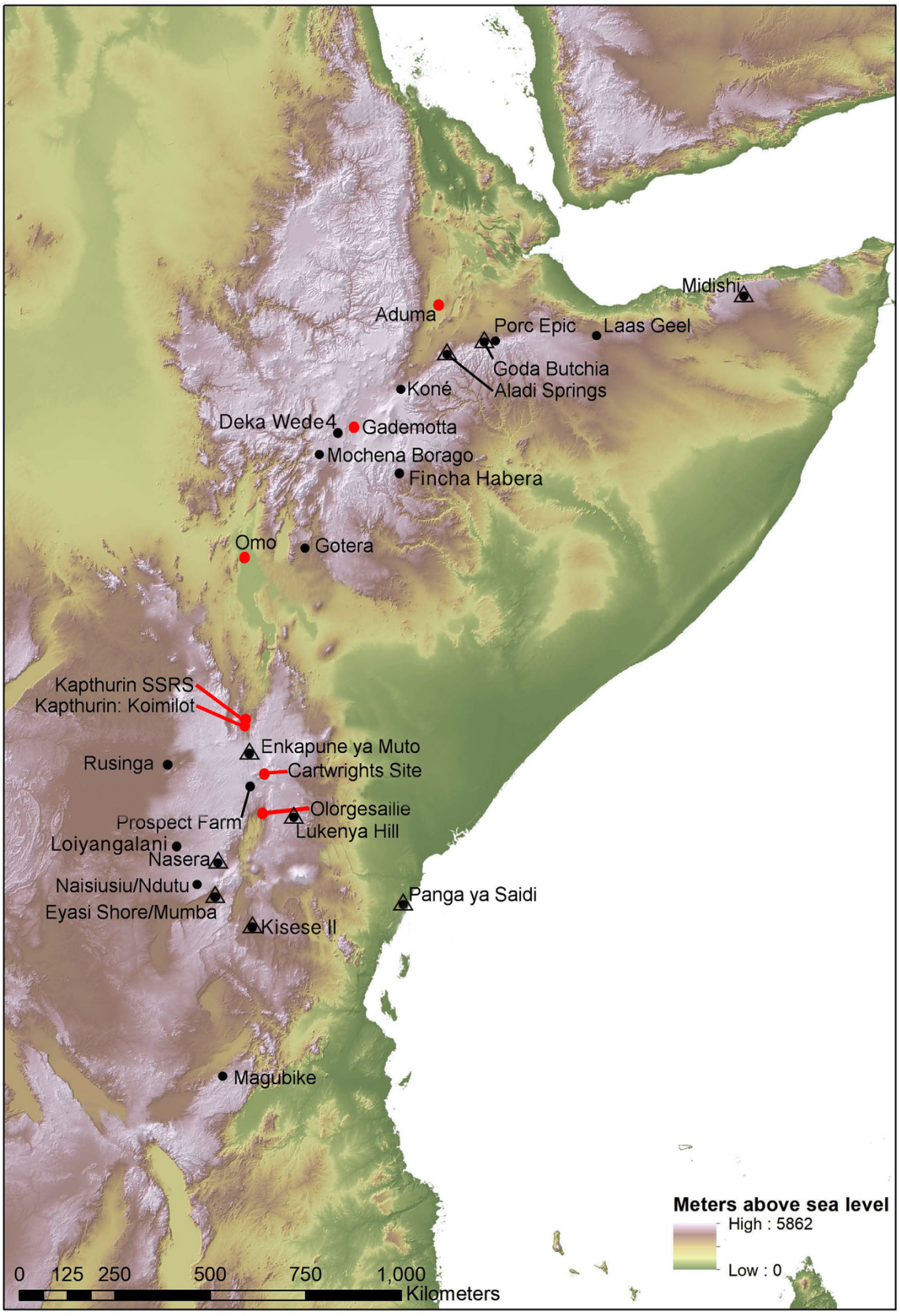


Figure 10: Location of the archaeological sites discussed in the chapter. In red EMSA sites. In black LMSA sites. Sites with MSA-LSA evidence are marked with a triangle (Modified after Blinkhorn and Grove, 2018: 4).

1.3.1 EMSA sites

The oldest site showing MSA features is the complex located in the Olorgesailie basin in southern Kenya and it is dated between ~320 ka and ~305 ka (Brooks et al. 2018). This site reveals important information since its occupation spans from the ESA to the MSA (Potts et al. 2018). Moreover, it also provides the oldest evidence of long-distance acquisition and transportation of raw materials associated with MSA technologies. Several obsidian MSA artefacts were made with raw materials sourced more than 270 km away (Brooks et al. 2018). The most used raw material is a local volcanic rock, with a limited presence of nonlocal obsidian and chert. From the technological analysis, the lithic assemblage has been attributed to the MSA. Prepared cores including Levallois and asymmetric cores are present, as well as cores used to produce blades and bladelets. Furthermore, there is evidence of bipolar-on-anvil cores on small obsidian nodules, as well as discoidal and multiplatform cores. At some localities (e.g. LOC B), assemblages defined as classic MSA (Brooks et al. 2018) have been found, and these include the presence of pointed artefacts, both retouched and unretouched. Retouched points are present mostly on obsidian and chert. Additionally, perforators, side and end scrapers, notched and denticulate pieces, along with various other retouched forms, are evident across the sites.

Elsewhere in Kenya, the Kapthurin Formation is a Middle–Late Pleistocene sedimentary sequence located west of Lake Baringo, named after the Kapthurin River (Tryon, 2023). The Kapthurin Formation represents a stratigraphic sequence that includes evidence of EMSA sites. A sequence of tephra has been dated and correlated to provide a secure chronological framework for the Acheulean and EMSA occupation. Layers containing EMSA artefacts have been dated ~280 ka while the whole sequence has been dated to between ~ 500-200 ka (Deino and McBrearty 2002).

Sites found within the Kapthurin Formation include small Levallois cores and points interstratified with Acheulean-like elements such as cleavers, which provides important data on the origin of MSA technologies. From the analysis of these sites, it has been shown that Levallois technologies probably derived from the Acheulean (Tryon et al. 2006; McBrearty and Tryon, 2006; Tryon and Faith, 2013).

One of the best dated EMSA sites is the open-air site complex at Gademotta and the Kulkuletti (GK) Formation, located in Ethiopia (Douze and Delagnes, 2013; Shale et al. 2014; 2023; Wendorf et al. 1975). These sites are situated on the slopes above the western bank of Lake Ziway in central Ethiopia (Douze, 2014; Douze and Delagnes, 2013). The Gademotta and Kulkuletti site complex is renowned as one of the richest EMSA sequences in eastern Africa. This is largely a result of the stratigraphic record preserved here, which includes

dated ash layers interbedded within the archaeological sequence, in addition to the substantial quantity of lithic artefacts recovered (Douze and Delagnes, 2016; Wendorf and Schild, 1974; Wendorf et al. 1975).

The oldest MSA assemblage discovered at Gademotta and Kulkuletti has been dated to approximately ~280 ka through the analysis of tephra layers (Douze and Delagnes, 2016; Wendorf and Schild, 1974). Obsidian was mostly used for toolmaking and is clearly visible across the entire area as a rich covering of obsidian artefacts and cobbles. The primary source for this raw material is likely a series of nearby obsidian flows.

Evidence of lithic technological variability begins early on in the sequence and continues throughout. The presence of projectile technology (e.g., stone-tipped throwing spears) has been inferred from morphological and damage patterns on some of the pointed stone artefacts (Sahle et al. 2023).

A particular feature of the GK lithic assemblages is the presence of uni-bifacial retouched points and a marked tradition of convergent tool production (Douze, 2014; Douze and Delagnes 2016). Three different technological changes in point retouch have been identified between 280 and 100 ka. In the earliest layers, point production is characterised by a shaping process used to produce convergent tools, which may reflect a continuation of the Acheulean tradition. Over time, a gradual shift is evident in the adoption of core reduction methods that enabled the creation of predetermined points characteristic of the MSA. The shift toward predetermined point production is particularly important for the understanding of the EMSA with Acheulean influences within the MSA (Douze and Delagnes 2016). The entire sequence is dominated by the use of obsidian, which accounts for more than 97% of all artefacts (Sahle et al. 2014; Wendorf & Schild, 1974).

The Omo Kibish Formation is a group of archaeological sites and hominin fossil occurrences located in the Lower Omo River Valley in Ethiopia, and dates to between ~195 - 100 ka (Vidal et al. 2022). This is also the location where the first early modern human fossils were discovered (Brown, 2008; Fleagle et al. 2008; McDougall et al. 2005; Shea, 2023; Shea, 2008; Sisk and). These were associated with MSA lithic technology, and the assemblages are characterised by high-quality raw materials obtained from local gravels, typically in the form of pebbles (McDougall et al. 2005; Sisk and Shea, 2008). The archaeological record primarily consists of chert, while lower-quality volcanic rocks such as rhyolite, basalt, shale, and others were less commonly used. The presence of Levallois centripetal and discoidal core reduction systems is frequent.

Retouched flakes are rare, foliate bifaces are present, and larger, heavy tools such as handaxes, picks, or lanceolate are mostly found on the surface and have not been

documented in excavated assemblages (McDougall et al. 2005; Shea, 2008; Sisk and Shea, 2008).

In the Middle Awash Valley, another group of sites shows important evidence relating to hominin evolution. Located in north-eastern Ethiopia, lithic artefacts have been reported in association with early *Homo sapiens* fossils in the Upper Herto member of the Bouri Formation (Clark et al. 2003; White et al. 2003). The assemblage has been dated to approximately 150 ka and includes artefacts collected from both surface and stratigraphic contexts. The primary lithic components that characterise the assemblage are picks and handaxes, along with a notable occurrence of Levallois elements, such as common radial/centripetal cores.

Aduma is another important reference point for knowledge of the EMSA in the region and is dated to MIS 5. Aduma is situated in the Ardu Beds, north of Herto in the Middle Awash Valley. The lithic assemblage from Ardu B has been dated to ~90 ka using U-series and OSL methods (Haile-Selassie et al. 2004; Yellen et al. 2005). This assemblage shares many similarities with the Upper Herto lithics, featuring a prominent Levallois core-reduction technology. Additionally, it includes retouched triangular points, foliate bifacial points, and small asymmetric discoidal cores. These are in addition to Levallois cores like those found in the Kibish Formation assemblages. The main raw materials exploited were volcanic rocks, including obsidian (Sahle et al. 2019a and b).

The Aduma lithic assemblages have been considered a regional MSA variant. This is due to the diversity of cores and retouched tool types, with an emphasis on small tool production (Yellen et al. 2005). The predominance of Levallois reduction methods, retouched flakes and blades, as well as points, scrapers, notches, and denticulates, together with a notable lack of Acheulean-like features, place the Aduma assemblages within the variability of the eastern Africa MSA. However, the miniaturized character of some cores and products (both retouched and non-retouched) in the younger assemblages suggest it may reflect a regional variation that was initially defined as the "Aduma Industry" (Yellen et al. 2005; Shale et al. 2023).

In Kenya, Cartwright's Site (GsJj75) is located on the edge of the Kinangop plateau at an elevation of 2420 masl. It is a Late Pleistocene open-air MSA occupation with artefacts exposed by the erosion of the site. The site was last occupied ~79 ka, but the underlying layers are still undated (Waweru, 2023). The lithic assemblage is mainly composed of obsidian artefacts, obtained from sources at Njorowa Gorge and Masai Gorge, 16 km west of the site (Merrick and Brown, 1984). The assemblage is characterised by the presence of Levallois and Discoidal cores, together with single, double, and multi-platform cores, and Bipolar cores. The retouched tools mainly consist of scrapers, as well as unifacial and partial-

bifacial points, used as projectiles (Waweru, 2023). Blades and bladelets are also present and produced with the bipolar-on-anvil technique. However, blade technology was evidently not a primary focus of lithic reduction at the site, since there is no evidence of blade cores, and the number of blades is very low.

Site	Date	Technology	Characteristic	References
Olorgesailie	~320-305 ka	Levallois and asymmetrical cores	Long-distance raw materials transportation	Potts, 2023
		Blade and bladelets cores		Brooks et al. 2018
		Bipolar cores		Potts et al. 2018
		Discoid and multiplatform cores		
		Points retouched		
Kapthurin Formation	~280 ka	Small Levallois cores and point	Acheulean+MSA elements	Tryon, 2023
		Acheulean-like elements		McBrearty and Tryon, 2005
		cleavers		Tryon and McBrearty, 2002
Gademotta and Kulkuletti	~280 ka	Uni-bifacial retouched points	Three different technological changes in point retouching have been identified between 280 and 100 ka.	Deino and McBrearty, 2002
		Point flakes		McBrearty et al, 1996
Omo Kibish formation	~195-100 ka	Levallois centripetal, preferential and recurrent	use of local crypto-crystalline silicate rocks. Presence of foliate bifaces on the surface. Handaxes," picks, and core axes on surface made on coarse-grained basalts heavy weathered	Shea, 2023
		Laminar methods		Shea, 2008
		Discidal cores		Fleagle et al. 2008
		Miniaturised flakes		McDougall et al. 2005
		Scrapers, notch and denticulates		
Middle Awash complex (Herto)	~150ka	Picks	Lithic assemblages from both surface and excavation	Beyene et al. 2023
		Handaxes		Negash et al. 2011
		Levallois cores		Clark et al. 2003
		Radial and centripetal cores		
Aduma	~90ka	Levallois cores	Regional variant oriented to small flake production (Aduma Industry)	Sahle et al. 2023
		Retouched triangular points		Sahle and Brooks, 2019
		Foliate bifacial points		Yellen et al. 2005
		Small Discoidal cores		
Cartwright's site (GsJj75)	~89ka	Levallois and discoid methods	Obsidian sources at more than 30km	Waweru, 2023
		Bipolar cores to produce blades		
		Single, double and multi-platform cores		
		Retouched points used as projectile		
		Few blade produced with bipolar technique		

Figure 11: Archaeological sites with EMSA evidence.

1.3.2 LMSA sites

The period dated to MIS 3-4 is characterised by climatic instability with a general trend towards aridification, with irregular interludes of more humid conditions. This has been already noted, in local responses to diverse environments and the development of lithic regional identities (Clark, 1988). In fact, LMSA lithic assemblages show an increased variability (Leplongeon et al. 2020).

LMSA site evidence is characterised by a limited number of localities and thus it is challenging to develop a solid model for the MSA-LSA transition involving the whole of the eastern Africa region.

One of the longest archaeological sequences containing materials spanning from ~78 to the Iron Age (~400 years ago) is the site of the Panga Ya Saidi, an open-roofed cave, in Kenya (Shipton et al. 2018; 2021; 2023). It is also one of the very few sites with evidence of coastal engagement in the eastern Africa MSA.

The site was discovered in 1960 but excavated only recently (Shipton et al. 2023). The lithic assemblage recovered from the sequence shows features related both to the MSA (Levallois cores and retouched points) and the LSA (prismatic blades and crescents). The major characteristic in the sequence is a shift in the use of coarser raw materials such as limestone, to finer-grained materials like quartz and chert, together with a reduction in lithic artefact size (Shipton et al. 2023). Panga Ya Saidi also provides some of the earliest evidence of LSA technical features in the region.

Porc Épic Cave is situated 2 km south of the town of Dire Dawa, in the southern part of the Afar Rift, Ethiopia. The cave is located atop the hill known as Gerard Erer, offering a view of the open area to the north and the Wadi bed leading southwards into the escarpment (Clark et al. 1984; Pleurdeau, 2005). It was first discovered in 1929 by P. Teilhard de Chardin and H. De Monfreid. The initial excavation was conducted by P. Wernert from the 'Institut de Paléontologie Humaine' in Paris in 1933. Subsequently, several excavations were carried out by Clark in 1974. The long stratigraphy of the cave has been divided into five main complexes (I-V) and technological analysis of the 1975-76 collection revealed no significant diachronic change through the sequence. Thus, the assemblages were defined as one analytical unit and referred to as MSA (Leplongeon, 2014; Pleurdeau, 2004; 2005; Pleurdeau et al. 2023). The chronology of the site is still uncertain. According to radiocarbon dating from the old excavations, it is placed around ~77-60 ka (Leplongeon, 2014; Negash et al. 2011; Negash & Shackley 2006; Pleurdeau 2004; 2005). However, attempts to date the site based on new OSL samples are ongoing but have preliminarily revealed an older date (Leplongeon et al. 2022; Tribolo et al. 2022.)

Chert is the dominant raw material knapped at the site, followed by basalt and obsidian. Obsidian was preferentially used for the manufacture of retouched pieces, and these artefacts were smaller compared to those made from other raw materials, especially those in basalt. Elongated blanks are present with a wide size range (including bladelets). Four reduction schemes have been identified with the predominance of a planimetric conception of *debitage* (Leplongeon, 2014; Pleurdeau et al. 2023). Retouched points are present, as well as scrapers and notches. The variability observed among the retouched points at the site is particularly marked. There is no evidence of backed microliths within the MSA assemblage. The only signature of this technology is found as part of a small sample from the 1933 collection and comes from the upper layers that reflect admixture from the LSA levels.

Extensive evidence of the use of ochre has been found at the site and dates to between ~45 and 40 ka (Rosso et al. 2016). There is also evidence of human modification of ochre in the form of flaking traces, as well as evidence of ochre-processing tools (grindstones), which

provides rare insights into the use of ochre during the eastern Africa MSA (Pleurdeau et al. 2023; Rosso et al. 2016).

A recent examination of the ochre collection from Porc Épic shows evidence that MSA occupants of the site could probably predict the properties of different types of ochre, and adapted their technology to cope with changes in raw material availability (Rosso et al. 2023).

Goda Buticha is located around 30 km west of Dire Dawa town and from Porc Épic. It is one of the very few sites in eastern Africa with a long and well-dated stratigraphy that documents Late Pleistocene human occupation from ~63 ka until ~700 years ago, with an occupational hiatus between MIS 2 and the beginning of the Holocene. This is similar to other contexts, especially in Ethiopia (Leplongeon et al. 2017; Pleurdeau et al. 2023).

Together with lithic assemblages, the sequence includes animal remains (including small vertebrates), hominin remains, and other behavioural evidence including the presence of ostrich eggshell beads and engraved fragments. The sequence has been divided into two main complexes (I and II) with a further subdivision into layers IIf-IIc (~63-24 ka) and layer IIc (~7-6 ka), while complex I is dated to ~ 4-1 ka). Each of the layers has yielded lithic artefacts. Chert was the most frequently used raw material, while obsidian, basalt, and quartzite were exploited less commonly. The lithic material bears characteristics of both the MSA and LSA, showing with the production of flakes and elongated blanks using diverse reduction methods (both Levallois and volumetric approaches), and reflects a toolkit in which retouched points, backed pieces, and (end)scrapers are well represented.

In the lower part of the sequence (layers IId–IIf; approximately 63–25 ka), the MSA is characterised by a predominance of flake production using various Levallois methods. The assemblage includes large and small elongated blanks produced using a planimetric *debitage*, with retouched elements primarily derived from obsidian and elongated blanks. Layer IIc (approximately 6–8 ka) displays a mix of MSA and LSA characteristics, with occasional Levallois methods and blade production, and obsidian use focused on retouched tool manufacture. The top layer (Complex I, approximately 4–1 ka) contains a small LSA assemblage, mainly on obsidian, with flake and blade(let) production. Technological continuity is observed across layers, including in the preference of obsidian for retouched tools, a focus on planimetric *debitage*, and the high frequency of elongated products. Technological differences include an increased use of obsidian over time, the use of volumetric *debitage* for elongated blanks in Layer IIc, and changes in the frequency of backed microliths over time. Layer IIc stands out for its unique combination of MSA and LSA features, raising questions about the temporal and cultural span of MSA lithic technology in the region.

The MSA layers at Goda Buticha and Porc Épic exhibit common lithic traits, including Levallois methods for flakes and elongated blanks, and a diverse array of retouched points. In contrast, Goda Buticha IIc reveals a late persistence of MSA characteristics alongside LSA tool types including elongated backed points. This late occurrence suggests possible technological reinventions or continuity during the arid conditions of MIS 2. The scarcity of archaeological evidence in the Horn of Africa during MIS 2raises questions about population movements and evolutionary/social mechanisms during this timeframe (Leplongeon et al. 2017; Pleurdeau et al. 2023).

Mochena Borago rockshelter, in southwestern Ethiopia, is another site that provides information about Late Pleistocene hunter-gatherer behaviour and offers a chronometrically dated sequence covering the past 50,000 years (Brandt et al, 2012; 2017). The sequence probably spans from MIS 4 to MIS 3 (Brandt et al. 2023). One initial focus of the project at Mochena Borago was to test whether the relatively moist environments of tropical highland SW Ethiopia may have sustained hunter-gatherer populations during arid periods, such as MIS 2 and MIS4 when other regions experienced significant human depopulation. Southwest Ethiopia may have served as a refugium for humans who later dispersed during early MIS 3 (Brandt et al. 2017). However, the current evidence is still not able to confirm this hypothesis.

The Mochena Borago sequence has been divided into several lithostratigraphic groups. Among them, three groups (T-Group, S-Group, and R-Group) yielded lithic artefacts primarily made of obsidian, with more limited evidence of the use of basalt and rhyolite.

The T-Group, subdivided into lower and upper, has provided the earliest evidence of human occupation at the site. The Lower T-Group is dated between ~50 and 47 ka and the Upper T-Group between ~47 and 45 ka. The assemblages exhibit a broad range of core reduction strategies, with a notable exception: volumetric blade/bladelet cores, generally rare, make their earliest appearance at the site. Small tabular elongated flake cores dominate, while Levallois cores, including preferential, recurrent centripetal, and Nubian point cores, are present but rare. Bipolar forms are absent.

Additionally, rare backed pieces emerge in the Lower T-Group and increase substantially in the Upper T-Group, forming the second-highest frequency of shaped tools alongside scrapers. Small unifacial to bifacial-pointed tools, primarily made on elongated flakes, are the most abundant shaped tools in Lower T-Group and nearly double in frequency in Upper T-Group, while other tools such as burins remain rare.

The S-Group is dated between ~46-45 ka and 45-43 ka. Bipolar core reduction schemes here increase significantly, while tabular elongated flake cores remain dominant. Blade cores show a slight increase in frequency but are still relatively rare, while Levallois cores,

including preferential, recurrent centripetal, and Nubian types are very rare. Scrapers and pointed tools are also present. Backed pieces become prevalent, constituting over 30% of shaped tools, while the continued absence of geometrics is notable.

The R-Group is dated to between ~43-42 and 39-36 ka. The lithic assemblage shares several similarities with the T- and S-Groups. Obsidian is still the predominant raw material used, but also in the presence of tabular cores, the increase in bipolar cores, and the absence of geometrics. There are several differences, however. The occurence of volumetric laminar cores (both prismatic and pyramidal) increases, Levallois cores (recurrent centripetal, preferential, and Nubian) are still rare but increase in frequency compared to T- and S-Groups, and there is a decrease in the number of backed pieces.

Fincha Habera provides the oldest evidence of high-altitude occupation of the world, and is located in the Ethiopian Bale Mountains, ~3000 masl (Ossendorf et al 2019). Its discovery contradicted the previous hypothesis that had suggested elevated environments in Africa were too challenging for human occupation. Archaeological evidence from Fincha Habera implies that foragers from the MSA demonstrated an adaptability that allowed them to thrive in difficult settings, including at altitudes beyond the hypoxia threshold and in frigid, glaciated terrain. Contrary to the hypothesis that humans may have sought refuge at high altitudes during harsh arid conditions, apparent growth in the population here aligns with a regional pattern of expansion during the interstadial intervals of MIS 3. However, evidence for any human presence in Ethiopia during the driest part of the last glacial (MIS 2) remains extremely limited.

The occupation of Fincha Habera coincides with the Last Glacial Maximum (LGM) which was characterised by notable environmental shifts such as the areal extension of glaciers and lower temperatures. The rockshelter was likely positioned at the boundary between the afro-alpine and Ericaceous belts during the local LGM. The lithic assemblage recovered reveals distinct patterns in raw materials and in manufacturing techniques. Obsidian once again predominates, with a single quartz artefact suggesting a potential long-distance transport pattern. Levallois technology was infrequently employed, while tabular single, double, and multi-platform cores are most common, emphasizing unipolar removals. Prismatic cores with a single platform are associated with blade removals. The site's inhabitants used the bipolar technique in the later stages of occupation, which is evident in the presence of splintered pieces. Elongated flakes and blades are the primary blank categories, and small cores were also exploited. Some retouched and unretouched artefacts exhibit macroscopic edge damage, with retouching prevalent on points and blades. Retouched tools include points, and scrapers, which often retain dorsal cortex. Basal thinning is common, particularly on points. Additional analyses of ostrich eggshell, ochre,

wood, charcoal, and hyena coprolites are ongoing. Notably, technological elements typical of the Late Stone Age, such as bladelets, backed artefacts, and geometric microliths, are absent from the assemblage.

Fincha Habera aligns with other MSA sites found at lower elevations in the Rift Valley, such as Mochena Borago and Goda Buticha. Similar artefact manufacturing traditions are observed at these sites, emphasizing possible cultural connections. Despite being positioned in a unique glaciated and high-altitude environment, Fincha Habera's MSA lithics lack LSA elements and show no direct impact from the specific subsistence behavior or environment. The absence of climate-driven isolation is evident, as MSA foragers at Fincha Habera maintained connections with the lowlands, supported by artefacts like ostrich eggshells and non-local quartz and obsidian.

The Bulbula River sites are a series of occupations around the omonim River located in the Ziway-Shala endorheic basin, within the Main Ethiopian Rift (MER). Archaeological surveys have here revealed sites from late MIS 3, the Late Glacial, and the Early Holocene. The oldest excavated sites (B1s3, B4, DW4) date back to late MIS 3 (around 45-30 ka), and reflect a period of landscape stability with the formation of paleosols that are associated with numerous lithic artefacts indicative of a relatively dense human population. The DW1 and ADS2 sites shed light on the cultural traditions of late MIS 3 in the region. ADS2, a more recently explored site spanning the boundary of MIS 2-3, is distinct compared to the older sites. Lithic production from the late MIS 3 sites, though spanning a considerable time frame, exhibit similarities and emphasize the importance of elongated blanks produced through Levallois bidirectional methods. The blanks vary in morphology, and feature thin, pointed products from the core's centre and thicker, asymmetric products from the cores' sides. The precise preparation of striking platforms (faceting) is evident, and smaller elongated blanks were produced through core-on-flake methods. Shaped tools such as convergent sidescrapers, unifacial points, and endscrapers are present, along with some artefacts that display inverse retouch related to proximal thinning. The low percentage of retouched artefacts suggests that most products were utilised without further modification. DW4 is chronologically correlated with DW1 and is characterised by the presence of cores-on-flake, Levallois cores, blades and flakes, and elongated points with basal thinning. However, these data are still unpublished.

In the Lake Victoria basin, Late Pleistocene sediments overlying Miocene deposits have been reported (Tryon, 2023; Tryon et al. 2010; 2012; 2015). At Rusinga Island, an MSA occupation has been reported in Late Pleistocene sediments (Tryon et al. 2012). The Wasiriya bed at Rusinga Island has been dated to ~45-33 ka (although tephrostratigraphic age estimates the age to be at least ~100 ka). The lithic assemblage includes artefacts made on chert, quartz,

and a variety of lavas, with a majority of artefacts probably made from nearby sources. A few artefacts are linked with raw materials not known to be locally available.

All artefacts from the Wasiriya Bed deposits are classified as MSA. The assemblage is characterised by Levallois, discoidal, single, and multi-platform cores, as well as cores with irregular removal patterns. Larger Levallois cores, were made on locally available lavas and these comprise a recurrent Levallois core and a Nubian Type 1 core. Blades and Levallois flakes are also present. A reduction in the size of Levallois cores made of chert is apparent and probably results from the availability of only small pieces of chert, more intensive reduction, and/or the intention to produce small elements (Tryon et al. 2012).

In Tanzania, several MSA sites with long stratigraphic sequences have been documented.

A late MSA occupation has been reported at Loiyangalani, in the Serengeti National Park, northern Tanzania (Maìllo-Fernandez et al. 2019). The site was discovered in 1977 (Bower and Gogan-Porter, 1981), and excavated for several seasons until 2005. The MSA occupation has been dated to ~64 ka and the lithic assemblage is characterised by four reduction systems belonging to two major groups: freehand and bipolar-on-anvil, using mainly quartzite, quartz, and chert as raw materials. The first group is composed mainly of lithics produced by Levallois and discoidal methods using quartzite and chert, while the second group is characterised by the bipolar-on-anvil technique, mainly involving quartz. Among the retouched tools, sidescrapers, notches, denticulated and retouched flakes are present, as well as bladelets, truncated pieces, and burins. Points and backed pieces are less well represented (Maíllo-Fernández et al. 2019). Comparison with lithic assemblages from the nearby sites of Nasera and Mumba has revealed that Loiyangalani includes greater evidence of scrapers, denticulates, and notches, while the other sites feature more points, bifacial pieces, and scrapers. They all share the use of discoid and Levallois methods, as well as the use of bipolar-on-anvil technique (Maíllo-Fernández et al. 2019).

At Olduvai gorge, well known for its rich evidence of Early and Middle Pleistocene occupation, research has focused on the MSA, and occupation by *Homo sapiens* is less clear (Eren et al. 2014). However, evidence of this time frame has been reported from the Ndutu Beds, which contain lithic artefacts with MSA features made on basalt, phonolite and quartz (Leakey et al. 1972). This includes flakes with thick and facetted platforms, discoidal and Levallois cores, a production oriented towards the manufacture of convergent tools, and a notable lack of retouched pieces. Subsequently, more MSA localities have been identified and are characterised by assemblages composed of Levallois and discoidal cores, and bipolar cores made on basalt, quartz, and phonolite. Interestingly, Levallois cores are only reported on basalt, indicating a probable constraint due to raw material type (Eren et al. 2014).

Interesting is a recently reported site named Dorothy Garrod Site (Maíllo-Fernández et al. 2022). It was discovered in 2017 on the northern side of the Olduvai Gorge, and probably corresponds to the place Eren referred to as RAC (Maíllo-Fernández et al. 2022). Although a secure chronology has not yet been provided, the sequence is located in the Ndutu Beds and it is likely older than 86-75 ka. The lithic assemblage is composed mainly of quartzite, phonolite, sandstone, basalt, quartz, and chert. Levallois and discoid (both bifacial and unifacial) methods are present, together with single platform cores. There is no evidence of bipolar-on-anvil technique. Retouched pieces are scarce, mostly represented by denticulates and retouched flakes (notches and sidescrapers), with no retouched points or Levallois points being present (Maíllo-Fernandez et al. 2022).

Site	Date	Technology	Characteristic	References
Olduvai gorge (Ndutu bed) Dorothy Garrod Site	~86-75ka (but also older)	Levallois and discoid methods Single Platform cores Sidescrapers Notch and denticulates	No Points, no Bipolar on anvil technique	Maíllo-Fernández et al. 2022 Eren et al. 2014
Panga ya Saidi	~78ka-400 year ago	Levallois bipolar and unipolar core Retouched points Laminar methods Blades Bladelets Backed pieces Crescents	MSA elements together with LSA, shift from coarser raw material to finer grain, reduction in lithic sizes from MSA to LSA	Shipton et al. 2023 Shipton et al. 2020 Shipton et al. 2018
Porc Epic	~70-60ka (old dates) end of MIS5 (new dates)	Levallois methods Elongated blanks Retouched points, scraper, notch no evidence of point production	Four reduction systems identified, with the planimetric one being the most used. Also used Volumteric and Intermediate reductions. Extensive use of ochre. Knowledge of properties of different type of ochre and technological adaptation to cope with this. Long distance obsidian procurement	Pleurdeau et al. 2023 Rosso et al. 2023 Leplongeon, 2014
Loiyangalani	~64 ka	Freehand group: Levallois and Discoid methods Bipolar on anvil technque Notches and denticulates Sidescrapers Few points Few backed pieces	Bipolar used only for quartz. Contraints by raw materials	Maíllo-Fernández et al. 2019
Goda Buticha	~63ka to 700 years ago	Levallois methods Volumetric methods Blades (both Levallois and volumetric) Retouched points 2 backed pieces	Engraved ostrich eggshell fragments. Only site in Ethiopia with a long sequence revealing MSA and LSA occupation. Levallois method present in the Holocene layers	Pleurdeau et al. 2023 Leplongeon et al. 2017
Mochena Borago	~50-36 ka	Levallois methods Multiplatform cores production of flakes and blades Backed pieces Retouched points, scraper	Several assemblages divided into T-Group (~50-45ka), S-Group (~45-43ka) and R-Group (~43-36ka).	Brandt et al. 2023; 2017;2012
Fincha Habera	~47-31 ka	Tabular single-double-multi-platform cores Prismatic cores for blade production Scrapers Unifacial points (with basal thinning) Retouched blades	High-altitude occupation, extensive exploitation of rodents. Probably long-distance raw materials transportation	Ossendorf et al. 2023; 2019
Rusinga Island	~45-33 ka	Levallois and discoid methods Nubian Technology Single and multi-platform cores Blades	Different exploitation of raw materials. Levallois and Discoidal cores made on Lava appear to be bigger to the Levallois cores made on chert. Lava was available locally, while chert represent a distant raw material	Tryon, 2023 Tryon et al. 2012 Tryon et al. 2010
Daka Wede4 (Ziway Sahla Basin)	~34-31 ka (correlation with DW1)	Core-on-flakes Levallois methods blades and flakes production elongated points with basal thinning		Ménard and Bon, 2023

Figure 12: Archaeological sites with LMSA evidence.

1.4 A definition of the Late Stone Age

As for the definition of MSA, the term LSA was also introduced by Goodwin and van Riet Lowe (1929) in their classification system of the Stone Age in South Africa, with the subsequent extension to all sub-Saharan contexts. The term LSA was introduced primarily to distinguish the African Holocene "cultures" (e.g. Wilton) from the previous MSA evidence. They based its definition on the flaked microlith tools documented ethnographically within the San groups (Clark, 1982; Goodwin and van Riet Lowe, 1929; Pargeter and Brandt, 2015). This classification was made upon the lithic record and, according to Goodwin (1946:94) the LSA "*introduces the (consistent) use of the flat striking platform as a dominant motif. The flake struck from such a platform will tend to lie parallel*".
However, it was already pointed out that *"we are dealing primarily with techniques, each of these techniques is foreshadowed in the previous phase. We only reach each new "Age" as the new technique becomes dominant and replaces previous modes"* (Goodwin, 1946: 94).
In 1970s radiocarbon dates revealed a Late Pleistocene age for some LSA industries. This led to the development of a more complex "modern human behaviour", reflected into a rapid shift from the MSA to the LSA during the Late Pleistocene. However, subsequent studies revealed the complex, asynchronous shift (in space and time) from the MSA to the LSA. In fact, a complex variability in lithic technology is seen already in the late MSA industries, especially in eastern Africa. Thus, what the LSA represents and what is its distinctive behavioural traits as well as if a transition can be really seen in the archaeological record has been questioned (Pargeter and Brandt, 2015).
Currently, the LSA is perceived as a wide-ranging term, extending from roughly 40-50 ka to about 4-6 ka, or during MIS 3-1. The definition of LSA is primarily based on some characteristics in lithic production, such as the presence of toolkits of smaller dimensions, an extensive use of volumetric cores to produce baldes and bladelets, the absence (or decrease) of retouched points, the increased presence of the bipolar on anvil technique and the predominant presence of backed microlith tools (Ambrose, 2002; Leplongeon et al. 2020; Ménard and Bon, 2015; Phillipson, 2005). Other behavioural features are represented by the increased presence of personal ornaments (e.g. ostrich eggshell beads), the use of ochre, differences in subsistence and mobility patterns among human groups. It is also noted for population growth and major dispersals in and out of Africa (Leplongeon et al. 2020; Shipton et al. 2018; Tryon and Faith, 2016).
However, as already noted above, the pattern of changes is very difficult to define, as the early LSA evidence appears in a different chronology across eastern Africa.

Therefore, as clearly seen, the challenge of defining these cultural complexes presents a significant obstacle to interpreting behavioral data. Even today, the distinction between the MSA and LSA remains elusive due to the absence of clear boundaries and the lack of a universally accepted definition that differentiates between them. This ambiguity is compounded by the intra-industries and inter-site variability within the LSA itself in time and space, further blurring this distinction.

As a result, Late Pleistocene archaeological sites often exhibit a mixture of MSA and LSA characteristics, making it difficult to categorize them definitively. This complexity is particularly pronounced in the archaeological record of eastern Africa, where transitions between these periods are nuanced and multifaceted (Leplongeon et al. 2020; 2023).

Moreover, recently the recognition of the use of different terminologies among researchers and the absence of a common vocabulary to describe and distinguish assemblages (e.g. the term microlith that encompass different interpretations, from small unretouched flakes to small retouched tool (Pargeter and Brandt, 2015: 168) has raised questions regarding the existence of a truly technological diversity that reflects significant variations in hunter-gatherer behavior or if it stems from the persistent use of outdated cultural-historical frameworks reliant on poorly defined techno-typologies (Pargeter and Brandt, 2015).

While this thesis does not aim to propose alternative terminology for the MSA and LSA, it is essential to acknowledge the potential impact of past archaeological classifications and use of such terminologies on the interpretation of behavioral changes associated with technological advancements.

By recognizing the influence of terminology on our understanding of prehistoric cultures, we can approach the analysis of archaeological data with greater nuance and sensitivity to the complexities of cultural evolution.

1.5 Archaeological evidence with MSA-LSA transition in eastern Africa

Among the earliest evidence of LSA technologies in eastern Africa, the Panga ya Saidi site in Kenya provides a good example of diachronic change within a single context (Shipton et al. 2018; 2021; 2023). This 3 m deep archaeological sequence is composed of 19 layers, and an MSA-LSA transitional horizon has been dated to 72-67 ka (Shipton et al. 2018). The earliest LSA layer is marked by a shift in raw material use from limestone to quartz and chert, and in a reduction in artefact size compared to the previous MSA layers (Shipton et al. 2018). These traits are believed to be common features of Late Pleistocene cultural change (Pargeter, 2016; Pargeter and Shea, 2019). Moreover, after 67 ka, the Panga Ya Saidi sequence reflects an increase in the use of bipolar-on-anvil technology, which is also seen as a marker

of the LSA (Grove and Blinkhorn, 2020). Despite the classic definition of the LSA involving a decrease in the use of Levallois methods, within the LSA layers at Panga ya Saidi there is a co-occurrence of the bipolar technique and Levallois blades, as well as the presence of backed crescent tools, and they remain consistently small throughout the upper part of the sequence (Shipton et al. 2018).

In addition to lithic artefacts, these LSA layers are also characterised by the presence at ~67 ka of beads made of *Conus sp.* shells , while afterwards beads were made of ostrich eggshells, which reach their highest frequency at around 25 ka. Ochre-modified fragments have also been found, as well as carved bone, one decorated long bone, and a small bone point (Shipton et al. 2018; 2021; 2023; d'Errico et al. 2020). These latter elements are often considered as characteristic of the LSA. This site marks an important body of evidence for understanding the key cultural innovations that started in the MSA and continued in later periods (d'Errico et al. 2020; Shipton et al. 2018; 2023).

In southern Kenya, the rock shelter site of Enkapune ya Muto has yielded artefacts defined as LSA from layers dated to ~46 ka (Ambrose, 1998). The site is located in the central Kenyan Rift Valley and it is characterised by a long sequence with archaeological layers dated from the MSA to the Iron Age (Ambrose, 1998). Three levels are dated to the Pleistocene, with the oldest dated to ~55 ka (RBL4) and characterised by a flake-based MSA assemblage defined as Endigi. It includes flakes with facetted platforms as well as radial and convergent cores. Among the retouched tools scrapers are common, with a rarer presence of points, burins, and a few backed tools.

The uppermost layers (GG and OL) contain the oldest LSA evidence, attributed to the Nasampolai industry, while the third (DBL) LSA layer is dated to ~35-40 ka and defined as representing the Sakutiek industry (Leplongeon, 2017). This latter industry seems to be characterised by the presence of discoidal cores and flakes with facetted platforms together with parti-bifacial knives as well as ostrich eggshell beads. It implies a non-linear change between the Pleistocene industries in this area (Ambrose, 1998; 2002; Leplongeon, 2017). The Nasampolai industry is by contrast characterised by the presence of large geometric microliths together with evidence of blade technology. However, a recent re-examination of the assemblages shows that both LSA assemblages can be considered blade and bladelet-oriented industries, thus more information is needed to understand the pattern of technological changes across the MSA and the LSA in this context.

Prospect Farm is another site located in the central Kenyan Rift Valley with evidence of a long archaeological sequence spanning the Middle Pleistocene to the Holocene, at several localities (Van Baelen et al. 2019). The site has revealed four horizons containing MSA materials (Merrick, 1975). The youngest evidence is dated to ~46-53 ka, however, the

understanding of the site, its chronology and function, as well as its importance within the general context of the eastern Africa MSA and LSA is difficult, because of the absence of reliable chronometric dates (Van Baelen et al. 2019).

The Lukenya Hill site complex, located in southern Kenya, provides some of the best evidence of the LSA in eastern Africa (Kusimba, 2001). Specifically, site GvJm-22, with a maximum age of >46 ka, has revealed the presence of both MSA and LSA lithic technologies (Tryon et al. 2015). The artefact analysis shows a gradual shift from the use of Levallois methods for flake production, to the production of blades using both single and double-opposed platform cores. Moreover, an increase in the occurrence of backed microliths is associated with a decrease in retouched points and scrapers. LSA elements are seen also in the presence of large grindstones, while ochre fragments and ostrich eggshell beads are also present (Tryon et al. 2015).

In Tanzania, the Mumba rock shelter has provided among the earliest evidence of microlithic industries in eastern Africa, particularly in Bed V, which is dated to ~65-55 ka and in which the Mumba Industry is found (Mehlman, 1989). Six distinct layers, defined as Beds I-VI, were identified based on differences in sediment composition. The top layer, Bed I, contains modern Hadza artefacts. Bed II held pottery indicative of the LSA and was dated to around 1800 years ago (Mehlman 1989). Bed III contained archaeological materials in loose sandy deposits, with ceramics found in the upper half and absent in the lower half. Bed IV consisted of sterile sand and single beach deposits with a few scattered artefacts. Bed V featured loose sandy deposits with some local cementation and abundant archaeological remains. Bed VI contained archaeological materials, although sediments below the coarse beach level had been extensively washed by high lake levels, resulting in the polishing of artefacts and the natural loss of smaller lithic fragments. Mehlman (1989), divided Beds III through VI into three cultural units: LSA with and without pottery (Bed III), transitional (Bed V), and generalized MSA (Bed VI) (Marks and Conard, 2007). Moreover, he defined the "Mumba industry" as being characterised by the co-occurrence of MSA retouched points alongside large, backed LSA pieces, and noted a decrease in artefact size toward the top of Bed V. However, the unclear stratigraphic provenance of this assemblage made its interpretation questionable (Diez-Martin et al. 2009). Recent re-examination of the Mumba industry from Bed V has shown the extensive use of the bipolar-on-anvil technique, while freehand cores are less frequent, but radial reduction as well as discoidal cores predominate. Moreover, the presence of Levallois methods is also attested, as are backed and geometric microliths (Prendergast et al. 2007; Gliganic et al. 2012; Diez-Martin et al. 2009). However, evidence of the MSA and early LSA at the Mumba rock shelter is still questionable since it

cannot be linked reliably to the stratigraphic sequence and the date of the transition is unknown (Tryon and Faith, 2016).

Nasera rock shelter, situated in northern Tanzania provides a long sequence that includes MSA, LSA, and the Pastoral Neolithic. It was excavated by L. Leakey in 1932, and then by M. Mehlman. The latter identified several archaeological levels with evidence spanning from the MSA to the Neolithic, with an average chronology that goes from ~56 ka to 2 ka (Solano-Megías et al. 2021). The archaeological sequence described by Mehlman from bottom to top as containing: 1) the MSA Kisele industry, dated to ~73–56 ka; 2) the MSA-LSA Mumba industry, dated to ~56–50 ka; 3) the MSA-LSA Nasera industry, dated to ~37–25 ka; 4) the early LSA Lemuta industry, dated to ~24–16 ka; 5) the LSA Silale industry, dated to ~8 ka; 6) the Kansyore/ceramic LSA Olmoti industry, dated to ~5 ka; 7) a series of Pastoral Neolithic occurences, dated to ~2 ka, and; 8) more recent Iron Age phases (Mehlman, 1989; Ranhorn and Tryon, 2018; Tryon and Faith, 2016).

The Nasera site represents the only site in eastern Africa with a long sequence spanning over 50 ka and with abundant evidence in lithic and faunal remains, and that features the MSA-LSA transition. It is therefore a critical locality to look for the nature of MSA-LSA technological shifts (Tryon and Faith, 2016). The analysis of the Nasera sequence shows a gradual shift from the use of Levallois and bipolar technologies, and the production of points, towards an increase in the use of backed microliths with a general trend towards artefact miniaturisation, which is seen as a trait of the MSA-LSA transition. Raw materials include locally available quartz and quartzite, chert sourced from distances of 30 and 60 km, and scarce obsidian from sources approximately 250 km away.

In the Kisele and Mumba industries, there is the prevalence of Levallois cores, while they decrease in the Nasera and Lemuta industries and are characterised by their smaller dimensions. Evidence of the Levallois method is absent within the Holocene layers and the Silale industry. The Kisele industry features an increase in bipolar cores. The presence of points clearly declines in assemblages postdating the Nasera industry and they become smaller (Tryon and Faith, 2016). Backed microliths, small flakes, blades, and bladelets with 'backed' retouch become more common relative to other retouched tools in later LSA strata, starting with the Lemuta industry during the Last Glacial Maximum. The few measurable backed pieces in the Kisele and Mumba industries are larger than those in the Nasera, Lemuta, and Silale industries.

Recent examination of lithic industries from the site confirmed a decrease in MSA core reduction systems (e.g. Levallois and Discoid) and an increase in the use of bipolar-on-anvil technique, as well as an abundance of blades and bladelets in the early LSA layers together

with the selection for finer-grained raw materials and a decrease in artefact dimensions (Solano-Megías et al. 2021).

The Kisese II rockshelter, located in the Kondoa region of Tanzania, is an important eastern African rock art site inscribed into the UNESCO world heritage site list. It was excavated in 1956. It provides a 6-meter-thick archaeological sequence containing evidence for the MSA-LSA transition. It incorporates lithic artefacts such as Levallois and bladelet cores, as well as backed microliths, along with recurrent use of red ochre and over 5,000 ostrich eggshell beads and fragments.

The Late Pleistocene layers contain an MSA assemblage characterised by the use of Levallois methods for flake production and probably also to produce retouched points. These occur alongside LSA elements such as backed microliths and bladelets. This technological shift towards more LSA technology is dated to ~39 ka. Moreover, there is evidence that the presence of ostrich eggshell beads and backed microliths dates back to ~46 ka and that they persisted throughout subsequent Late Pleistocene and Holocene layers (Tryon et al. 2018).

The Magubike rock shelter, in southern Tanzania, contains rich artefact bearing deposits that include recent Iron Age deposits, an LSA layer, a layer containing artefacts with mixed MSA and LSA characteristics, followed by a deeper layer with the predominance of MSA artefacts. The latter are characterised by their larger sizes and a wider range of raw materials, when compared to the upper levels (Willoughby, 2023; Willoughby et al. 2018).

In Ethiopia, evidence regarding the MSA-LSA transition is very scant, and only two sites are seen as containing long stratigraphic sequences spanning this shift: Goda Buticha and Porc Épic. Both are located in south-eastern Ethiopia, in the Dire Dawa district (Leplongeon, 2014; Leplongeon et al. 2017). However, Porc Épic has a problematic chronological attribution: recent OSL dating has revealed a much older date for its MSA layers, while the upper LSA deposit has been completely lost. We can thus consider the Goda Buticha rock shelter as the only evidence in Ethiopia for the MSA-LSA transition, since it includes levels of both occupations (Pleurdeau, 2006). However, the lower complex (IId-IIf) dated to 63 - 24 ka is characterised by a homogenous lithic assemblage, with no evidence of changes in lithic technology and, subsequently, there is an occupational hiatus from 24 - 8 ka (Leplongeon et al. 2017; Tribolo et al. 2017), as already explained (for a more detailed review of the site, refer to Chapter 5).

Aladi Springs is another site in Ethiopia that is considered to show an archaeological sequence spanning from the late MSA to the LSA (Gossa et al. 2012). The site is located in the southern Afar Rift, not far from Porc Épic and Goda Buticha and it was discovered by D. Clark in the 1970s (Clark and Williamson, 1978; Gossa et al. 2012). The archaeological material was considered to represent a late MSA assemblage (a first wet phase characterised

by a green clay loam horizon) and an LSA assemblage (the second wet phase) dated ~12 ka (Gossa et al. 2012). However, there are no dates for the MSA occupation, thus a precise chronology for this lithic technology and the transition cannot be established. Subsequent excavations at the site revealed that LSA and MSA materials may have been mixed in the sequence as a result of taphonomic processes (Brandt, 1986). However, these results have been never published. Thus, a recent examination of the lithic collection has been done on the materials from the 1974 excavation (Gossa et al. 2012).

There is in fact a difference between the assemblages classified as MSA and LSA at Aladi Springs. In the MSA scrapers were made from larger blades and flakes, while in the LSA these formal tools are mostly made on smaller blades and bladelets. Moreover, the presence of bladelet cores increases in the LSA level together decrease in their dimensions. This data has been explained as the result of a preference for high-quality raw materials such as obsidian and chert. In fact, the LSA lithics are made on cryptocrystalline silicates while the MSA lithics are characterised by a wider range of different raw materials (Gossa et al. 2012).

The Laas Geel rock shelter in Somaliland, located around 80km from Hargeisa, has yielded lithic assemblages and rock paintings (Gutherz et al. 2003). Excavations at the rock shelter have revealed a stratigraphic sequence divided into two main units: the upper part is dated through 14C to 10-5 ka cal BP while the lower part has been dated between 40 and 13 ka cal BP (Diaz, 2009; Gutherz et al 2014). However, these dates are still problematic (Gutherz et al. 2014; Leplongeon et al. 2020). The lithic assemblage from the upper unit is made mainly of flint and quartz. The latter was used to produce small flakes, some of them elongated, alongside discoid and bipolar-on-anvil technique, while chert was mostly used for irregular bladelets, as well as discoidal flakes (Gutherz et al. 2014). Toolkits include segments, scrapers, and backed bladelets.

The lower unit is characterised by a reduced use of quartz, and longer and more regular bladelets produced with different reduction systems. Blades and bladelets were produced through unipolar reduction from prismatic cores with opposite striking platforms, involving a crested preparation. There is evidence of flakes and point production using the Levallois methods. The formal tools are composed of Levallois points, scrapers as well as backed pieces. These characteristics demonstrate the mixed MSA-LSA nature of this assemblage; however, the stratigraphic and chronological problems challenge this interpretation (Gutherz et al. 2014; Leplongeon et al. 2020; 2023).

The Midhishi 2 cave is located in the Somali mountains. It is among one of the very few Somali sites known because of the difficult political context of the country. Excavations at the site were conducted in 1982, where a long sequence with MSA and LSA was uncovered (Brandt and Brook, 1984; Brand, 1986). The sequence is characterised by three "cultural

stratigraphic units" (Gresham, 1984). The lowest one yielded an MSA lithic assemblage dated to ~40 ka, that has been compared to the Stillbay (Gutherz et al. 2014). The lithic assemblage is characterised by the presence of the Levallois method, retouched points, scrapers, and a lack of microliths (Brandt and Gresham, 1990; Brandt and Brook, 1984; Gresham, 1984). The second layer is dated to 18790 +/- 340 BP and has yielded lithics with mixed MSA and LSA characteristics. It has been compared to the Hargeisan because of the presence of Levallois technology, retouched points, scrapers, and some microliths.

The uppermost unit is characterised by retouched microliths and the absence of retouched points. However, two Levallois cores have been reported. Also, the stratigraphic context of the site is still to be fully understood and a mixture of the artefacts could have taken place (Gresham, 1984). This limits the site's ability to inform us about the cultural dynamics that occurred during a period that is almost unknown in the Horn (MIS 2).

This review has clarified the inter and intra-regional variability and temporal spread of some technical characteristics within the lithic assemblages associated with MSA-LSA transition in eastern Africa. In fact, in some contexts, MSA flake-based industries persist until 30 ka (in very few cases they may even extend into the Holocene, however, the only well-dated evidence is that from Goda Buticha). In other cases, LSA traits such as backed microliths, a reduction in artefact sizes, and the greater use of fine-grained raw materials appear very early in time (as is the case at Panga ya Saidi). Some of the earliest LSA assemblages seem to contain persistent MSA features, and this reflects a nuanced border between these two cultural entities. This is also true for some other evidence, such as the presence of beads made of shell or ostrich eggshell, the use of ochre, as well as long-distance transportation, that are all well-established featured of older MSA contexts. These observations make it even more challenging to define the MSA-LSA transition. This is why more sites and more intra-site and inter-site comparisons at regional scales are necessary, as these can provide new data and hypotheses regarding this cultural phenomenon.

Site	Date for the transition	Technology	MSA-LSA features	References
Panga ya Saidi	~67 ka	Levallois bipolar and unipolar core Retouched points Laminar methods Blades Bladelets Backed pieces Crescents	Shift from coarse raw material (limestone) to finer raw material, reduction in artifacts size, increase of bipolar technique in the upper layers, increase in small backed crescent. Shell and Ostrich eggshell beads (more after 25ka). Modified ochre fragments, carved bone.	Shipton et al. 2018
Mumba rockshelter	~65-55 ka	Discoidal and radial cores Levallois method Retouched points Large backed pieces More bipolar technique	Mumba industry: co-occurrence of MSA retouched points and LSA backed pieces, decrease in artifacts dimensions	Diaz-Martin et al. 2009 Marks and Conard, 2007 Mehlman, 1989
Nasera rockshelter	~56–50	Levallois method Bipolar technology Less points More backed microliths	General trends to miniaturization, increase in the presence of bipolar cores, increase in the production of blades and bladelets; selection of finer-grain raw materials; obsidian source away 250km	Solano-Megías et al. 2021 Ranhorn and Tryon, 2018; Tryon and Faith, 2016 Mehlman, 1989;
Enkapune ya Muto	~46-55ka	MSA industry: flakes with facetted platforms, radial and convergent tools, scrapers, point and few backed tools. LSA oldest industry: large geometric microliths together with evidence of blade technology, blade and bladelet oriented industry; LSA youngest industry: discoidal cores and flakes with facetted platforms together with parti-bifacial knives as well as ostrich eggshell beads	Evidence of ochre and grindstones, major change in technology between the MSA level. MSA level: assemblage oriented towards the production of faceted platform flakes and pointed blanks; LSA levels: blade(let)- based assemblages. The early LSA assemblage (Nasampolai): few volumetric blade cores, and retouched tools (large backed segments); the later LSA assemblage (Sakutiek): numerous cores-on-flakes/blades for bladelet production, rare retouched tools (end-scrapers, scaled pieces and few geometrics).	Leplongeon, 2017 Ambrose, 1998
Lukenya Hill - GvJm-22	>46 ka	Levallois method Single and double opposed platfrom cores More backed microliths Few retouched points Few scrapers	Gradual shift from Levallois to the production of blades using both single and double-opposed platforms, increase in the presence of backed microliths, decrease in the presence of retouched points and scrapers, presence of large grindstones for grinding. Ochre fragments, ostrich eggshell beads	Tryon et al. 2015
Kisese II rockshelter	~46ka and 39±34.3 ka	Levallois method Retouched points Backed microliths Bladelets	Backed pieces, bladelets and ostrich eggshell beads	Tryon et al. 2018
Goda Buticha	~24 ka (occupational hiatus after)	Levallois cores, Blades and flakes, Retouched points, Rare backed pieces	Trend towards small artefacts, persisting of Levallois into Holocene layers, Engraved ostrich eggshell fragments	Leplongeon et al. 2017
Aladi Springs	~12 ka (MSA layers undated)	Scrapers Blades Smaller blades and bladelets	Bladelet core increases in the LSA level, increase in smaller dimensions. Preference for high-quality raw materials (obsidian and chert).	Gossa et al. 2012
Midhishi 2	~18ka BP (possible disturbed)	Levallois technology, retouched points, scrapers, Microliths and retouched microliths	MSA tool types associated with LSA tool types but small sample	Brandt & Gresham 1990 Brandt and Brook, 1984 Gresham 1984

Figure 13: Archaeological sites with MSA-LSA transition.

Chapter 2 – The Gotera area

2.1 Introduction

In this chapter, I will present the details of survey and excavation activities in the Gotera area, along with the results of each of the field seasons.

The Gotera area in southern Ethiopia has been known scientifically since the late second half of the 20th Century as a zone rich in Pleistocene deposits and materials (Chavaillon and Chavaillon, 1985; Clark, 1988; Spinapolice et al. 2017). The area was identified to be of scientific importance in 1974 by Claude Guillemot while he was traveling to the Omo Valley. Following the discovery, the Gotera area was surveyed and then excavated by Guillemot, Jean Chavaillon, Jean-Francois Ballais, and Jean-Luc Boisaubert between 1978 and 1979. On those occasions, a significant amount of archaeological material was reported (Chavaillon and Chavaillon, 1985; Spinapolice et al. 2017).

The Gotera area is located approximately 300 km eastern of the Main Ethiopian Rift (MER) (Figure 14). The MER landscape is characterized by the presence of several long-lasting lakes, a key feature linked to the occupation of this region by early modern humans (Chavaillon and Chavaillon, 1985; Molin and Corti, 2015; Sagri et al. 2008; Williams, 2016; Woldegabriel et al. 1990). The main lakes present in Ethiopia are Lake Ziway, Lake Langano, Lake Abiata, Lake Shala, Lake Awasa, Lake Abaya, Lake Chamo, Lake Chew Bahir, and the northern portion of Lake Turkana. These lakes are mostly situated along the Rift Valley line, from central to southern Ethiopia They are fed by several sources of water, including rivers and stream channels (Molin and Corti, 2015; Sagri et al. 2008; Williams, 2016). One of these channels is the Sagan River Basin, located on the bank of the eastern plateau, following the Rift Valley from eastern to west, and then flowing southward into Lake Chew Bahir. This lake is situated about 90 km west of the Gotera depression (Chavaillon and Chavaillon, 1985; Foerster et al. 2012; 2015; 2022; Spinapolice et al. 2017).

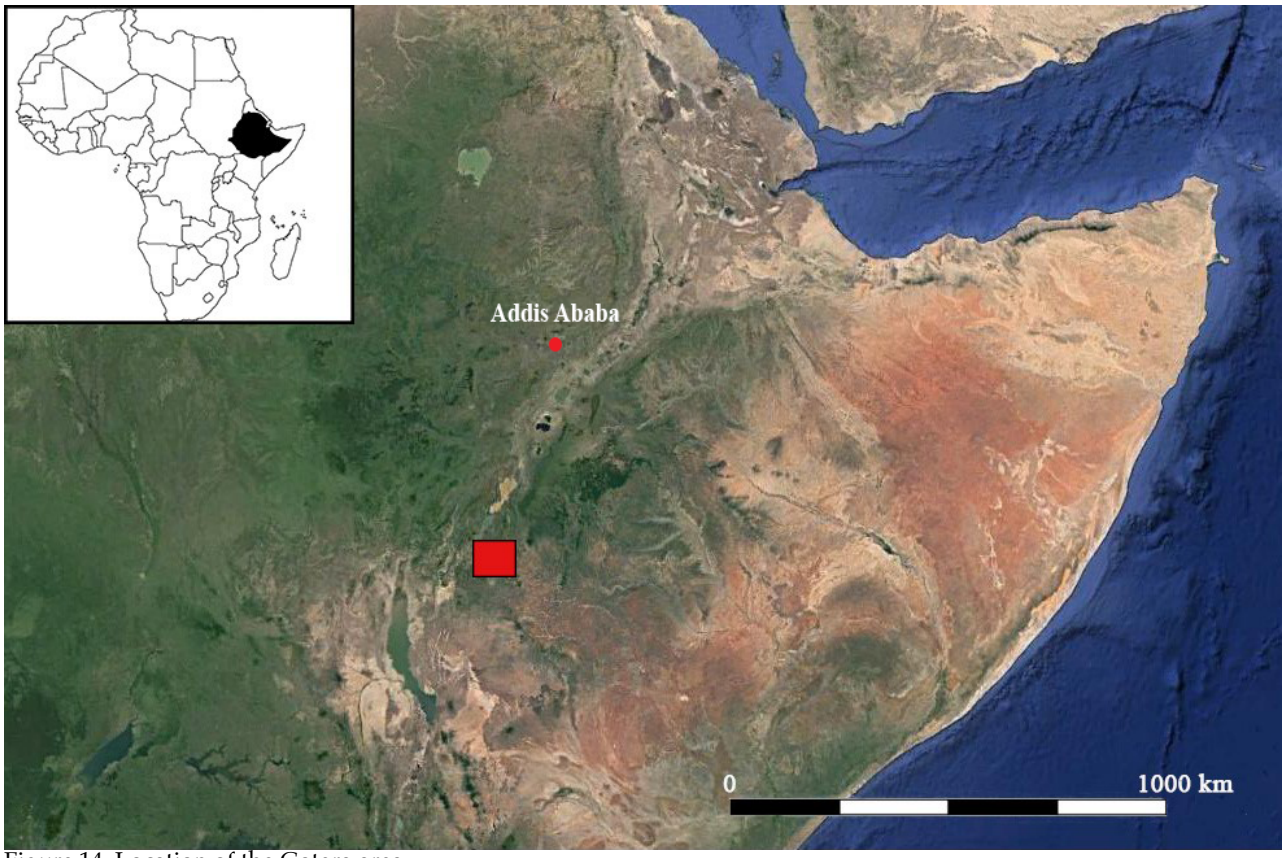


Figure 14: Location of the Gotera area.

During the Pleistocene, the Gotera area was characterized by the presence of a basin situated between the modern town of Teltele and the Sagan River. However, at present, the site is a depression covered by bushes, and features a contemporary semi-arid savannah environment. The predominant vegetation cover consists of *Acacia-Commiphora* bushland and thicket. The region experiences a bimodal precipitation pattern, with the long rainy season occurring between March and May, and the short rainy season between September and November. The average annual precipitation varies from 400 mm in the southern part of the Borana area to 600 mm in the north. Similarly, the average annual temperature ranges from 13.1°C to 25.2°C (White, 1983).

The Gotera depression is bordered by the escarpment of the Teltele-Konso range, which exposes Miocene to Oligocene basalts and trachytic formations that overlie Precambrian basement units (Figure 15: A) (Chavaillon and Chavaillon, 1985; Fusco et al. 2021; Fusco et al. in press; Spinapolice et al. 2017). The area is located in the eastern part of the Chew Bahir Lake catchment, where recent drilling has recovered a core that potentially covers the last 600,000 years (Foerster et al. 2012; 2015; 2022). This core represents a valuable high-resolution archive for paleo-environmental reconstructions for the region (Spinapolice et al. 2017). The current landscape results from substantial erosion, which has dissected the fluvial-lacustrine deposits of the Gotera depression. The general geological deposition of

the area is characterized by the presence of fragile sediments (e.g., silty, clay) that have undergone erosion. Consequently, the ancient basin fill is mostly represented by several hills, referred to as mounds, that overlook a bushy plain (Figure 15: B). The height difference between the highest and lowest mounds can reach more than 10m. The mounds are outcrops located between the channels of small ravines and are composed of various sediments, including clay, silts (silty-clays), sands, and some gravel layers, that are typically the result of fluvial-lacustrine deposition. The most prominent sediment is a compact dark clay, which is visible along the hill slopes around the modern Gotera area (Chavaillon and Chavaillon, 1985; Spinapolice et al. 2017).

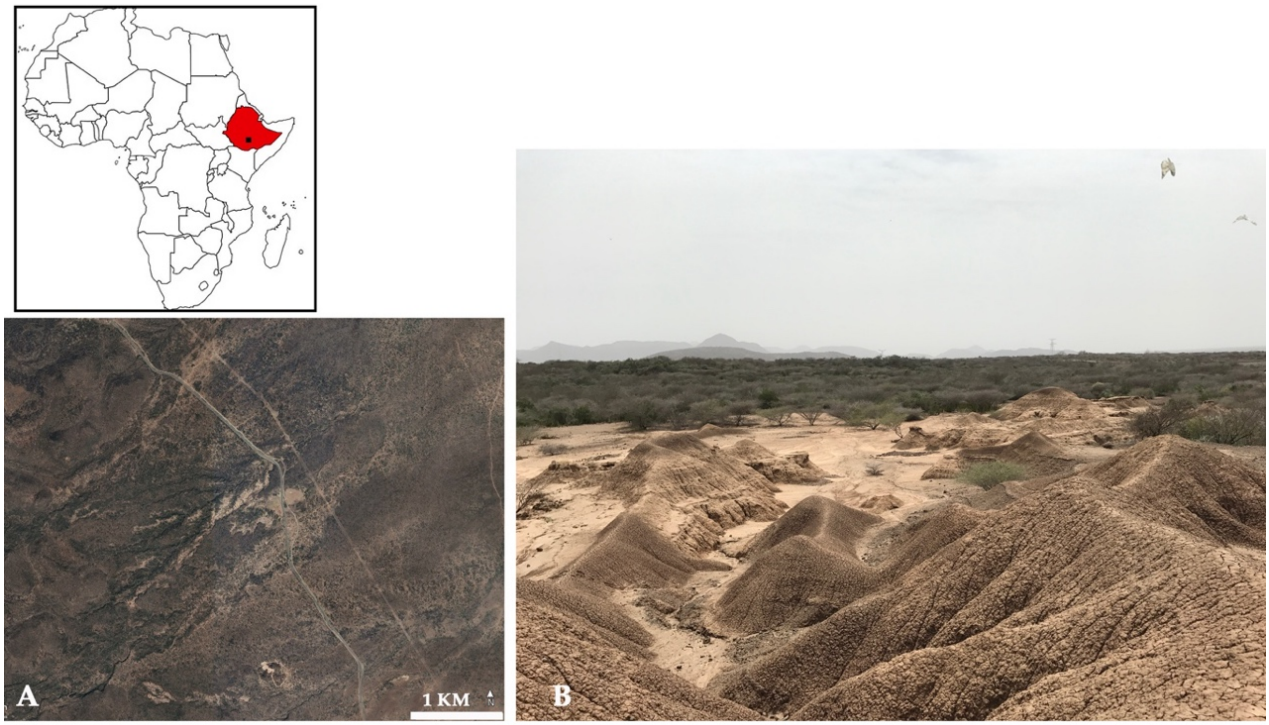


Figure 15: The Gotera area. A: satellite image of the area (© Google Earth); B: general view of the area (© GOTAM mission).

Within the framework of Chavaillon's investigations, sedimentological and litho-facial analyses revealed the Gotera depression was filled with alluvial and marsh deposits during the Pleistocene and featured the presence of an alluvial fan at its margins. More recently, the accumulation of sediments was interrupted, and the sedimentary sequence underwent a linear erosion phenomenon. Today this process becomes active occasionally and is driven by the reactivation of ephemeral streams during heavy rains (Fusco et al. 2021; Chavaillon and Chavaillon, 1985; Spinapolice et al. 2017).

2.3 Chavaillon's interpretation of the Gotera area

During the 1970s and 1980s, fieldwork led by Jean Chavaillon identified nine archaeological localities within the Gotera open-air complex. These sites were situated in the north-eastern part of the Lake Chew Bahir catchment and were designated with numbers from I to IX. Sites I and II were discovered and investigated in 1974, sites III, IV, V, and VI were explored in 1978, and finally, sites VII, VIII, and IX were discovered and investigated in 1979. (Chavaillon and Chavaillon, 1985) (Figure 16).

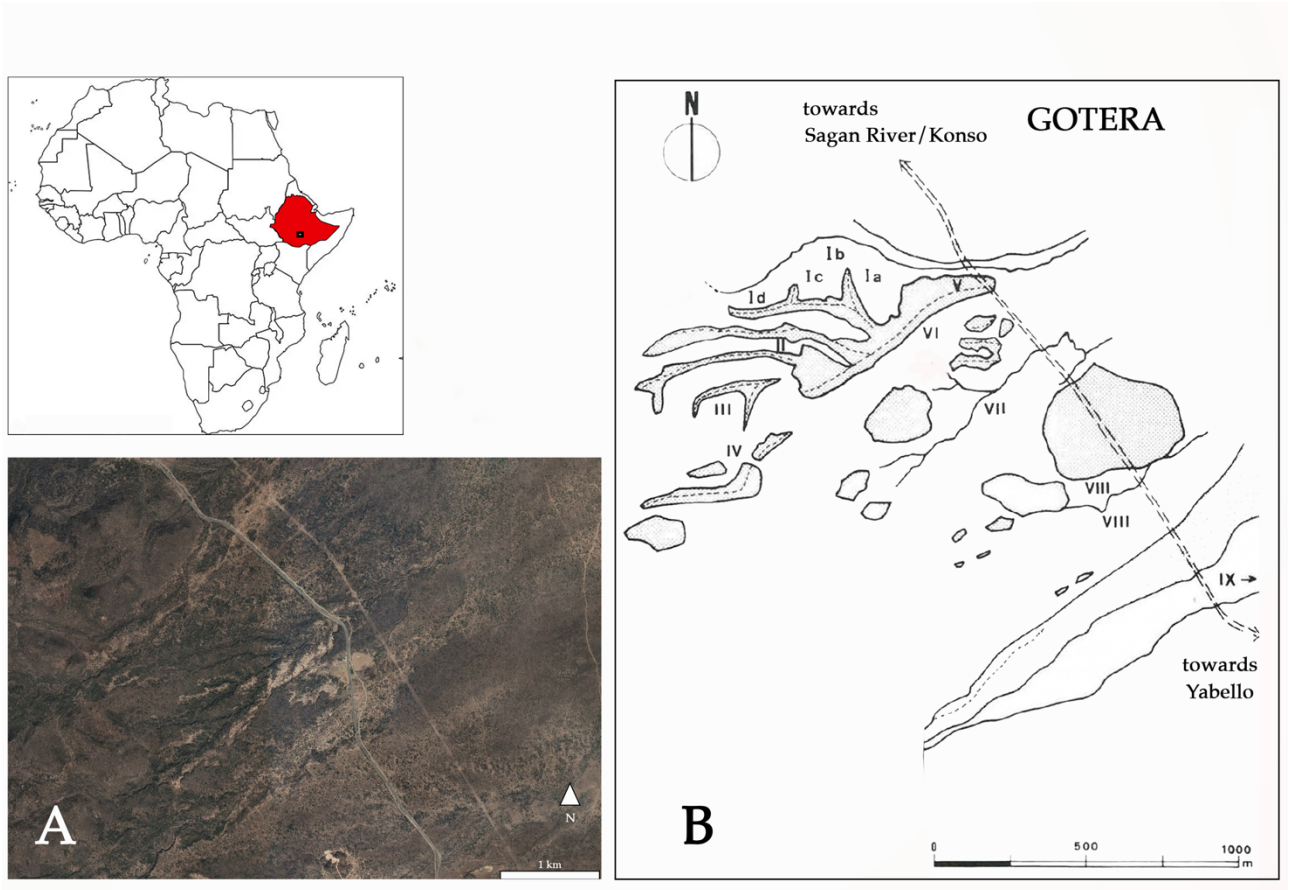


Figure 16: A: satellite image of the Gotera area with the indication of the road from Konso to Yabello. B: map of localities investigated by Chavaillon (Modified after Chavaillon and Chavaillon, 1985).

After the discovery and excavation of the sites, it was possible to define a stratigraphic sequence for the deposits where traces of human occupation were identified. The stratigraphy of Gotera indicated by Chavaillon consists of several units and has been described in detail in a monograph (Chavaillon and Chavaillon, 1985). A complete analysis of his interpretation is provided below, in a sequence from bottom to top:

Layer 1: Gravel and pebbles. This layer is only visible at the bottom of small ravines or cuts. It corresponds to archaeological Level A. This does not exclude the possibility that sediments exist beneath this gravel unit (Figure 17).

Layer 2: A dark brown clay unit.
Layer 3: A unit of gravel with basalt and quartz pebbles of variable thickness, found towards the base of the sequence. This unit is also recorded as Level B, the main layer from which archaeological materials have been collected.
Layer 4: A dark clay unit.
Layer 5: A layer of brown clay and silt with gravels, that corresponds with Level C. Above unit 5 there is a small layer of calcareous concretions.
Layer 6: Dark compact clay unit.
Layer 7: A light brown silty clay unit.
Layer 8: Gravels with sporadic basalt pebbles. This corresponds to Level D and is frequently covered by sandy units.
Layer 9: Dark brown clays, sometimes with whitish limestone concretions on the top of the layer.

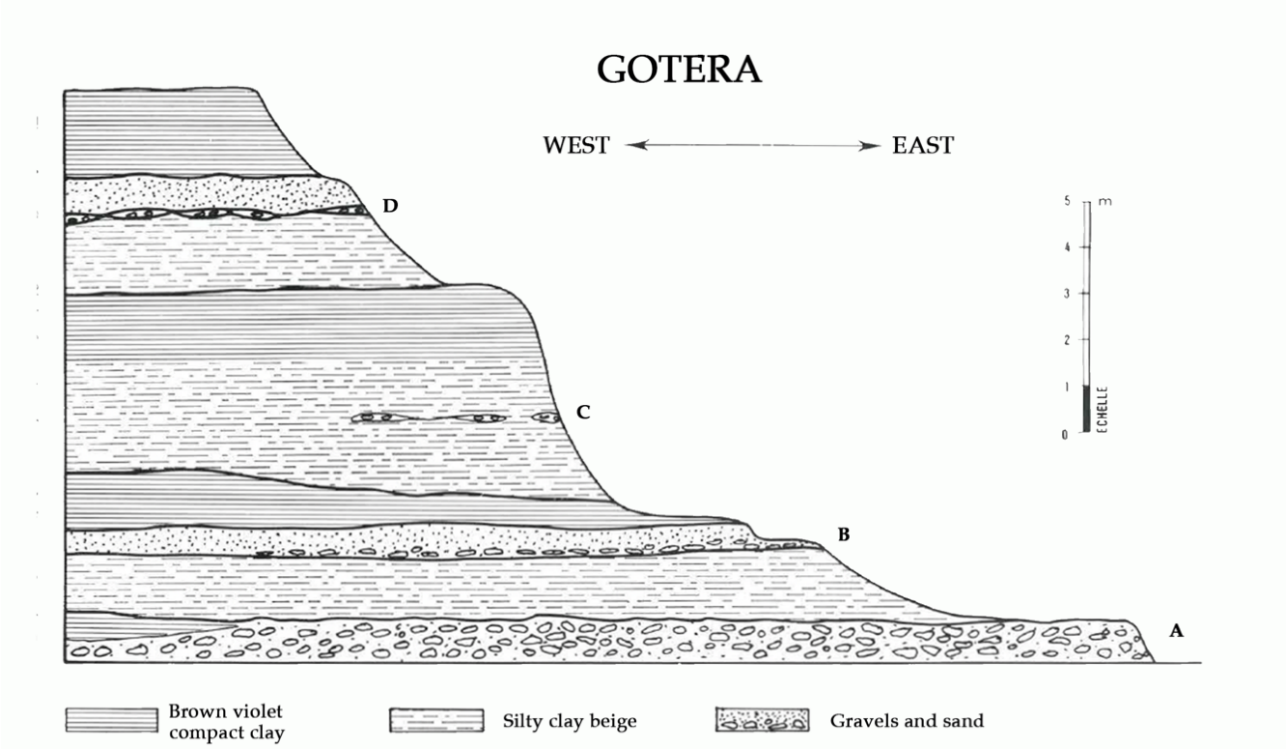


Figure 17: Section drawing of the stratigraphic profile of the Gotera site (modified after Chavaillon and Chavaillon, 1985)

This sequence preserves four levels with archaeological remains (Level A-D) (Figure 17). The sediments that comprise the sequence are mostly of lacustrine, fluvial, or fluvial-lacustrine origin. The gravels and sands likely correspond to a fluvial deposit, while clay sediments correspond to lacustrine deposits. The upper deposits north of the ancient basin of Gotera are characterized by alternation between four levels of fluvial-gravel

sedimentation. The three largest units of gravel contain archaeological materials, indicating four phases of basin retreat and four stream sediments. In contrast to this phase of lake regression, lacustrine clay sediments may be related to transgression phases. There is minimal evidence of fluvial erosion before the deposition of the gravel layers. At the end of the sedimentation of the layers, the basin records a drying phase. This is attributed to the activity of fluvial and wind erosion in the area. The lacustrine deposits thus now represented by small hillocks, called mounds, that are separated by several channels that expose old layers of gravel, i.e., Levels A and B.

Archaeological materials originate from three different layers of gravels and pebbles, however the majority of the archaeological materials are associated with Level B. Some materials come from lowermost Level A, and others come from Level D at locality VI. Despite the scarcity of *in situ* artefacts, the significance of these materials is considerable since it is possible to determine and confirm their original stratigraphic positions (Chavaillon and Chavaillon, 1985).

Animal remains were found in association with the layers of gravel and sands, with some also identified in the layers immediately above. Faunal remains were only collected from archaeological layers. Among the faunal remains collected by Chavaillon and his team, there are some carnivorous species such as the genus *Herpestes*, a genus of the mongoose family, and the otocyone (*Oticyon megalotis)*. The presence of rodents and the Cape here (*Lepus capensis*) is also noted. Among the bovids, the presence of reduncini is attested, and among antelopes, the *Gazelle ganti* is documented. Reptiles are also present, with elements attributable to the snake species *Coluber*. According to Chavaillon, the Gotera fauna displays a rich variety but also forms a cohesive assemblage, representing the majority of expected faunal groups in this area. Most of the species are in fact related to open environments, such as savannahs or prairies, which perhaps suggests the area was located at the edge of a small temporary lake or a flooded prairie (Chavaillon and Chavaillon, 1985).

The lithic material documented by Chavaillon includes MSA artefacts along with a small component of large cutting tools (LCTs). He categorized them as MSA based on the presence of typical MSA features such as Levallois unipolar flakes (Chavaillon and Chavaillon, 1985; Spinapolice et al. 2017). Therefore, even if the collection lacks of chronological information, it can be assumed that the lithic assemblage belong to the MSA, due to the presence of typical MSA elements.

The raw materials used to make the lithics include quartz, basalt, and occasionally jasper. For a comprehensive analysis of Chavaillon's materials, please refer to the next section of this chapter.

2.4 Gotera area and site distribution: the GOTAM project

Since 2016, the Gotera area has been the focus of new surveys and investigations within the framework of the former (H)ORIGIN Project (Fusco et al. 2021; Fusco and Spinapolice, in review; Spinapolice et al. 2017) and is currently under examination as part of the GOTAM project (Fusco et al. in press).

The recent research activities undertaken in the Gotera area began with a survey of the zone, which identified that sites are frequently visible along recent fluvial cuts. The preliminary analysis of the exposed stratigraphy also confirmed the presence of fluvial and pond sediments: gravel-bearing deposits corresponding to fluvial sedimentation alternate with silty strata that correspond to pond or lake sediments.

During the 2016 field season, five MSA surface scatters (GOT 1-5) were identified, indicating an overall high site density, and implying the area has very promising research prospects (Figure 18). From a preliminary analysis of the identified localities, the MSA lithics associated with fluvial sediments include pieces with both fresh and damaged edges indicating they may have undergone various degrees of transport. They are made from different raw materials, including basalts, quartz, quartzite, and occasionally chert. The Levallois method is present, along with other knapping methods. Fossilized bones were identified along with the MSA lithics especially in the exposed section, as previously outlined by Chavaillon (Spinapolice et al. 2017).

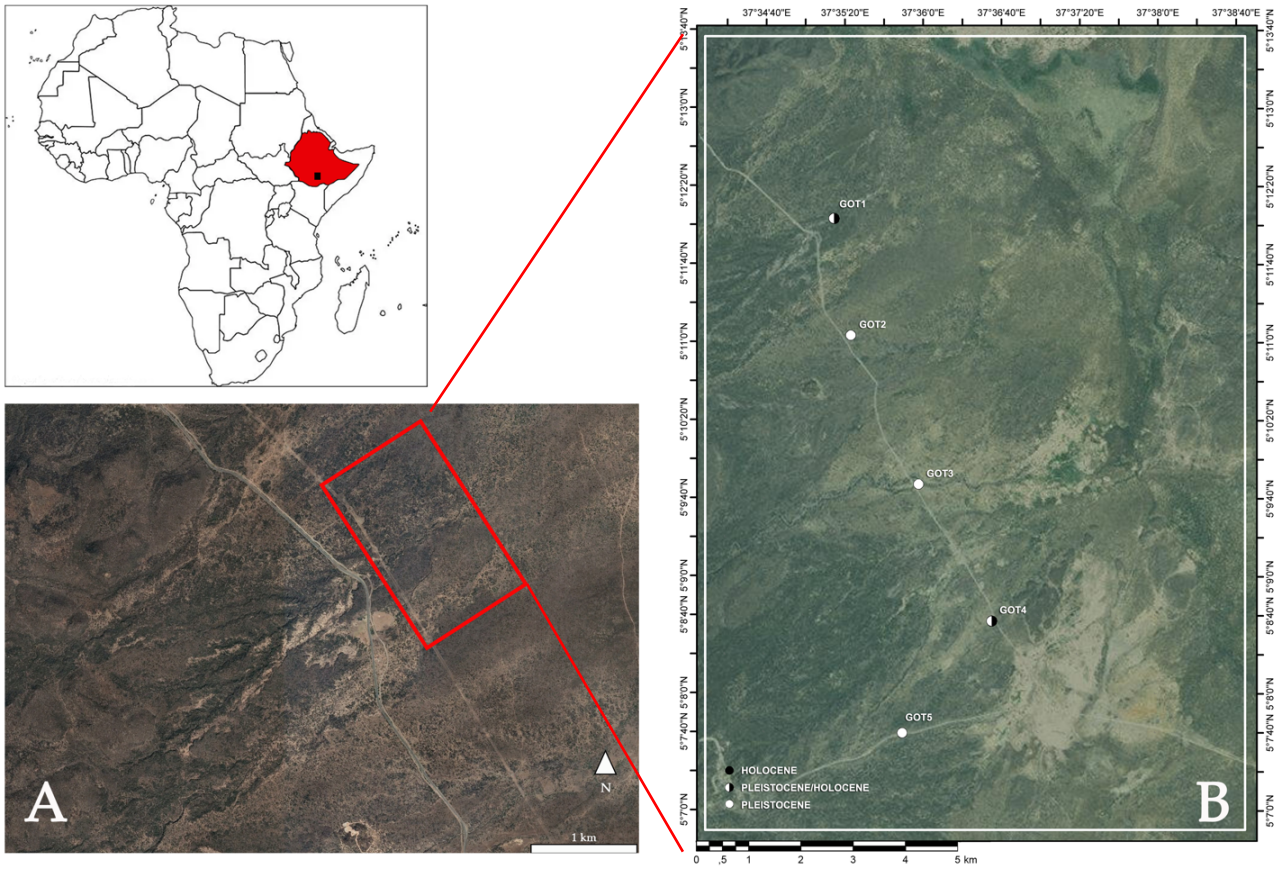


Figure 18: Distribution of sites found during the 2016 field activities (modified after Spinapolice et al. 2017).

Clear evidence of a LSA presence in the Gotera area is nearly absent, with only one site (site GOT4) apparently featuring LSA surface lithics, that are primarily made of obsidian. Evidence of the Pastoral Neolithic is also present, though scarce, in the area, with a few pottery sherds discovered. The area shows greater promise from an ethnoarchaeological perspective. Abandoned camps from the pastoral Borana group have been discovered and mapped. Additionally, evidence of artificial depressions, dug to provide water for sheep, has been found. These depressions are still in use today as a primary water source during periodic droughts. Moreover, large flat-topped tumuli, common in eastern Africa, are scattered across both surveyed areas. These structures exhibit a wide variability of shapes and sizes, are constructed from various lithotypes, and display different degrees of varnishing. Some circular megalithic structures are still utilized by particular ethnic groups as graves for important individuals (e.g., Konso and Borana groups). However, their diversity and overall distribution suggest a long-lasting use of these ceremonial structures. Further investigations should allow for the assessment of the regional and chrono-cultural extension of this phenomenon and, possibly, its connections with adjacent regions.

During the 2017 field season, the Gotera area was explored over an area exceeding 2 km^2, with lithics and faunal remains being found in concentrations (scatters) and as isolated

pieces. Field activities were primarily focused in the area south of the main road that connects Konso to Yabelo. This area is a continuation of the GOT1-5 sites discovered in 2016 (Spinapolice et al. 2017). The main goal of the survey was to identify the nine localities previously discovered and studied by Chavaillon. Since Chavaillon's earlier publications lack coordinates and specific information (Fusco et al. 2021), photographic records were used to locate and match the excavation localities at Gotera. It is likely that during the 2017 field season one of the locations identified in the 1970s and 1980s was found within the southern portion of the Gotera area (GOT1-S) investigated in 2017 (Figure 19). This locality is defined as the Main Site and features a dense concentration of lithics and fauna on the surface and along the slopes of the mounds.

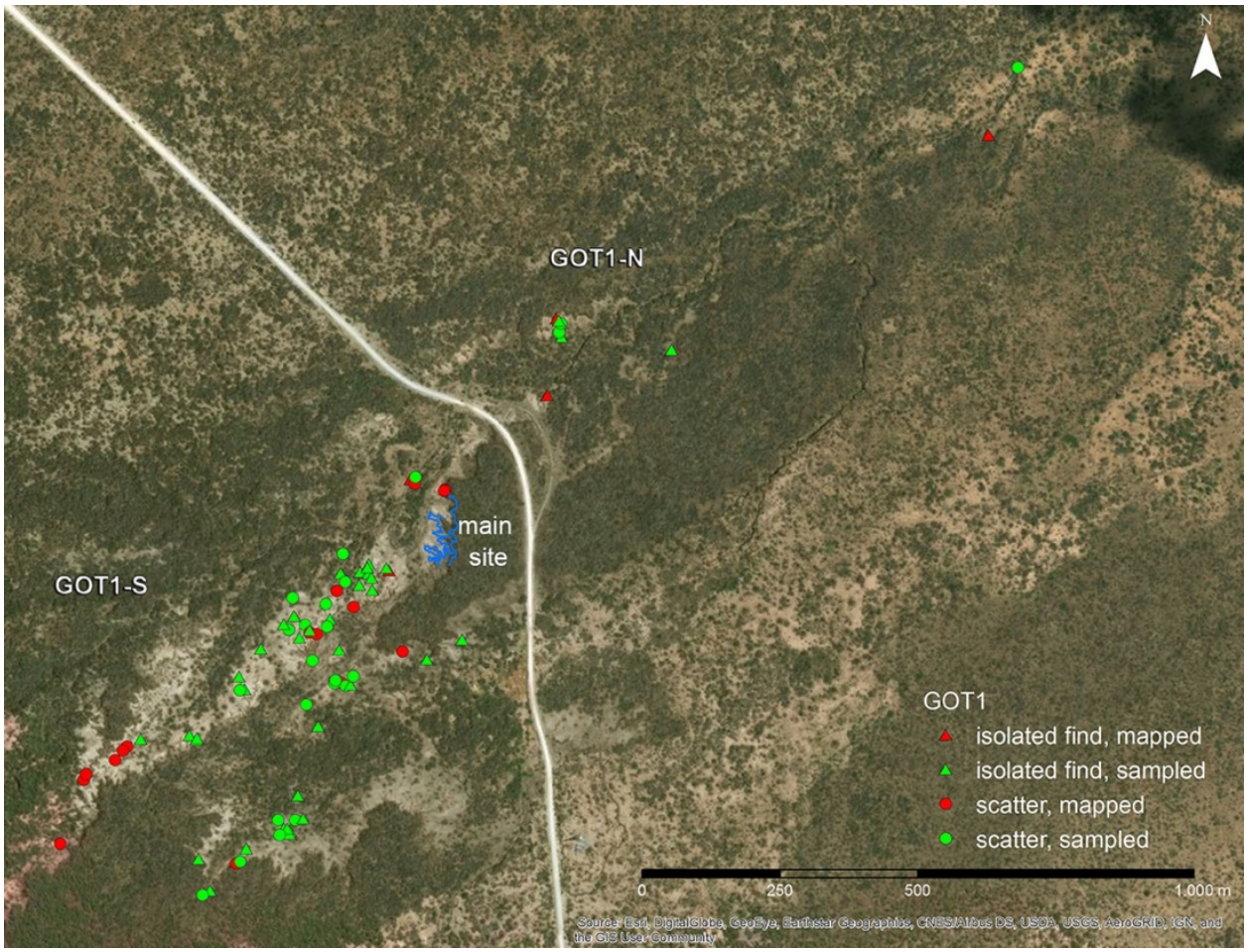


Figure 19: location of the scatter and isolated finds collected during the 2017 survey activities in Gotera (Fusco et al. 2021).

The Main Site's topographic, geological, and archaeological features were mapped with a total station and other recording equipment. The site principally consists of exposed sediments representing silty-playa deposits as well as two different paleosoils that are associated with lithic remains and reflect different human occupations (Figure 7).

From the palaeoenvironmental point of view, the GOT1-S site is part of the same sedimentary sequence previously described for Gotera – it is constituted by alluvial and marsh deposits, with alternating lenses of coarser sediments (channel facies). The general sedimentary setting of the area is one of a low-energy fluvial environment – likely an endorheic delta environment – that featured occasional (or seasonal) phases of higher energy. The sequence consists of massive silty to clayey strata, locally very rich in organic matter, mostly related to decantation processes. Layers representing low energy processes are occasionally interlayered with lenses of sandy sediment, which are interpreted as channel facies, and that testify to sporadic changes in the load and intensity of the streams or paleochannels (Figure 20). At least two palaeosoils are described within the main sedimentary sequence and are related to buried topographic surfaces. Recently, intense erosion has dissected the sedimentary sequence into a 'badlands' landscape and promoted the dispersion of archaeological material (Figure 15).

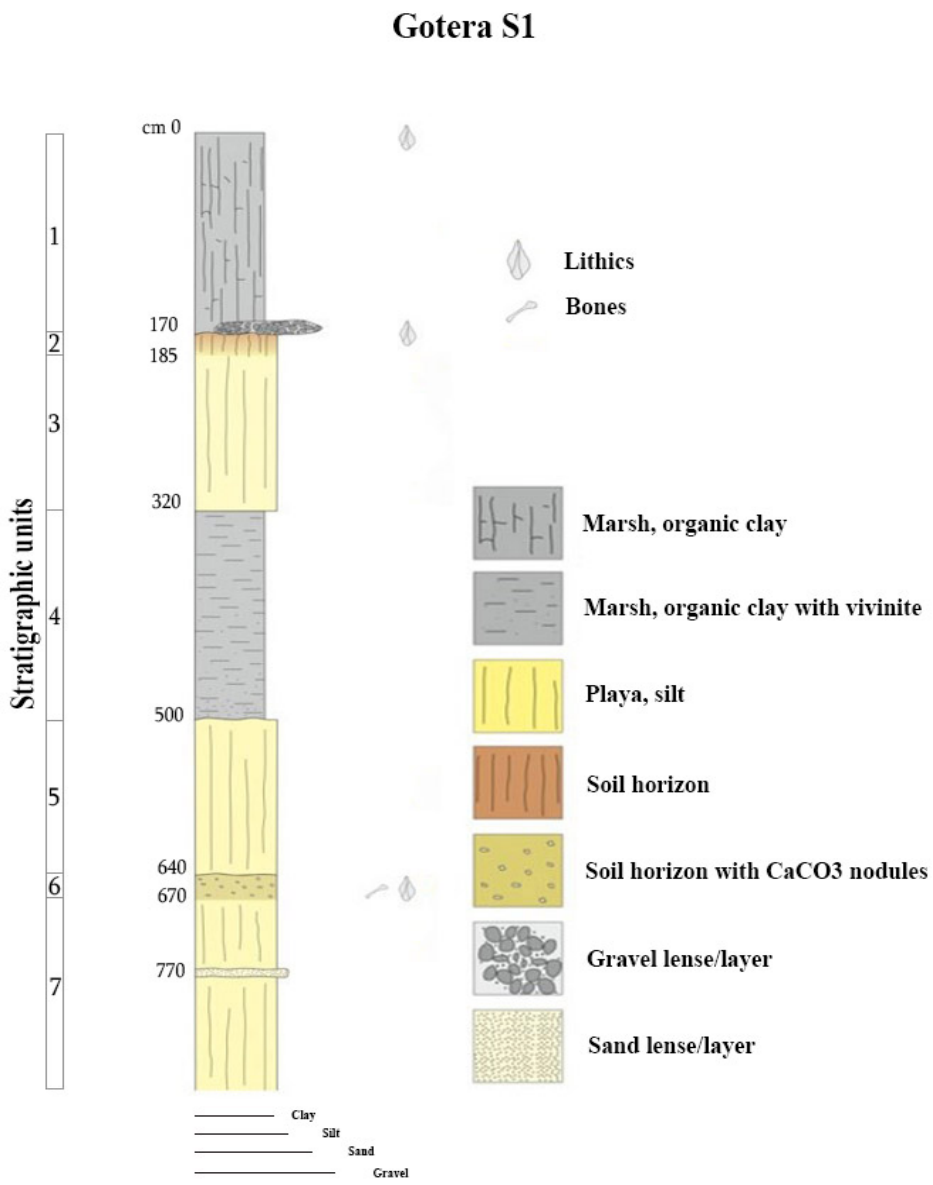


Figure 20: Schematic log of the GOT1-S site stratigraphy (Fusco et al. 2021).

The surface of the site is characterized by the presence of three concentrations of archaeological material (Figure 21: top), with two of them consisting only of lithic artefacts (Scatters 1 and 3) and one composed of animal bone fragments (Scatter 2). Collections were made at two of them: Scatter 1 and Scatter 2.

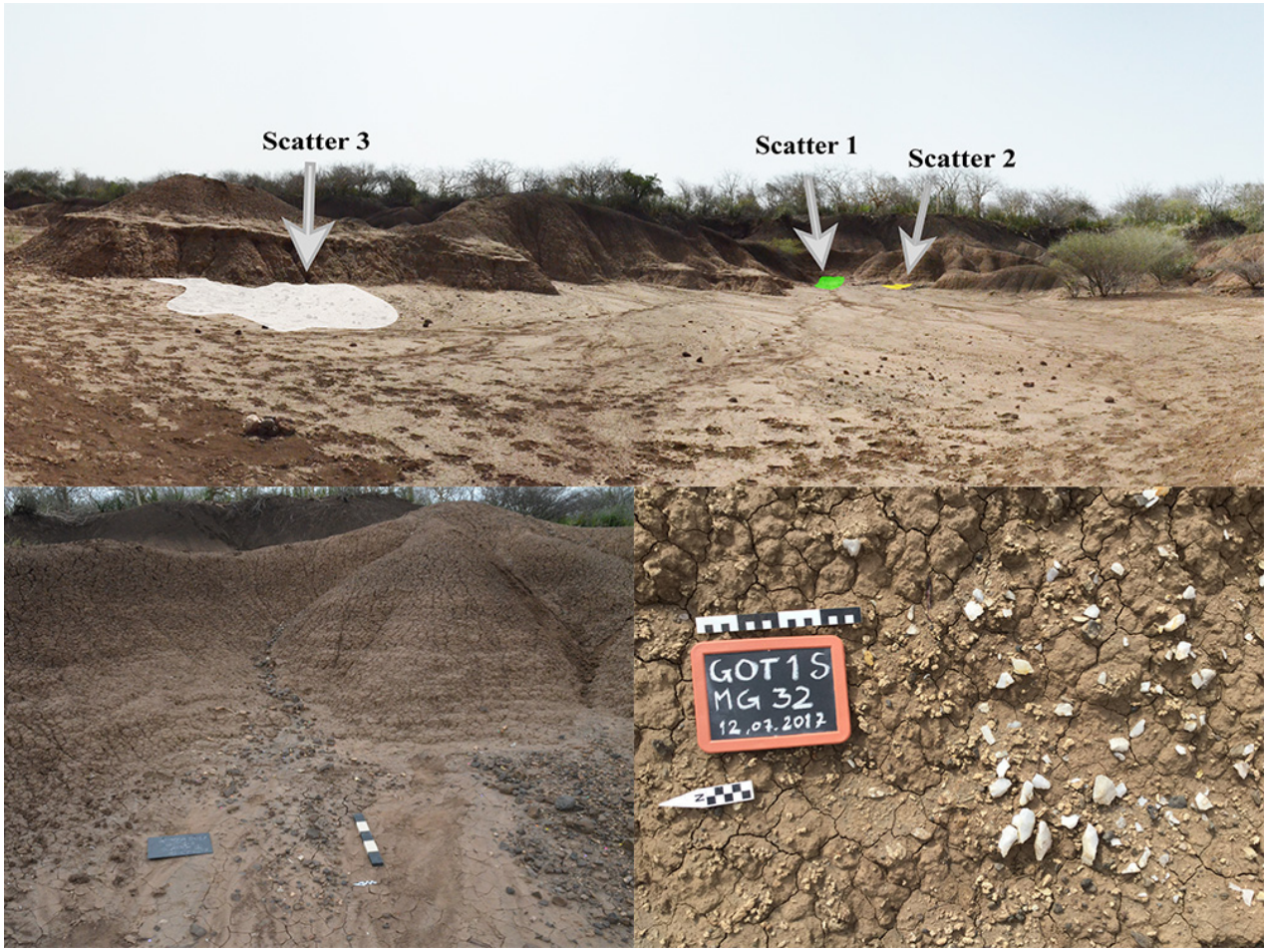


Figure 21: Surface scatters at the GOT1-S site. Top: Scatters in the Main Site (Fusco and Spinapolice, in review). Bottom: Scatters found within the GOT1-S site and around the Main Site.

Scatter 1 is probably the result of an accumulation of lithic elements stemming from the erosion of the sequence's archaeological layer. Lithic material has eroded from the top of the sequence and mixed with material already present on the surface. Seventy-one lithic implements were recorded and collected. The lithic artefacts here primarily feature fresh edges and are principally made of basalt. The results are presented here in Chapter 4. Scatter 2 is a concentration of animal bones and fragments. The analysis of these faunal remains is ongoing.

The topography of the mounds that surround the archaeological materials has been recorded, together with the archaeological items present across the site surface.

The importance of surveying the entire Gotera depression is emphasized by the continuity between sites, which is demonstrated by the homogeneity of the recorded archaeological materials. Furthermore, this spatial continuity indicates the entire Gotera depression was occupied. It is therefore likely possible to consider the entirety of GOT 1 as one single site, as shown also by the analysis of lithic assemblages from the surface (Fusco et al. 2021). Within the entire GOT1-S site, several scatters of lithic implements have been discovered

and documented (Figure 21: bottom). All the scatters have been marked with a GPS point and registered.

Throughout the survey of the area, various concentrations of archaeological material have been identified and labeled as scatters (Figure 22). These scatters primarily consist of lithic implements and fragments of animal bones. The archaeological materials were documented using a tablet, which was also used to record archaeological features, geographical locations, and to document them using photographs. Across the area, concentrations of basalt and quartz lithics were recorded and collected. Mixed concentrations including both basalt and quartz are very rare.

For a complete analysis of the lithic artefacts found on surface within the GOT1-S site, please refer to the next section of this chapter.

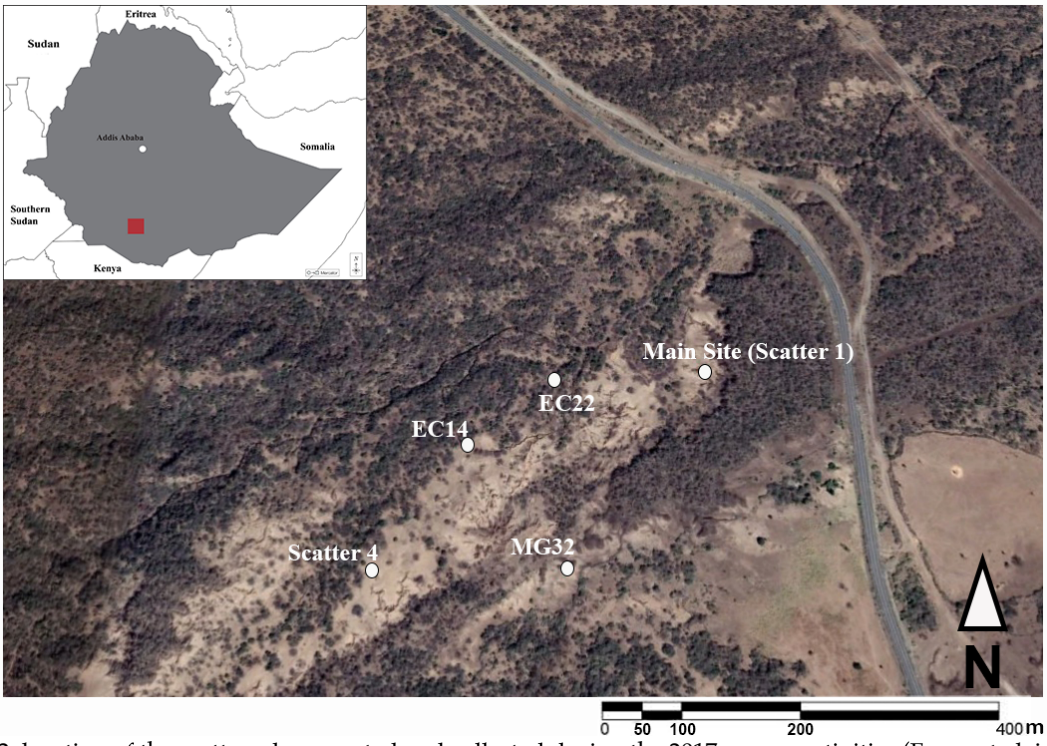


Figure 22: location of the scatters documented and collected during the 2017 survey activities (Fusco et al. in press).

During the 2017 survey activities, several isolated finds were also recorded and collected. The isolated finds include cores, flakes, and tools, and are consistent with the technological features of the scatters identified within the Gotera area. They are mostly fresh with a low occurrence of white or reddish patina, which is seen on both on basalt and quartz pieces (Figure 23).

To establish a potential stratigraphic correlation between materials on the surface and the hill slopes that expose geological and archaeological layers, in 2018 a test excavation was undertaken on a mound located within the GOT1-S site.

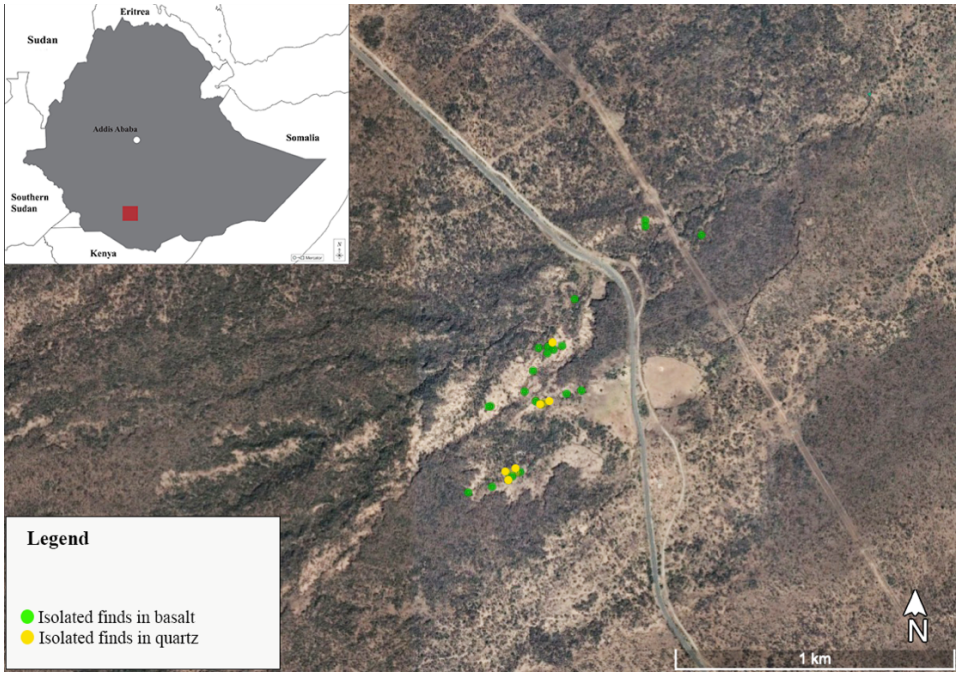


Figure 23: Location of the isolated finds documented and collected during the 2017 survey activities (Fusco et al. in press).

The excavation of GOT1-S followed standard excavation protocols for Stone Age archaeological sites. The whole area was divided into six squares, and all sediment within the 1m x 1m excavation square was sieved. However, no archaeological materials were found.

In 2018, a survey was focused on the area further to the south of GOT 1-S, and here a new, dense concentration of archaeological material was found ~2 km south of the Main Site (Figure 24). The new concentration of archaeological material has been renamed as GOT-10.

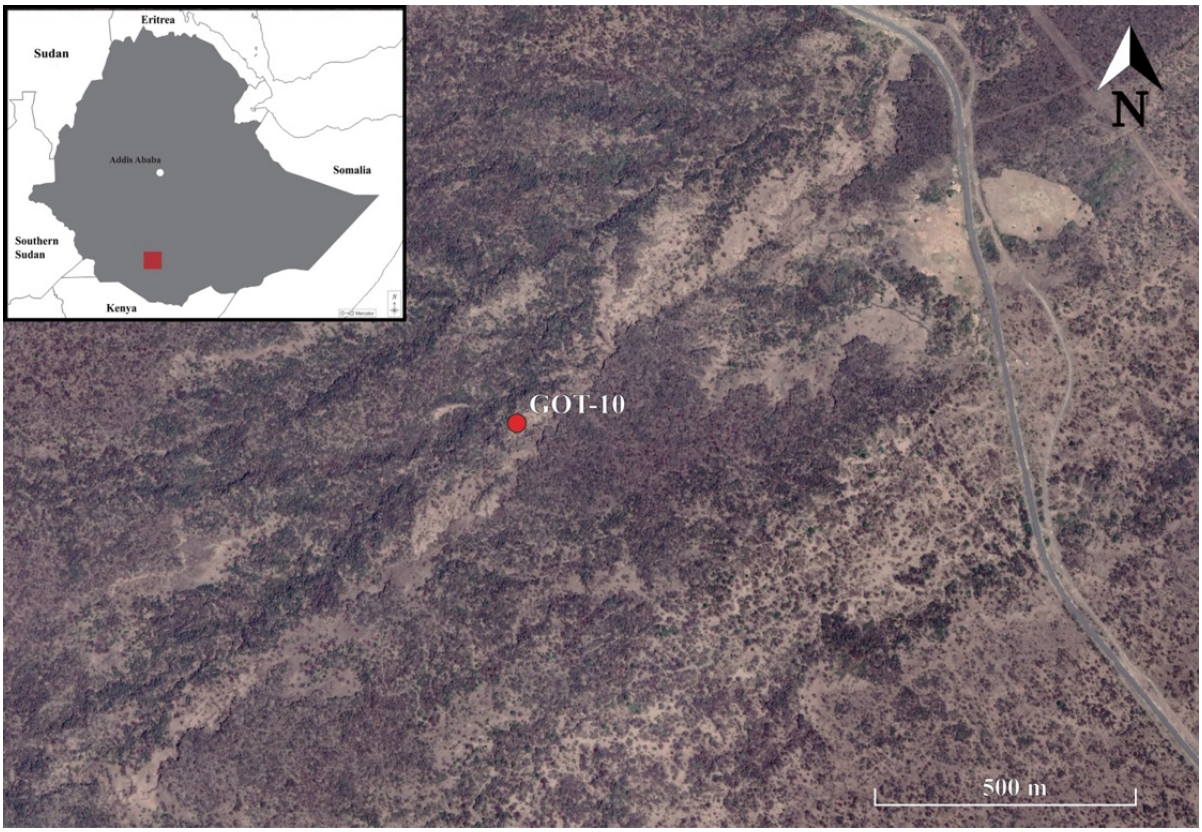


Figure 24: location of the GOT-10 site within the general Gotera area.

The GOT-10 site presents a dense concentration of surface materials (lithic artefacts and bone fragments, with few occurrences of ostrich eggshell fragments), that surround several small mounds (Figure 25). We identified and mapped three mounds, all of which exposed stratified archaeological materials on their slopes (Figure 25, bottom). Throughout the site, it is clear that these mounds incorporate archaeological layers in stratigraphic context. Archaeological remains are still embedded in the sections exposed along these slopes and were particularly visible on the highest mound (Mound 1). It was thus decided to focus research efforts on the archaeological deposit called Mound 1 since it still preserved a good portion of archaeological deposit. It was clear in fact that the archaeological material visible were placed at different depths along the slope. Moreover, the surface of the site was recorded as clusters and scatters.

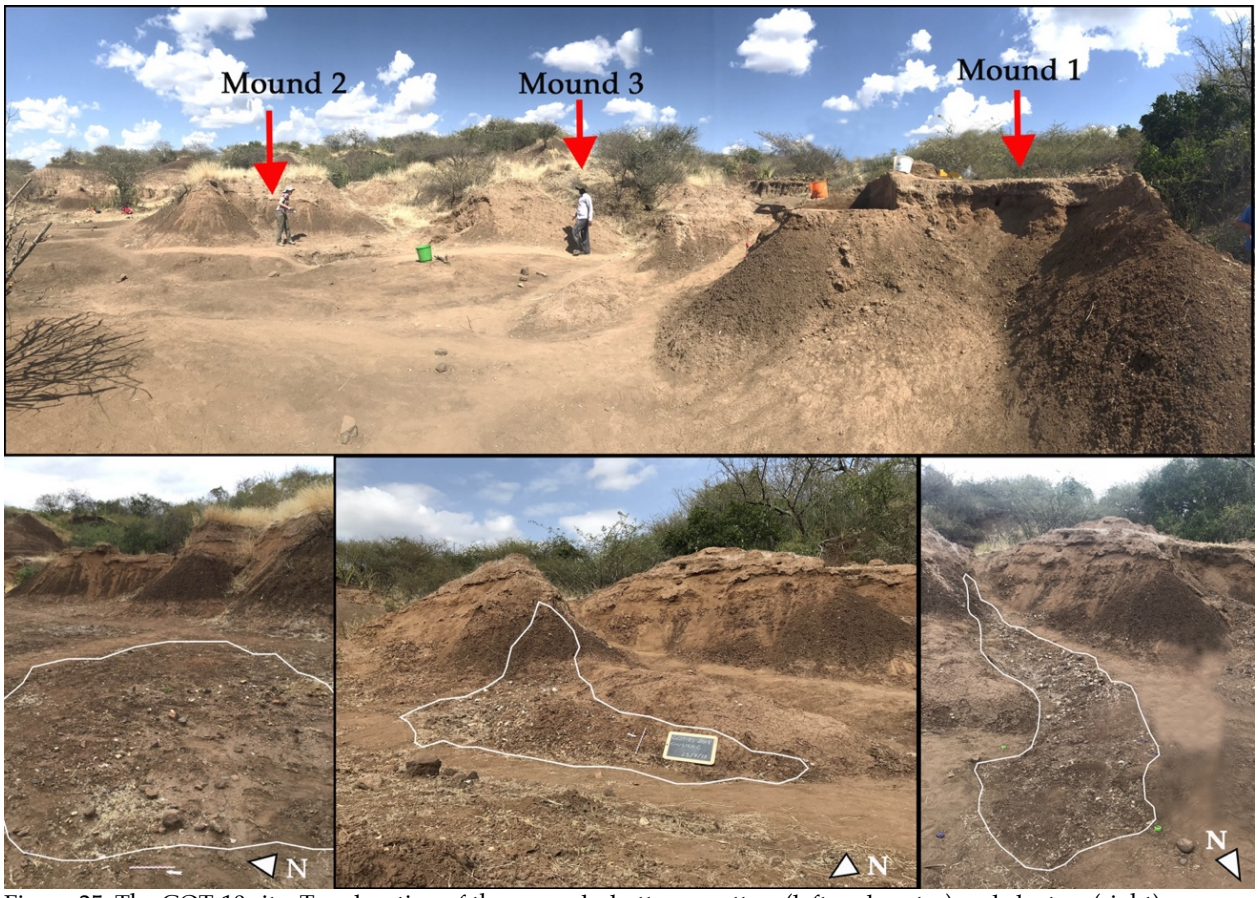


Figure 25: The GOT-10 site. Top: location of the mounds; bottom: scatters (left and centre) and clusters (right) documented within the site.

In the context of GOT-10, "clusters" denote concentrations of archaeological material, lithics, and animal bones in association with the archaeological deposit of Mound 1, 2, and 3 (Figure 25, bottom central and right). These clusters consist of sediment flows containing archaeological materials, that have originated directly from the erosion of the surface and the slopes of the mounds. This erosion phenomenon dissolves fine sediments characteristic of the sediments and is prevalent across the Gotera area. Rainfall in particular results in the disaggregation of the sediments, the flow of sediments including materials contained within them, with the formation of these 'slurries' being guided by a series of ephemeral channels or gullies that are formed by heavy rains. "Scatters", on the other hand, consist of concentrations of archaeological material, of different sizes, that are found on the surface at the GOT-10 site and not along the slopes of the mounds (Figure 25, bottom left). Therefore, these do not show a clear connection to the archaeological deposits. The scatters are delimited by the gullies that have formed during rainfall. However, at the moment it is not possible to determine whether these are the result of the erosion of the archaeological levels of the GOT-10 mounds. In 2018, the following clusters and scatters were identified and mapped at the GOT-10 site (Figure 26: left):

- Cluster A: a dense concentration of archaeological material located north-eastern of Mound 1, along its eastern slopes, consisting of lithics (basalt, quartz, and little evidence of chert), ostrich eggshell fragments, and animal remains.
- Cluster B: a concentration of archaeological material located northeastern of Mound 1, consisting of lithics (basalt and quartz) and animal remains.
- Cluster C: a small concentration of archaeological material located northeastern of Mound 1, consisting of lithics (basalt, quartz) and animal remains.
- Cluster D: a concentration of archaeological material located northeastern of Mound 1, consisting of lithics (basalt and quartz) and animal remains.
- Cluster E: a concentration of archaeological material located northeastern of Mound 1, consisting of lithics (basalt and quartz) and animal remains.
- Cluster F: a small concentration of archaeological material located northwest of Mound1, along its slopes, consisting of lithics (basalt and quartz) and animal remains.
- Cluster G: a small concentration of archaeological material located northeastern of Mound1, along its slopes, consisting of lithics (basalt and quartz) and animal remains.
- Scatter 1: a large scatter of archaeological material located northeastern of Mound 1, consisting of lithics (basalt and quartz) and animal remains. Below the archaeological material, evidence of a hearth has been uncovered and documented.
- Scatter 2: a concentration of archaeological material located northeastern of Mound 1, consisting of lithics (basalt and quartz) and animal remains.
- Scatter 3: a concentration of archaeological material located northeastern of Mound 1, consisting of lithics (basalt, quartz) and animal remains.

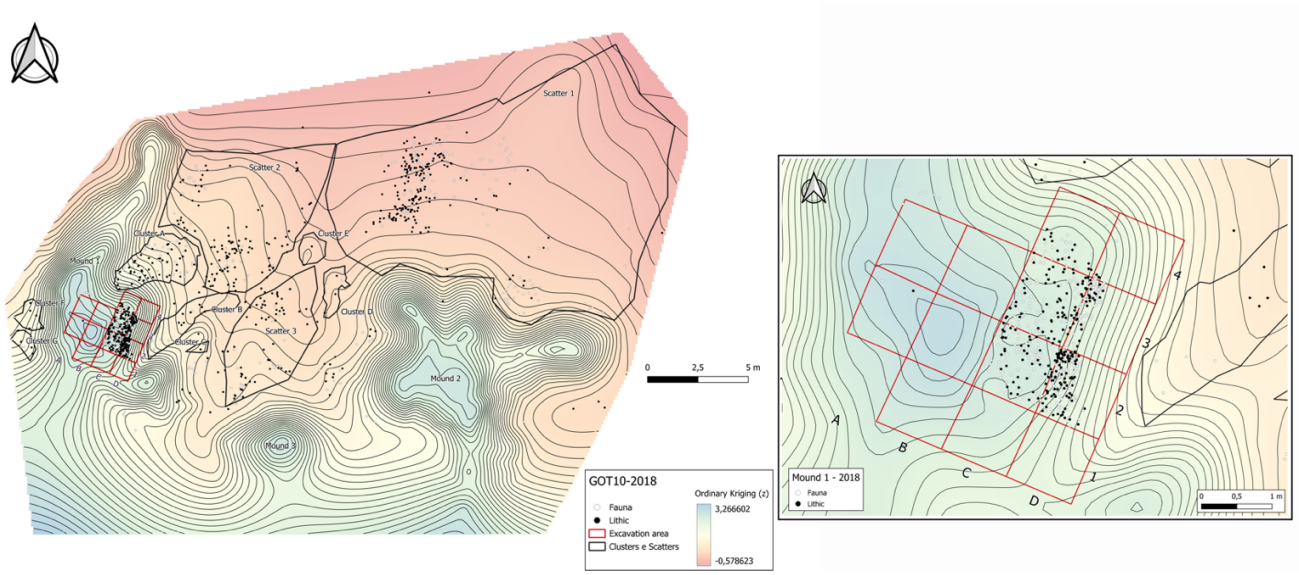


Figure 26: Map of the GOT-10 site in 2018 with the location of the mounds, clusters, and scatters (left); detail on the excavation area (right) (map created with QGIS ©Francesco Lucchini).

Evidence from the surface of the GOT-10 site has been recorded using a total station and a topographic survey of the whole area has documented the shape of the site, the location of the mounds, gullies, and archaeological concentrations (Figure 26: left). This serves the dual purpose of documenting and collecting the archaeological material found on the site and documenting the level, trends, and timing of erosion phenomena that annually contribute to the physical changes in the site's topography.

Moreover, the archaeological layers of Mound 1 have been excavated (Figure 26: right). The western side of the mound includes evidence of bioturbation in the form of animal burrows, while the eastern side preserves better stratigraphic integrity. Therefore, the excavation was focused on the eastern part of the mound (Figure 27: A). The excavation area, defined as Top-Mound 1, was divided into 1x1 $m^{2,}$ squares, and all the locations of all archaeological materials were recorded with the total station and collected. All of the removed soil was sieved using a 0.02 cm mesh sieve, and all the archaeological materials recovered from the sieve were also documented and collected.



Figure 27: A: view of the excavation of Mound 1; B: stratigraphic section of Mound 1; C: archaeological layer exposing lithics and bone.

The sedimentary sequence consists of silty to clayey fluvial sediments deposited in a low-energy environment that periodically alternated to marsh deposits rich in organic matter. Several channel cuts filled with sand and fine gravel are evident in the sequence. These observations are best interpreted as resulting from the terminal part of an endorheic fluvial system that is characterized by alternating periods of flooding and swamp formations (Figure 27: B).

The archaeological deposits are mostly comprised by dark brown silty layers that alternate with sandy to fine gravel layers. These are related to the presence of paleochannels. There is a consistent presence of lithic artefacts in the archaeological horizons, that consist of quartz bladelets, basalt flakes, and bone fragments (mostly long bone fragments) (Figure 27: C). Moreover, the presence of vertical and horizontal concentrations of charcoal was identified, sampled, and recorded with the total station. During the excavation, the remains of combustion features were also identified, and sampled to understand the nature of the deposit. These features were sampled for OSL and radiocarbon dating. Results from the analysis of charcoal for radiocarbon dating (AMS C14) have revealed an estimated age of ~43-42 ka for the deposit. However, more samples are currently under analysis as well as samples for OSL dating.

The lithic assemblage was recovered both from the surface and from *in situ* layers and is composed of cores and *débitage* flakes made of basalt and quartz (Figure 27: C), i.e. two of the most common raw materials in the Gotera area. Faunal remains found both in open-air and stratigraphic contexts consist of highly fragmented indeterminate bones, together with several mandibles and teeth principally from ungulates. Small bones are also abundant and mostly correspond to small mammals and herbivores.

After two years of a break due to the COVID-19 pandemic, excavation activities at the GOT-10 site were reprised only in July 2022. During the four-year break, the site had been affected by strong erosional phenomena. Indeed, not only had the topography of the mound undergone significant changes marked by considerably reduced dimensions, but new concentrations of materials were also noted on the surface and slopes of the mound (Figure 28: A and C) as a result of erosion.

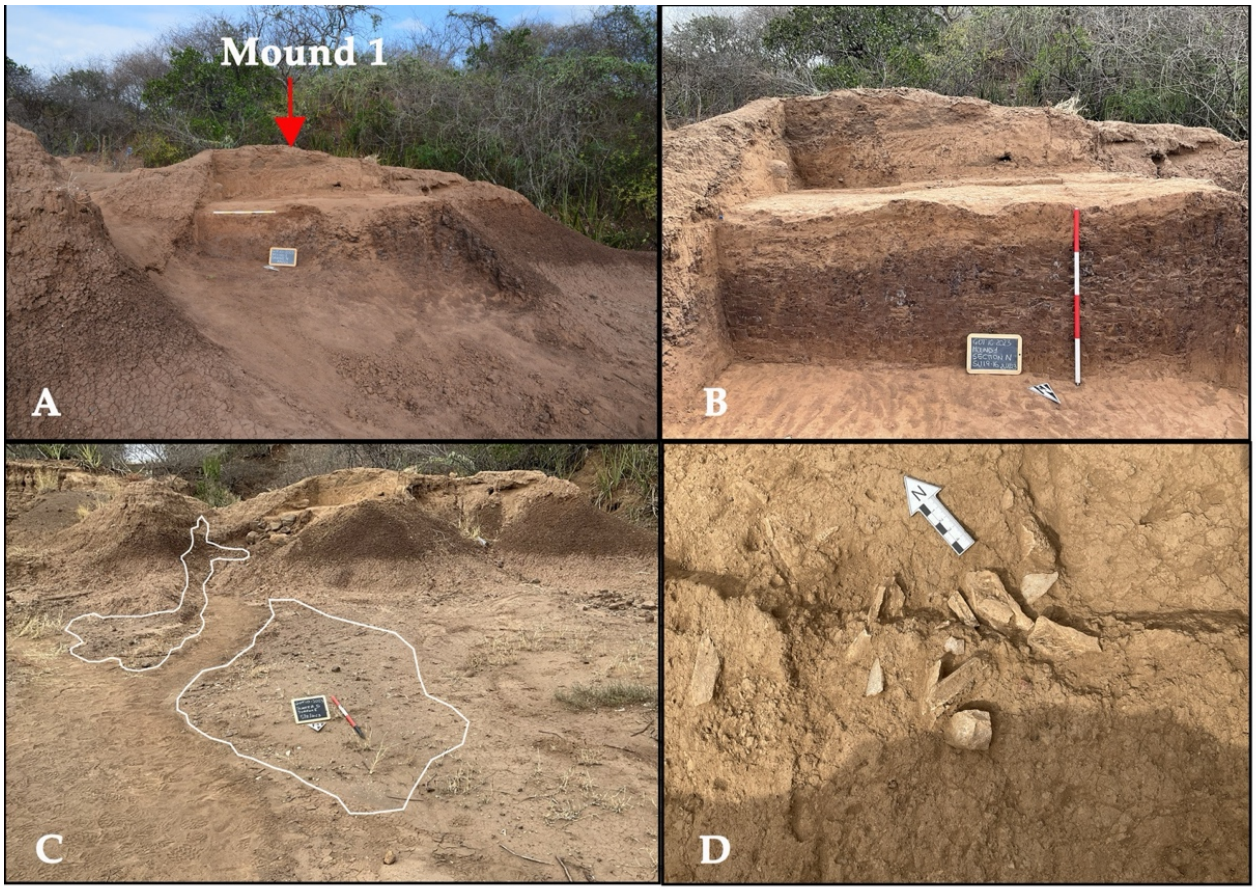


Figure 28: A: excavation area of Mound 1 in 2022; B: stratigraphic section of Mound 1; C: Cluster and scatter in the GOT-10 site in 2022; D: archaeological layers exposing bones and lithics in 2022.

The appearance of the site and the formation of new concentrations of archaeological material mixed with the mound sediment provide new information on both the site's erosion dynamics and the nature of post-depositional processes across the wider Gotera

area. The loose sediments with archaeological material on the slopes of the mounds show a clear connection with the archaeological deposit, which is subject to intense erosion. Therefore, the dynamics and pace of the erosion of the archaeological deposit and, consequently, the nature of the surface concentrations found at GOT-10 in both 2018 and 2022 are clear (Figure 28: C).

The new concentrations of surface materials were named as 'Clusters' with their unequivocal connection with the stratigraphy differentiating them from the scatters, as previously defined. In 2022, the following clusters and scatters were identified and mapped at the GOT-10 site (Figure 29: left).

- Cluster H: a dense concentration of archaeological material (quartz and basalt lithics, animal bones, teeth) located along the northern slopes of Mound 1, completely covering them, and extending onto the ground surface adjacent to the modern site.
- Cluster I: a concentration of archaeological material, smaller than Cluster H, that includes lithics and faunal remains. It is situated along the slopes of Mound 1, to the eastern of Cluster H.
- Cluster L: a smaller concentration of archaeological material containing lithics and faunal remains. It is located along the slopes of Mound 1, to the eastern of Cluster I.
- Cluster M: a smaller concentration of archaeological material, containing lithics and faunal remains. It is situated in the southern and easternern part of Mound 1, along its slopes, extending to the lower section of the Mound.
- Scatter 4: a dense concentration of archaeological material found on the surface, containing quartz and basalt lithics, along with elements made of flint and animal bones. This concentration is located in the northeastern part of the site, between Mound 1 and Mound 2.

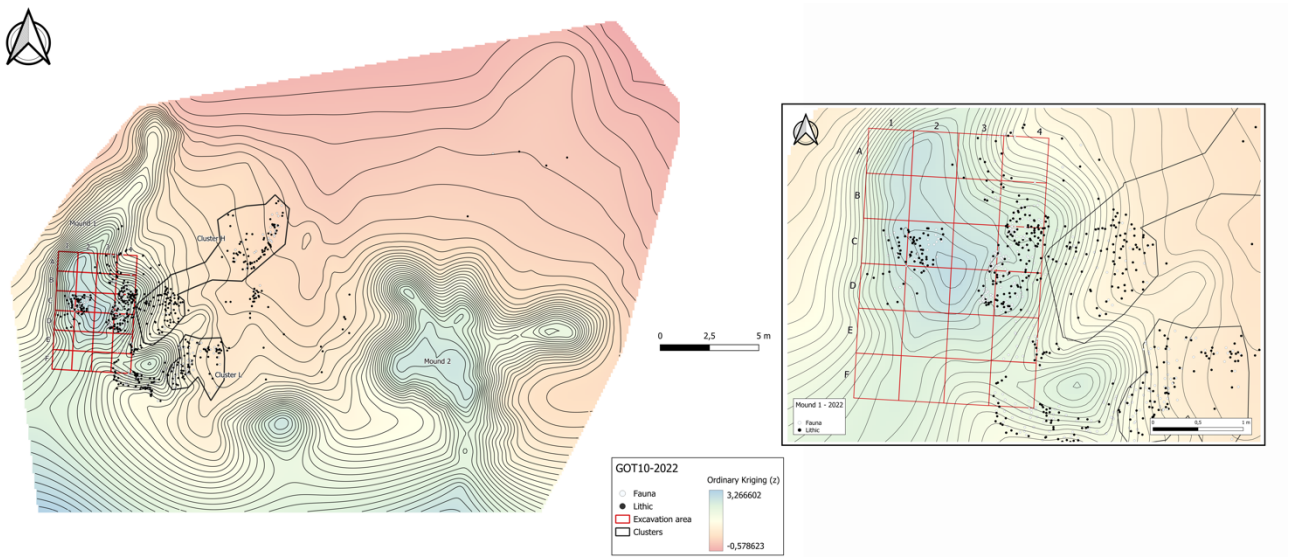


Figure 29: map of the GOT-10 site in 2022 with the position of the mounds, clusters, and scatters (left); detail on the excavation area (right) (map created with QGIS ©Francesco Lucchini).

The new excavation area, defined as Top-Mound 1_2022, has been divided into a new 1x1 m^2 grid, and all the archaeological materials have been registered with the total station and collected. All of the excavated sediment and all the archaeological materials recovered from sieving activities were documented and collected (Figure 29: right).

The analysis of the stratigraphic sequence revealed a deposit of fluvial-lacustrine origin, confirming the stratigraphy already seen in the 2018 excavation and, in general, the geological interpretation of the broader Gotera area. The archaeological deposits, in fact, mostly consisted of dark brown silty layers, alternating with sandy to fine gravel layers (related to the presence of paleochannels), and are characterized by the presence of lithic artefacts (quartz bladelet elements, basalt flakes, etc.), and bones (mostly long bone fragments).

Moreover, the presence of charcoal that occurs in concentrations that are localised in both vertical and horizontal axes was recorded with the total station and sampled. During the excavation, the remains of combustion features were also identified and sampled. These combustion features are in clear association with lithics and bones. They present a red soil covered with dark and grey ash. The state of preservation of these features makes of this evidence the only one for the eastern Africa open air contexts. Moreover, the *in situ* nature of the archaeological material is confirmed by the excavation activities in the site showing the absence of secondary disturbance in the deposit.

A pedogenic layer was also identified that seems to represent the limit of the archaeological deposit, since no materials have been found within or underneath the layer (Figure 30: bottom left).

Samples from archaeological layers were collected for the analysis of soil micromorphology, OSL Dating, and pollen analysis. The results of these analyses are forthcoming.



Figure 30: Top: location of the trench excavated in 2022; bottom left: fireplace located in the 2022 excavation area; bottom right: stratigraphic sequence and date of the deposit.

Further excavation activities are planned for the Gotera area, with the focus on continuing the excavation of the mounds to test the archaeological significance of the stratigraphic sequence, the archaeological materials already collected from the surface, and to identify potentially older layers. Moreover, it will be extremely important to continue the survey around the GOT-10 site, to evaluate its spatial extension and density variations. Finally, in order to understand the occupation dynamics of the wider area, it will be useful to continue

survey of the area north of the main road in addition to the area already explored, to evaluate the archaeological potential of the entire area.
In 2023 the analysis and excavation of the Mound 1 archaeological deposit was continued and it has been possible to describe the whole of the sequence.

2.5 The GOT-10 site stratigraphic description

The following description of the stratigraphic units and deposit characteristics has been provided by the geoarchaeologists in charge of the paleoenvironmental, geological, and sedimentological reconstruction of the site: Prof. Andrea Zerboni (University of Milan) and Dr. Carlo Mologni (Université Côte d'Azur, Nice). The Sedimentary Units (SU) are representative of the main depositional events that characterise the sequence (shown as red lines in the illustration). The Sub-Sedimentary Units (SSUs) are defined as sedimentary processes that are sub-variations of the main sedimentary phases (5.1, 5.2, 5.3, etc). The SSU's detailed description is provided in the table 1 and illustrated in Figure 31.

SU	SSU	Description	Notes/Interpretation
5	5.1	Silty-fine sand, massive to granular structure, loose sediment, moderately sorted, common fine to medium gravel inclusions (subrounded-to-rounded), few roots (recent). Sharp contact.	Reworking of recent sediment of 2022 post-excavation material.
	5.2	Coarse sand to fine/medium gravel, light grey, poorly sorted, oblique laminations to the West (coarsening upward texture, sand to gravels). Sharp contact.	Fluvial channel.
	5.3	Medium sand, light brownish-grey, moderately sorted, oblique laminations to the West, few roots, discontinuous silty lenses (<2mm thick). Sharp contact.	Fluvial channel.
	5.4	Very fine sand, light brown, moderately sorted, planar horizontal microlaminatons. Sharp contact.	Low energy fluvial traction process.
	5.5	Medium sand, moderately sorted, light brownish grey, massive to microlaminated, very few vertical ryzoliths. Gradual contact.	Low energy fluvial traction process.
	5.6	Medium sand to coarse/medium gravel (subangular to subrounded), brownish-grey, moderately to poorly sorted, oblique laminations to the eastern. Sharp contact.	Fluvial Channel
	5.7	Large pedorelicts of SSU 6.1 with few gravel inclusions of SSU 5.6.	Fluvial local reworking of SSU 6.1
6	6.1	Silty-clay, light brown, very well sorted, polyhedral structure (5mm – 1cm peds), few fine gravel inclusions (rounded), very few secondary carbonate impregnations (<1mm). Gradual contact.	

	6.2	Silt, light yellowish brown, very well sorted, massive, few secondary carbonate impregnations (<1mm). Sharp contact.	
	6.3	Fine to medium sand, grey, well sorted, massive to microlaminated. Sharp contact.	Low energy fluvial traction process.
	6.4	Silt, light yellowish brown, very well sorted, massive, few secondary carbonate impregnations (<1mm). Lithic artefacts. Sharp contact.	
	6.5	Fine sand, very well sorted, grey, massive. Sharp contact.	Low energy fluvial traction process.
	6.6	Silt, very well sorted, light yellowish brown, massive to polyhedral structure, common secondary carbonate impregnations along the rootles (<1mm), lithic artefacts. Gradual contact.	
	6.7	Silt to fine sand, well sorted, massive to granular structure (granules peds 1-2mm), common secondary carbonate impregnations, light brownish-red (rubefied sediment), few charcoals, bones and lithic artefacts. Gradual contact.	Rubefied sediment induced by anthropogenic combustion.
	6.8	Silt, well sorted, yellowish light brown, common secondary carbonate impregnations, few fine sand inclusions, massive to granular structure (granular peds 1-3mm), abundant lithic, charcoals and bones. Few rubefied sediment patches (5mm – 1 cm). Gradual to sharp contact.	Anthropic floor.
	6.9	Silt, very well sorted, massive, light yellowish brown, common secondary carbonate impregnations (<1mm), few fine sand inclusions, few charcoals. Gradual contact.	
	6.10	Silt to fine sand, well sorted, massive to granular structure (granular peds 1 – 3 mm), few coarse sand inclusions, common secondary carbonate impregnations. Gradual contact.	
7	7.1	Clay, dark brown, well developed polyhedral to prismatic structure, very few fine gravel inclusions, few secondary carbonate impregnations. Gradual contact.	Pedogenised palustrian deposit?
	7.2	Silty-clay, brown, massive to polyhedral structure, very well sorted, few medium sand inclusions, very few secondary carbonate impregnations (<0.5 mm). Sharp contact.	Pedogenised palustrian deposit
8	8.1	Silt to very fine sand, light brown, very well sorted, massive to granular structure, few roots. Gradual contact.	
	8.2	Silt to fine sand, very well sorted, light brown, well developed granular structure, common coarse sand inclusions (rounded), few secondary carbonate impregnations, common roots pores (<1mm). Gradual contact.	

	8.3	Silt, very well sorted, light yellowish brown, massive, few secondary carbonate impregnations (<1mm), common roots pores (<1mm). Gradual contact.	
	8.4	Silt to fine sand, well sorted, light brown, polyhedral to granular structure, very few current roots and common roots pores, few coarse sand to fine gravel inclusions (rounded). Gradual contact.	
9	9.1	Silty-sand, moderately sorted, brown, granular to polyhedral structure, very common coarse sand to fine gravel inclusions (subangular to subrounded), abundant secondary carbonate impregnations. Very few pebbles (<3 cm, subrounded to rounded).Discontinuous layer of medium to coarse gravel at the bottom (contact with 9.2).Gradual/undulated contact.	Slightly pedogenised alluvium?
	9.2	Fine to medium sand-fine silts, poorly sorted, massive to granular structure, brown, common secondary carbonate impregnations, very common fine to medium gravel inclusions (rounded). Gradual contact.	Slightly pedogenised alluvium?
	9.3	Medium gravel to pebbles (<3 cm) lenses, very poorly sorted, massive, Fine sand to to silty brownish matrix. Gradual contact.	Fluvial channel
	9.4	Sandy-silt, poorly sorted, granular to polyhedral structure, brown, few medium to coarse sand inclusions, few secondary carbonate impregnations, lenses of gravel (=SSU 9.3) at the bottom of the layer. Gradual contact.	Slightly pedogenised alluvium?
	9.5	Silty sand, light brown, massive to polyhedral structure, few medium sand inclusions, very few secondary carbonate impregnations.	Slightly pedogenised alluvium?

Table 1:Description of the stratigraphic units found at Mound 1.

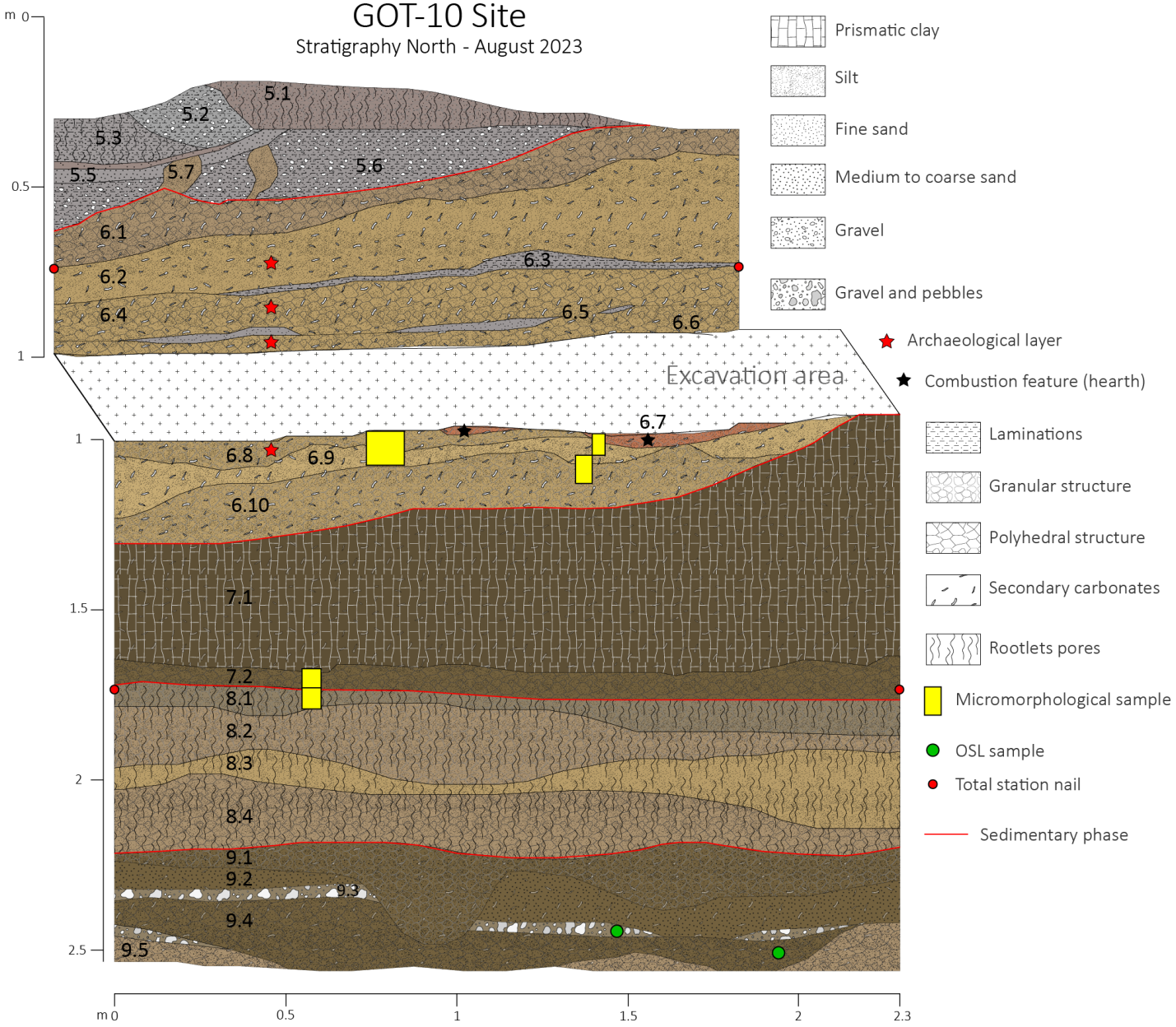


Figure 31: Schematic log of the stratigraphic sequence of the Mound 1 deposit in the GOT-10 site (© Dr. Carlo Mologni).

The discovery of the GOT-10 site holds great potential for improving our understanding of the occupation and behavioural dynamics of early modern humans in this region. The presence of a stratified sedimentary sequence with a well-preserved archaeological record dated to MIS 3 is rare in eastern Africa (Leplongeon et al, 2020; 2023), particularly in open-air contexts. Understanding the deposition of the *in situ* and related surface archaeological materials will provide new insights into the MSA occupation dynamics at a regional scale. Sedimentological and geochronological analyses regarding the exact nature and chronology of the GOT-10 deposits are ongoing, including analysis of the seasonal exploitation of the basin and its implications for human behaviour. Importantly, the stratified nature of the deposit provides us with the opportunity to establish a robust geochronological framework

for the GOT-10 site. This will be achieved by combining micromorphology with radiocarbon and optically stimulated luminescence (OSL) dating.

Furthermore, a comprehensive analysis of lithics assemblages from the whole Gotera area that consist of lithics attributes to the MSA and lithics collected from a stratigraphic sequence dated to the MIS 3 may contribute significantly to the evaluation of the Late Pleistocene lithic variability in the Horn of Africa, the evaluation of potential significance of technological traits in a period with evidence of by the MSA-LSA transition.

Chapter 3 – Technological analysis of GOT-10 lithic assemblage

3.1. Introduction

In this chapter, the results of the technological analysis of the lithic assemblage from the GOT-10 site are presented. The assemblages under study were collected during excavations carried out in 2018 and 2022 at the GOT-10 site.

The data collection pertaining to the lithic assemblages was funded by a fieldwork grant provided by the French Center for Ethiopian Studies (CFEE) and a Thematic Research Grant issued by the British Institute in eastern Africa (BIEA). These grants helped support the research efforts and analysis of the lithic implements. The sample analysed in this chapter comprises all the lithic implements discovered in the stratigraphy and on the surface of the GOT-10 site. A total of 2000 lithic pieces were examined and analysed as part of the doctoral thesis conducted in the frame of this research.

3.2 Materials

In the frame of the GOT-10 lithic assemblage analysis, all the objects have been divided into three basic categories: cores, flakes, and retouched flakes. These categories provide a general overview of the assemblage composition and can be used to evaluate whether stages of the stone knapping sequence occurred on the site. For this analysis, all lithics that preserve sufficient technological information, including complete and incomplete flakes, blades, bladelets, and/or fragments, as well as cores and core fragments, with no size cut-off, were selected and analysed. The total number of artefacts analysed is 1943, composed of the following: 45 cores (N=45), 1443 flakes (N=1443), 69 retouched flakes (N=69), 266 chunks (N=266), 117 bipolar pieces (N=117), 2 hammerstones (N=2), and 1 unworked stone (N=1) (Table 2).

Tooltype	**N**	%
Chunks	266	13,69%
Core	45	2,32%
Flake	1443	74,27%
Retouched flakes	69	3,55%
Hammerstone	2	0,10%
Bipolar	117	6,02%
Unworked/manuport	1	0,05%
Total	**1943**	**100%**

Table 2: The amount of lithics from the GOT-10 site analysed in the frame of this doctoral research (March 2023).

The lithic assemblage has been divided based on its provenance and location within the GOT-10 sites. First, all the lithics found and collected from the stratigraphic units (SU) of the Mound 1 deposit, according to their specific SU provenance. Then all the lithics found on the surface that have been directly correlated to the stratigraphic sequence based on their position within the site and its geomorphological description have been categorized into Clusters (A, H, L, M). Finally, other lithics found on the surface that are not directly associated with the stratigraphic sequence have been grouped into scatters (1, 2, 3, and 4) (Table 3).

	Cores		**Flakes**		**Ret. flakes**		**Bipolars**		**Chunks**		**Hammerstones**		**Total**	
Contexts	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%
Cluster A	1	2%	121	8%	7	11%	6	5%	55	21%	0	0%	191	10%
Cluster H	2	5%	170	12%	9	14%	9	7%	48	18%	0	0%	238	12%
Cluster L	0	0%	49	3%	3	5%	3	2%	15	6%	0	0%	70	4%
Cluster M	1	2%	33	2%	0	0%	3	2%	8	3%	0	0%	45	2%
Mound1	16	36%	482	33%	17	26%	24	20%	67	25%	1	50%	607	31%
Scatter 4	1	2%	14	1%	0	0%	4	3%	7	3%	0	0%	26	1%
Scatter1	5	11%	77	5%	10	15%	15	12%	4	2%	0	0%	111	6%
Scatter2	8	18%	78	5%	1	2%	25	21%	0	0%	0	0%	112	6%
Scatter3	10	23%	413	29%	15	23%	29	24%	62	23%	1	50%	530	27%
Surface	0	0%	5	0%	3	5%	3	2%	0	0%	0	0%	11	1%
Total	**44**	**2%**	**1443**	**74%**	**65**	**3%**	**121**	**6%**	**266**	**14%**	**2**	**0%**	**1941**	**100%**

Table 3: Total number of lithics from the GOT-10 site grouped by archaeological context

3.2.1 Mound1 – stratigraphic units

The Mound 1 archaeological sequence consists of N=599 lithics. The assemblage is composed of N=14 cores, N=493 flakes, and N=23 bipolar elements (Tab 3).

	Mound 1											
	Chunks		**Cores**		**Flakes**		**Hammer**		**Bipolar**		**Total**	
Stratigraphic Unit	N	%	N	%	N	%	N	%	N	%	N	%
SU2	0	0%	0	0%	2	0%	0	0%	0	0%	2	0%
SU4	9	0%	2	14%	26	5%	0	0%	3	13%	40	7%
SU6	36	54%	5	36%	219	44%	1	100%	10	42%	271	45%
SU7	2	3%	3	21%	52	11%	0	0%	1	4%	58	10%
SU8	0	0%	0	0%	2	0%	0	0%	0	0%	2	0%
SU11	18	27%	4	29%	186	11%	0	0%	9	38%	217	36%
SU10	2	3%	0	0%	6	1%	0	0%	1	4%	9	2%
Total	**67**	**11%**	**14**	**2%**	**493**	**82%**	**1**	**0%**	**24**	**4%**	**599**	**100%**

Table 4: Total number of lithics collected within the Mound1 stratigraphic sequence.

Cluster A consists of N=190 lithics. The lithic assemblage consists of N=1 core, N=121 flakes, N=7 retouched flakes, N=55 fragments, and N=6 bipolar elements (Table 4).

	Cluster A	
Tool Category	**N**	%
Cores	1	1%
Flakes	121	64%
Retouched flakes	7	4%
Chunks	55	29%
Bipolar	6	2%
Total	**190**	**100%**

Table 5: Number of lithic from Cluster A

Cluster H is composed of N=238 lithics. The assemblage consists of N=2 cores, N=170 flakes, N=9 retouched flakes, N048 chunks/fragments, and N=9 bipolar elements (Table 6).

	Cluster H	
Tool Category	**N**	%
Cores	2	1%
Flakes	170	71%
Retouched flakes	9	4%
Chunks	48	20%
Bipolar	9	4%
Total	**238**	**100%**

Table 6: Number of lithic from Cluster H

Cluster L is composed of N=70 lithics. The assemblage consists of N=49 flakes, N=3 retouched flakes, N =15 chunks/fragments, and N=3 bipolar elements. No cores have been found within this cluster (Table 7).

	Cluster L	
Tool Category	**N**	%
Cores	0	0%
Flakes	49	70%
Retouched flakes	3	4%
Chunks	15	22%
Bipolar	3	4%
Total	**70**	**100%**

Table 7: Number of lithic from Cluster L

Cluster M is composed of a total of 45 lithics. The assemblage consists of N=1 core, N=33 flakes, N=8 chunks/fragments, and N=3 bipolar elements. No retouched tools have been found within Cluster M (Table 8).

	Cluster M	
Tool Category	**N**	%
Cores	1	2%
Flakes	33	73%
Retouched flakes	0	0%
Chunks	8	18%
Bipolar	3	7%
Total	**45**	**100%**

Table 8: Number of lithic from Cluster M

Scatter 1 is composed of N=111 lithics. The assemblage consists of N=5 cores, N=77 flakes, N=10 retouched flakes, N=4 chunks/fragments, and N=15 bipolar elements (Table 9).

	Scatter 1	
Tool Category	**N**	%
Cores	5	5%
Flakes	77	68%

Retouched flakes	10	9%
Chunks	4	4%
Bipolar	15	14%
Total	**111**	**100%**

Table 9: Number of lithics from Scatter 1

Scatter 2 is composed of N=116 lithics. The assemblage consists of N=8 cores, N=78 flakes, N=1 retouched flakes, N=4 chunks/fragments, and N=25 bipolar elements (Table 10).

	Scatter 2	
Tool Category	**N**	%
Cores	8	7%
Flakes	78	67%
Retouched flakes	1	1%
Chunks	4	3%
Bipolar	25	22%
Total	**116**	**100%**

Table 10:Number of lithics from Scatter 2

Scatter 3 is composed of N=530 lithics. The assemblage consists of N=10 cores, N=413 flakes, N=15 retouched flakes, N=62 chunks/fragments, N=1 hammer, and N=29 bipolar elements (Table 11).

	Scatter 3	
Tool Category	**N**	%
Cores	10	2%
Flakes	413	77%
Retouched flakes	15	3%
Chunks	62	12%
Hammer	1	1%
Bipolar	29	5%
Total	**530**	**100%**

Table 11: Number of lithics from Scatter 3

Scatter 4 is composed of N=26 lithics. The assemblage consists of N=1 core, N=14 flakes, N=7 chunks/fragments, and N=4 bipolar elements. No retouched flakes have been found within the scatter (Table 12).

	Scatter 4	
Tool Category	**N**	%
Cores	1	4%
Flakes	14	54%
Retouched flakes	0	0%
Chunks	7	27%
Bipolar	4	15%
Total	**26**	**100%**

Table 12: Number of lithics from Scatter 4.

3.3 Methods

3.3.1 State of the art

Lithic assemblages have been considered the principal archaeological feature to understand and interpret prehistoric sites. The main reason is that stone artefacts are often the best preserved in the archaeological record.

At the beginning of the research on Palaeolithic contexts, scholars aimed and attempted to create a systematic typology of stone artefacts based on their morphological attributes. This methodological approach is defined as a typological classification of archaeological materials according to several key features of the lithic products, especially for retouched flakes (Bar Yosef and Van Peer, 2009; Inizan et al. 1999; Soressi & Geneste, 2011).

In the late '50s and the first half of the '60s of last century, with the introduction of the typological analysis of the lithic artefacts developed by François Bordes in his volume on the Lower and Middle Paleolithic (Bordes, 1961), the analysis of prehistoric stone tools knew a great boost. The method was based on typological identification and classification of retouched artefacts (scrapers, gravers, etc.) and their comparison. Bordes created a type-list for the Acheulean and the Middle Palaeolithic artefacts with the basic definition of core reduction strategies (Bar Yosef and Van Peer, 2009).

However, despite the importance that Bordes' method gave to the technology of production, the focus of the typological approach was on retouched artefacts, neglecting the general interpretation of the production processes and related activities.
Moreover, the limits of this approach due to the diversity of lithic production and end-products triggered the scientific community to go beyond the classification of artefacts based on defined types and morphology of stone, in order to understand the technical and manufacturing processes behind a certain morphology or typology. This concept led to the development of the *chaîne opératoire* or technological approach. This approach to the analysis of prehistoric objects is referred to as a methodological approach to the study of material culture, based not only on the classification of morphological features but also on the analysis of techniques and technological stages involved in the production of stone objects. It is important to consider the complexity of techniques and technologies involved to fully identify a human behaviour. To interpret an archaeological site or to reconstruct a past behaviour expressed into a culture, the typology cannot be useful without the study of techniques and technological actions. Typology and technology need to be studied concurrently comparing the result they yield (Inizan et al. 1999).
Conversely, the technological approach aims to reconstruct the production process rather than on the formal description of types. The approach, developed in the second half of the '60s in France, is based on a vision that includes the combination of strictly technological parameters for the understanding of the productive activities of prehistoric human groups, which can be reached through experimental research in prehistoric archaeology (Bar Yosef and Van Peer, 2009; Inizan et al. 1999).
This innovation in the study of material culture was elaborated after the work of André Leroi-Gourhan, who published "*L'homme et la matière*" in 1943. His research referred to the study of mankind through the analysis of technical, social, and symbolic patterns of behaviour (Geneste, 1991; Inizan et al. 1999; Soressi and Geneste, 2011). One of Leroi-Gourhan's original contributions was the introduction of the concept of the *chaîne opératoire* (1964), which allows the study of the different stages of lithic exploitation and production. This concept has been used first by French prehistorians for the purpose of lithic analysis. From the late 1970s to the early 1990s, in fact, J. Tixier, M.L. Inizan, H. Roche, and their colleagues introduced a new approach to prehistoric societies through the study of stone artefacts, which they qualified as a technological approach, i.e., not only a typological one designed to classify but one that could result in a deeper understanding of the social significance of the techniques used in the past (Tixier 1978, 1979, Tixier et al. 1980). The focus of this approach shifted from the study of prehistoric humans through their stone tools to the study of prehistoric societies through their techniques. From this perspective, a

technique is understood as a social product (Soressi and Geneste, 2011). The division of the whole process into different steps allows the analysis of the artefacts from the raw materials procurement until the use of the retouched tool and final abandonment or their possible re-use. This concept makes it possible to place each artefact in a technical context, offering a methodological framework for each level of interpretation. Moreover, this approach allows the understanding of the geographical organization of the technical process since each stage of the process can be identified by the presence or the absence of its products within a site (Geneste, 1991). According to the basic principle of the *chaîne opératoire* method, even fragmented *debris* is useful to understand the coherence of the assemblage into a methodical scheme (Bar Yosef and Van Peer, 2009; Inizan et al. 1999).

The technological approach here described has been then applied to the study of knapped stone assemblages from prehistoric sites. The technological analysis of lithic artefacts is based on two different levels:

1: observation and reading of knapped scars present on lithic products. This consists of a technical reading of each artefact to place it into the *chaîne opératoire*, independently by its archaeological context.

2: interpretation of the relation between the artefact and the *chaîne opératoire* stage in which it is placed. On a site, all the stages of a *chaîne opératoire* are not necessarily represented, through this analysis it is possible to understand what kind of activity or action is behind a lithic object.

The early stages of the *chaîne opératoire* concept are represented by the procurement of raw materials. Prehistoric people used to knap several varieties of raw materials, both at a local and non-local level. The presence of non-local raw material (or exotic) within an assemblage in fact is an indicator of human mobility. This allows us to define the economic management of raw material within a territory and the landscape knowledge (Perlés, 1991; Perlés, 2007). The analysis and identification of raw materials represents the first step of a technological analysis of prehistoric artefacts in order to understand past human behaviours. The second step is the recognizing of techniques and methods employed in the production of lithic artefacts. Finally, each artefact is analysed in order to define which stage of the *chaîne opératoire* is represented within the assemblage and/or a site. The subsequent stages consist of the production of tools, through the different knapping methods employed. The final stage consists of the discarding of a core, which can be abandoned if it is completely exhausted (Shott, 1989).

3.3.2 Methods used for the Gotera lithic assemblages

The methodology used for the lithic analysis of the GOT-10 site artefacts is based on the approach described above, integrating the *chaîne opératoire* approach with a quantitative attribute-based analysis of lithic artefacts. This approach is based on the division of the assemblages into individual lithic artefacts that are seen as individual elements (attributes), constituting the analytic units. These units are measurable and observable, both from a mechanical, shape and reduction sequence point of view and remains constant within a technological framework (Tostevin, 2012; Scerri et al. 2016; Van Peer, 1992). The main goal of this approach is to reconstruct the methods and techniques employed in stone artefact production based on the quantitative and qualitative analysis of the artefact's attributes, to generate verifiable Interpretations and hypotheses on reduction sequences.
This method is based on the measurement, analysis, and acquisition of different lithic attributes (raw materials, cortex percentage, reduction systems, platform types, number of dorsal scars; length, width, etc.) on cores, flakes, and retouched tools. For this research project, this approach has been applied to facilitate the comparison between assemblages (Scerri et al. 2016). The attributes collected for the lithic assemblages analysed in the frame of this doctoral thesis have been used to perform statistical multivariate analysis for intra-site and inter-site assemblages' comparison.

3.3.3 Database entries

Each lithic implement of the GOT-10 lithic assemblage with its features has been catalogued and integrated within a database set up using the E4 software (www.oldstoneage.com).
This software is a flexible data entry program created to make data entry faster and reduce errors. The data are written directly to an Access MDB format database, but data can be also processed through any other program (including Microsoft Excel).

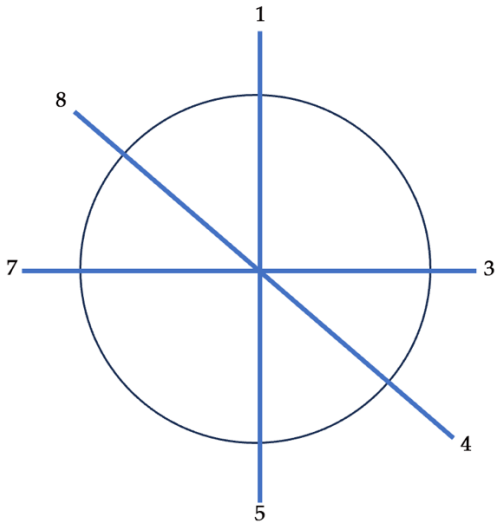


Figure 32: Example of clock orientation methodology using numbers from 1 to 8.

The lithic analysis has been conducted using the methodology of clock code (Figure 32) invented by Prof. Robert Foley, from the University of Cambridge, to identify and describe the morphological and technological traits of each lithic implement. This code has been improved to solve issues linked to the absence of landmarks in describing the location of traits on lithic tools.

To describe the location of specific traits such as retouch or edge damages the piece is oriented to the platform and then we use a clock system of measurement. The 360 is divided up into 40-degree sectors, with '1' being oriented from the platform, in the direction of striking. The flake is subdivided into one or more 45-degree sectors numbered from 1 to 8. Based on this division attributes are located on the flake. All these attributes are reported and described in a database. The first section is linked to the description of location and context (CXT) in which the lithics have been found. The principal information related to the first section of the database is **locality** identification (LOC), **dataclass** (C/F), and mode of lithic implements. Dataclass is a category that provides broad information about the structure of an assemblage. The distinction between core and flakes is the most important feature of the sector and all lithic analysis.

A flake is generally described as a piece of *débitage* stuck off a core, with the presence of a platform, ventral and dorsal surfaces, and evidence of a conchoidal fracture. The core, on the contrary, will have the inverse evidence for the removal of flakes from it. The subsequent section concerns **Mode** classification (MODE). Clark's modes division (Clark, 1977) provides a stable system to describe large-scale patterns in variation of stone tool production. The database used for this lithic analysis is useful to give a general division based on the characteristic traits of knapping. Modes are five and divided into:

Mode 1: characterized by a simple platform and lack of preparation. The flakes struck off are small compared to the cores and lack of retouch.

Mode 2: comprises two elements. First: the ability to strike off large flakes, with a narrow cross-sectional area suitable for an invasive retouch. Second: the possibility of retouching the flakes produced in a way that secondary flakes were removed across the whole surface of the flake, and this could occur on both sides, so they are defined bifaces. Bifaces can also be produced by the single knapping of a nodule, shaping, and flaking it on both sides.

Mode 3: it represents a shift in lithic production. The core here is prepared prior to striking off a major flake or flakes of the desired shape. This means to have greater control over the shape and thickness of the flake which is the predetermination of the flake or tools they wanted to produce through the previous preparation of the cores. In this way, the

assemblage is characterized by a much more diverse set of finished blanks and tools with greater variability.

Mode 4: even with this the core is previously shamed and prepared to strike off blanks and tools with a predetermined shape. However, there is a change in the way the core was oriented shifting from a surface debitage to a volumetric débitage (laminar débitage). Here the preparation is made to produce long flakes in a complete reduction of the core, resulting in cylindrical prismatic cores and elongated blades with cross sections reworked into a diverse set of tool types. The mode 4 system is principally based on prismatic cores.

Mode 5: characterized by the presence of microlithic technology. This is defined by the high standardized production of very small flakes and blades, unmodified or retouched into various shapes, used also as composite tools. The latter is characterized by the combination of a hafting element in organic material such as wood or bone.

Raw material attributes are the second section analysed in the first part of the database, related to context. The analysis and recording of the raw materials are very important to the study of lithic assemblages because they provide information about the provenance of materials and thus the territories of the human groups. The aim of this section is to have the basis for systematic comparison and geological sampling and mapping of the raw material sources. Among the attributes considered, there is the quality and nature of the **raw materials** (RM2), which is descriptive and useful to identify the local differences between them. The other attribute related to raw materials is the morphological characteristics of raw materials and the surface of lithic implements (RM3). It is referred to as **colour** (CLR) and shape, presence of **cortex** (CTX), and its amount on the lithic surface. Other aspects important to the morphological description of the lithic implements are the **alterations** (CON2). These alterations can be physical or chemical. The analysis of alterations and, above all the abrasion of lithic edges provides information about the post-depositional history of the assemblage and the probabilities of whether it may have been affected by post-depositional processes. This section only describes the degree of changes and not its nature which is described in further sections. **Patina** (PAT) is a very important variable to read on lithics. Patination is the result of a transformation that affected the lithic objects. This transformation is visible on the surface as a change in colour and/or a loss of transparency. This feature varies also across the surface, and this could be linked to differences in the side facing the ground and the face exposed.

One of the important features of the patina is the colour (PAC). It is important to correlate it with the kind of chemical process the lithic has been affected by to understand the post-depositional history related to it. Based on the characteristics of the patina it is possible to determine the post-depositional process that occurred on lithic surfaces (CON1).

Another important alteration to be recorded is if the lithic is **burned** or not (BRN). The burned traces can be unintentional, or the results of heating and it is important to record in order to understand the functional history of lithics and also the post-depositional processes. Typically, burning damages the rock by a colour change (dark or reddish), lustre and sometimes diagnostic cracks and pot-lid fractures from the heated surface is also present.

The analysis of surfaces continues with the recording of **edge damages** (ED). The edge damages are generally due to use or post-depositional actions. This section records the edge damages which cannot be identified as retouch so as an intentional alteration of the edge surfaces. Usually, damage has not a clear pattern of detachments as a retouch generally has and this is the principal difference between them. The edge damages quantification is useful, at a spatial analysis level, to identify post-depositional factors that affected archaeological assemblages. In this section also the location of edge damages (LEDF) on both cores and flakes will be recorded using the clock orientation methodology. From this section on, the database focuses on **cores** and all their attributes. The first section describes whether a core is **complete** or not (COM). The completeness of a core is not related to core reduction, as the reduction process is of course a process of breaking the stone. The variable recorded in the further section is about the core **reduction** (CRD), how a core has been completely exploited from the initial phase as a block until the last flake has been struck off it. The possibilities available are primary, secondary, tertiary, and exhausted. A primary core belongs to the first stages of the knapping process, the preparation for example, and it might have still part of its original surface or a percentage of the cortex. A secondary core is characterized by a more advanced stage of flake production, but it may still have some cortex/original surface. A tertiary core is extensively flaked and reduced and when a core is exhausted it is not possible to produce any flakes more from it. The latter is an extreme case. To define these stages, it is important to evaluate the site context, the raw material economy, and the completeness of the reduction sequences of the site.

One of the most important technological features of the cores is the number of striking platforms both technological and morphological. This attribute may give the possibility to understand the knapping strategy and evaluate the reduction system of the lithic implement. The **number of technological striking platforms** (NTSP) is used especially with regular cores related to specific knapping methods. In these cases, several platforms are used to prepare the surface. The number of the morphological striking platform (NSP) indicates the number of places where flakes have been struck off the core and the striking platform may be plain, prepared, or cortical. The number of **flake scars** is the number of major intentional flakes (CNSF) that have been removed from a core. These concern the

flakes which are not part of the process of preparation of the striking platform on the core surfaces. For technological analysis, it is important to indicate the direction of flake scars (CFSD). The direction is indicated by the ripples on the surface of the cores associated with the impact point. These features indicate if the flakes have been removed in one direction (Unidirectional) or two opposite directions (Bidirectional), which can be regular or not. Sometimes the struck axis is directed to the centre of the core (Centripetal). When the flake scars converge to create a point to one end of the core, they are Convergent but where there are several patterns of direction, the scars pattern is Multidirectional.

The fourth section of the database describes the **flake**/*débitage* specific variables. Flake type (FT) is referred to as the simple procedure to identify the flake, ordinary, or trimming ones. In addition to the first identification, there is the description of the **technological flake type** (FLTCH), which records its technological origin. This section describes flakes that have been struck off a regular core, and they are divided into flakes, blades, or bladelets. The subsequent parts of this object are referred to as the division of flakes into proximal (FPR), medial (FMD), and distal (FDL) parts. The variables useful to the technological analysis which can be read on flakes are:

1: truncation (TRC), a line of continuous retouch truncating the distal, proximal, or lateral part of the flake.

2. cross-section of the flake (FSPN), which gives information about the volume of the flake, related to the production method.

3. symmetry of flakes in section (FSS), which gives an estimation of the original volume and morphology of the core, and regularity and intensity of reduction.

4. symmetry of the flake longitudinally, which gives information about the managing of the lateral surface.

5. symmetry of flake transversely (LGS), which gives information about the plan view shape of the flake end.

6. flake curvature (FLC), which gives information about the production process, either in surface or volumetric knapping.

7. flake termination (DS), which gives information about the identification of knapping accidents.

The next section is related to the identification and description of the **platform variables**, with the first notification of its presence (PLP). The platform type (PLM) is referred to several categorized platforms: cortical, dihedral, plain, facetted, abraded, linear, and punctiform. Another variable is the integrity of the platform (PLC) which indicates if a platform is broken or not or if it has been intentionally removed. The subsequent variable indicates the presence of a Hertzian cone (HTZ), impact point (IMP). The presence of bipolar

flake (BIP) is the result of anvil percussion, striking the core while it lies on an anvil, i.e., striking the core while it lies on an anvil. It is possible to identify or by the presence of double impact points and bulbs or the ventral face can show double ripples.
The identification of specific morphological traits on artefacts surface associated with the use of the bipolar on anvil technique is based mostly on the analysis of bulbs and splintering on cores and flakes, according to experimental data (Bietti et al. 2010; Grimaldi et al. 2008).
In order to record the presence of the bipolar technique on anvil, the following attributes have been identified and registered both from cores and flakes. Once the artefact has been identified as a core (Detachments: yes) or a flake (Negatives: yes), the following specific variables for the bipolar on anvil technique have been registered: type of bulb (Dihedral; Negative) and the number of bulbs (Integer). The position of the bulbs is referred to a specific list: single, single biface, opposite same surface, opposite different surface, orthogonal same surface, orthogonal different surface, multiple. Furthermore, the presence of *ecaillures, and the* number of *ecaillures* (Integer). The position of the *ecaillures* is referred to a specific list: opposite same surface, opposite different surface, connected to the bulb on different surface, orthogonal to the bulb same surface.
The next section is referred to the number and direction of flake scars (NFSD) and it records the number of dorsal flake scars. This is important to recognize the overall nature of a core reduction strategy and it is helpful to use a drawing to indicate the directions.
The next section indicates the primary flake direction (PFSD) of the dorsal face scars. To record this variable, it has been used the clock method has been read relative to the position of the platform, looking at the flake dorsally. The predominant flake direction has been indicated and if there is no predominant direction, it will be used as "No primary directions". The variable referred to as the platform position (PLPO) is registered in relation to the maximum length, orienting the flake longitudinally to respect the length, with the platform closest to the top. To indicate the platform position, the clock method has been used. The number of dorsal scars (PFL) does not include preparation scars and it is useful and helpful to use a drawing with the direction of the scar to make the reading clearer.
The next section of the database is referred to the flake metric variables. They are presented in order:

- Absolute maximum length of the flake (XL).
- Maximum flake breadth (XB).
- Maximum thickness of the flake (XT).
- Position of maximum breadth (DXFB).

- Technological length of the flake (XTL): Maximum length of the flake taken from the platform and running in the direction in which the flake was struck off.
- Technological breadth of the flake (XTB): Maximum breadth, taken perpendicular to XTL.
- Point of maximum technological breadth (DXB): it is the distance from the point of origin of XTL to the point on the flake where XTB occurs, as a line running parallel to XTB.
- Point of the maximum technological thickness (DXT): it is the distance from the point of origin of XTL to the point on the flake where XT occurs, as a line running parallel to XTL.
- Maximum length of the largest flake scar present on the dorsal surface, taken in the direction of removal (XSL).
- Maximum breadth of the largest flake scar present, defined as the maximum dimension perpendicular to XSL.
- Maximum platform breadth (XPW).
- Maximum platform thickness (XPT).
- Platform angle (PLA).

The next part regards the *façonnage* general and variables. The first section, ***façonnage*** (FAC), is related to the knapping explanation of this method so if the flake is a *façonnage* product or not. This method is related to the manufacturing of a lithic object by shaping a single raw material block into the desired form. The most commonly shaped tools are bifaces. The subsequent section regards the biface type (BFT). The morphologies of a biface tool can be very variable but some typological patterns occur frequently, this variability in biface shapes contributes to creating a classification with the presence of most common shapes here listed from the typological list made by Bordes (1961): 1: Triangular; 2: Cordiform; 3: Ovate; 4: Limande; 5: Lanceolate; 6: Micocquian; 7: Nucleiform; 8: *Biface à dos*. Other attributes are related to the *façonnage* product morphology. There is a section like a biface worked edge (BFE), biface blank form (BFS) recording, when possible, the original form of the piece prior to the shaping of the bifaces; biface base morphology (BFB); biface tip morphology (BFT); biface production stage (BFPS) is an evaluation of the stage of the production in which the biface entered the archaeological record (i.e., was abandoned). It can go from the blank through the preform, to a finished one. The subsequent variables are related to the biface measurements and are listed as - Maximum biface length (XBL); - Maximum biface width (XBW); - Maximum biface thickness (XBT); - Maximum tip length

(XBTL); - Maximum tip width (XBTW); - Maximum tip thickness (XBTT); - Maximum base length (XBBL); - Maximum base width (XBBW); - Maximum base thickness (XBBT).

The next section is referred to all the morphological and technological attributes of **retouch**. Retouch can be referred to the cores and the first section is related to the indication of the presence of retouch on cores and flakes (RET). The part of the description of the type of retouch is indicated with (DRT). Since a retouch is the intentional transformation of lithic objects through removals on the edge of the tool, it is necessary to identify the type of retouch. It can be identified as:

1. shallow: the most common type of retouch, which consists of very small flakes removed from the edge on the dorsal side.
2. steep: retouch at a much steeper angle to the end and it can be visible on some cores.
3. invasive: when a tool has been retouched extensively and invasively by flat removals obtained by pressure flaking. Retouch on cores is not common but it is important to define the economy of the site we need to indicate its position on cores (LRC). To locate the retouch a simple procedure has been used. The core has been oriented along its longest axis and positioned to let the next longest dimension be horizontal and the retouch has been described, referring to the distribution of any retouch in terms of top, bottom, or side. The top is described as the surface closest to the striking platform of the largest flake visible on the core.

The presence of an alternating retouch can be registered within the database in the next section (ARET). It is referred to the position of retouch removals, alternatively on the dorsal and ventral face of the lithic object on the same edge. Moreover, the alternate retouch can be also present (ALT), and it is referred to the position of retouch removals alternatively on the dorsal and ventral faces on two opposite edges. Dorsal retouch can be also present (DRET) on the dorsal part of the flake and its location (LDR) is indicated using the 8-point 45-degree clock.

The next section is referred to the dorsal retouch type (DRT). The ventral retouch (VRET) is registered into the database first as presence/absence and it is rarer than a dorsal retouch. As for dorsal retouch, also ventral retouch is registered in terms of location (LVR) using the clock method, and in terms of type of retouch (VRT). For the latter, the same division of retouch type has been done as dorsal retouch type. Another type of retouch is the notch (NCH). Notches are obtained with different retouch techniques and the location (NCHL) is indicated with the clock method. The registration of the number of notches (NCHN) is also present. The following record is referred to denticulate retouch (DEN) when a tool presents

a series of adjacent notches. The location of denticulate retouch (DENL) is indicated with the clock method as well.

The next part of the database is dedicated to typological indications of lithic objects. The **tooltype** is referred specifically to the typology of the tool, following standard typological approaches (e.g. Bordes's 1961). Tools having recurrent shapes and morphologies, starting from Mode 1 technologies, induced archaeologists to classify the tool forms into standardized tool types. Those types take their name from the presumed use or from the description of their shape. Unfortunately, often the morphology of tools does not correspond to the shape of the tool intended by the tool maker. Nevertheless, the typological classification is still used to quickly describe the tools and to have a common vocabulary among scholars.

After the typology, a technology comprehensive description is also present. The **technological stage** (TCHST) indicates the place where a lithic object should be placed within the *chaîne opératoire*. The transformation of a raw material block into a tool comes in different stages. The principal stages are the raw material procurement, the initialization of the production, the production itself, and the exploitation of the product. These stages allow archaeologists to identify the presence or absence of the characteristic product within an assemblage and in consequence at a site scale. It is useful if we want to compare assemblages in terms of how much they reflect different stages of the process. This is useful to establish site function through the landscape and to have an idea about the choices and constraints of the knapping process. It is necessary to subdivide this category within the database with an additional **technological type section** (TCHTY). This section is subdivided into phases and every point is referred to as a technological type. The section will be filled with the lithic object relative to technological type:

Phase 1:

- 1.1: Tested cobble.
- 1.2: Fully cortex flake (whole dorsal surface covered with cortex and the platform is cortical).

Phase 2: *Débitage* produced to modify the core for subsequent exploitation or to prepare the preform for *façonnage* tools:

- 2.1: Non-standardised cortical flake (a flake that may have a great portion of the cortex, but it is not complete, and the platform will not usually be cortical.
- 2.2: Janus/kombewa (a flake with two ventral faces).

- 2.3: *Tablettes/semi-tablettes* (flakes removed to rejuvenate the striking platform surface. It shows the negative scars of the platform preparation, and it may be the whole of the platform core or only a part of it).
- 2.4: Debordant flake (flakes removed from discoidal or Levallois cores to create a lateral convexity of the core).
- 2.5: Striking platform preparation flake (flake removed from discoidal or Levallois core to create a lateral or distal convexity of the core and to create the striking platform of the core. The difference between this flake and a debordant flake is that the former is struck off parallel to the striking plane, and the latter is removed perpendicular to the striking plane. It is convergent in shape with a thick butt).
- 2.6: Pseudolevallois point (flake removed from a discoidal or Levallois core as part of the preparation for a full Levallois removal and it is parallel to the striking plane. The difference with a Levallois point is that the pseudo-point has its longest axis divergent from the technological axis).
- 2.7: Crest blade/bladelet (first blade/bladelet removed from a blade core, it has a triangular cross-section, and it may be partially cortical if the raw material morphology requires preparation).
- 2.8: Cordal flake (a debordant flake knapped following a cordal direction, generally part of discoidal débitage).
- 2.9: Débitage surface rejuvenation flake (a flake of re-preparation of the débitage surface and/or the platform).
- 2.10: Trimming/bifacial-shaping flake.
- 2.11: Backed bladelet.

Phase 3: Exploitation of débitage products

- 3.1: Ordinary flake.
- 3.2: Unipolar flake.
- 3.3: Ordinary flake with cortex.
- 3.4: Unipolar flake with cortex.
- 3.5: Centripetal flake.
- 3.6: Centripetal flake with cortex.
- 3.7: Preferential Levallois flake.
- 3.8: Unipolar Levallois recurrent.
- 3.9: Bipolar Levallois recurrent.
- 3.10: Centripetal Levallois recurrent.

- 3.11: Levallois Point.
- 3.12: Levallois Blade.
- 3.13: Nubian point.
- 3.14: Nubian flake.
- 3.15: Preferential Levallois with cortex.
- 3.16: Unipolar Levallois recurrent with cortex.
- 3.17: Bipolar Levallois recurrent with cortex.
- 3.18: Centripetal Levallois recurrent with cortex.
- 3.19: Levallois point with cortex.
- 3.20: Levallois blade with cortex.
- 3.21: Nubian point with cortex.
- 3.22: Nubian flake with cortex.
- 3.23: Ordinary blade.
- 3.24: Ordinary blade with cortex.
- 3.25: Ordinary bladelet.
- 3.26: Ordinary bladelet with cortex.
- 3.27: Indeterminate blade/bladelet/flake fragment.
- 3.28: Point blade/bladelet.

Phase 4: Use of tools and *débitage* products

- 4.1: Chip/retouch flake
- 4.2: Burin spall.

Phase 5: Discard of lithic objects

- 5.1: Chunk.
- 5.2: Knapped rock fragment.
- 5.3: Core.
- 5.4: Other.
- 5.5: Broken tool/flake.

3.4 Results of technological analysis

All the contexts registered at the GOT-10 sites show evidence of all the production stages, represented by cores, flakes, retouched flakes, and chunks. The most abundant category is the flakes, while the less represented are the cores and the retouched flakes (Figure 33).

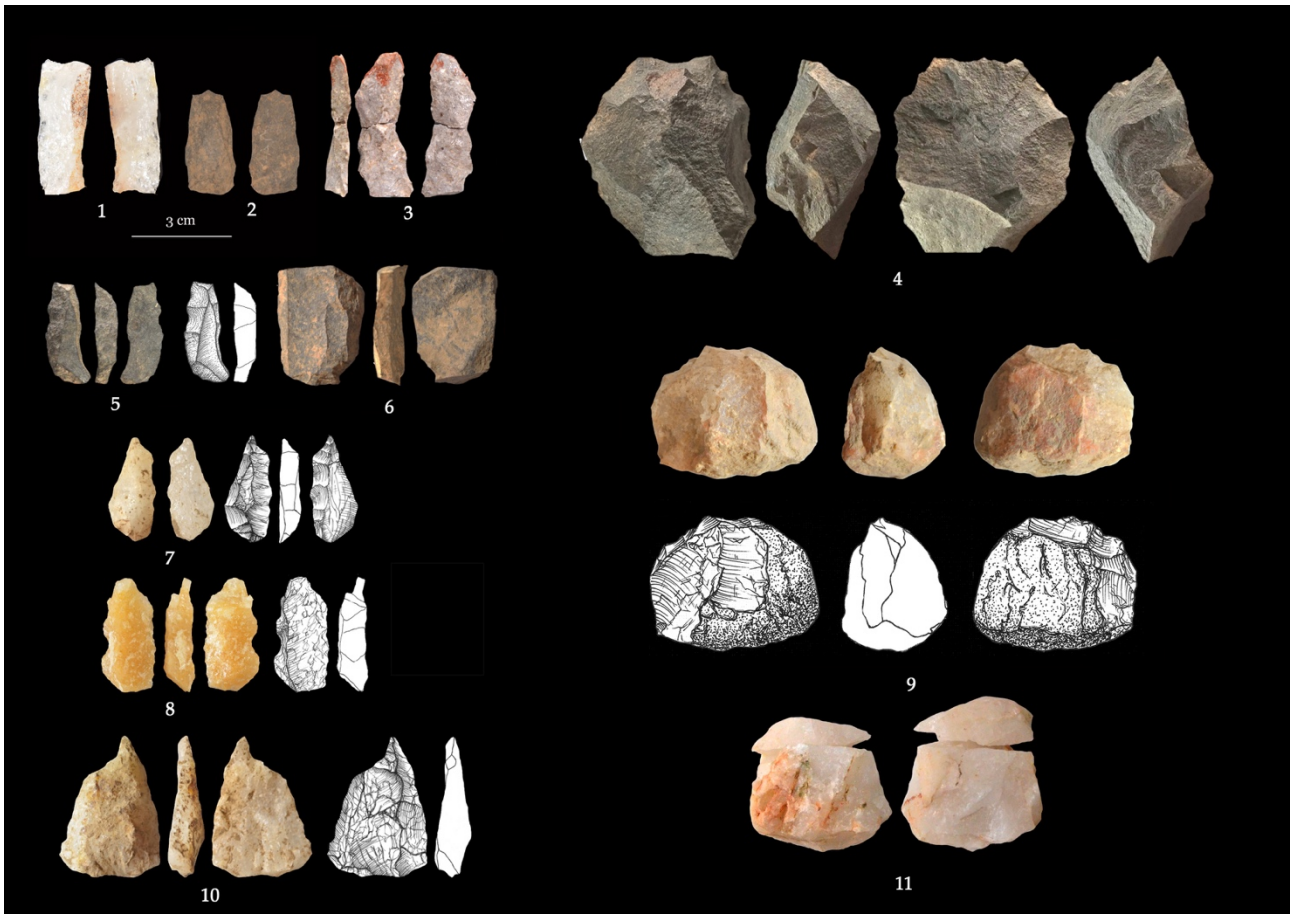


Figure 33: Artefacts from the GOT-10 site. Bladelets (1-3, 5), planimetric centripetal core (4), blade (6), denticulate (7-8), Levallois point (10), volumetric core (9 and 11), refit (11) (drawings Dr. M.P. Maiorano).

3.4.1 Raw materials analysis

A useful tool to understand the exploitation of territories, and how far and in which directions of lithic resources lithic resources were moved across the landscape is the analysis of raw materials (Perlés, 1991; Perlés, 2007). While it is necessary a specific methodology and approach to evaluating the origin of lithic resources, I performed a general analysis on raw materials to provide the basic knowledge of the exploitation of the area.

The raw materials exploited at the GOT10 site are coherent with the rest of the area confirming the use of local resources such as quartz and basalt, easily available across the area (Fusco et al. 2021; Spinapolice et al. 2017). However, there is very scanty evidence of chert exploitation in the area.

Basalt is of local origin, and it is present in the alluvial deposit in the whole area, and it has been found in cobbles, pebbles, and nodules across the Gotera area (Fusco et al. 2021). In addition, outcrops of quartz are present around Gotera as well as pebbles/cobbles found on the surface throughout the area.

Furthermore, it is confirmed the presence of three different types of quartz: one characterized by a crystalline structure, one characterized by a vitreous structure, and another defined as hyaline (Fusco et al. 2021; Fusco and Spinapolice, in review). This classification has been done on the physical appearance of the raw materials. Further elemental and chemical analyses will be performed to clarify the nature of the quartz exploited within the Gotera area.

Finally, the presence of chert is attested within the assemblage in a very low occurrence. During the exploration of the area, no chert sources have been found, thus it is likely possible that this raw material has been brought to the site from elsewhere. Moreover, no cores or elements belonging to the early stages of the reduction processes have been identified on chert. However, this data needs to be confirmed through specific analysis of provenance on the chert found within the site.

The analysis of raw material from the stratigraphic sequence of the Mound 1 shows a predominance of quartz, which represents 65% of the assemblage (Table 13), while basalt is less present and represents 33% of the whole assemblage. Chert is present in a very low occurrence, and it represents 1% of the assemblage from the archaeological layers.

	BASALT		**CHERT**		**QUARTZ**		**Total**	
Startigraphic Unit	N	%	N	%	N	%	N	%
SU2	0	0%	0	0%	2	1%	2	1%
SU4	8	4%	0	0%	32	8%	40	7%
SU6	77	39%	5	63%	188	48%	270	44%
SU7	23	12%	0	0%	36	9%	59	10%
SU8	0	0%	0	0%	2	1%	2	1%
SU10	4	2%	0	0%	5	1%	9	2%
SU11	87	44%	3	38%	127	32%	217	35%
Total	**199**	**33%**	**8**	**1%**	**392**	**65%**	**599**	**100%**

Table 13: Raw materials distribution within lithic assemblage from Mound 1

In general, the GOT10 site is characterized by massive exploitation of quartz, which represents 68% of the whole assemblage. Basalt is also heavily exploited, and it represents 30% of the assemblage. Other raw materials are present, such as chert (2%), obsidian (N=1), Lava (N=1), and phonolite (N=1) (Table 14).

	BASALT		CHERT		OBSIDIAN		LAVA		PHONOLITE		QUARTZ		Total	
Contexts	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Cluster A	45	8%	8	23%	0	0%	0	0%	1	0%	137	10%	191	9%
Cluster H	72	12%	4	11%	0	0%	0	0%	0	0%	162	12%	238	17%
Cluster L	10	2%	1	3%	0	0%	0	0%	0	0%	58	4%	70	4%
Cluster M	21	4%	0	0%	0	0%	0	0%	0	0%	24	2%	45	2%
Mound 1	201	34%	8	23%	0	0%	0	0%	0	0%	398	30%	608	30%
Scatter 4	3	1%	0	0%	0	0%	0	0%	0	0%	23	2%	26	1%
Scatter1	34	6%	0	0%	0	0%	1	100%	0	0%	76	6%	111	5%
Scatter2	35	6%	1	3%	0	0%	0	0%	0	0%	76	6%	112	5%
Scatter3	167	28%	13	37%	0	0%	0	0%	0	0%	350	27%	530	26%
Surface	0	0%	0	0%	1	100%	0	0%	0	0%	10	1%	11	1%
Total	**588**	**30%**	**35**	**2%**	**1**	**0%**	**1**	**0%**	**1**	**0%**	**1315**	**68%**	**1942**	**100%**

Table 14: Raw materials distribution within lithic assemblage from the GOT-10 site.

3.4.2 Artefacts condition analysis

A complete analysis of the surface alterations has been carried out. This analysis involved the estimation of presence/absence of physical and chemical modifications that may have affected the lithics, due to mechanical or post-depositional and taphonomic processes; the presence/absence of patina due to chemical alterations of soils and it influences the structure and colour of raw materials, as well as the presence/absence of burning traces.

The analysis of lithic assemblage from the Mound1 archaeological sequence shows a very low degree of alteration, with 96% of the assemblage being considered fresh, while only 3% have been classified as slightly worn This means that the flakes, cores, and retouched tools' edges still preserve their cutting capacities. This means that the lithics coming from the Mound1 layers have been exposed to relatively low post-depositional processes, making the archaeological context in general a primary deposition (Appendix 1, supplementary table 1).

The alteration analysis shows the same pattern of the lithics from the archaeological layers (Appendix 1, supplementary table 2). Fresh artefacts represent 97% of the assemblage, while worn and slightly worn artefacts made up only 1% of the lithics analysed.

Lithics from the Mound 1 stratigraphy (3%) and from Scatter 3 (3%) are those who present their surface slightly worn. This analysis confirmed the fresh nature of the assemblages. This analysis confirmed the fresh nature of the assemblages. It shows that the archaeological materials were exposed for a relatively short period before their burial, and that the lithics

recovered from the surface have only experienced limited additional change since they eroded out from the deposit.

The analysis of the patina on the Mound 1 lithic assemblage reveals a consistent pattern. About 70% of the lithic artefacts in Mound 1 display a slight degree of patination. This suggests that these artefacts have undergone some weathering or chemical alteration over time, resulting in a thin layer of patina on their surfaces.

In contrast, a smaller portion of the lithic assemblage, approximately 15%, shows signs of moderate patination. This indicates a more noticeable and developed layer of patina, suggesting a longer exposure to environmental factors.

Furthermore, only around 2% of the lithic artefacts in Mound 1 exhibit heavy patination. These artefacts likely have a substantial layer of patina, indicating an extended period of exposure to weathering processes.

This distribution of patination levels within the lithic assemblage suggests that most of the artefacts have experienced similar environmental conditions and timeframes for patina formation. However, a smaller percentage of artefacts have undergone more intense weathering or have been exposed to different environmental factors (Appendix 1, supplementary table 3).

The analysis of patina on the lithic assemblage yields similar results to the analysis conducted on the lithics from the stratigraphic sequence of Mound 1 (Appendix 1, supplementary table 4). In this case, approximately 62% of the artefacts show a slight degree of patination. This indicates that these artefacts have undergone some level of weathering or chemical alteration over time, resulting in a thin layer of patina on their surfaces.

Furthermore, about 27% of the lithic assemblage exhibits no patina. These artefacts appear to have been relatively less exposed to environmental factors or have undergone less weathering compared to most of the assemblage.

The similarity in patination patterns between the lithic assemblage and the Mound 1 stratigraphic sequence suggests that the artefacts from both sites have experienced comparable environmental conditions and timeframes for patina formation.

It is worth noting that the absence of patina on a portion of the assemblage indicates a lack of exposure to weathering processes or a relatively shorter period since their deposition or manufacture. This information can provide valuable insights into the chronological and environmental context of the site.

To fully understand the significance of these findings, it is important to consider additional archaeological and geoarchaeological data, such as stratigraphic relationships, associated artefacts, and contextual information from the site.

The analysis of burning traces on the lithic surfaces from Mound 1 reveals a low occurrence of such traces (Appendix 1, supplementary table 5). Approximately 92% of the pieces show no signs of burning, indicating that they have not been exposed to significant heat or fire-related processes. On the other hand, only 6% of the artefacts display partial burning traces, suggesting that they have experienced exposure to fire. A small percentage, around 2%, exhibit total burned surfaces, indicating a more intense and widespread exposure to fire.
The analysis conducted on the entire lithic assemblage reveals a similar pattern. Most of the artefacts show no traces of burning, suggesting that they have not been subjected to significant fire. Only a few pieces show partial traces of burning, indicating localized heating or exposure to fire, while most of the assemblage appears fresh and not burned.
The low occurrence of burning traces in both the Mound 1 and GOT-10 assemblages suggests that fire-related activities were not extensively practiced or were not significant factors in the use or deposition of the lithic artefacts. It is important to consider other archaeological data, such as associated features and materials, to better understand the context and potential implications of the absence or presence of burning traces within the assemblages.
The lithic assemblage from the GOT-10 site exhibits minimal occurrences of alterations resulting from post-depositional processes. Overall, the degree of alteration within the assemblage is very low. This indicates that the lithic artefacts have been relatively well-preserved and have undergone minimal changes since their deposition.
The absence of significant post-depositional alterations suggests that the artefacts have been relatively protected from environmental factors, such as weathering, chemical alteration, or biological activity. This could be due to factors such as burial conditions, sediment composition, or other site-specific factors that have contributed to the preservation of the lithic materials.

3.4.3 Core analysis

The lithic assemblage from the GOT-10 site, analysed for this dissertation, consists of a total of N=44 cores. These cores have been thoroughly examined to understand their technological characteristics. Interestingly, despite their low occurrence, the analysis reveals a significant technological variability in terms of reduction strategies, observed in both regular and irregular cores (Table 15).
Among the cores in the lithic assemblage, irregular cores are more abundant, comprising 61% of the entire collection. Furthermore, it is noteworthy that the majority of irregular cores (44%) were collected from the Mound1 stratigraphy. This implies that a substantial

proportion of the irregular cores was found within the specific archaeological context associated with Mound1.
Overall, these findings suggest that the lithic assemblage at the GOT-10 site demonstrates a diverse range of reduction strategies in the production of cores.

Cores						
	IRREGULAR		**REGULAR**		**Total**	
Contexts	N	%	N	%	N	%
Cluster A	0	0%	1	5%	1	2%
Cluster H	1	4%	1	5%	2	5%
Cluster M	1	4%	0	0%	1	2%
Mound1	12	48%	4	21%	16	37%
Scatter 4	0	0%	1	5%	1	2%
Scatter1	2	8%	3	16%	5	11%
Scatter2	3	12%	5	26%	8	18%
Scatter3	6	24%	4	21%	10	23%
Total	**25**	**57%**	**19**	**43%**	**44**	**100%**

Table 15: Regular and irregular cores distribution within the GOT-10 site.

The lithic assemblage from the Mound1 stratigraphy shows a predominance of irregular cores (71%) as well (Table 16). The majority have been found within the SU6 (50%) while the regular cores represent 29% of the assemblage.

Mound 1						
	IRREGULAR		**REGULAR**		**Total**	
Stratigraphic Unit	N	%	N	%	N	%
SU19	0	0%	1	25%	1	7%
SU4	2	20%	0	0%	2	14%
SU6	5	50%	0	0%	5	36%
SU7	1	10%	1	25%	2	14%
SU9	0	0%	1	25%	1	7%
SUZ	2	20%	1	25%	3	22%
Total	**10**	**71%**	**4**	**29%**	**14**	**100%**

Table 16: Regular and irregular cores distribution within the Mound 1

The regular cores among the entire assemblage are Blade cores, Discoid cores, and Levallois cores. The most common among regular cores are Levallois cores, which represent 18% of the assemblage. Then discoid represents the 16% and blade cores (5%). The irregular cores

are more represented (57%) in the whole assemblage. The majority are polyhedral cores (27%), then cores reduced from flakes (25%), and finally triangular cores (2%). This classification is only based on the core morphology (Appendix 1, Supplementary table 6).
Although the number of cores is small, comprising only 2% of the total assemblage, they have demonstrated technological variability. The results of the core analysis suggest the presence of different reduction strategies that are not solely dependent on the exploitation of raw materials. This contrasts with the previous analysis of the surface assemblage from the GOT1-S site, which showed a different pattern (Fusco et al. 2021). These findings indicate high variability in lithic production across the Gotera area (Fusco et al. 2021; Fusco and Spinapolice, in review). The regular cores found at the site include Levallois, discoid, and blade cores.

3.4.4 Irregular cores

In the GOT-10 lithic assemblage, also irregular cores have been identified. These include core on flakes, polyhedral cores, and triangular cores, which suggest opportunistic exploitation of convexities to produce flakes, points, and elongated blanks mostly (Appendix 1, supplementary table 7).
The cores-on-flakes are flakes that have been recycled to be exploited for the production of more flakes. Thus, they show one or more striking platforms chronologically after the original flake. At the GOT-10 site, these cores consist of ordinary bipolar or unipolar elongated flakes with the striking platform obtained by a subsequent detachment along one of the two long edges. Other examples are constituted by cortical flakes used to produce pointed flakes, through a minimal preparation of distal convexities to obtain predetermined pointed flakes with a plain platform. Polyhedral irregular cores at the GOT-10 site are characterized by cores with one or two striking platforms, not opposed, that don't follow a specific reduction system for the production of flakes or elongated blanks. Usually, their convexities are minimally prepared to detach flakes and blade/bladelets, and often the same core was exploited for the production of both flakes and elongated blanks. Irregular cores at the GOT-10 site have been found both on basalt and quartz.

3.4.5 Regular cores

The regular cores consist of Levallois, discoid, and blade cores. Among these, Levallois cores are the most prominent type. Levallois cores account for approximately 18% of the total cores. However, when considering the stratigraphic sequence specifically from Mound 1, Levallois cores make up around 13% of the assemblage (Table 17).

Levallois cores are found in both basalt and quartz, and their presence is relatively equal in number. This suggests that the human groups at the GOT-10 site utilized Levallois core technology for stone tool production on both basalt and quartz, even if the quartz evidence is more abundant (71%) (Table 17).

Within the assemblage, preferential, centripetal, and bipolar-recurrent variants are present. However, centripetal Levallois is the most numerous (N=5) and it is represented both on quartz and basalt.

Levallois Cores						
	BASALT		**QUARTZ**		**Total**	
Levallois variants	N	%	N	%	N	%
Mound1	**1**	**50%**	**1**	**20%**	**2**	**29%**
Preferential-classical	0	0%	1	20%	1	14%
recurrent-centripetal	1	50%	0	0%	1	14%
Scatter1	**0**	**0%**	**1**	**20%**	**1**	**14%**
recurrent-centripetal	0	0%	1	20%	1	14%
Scatter2	**1**	**50%**	**2**	**40%**	**3**	**43%**
Recurrent-bipolar	0	0%	1	20%	1	14%
recurrent-centripetal	1	50%	1	20%	2	29%
Scatter3	**0**	**0%**	**1**	**20%**	**1**	**14%**
recurrent-centripetal	0	0%	1	20%	1	14%
Total	**2**	**29%**	**5**	**71%**	**7**	**100%**

Table 17: Levallois cores distribution within the GOT-10 site

Blade cores are found in basalt, quartz, and volcanic rock, and their presence is relatively equal in number.

Blade cores exhibit two main shapes: cylindrical (Figure 34: 3) and prismatic (Figure 35: 1, 4, 6). However, the most represented type of blade core is the prismatic blade core, with both bipolar and unipolar variants. The prismatic blade cores are the most numerous, with a total count of three (N=3) within the assemblage (Tab 18).

Blade cores								
	Basalt		Quartz		Volc		Total	
Contexts	N	%	N	%	N	%	N	%
Mound1	**0**	**0%**	**1**	**100%**	**0**	**0%**	**1**	**25%**
CYLINDRIC-UNIP	0	0%	1	100%	0	0%	1	25%
Scatter1	**1**	**50%**	**0**	**0%**	**1**	**100%**	**2**	**50%**
PRISMATIC-BIP	1	50%	0	0%	1	100%	2	50%
Scatter2	**1**	**50%**	**0**	**0%**	**0**	**0%**	**1**	**25%**
PRISMATIC-BIP	1	50%	0	0%	0	0%	1	25%
Total	**2**	**50%**	**1**	**25%**	**1**	**25%**	**4**	**100%**

Table 18: Blade cores distribution within the GOT-10 site

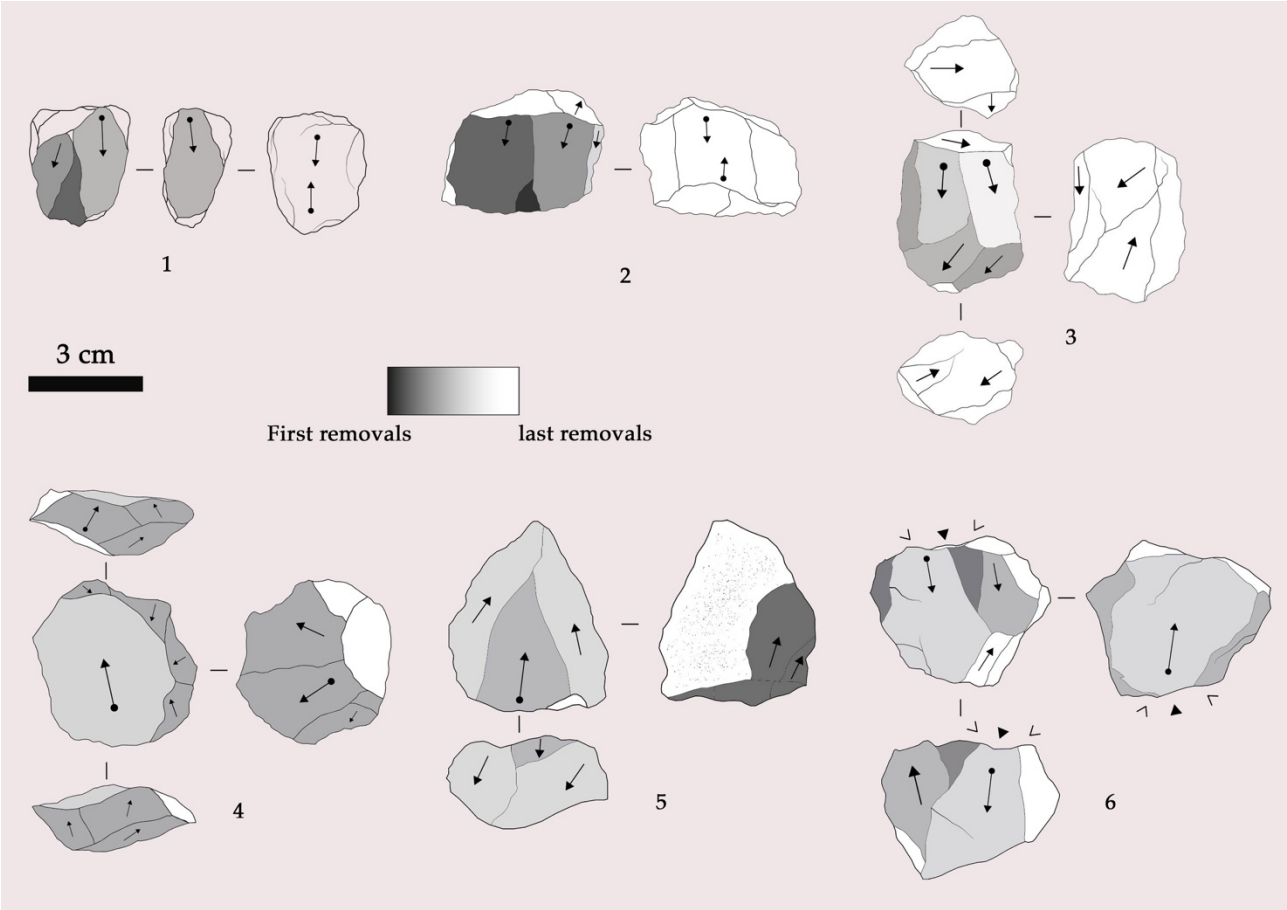


Figure 32: Cores from the GOT-10 site. Quartz (1-4, 6); Basalt (5). Bladelet bipolar core (1); volumetric laminar core (2); bladelet semi-tournant core (3); Levallois preferential core (4); Point core on flake (5); Volumetric double platform core (6).

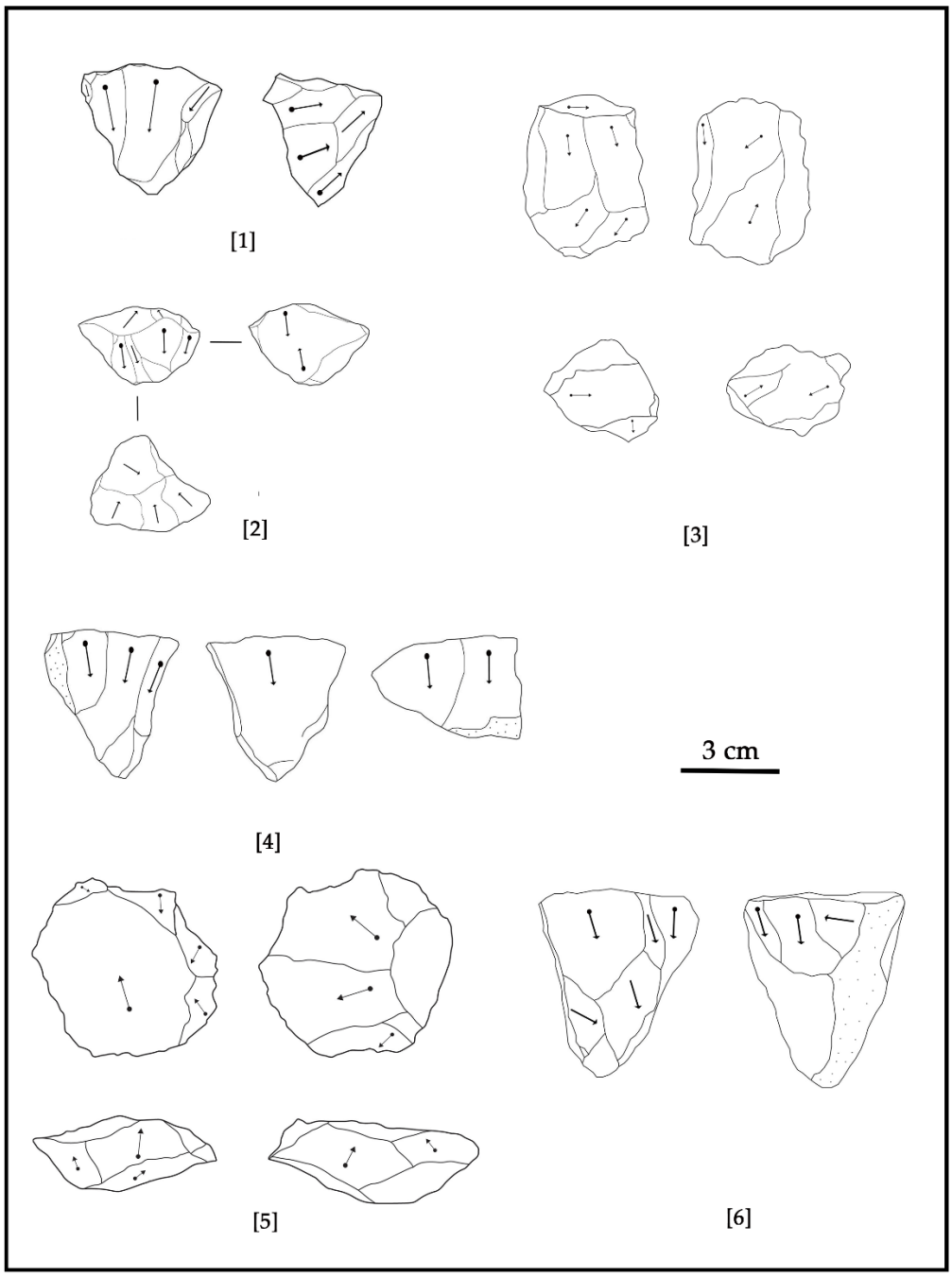


Figure 33: Examples of regular cores from GOT-10. Volumetric cores: prismatic cores (1; 4; 6) cylindrical core (3); intermediate core (2); planimetric core: Levallois preferential (5). Basalt (1; 4; 6), quartz (2; 3; 5).

3.4.6 Flake analysis

A comprehensive analysis of unretouched flakes has been conducted, allowing for a detailed understanding of their characteristics and their place within the reduction system.

According to the analysis, unretouched flakes comprise the largest proportion (74%) of the entire lithic assemblage. To further categorise and understand the knapping activities held within the site, they have been classified based on their place within the reduction system. This classification likely considers various technological criteria and characteristics of the flakes, allowing for a more nuanced interpretation of their roles within the knapping process.

The analysis reveals that most flakes (N=570) belong to the preparation stage (Appendix 1, supplementary table 8). The preparation stage involves the initial stages of flake production, such as the removal of the cortex or the creation of suitable platforms for flake detachment from the cores.

On the other hand, the production stage is represented by a slightly smaller number of flakes (N=396). These flakes have likely undergone more extensive shaping and modification, potentially resulting in the creation of specific tool blanks.

By examining the flakes in relation to their stage within the reduction system, it is possible to gain insights into the technological processes and strategies employed by human groups of the GOT-10 site. These findings contribute to a better understanding of lithic production and tool-making practices in the area under study.

Among the preparation flake types, the most represented are the debordant flakes (38%). The following most present flake types are debordant blade/bladelets (15%), striking platform preparation flakes (13%), and crested blade/bladelets (12%). Cortical flakes and blade/bladelets only represent respectively 5% and 4%, and this probably means that the initial knapping activities, such as testing blocks and cortex removals may have taken place somewhere else and not on the GOT-10 mound.

Pseudolevallois points and cordal flakes are very low in number, while Levallois striking platform preparation represents only 2% of the assemblage testifying to a small presence of Levallois methods.

According to the information provided by the technological analysis, the production stage assemblage at the GOT-10 site consists of various flake types (Appendix 1, supplementary table 9). The most common type is ordinary flakes, accounting for 48%. These flakes are characterized as being struck off from a prepared core but do not fit into any other specific technological flake category. They typically lack a dihedral or facetted platform and cannot be classified as Levallois or discoid flakes.

The second most represented technological category is ordinary bladelets, comprising 8% of the total. Following that, centripetal flakes make up 7% of the assemblage. Levallois points and points both account for 6% each.

However, the other technological categories, which include Levallois flakes (bipolar, unipolar, preferential, centripetal), are significantly under-represented. This suggests a low level of utilization of Levallois methods and their variants at the GOT-10 site (Figure 36).
Flake dimensions within the Mound 1 assemblage show that Basalt products are relatively bigger than quartz. However, data changes when it comes from elongated blank (blades and bladelets) dimension analysis that shows instead a relative homogeneity of blank dimensions for both quartz and basalt exploitations. This may suggest the orientation toward a unique production system concerning the production of elongated blanks at the Mound1 stratigraphy (Table 19).

Mound 1							
		Flakes length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Basalt	101	31.65	11.58	23.47	9.57	8.81	5.28
Quartz	142	24.59	7.88	18.58	6.04	6.72	2.77
		Blade length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Basalt	9	38.01	9.45	20.06	3.58	7.57	3.05
Quartz	10	31.09	5.76	19.01	2.99	9.42	2.73
		Bladelet length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Basalt	29	25.13	7.50	11.80	3.36	4.54	1.76
Quartz	26	22.12	5.24	11.64	3.37	5.07	1.53

Table 19: Distribution of flakes, blades, and bladelets dimensions within the Moun1 assemblage

The analysis of flake dimensions from the Clusters shows the same pattern as for the Mound 1 stratigraphy, with a bigger differentiation between quartz and basalt exploitation for flake production. However, in this case, the length distribution for blades highlights a difference between quartz and basalt. Bladelet dimension distributions seem however to confirm data from the Mound 1 stratigraphy (Table 20).

Cluster							
		Flake length		breadth		thickness	
	N	Mean	SD	Mean	SD	Mean	SD
Basalt	77	36.09	10.11	24.97	7.95	9.32	4.77
Quartz	139	29.37	8.05	22.07	6.80	8.45	3.54
		Blade length		breadth		thickness	
	N	Mean	SD	Mean	SD	Mean	SD
Basalt	13	44.67	12.03	19.35	3.52	10.34	4.21
Quartz	14	34.59	6.81	19.65	2.61	8.97	3.54
		Bladelet length		breadth		thickness	
	N	Mean	SD	Mean	SD	Mean	SD
Basalt	16	26.04	7.82	13.07	3.77	4.25	1.37
Quartz	27	24.92	3.56	13.17	1.89	6.13	1.63

Table 20: Distribution of flakes, blades and bladelets dimensions within the Cluster assemblage

The analysis of dimensions distribution for Scatters shows a bigger difference between quartz and basalt flakes. While dimensions of elongated blanks are more similar both for quartz and basalt exploitation (Table 21).

The fact that there is this difference in the dimensions of flakes in quartz and basalt throughout the GOT-10 assemblage, and that this difference is significantly reduced when observing the distribution of dimensions of elongated blanks, may depend on a series of factors: a) flakes differ in size due to a wider variability in desired products, adapting to the dimensions of raw material blocks, which are different for basalt and quartz. b) Elongated blanks, on the other hand, represent a widely represented final product in Gotera, both for the exploitation of quartz and basalt. The smaller dimensions of quartz, on the one hand, favor the production of small blades, but on the other hand, make it complex, which is why evidence of the use of the bipolar technique on an anvil is only attested in the exploitation of quartz. However, despite the dimensions of basalt blocks, the goal of human groups in the GOT-10 site to produce homogeneous elongated blanks for both raw materials is evident through various reduction methods present for both quartz and basalt.

Scatters							
		Flake length		breadth		thickness	
	N	Mean	SD	Mean	SD	Mean	SD
Basalt	155	41.09	14.11	27.45	9.69	10.73	5.23
Quartz	166	29.94	8.39	22.74	7.03	9.46	3.76
		Blade length		breadth		thickness	
	N	Mean	SD	Mean	SD	Mean	SD
Basalt	7	46.12	13.45	19.43	4.30	9.21	3.03
Quartz	11	42.47	6.96	20.02	4.12	10.38	2.23
		Bladelet length		breadth		thickness	
	N	Mean	SD	Mean	SD	Mean	SD
Basalt	20	28.95	7.78	12.64	2.41	5.63	1.79
Quartz	39	30.61	15.83	13.97	3.22	6.52	2.11

Table 21: Distribution of flakes, blades and bladelets dimensions within the Scatter assemblage

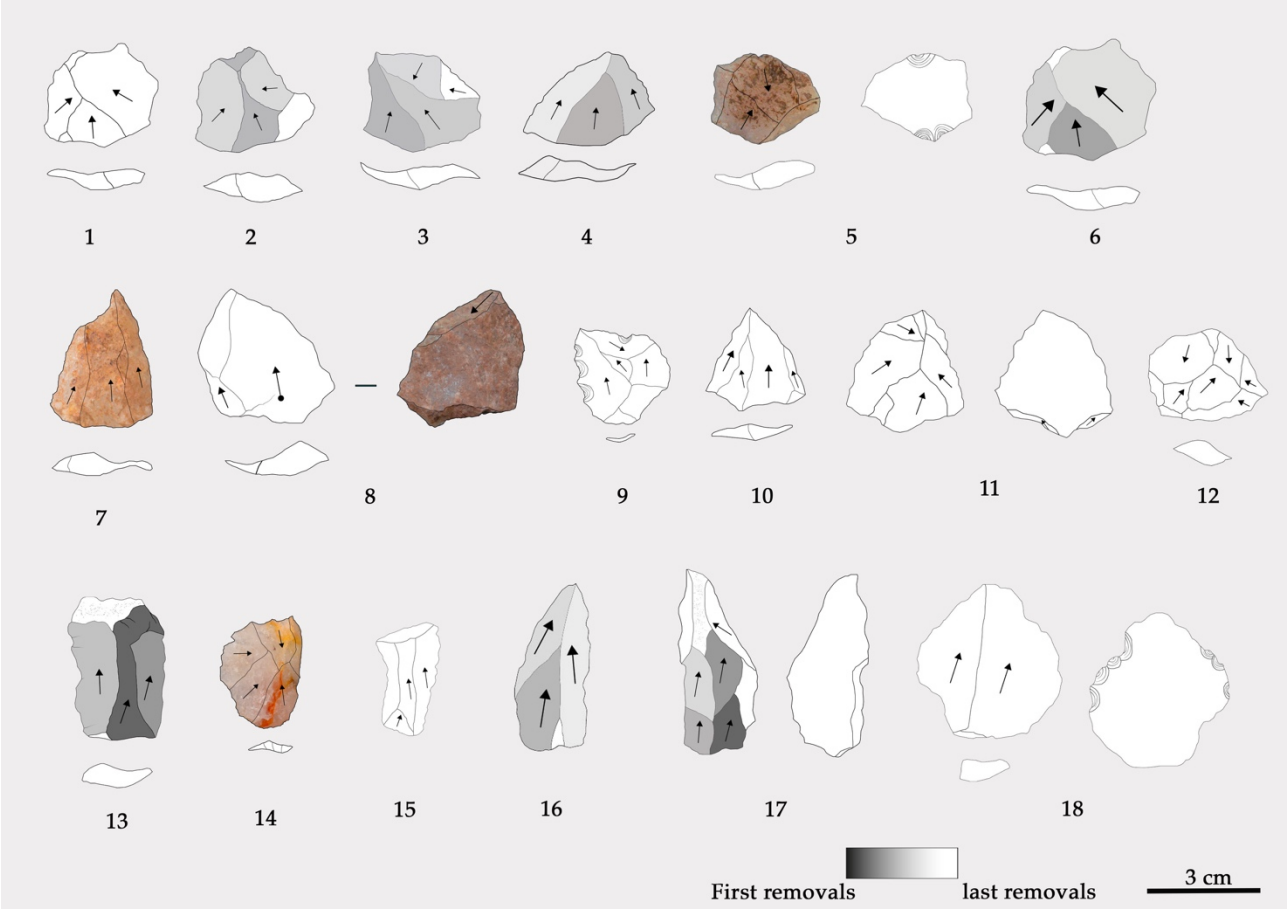


Figure 34: Flakes from the GOT-10 site. Quartz (5, 7-9, 11-12, 14-15); basalt (1-4, 6, 10, 13, 16-18). Levallois flake (1, 2, 5, 6), discoid flake (3, 4), Levallois point (7), Pointed flake (8), denticulate (9), points (10,11), centripetal flake (12, 14), cortical blade (13), bladelet (15, 16), elongated pointed flake (17), retouched flake on ventral face (18).

3.4.7 Bulb and platform analysis

In the analysis of the flake assemblage from the GOT-10 site, a comprehensive examination of platform and bulb morphology has been conducted, encompassing the entire collection of flakes. The identified platform type morphologies include abraded, cortical, dihedral, facetted, linear, plain, and punctiform types.

The analysis reveals a notable predominance of plain platforms, which constitute 70% of the entire assemblage. This pattern holds true across all the raw materials exploited in the site (Appendix 1, supplementary table 10). The second most represented platform type is the dihedral type, making up 14% of the entire assemblage, and this pattern is also consistent across the various raw materials found in the area.

On the other hand, the occurrence of cortical, abraded, and facetted platform types is relatively rare within the assemblage, representing 2%, 0%, and 5% respectively.

To summarize, the analysis indicates a clear predominance of non-prepared (plain) or minimally prepared (dihedral) platform types. This pattern is consistent across different raw materials exploited at the site. The analysis of platforms on retouched flakes exhibits a similar trend, with a majority of plain and dihedral platforms, albeit in lower quantities.

The analysis of platform types from the stratigraphic sequence of Mound 1 aligns with the observations made in the overall lithic assemblage from the GOT-10 site (Appendix 1, supplementary table 11). The predominance of plain platforms remains consistent, constituting 65% of the entire lithic assemblage within Mound 1.

Similarly, the dihedral type continues to be the second most represented platform type, accounting for 16% of the assemblage. This finding confirms the previously identified pattern observed in the entire collection from the GOT-10 site.

In terms of other platform types, the analysis reveals that abraded platforms make up 0% of the assemblage, cortical platforms represent 1%, and facetted platforms account for 7%. This distribution pattern remains consistent for both retouched and unretouched flakes.

The predominance of plain platforms and the consistent representation of dihedral platforms within the stratigraphic sequence of Mound 1 indicate a continued prevalence of non-prepared or minimally prepared platforms throughout the layers of the archaeological site. This suggests a consistent technological approach or preference for these platform types among the human groups at Mound 1.

The analysis of bulbs has been conducted, complementing the study of platforms (Appendix 1, supplementary table 12). This analysis plays a crucial role in understanding the knapping techniques employed in the production of flakes, blanks, and retouched flakes. The GOT-10

lithic assemblage exhibits visible bulbs, along with impact points indicating direct percussion with a hard hammer.
The analysis of bulbs reveals a higher occurrence of flat and normal bulbs for both non-retouched and retouched flakes. Specifically, flat bulbs are present in 38% of the non-retouched flakes and 42% of the retouched flakes. This suggests that a significant proportion of flakes, both retouched and non-retouched, exhibit a flat bulb morphology resulting from the knapping process.
Similarly, normal bulbs are observed in 38% of the non-retouched flakes and 33% of the retouched flakes. The presence of normal bulbs indicates that a substantial number of flakes, both retouched and non-retouched, exhibit a more typical bulb morphology associated with percussion knapping techniques.
Overall, the analysis of bulbs provides insights into the knapping techniques utilized in the production of flakes and retouched flakes.
Among the assemblage collected from the Mound1 stratigraphic sequence, bulb analysis has been conducted as well (Appendix 1, supplementary table 13). The results of the analysis indicate that the majority of the lithics in the assemblage are characterized by flat bulbs, which account for 43% of the total lithics. Following that, normal bulbs are the next most common, representing 37% of the lithics. On the other hand, dihedral bulbs and negative bulbs are much less frequent, making up only 2% and 3% of the assemblage, respectively. Furthermore, the presence of dihedral and negative bulbs is found exclusively on the lithics that show evidence of the bipolar-on-anvil technique.
A distinction has been made between retouched and unretouched flakes. However, the bulb analysis reveals a similar pattern to that of the unretouched flakes, with flat and normal bulbs being the most prevalent.
Overall, this information provides insights into the lithic assemblage from the Mound1 stratigraphic sequence, highlighting the dominance of flat and normal bulbs.

3.4.8 Retouched flakes

The presence of retouched flakes within the whole GOT-10 lithic assemblages is limited or scarce. The classification of retouched flakes in this analysis has been conducted using the typology list for the Lower and Middle Palaeolithic, which was developed by François Bordes in 1966. This typology provides a framework for categorizing and identifying different types of retouched flakes based on their characteristics. Among the retouched flakes identified in the assemblages, the most represented tool types are denticulates and notches. Backed pieces are also present. Backed pieces are tools where one edge of the flake

has been intentionally blunted or truncated, creating a backed or steepened edge. Levallois flakes and point are very underrepresented as well as scrapers.
The information provided gives an overview of the representation of different retouched flake types within the GOT-10 lithic assemblages, highlighting the prevalence of denticulates, notches, and backed pieces as the most common tool types identified through technological analysis.
Retouched flakes at the Mound1 are made on both preparation and production blanks, however, preparation retouched blanks are made exclusively on quartz (Table 22). They are mostly crest bladelets with only one evidence of cortical flake with a denticulation (Table 22).

Mound 1 Retouched tools on preparation blank		
Tool types	**N**	%
SU11	**2**	50%
Cortical flake	1	25%
Denticulate	1	25%
Crest bladelet	1	25%
Irregular retouch internal face	1	25%
SU12	**1**	25%
Crest bladelet	1	25%
Denticulate	1	25%
SU9	**1**	25%
Crest bladelet	1	25%
Denticulate	1	25%
Total	**4**	100%

Table 22: General distribution of retouched flakes made on preparation blanks within the Mound1 stratigraphy made on quartz only.

The number of retouched tools made on production blanks is homogeneous compared to those made on preparation blanks (Table 23). The blanks are mostly ordinary flakes, with only one Levallois centripetal retouched flake. The variability of forma tools here is higher, however the very scanty number of tools make any statistic irrelevant.

Mound 1 retouched tools on production blanks						
	CHERT		**QUARTZ**		**Total**	
Tool type	N	%	N	%	N	%
SU12	**0**	**0%**	**1**	**25%**	**1**	**20%**
Ordinary flake	0	0%	1	25%	1	20%
Denticulate	0	0%	1	25%	1	20%
SU4	**0**	**0%**	**1**	**25%**	**1**	**20%**
Ordinary flake	0	0%	1	25%	1	20%
Single Straight Scraper	0	0%	1	25%	1	20%
SU6	**1**	**100%**	**0**	**0%**	**1**	**20%**
Ordinary flake	1	100%	0	0%	1	20%
Irregular retouch internal face	1	100%	0	0%	1	20%
SU7	**0**	**0%**	**2**	**50%**	**2**	**40%**
Ordinary flake	0	0%	1	25%	1	20%
Notch	0	0%	1	25%	1	20%
Centripetal Levallois recurrent	0	0%	1	25%	1	20%
Levallois retouched flake	0	0%	1	25%	1	20%
Total	**1**	**20%**	**4**	**80%**	**5**	**100%**

Table 23: General distribution of retouched flakes made on production blanks within the Mound1 stratigraphy.

The distribution of retouched flake types is reported to be relatively similar to the general distribution, further confirming that denticulates and notches are the most prevalent retouched flake types across all the archaeological contexts at the GOT-10 site. This consistency suggests a consistent technological pattern or cultural preference for these tool types throughout the site.

Additionally, the analysis reveals the presence of retouched Levallois products within the Mound1 stratigraphy and Scatter1, but they represent only a small proportion of the entire assemblage. This confirms the overall low occurrence of artefacts produced using Levallois methods at the GOT-10 site.

The analysis of retouched flakes show that preparation blanks were more represented than production blanks within the whole GOT-10 assemblage (Table 24 and 25).

Most of the retouched pieces come from debordant flakes on basalt and quartz, used to produce denticulate and backed pieces. The latter are characterized to be a flake with a prominent back derived from the preparation of cores convexities, and then retouched along the thick edge to slightly modify the edge curvature.

GOT-10 site retouched tools on preparation blanks								
	BASALT		**CHERT**		**QUARTZ**		**Total**	
Tool types	N	%	N	%	N	%	N	%
Cluster A	**2**	**50%**	**0**	**0%**	**2**	**22%**	**4**	**29%**
Debordant blade	**2**	**50%**	**0**	**0%**	**1**	**11%**	**3**	**21%**
Backed piece	2	50%	0	0%	1	11%	3	21%
Debordant flake	**0**	**0%**	**0**	**0%**	**1**	**11%**	**1**	**7%**
Backed piece	0	0%	0	0%	1	11%	1	7%
Cluster H	**0**	**0%**	**1**	**100%**	**3**	**11%**	**4**	**29%**
Debordant flake	**0**	**0%**	**0**	**0%**	**3**	**33%**	**3**	**21%**
Backed piece	0	0%	0	0%	2	22%	2	14%
Denticulate	0	0%	0	0%	1	11%	1	7%
Pseudolevallois point	**0**	**0%**	**1**	**100%**	**0**	**0%**	**1**	**7%**
PseudoLevallois Point retouched	0	0%	1	100%	0	0%	1	7%
Cluster L	**0**	**0%**	**0**	**0%**	**0**	**0%**	**2**	**14%**
Debordant blade	**0**	**0%**	**0**	**0%**	**2**	**22%**	**2**	**14%**
Backed piece	0	0%	0	0%	1	11%	1	7%
Denticulate	0	0%	0	0%	1	11%	1	7%
Scatter1	**2**	**50%**	**0**	**0%**	**1**	**11%**	**3**	**21%**
Debordant flake	**2**	**50%**	**0**	**0%**	**1**	**11%**	**3**	**21%**
Single Straight Scraper	2	50%	0	0%	0	0%	2	14%
Denticulate	0	0%	0	0%	1	11%	1	7%
Scatter3	**0**	**0%**	**0**	**0%**	**1**	**11%**	**1**	**7%**
Crest bladelet	**0**	**0%**	**0**	**0%**	**1**	**11%**	**1**	**7%**
Denticulate	0	0%	0	0%	1	11%	1	7%
Total	**4**	**29%**	**1**	**7%**	**9**	**64%**	**14**	**100%**

Table 24: Retouched flakes distribution made on preparation blanks within the GOT-10 site.

Formal tools made on production blanks are made mostly on ordinary flakes, Levallois points, and one ordinary bladelet. Notches and denticulate are again the most desired end products among the GOT-10 assemblage. The analysis of retouched tools in the GOT-10 assemblage appears to reveal a difference in the choice of blanks used for various purposes. For instance, the presence of backed tools exclusively using debordant flakes may indicate opportunistic utilization of forms already obtained during the initial stages of core reduction. These blanks are then employed by modifying the edges in a specific manner taking advantage of the already existing backed edge.

GOT-10 site retouched tools on production blanks						
	BASALT		**QUARTZ**		**Total**	
Tool type	N	%	N	%	N	%
Cluster A	**1**	**25%**	**0**	**0%**	**1**	**17%**
Ordinary flake	**1**	**25%**	**0**	**0%**	**1**	**17%**
Notch	1	25%	0	0%	1	17%
Scatter1	**1**	**25%**	**0**	**0%**	**1**	**17%**
Levallois point	**1**	**25%**	**0**	**0%**	**1**	**17%**
Levallois retouched point	1	25%	0	0%	1	17%
Scatter3	**2**	**50%**	**2**	**100%**	**4**	**67%**
Ordinary flake	**1**	**25%**	**1**	**50%**	**2**	**33%**
Notch	1	25%	0	0%	1	17%
Denticulate	0	0%	1	50%	1	17%
Levallois point	**1**	**25%**	**0**	**0%**	**1**	**17%**
Notch	1	25%	**0**	0%	1	17%
Ordinary bladelet	**0**	**0%**	**1**	**50%**	**1**	**17%**
Notch	**0**	0%	1	50%	1	17%
Total	**4**	**67%**	**2**	**33%**	**6**	**100%**

Table 25: Retouched flakes distribution made on production blanks within the GOT-10 site.

3.4.9 Bipolar on anvil evidence

Bipolar percussion on an anvil is well-documented in the Gotera assemblage (Figure 37). However, it is interesting to note that evidence of this technique is only present in the exploitation of quartz. This could be explained by the natural sizes of quartz pebbles found at Gotera (approximately 3-6 cm in size).

Bipolar on anvil evidence is attested within the Mound 1 stratigraphy exclusively through the presence of negative bulbs and they are more frequent in the SU 6. The most numerous evidence consists of flakes with two bulbs (67%) located in opposite position on the same surface (50%) (Table 26).

	SU10		SU11		SU4		SU6		Total	
Negative bulbs	N	%	N	%	N	%	N	%	N	%
1 Bulb	**0**	**0%**	**0**	**0%**	**1**	**33%**	**2**	**29%**	**3**	**25%**
Single	0	0%	0	0%	1	33%	2	29%	3	25%
2 Bulbs	**1**	**100%**	**1**	**100%**	**1**	**33%**	**5**	**71%**	**8**	**67%**
Opposite different surface	0	0%	0	0%	0	0%	1	14%	1	8%
Opposite same surface	1	100%	1	100%	1	33%	3	43%	6	50%
Orthogonal same surface	0	0%	0	0%	0	0%	1	14%	1	8%
4 Bulbs	**0**	**0%**	**0**	**0%**	**1**	**33%**	**0**	**0%**	**1**	**8%**
Opposite same surface	0	0%	0	0%	1	33%	0	0%	1	8%
Total	**1**	**8%**	**1**	**8%**	**3**	**25%**	**7**	**58%**	**12**	**100%**

Table 26: Bipolar on anvil technique evidence among flakes from the Mound 1 stratigraphy.

All the flakes showing evidence of bipolar on anvil technique has negative bulbs, most of them have two bulbs (62%) and they are opposite located on the same surface. Mound 1, Scatter 2, and Scatter 3 show the most numerous evidence of flakes with bipolar on anvil technique (Appendix 1, supplementary table 14).

Evidence of cores showing traces of the Bipolar technique on anvil is also present at the GOT-10 site, both in the stratigraphy and in the surface contexts (Tables 27). Here the bulbs are negative and among the Mound 1 stratigraphy, most of the evidence of bipolar cores shows two bulbs located opposite on the same surface. However, the evidence of bipolar cores here is very scanty (N=3) (Table 27).

	SU12		SU6		SUZ		Total	
Negative bulbs	N	%	N	%	N	%	N	%
1 Bulb	**0**	**0%**	**0**	**0%**	**1**	**100%**	**1**	33%
Single	0	0%	0	0%	1	100%	1	33%
2 Bulbs	**1**	**100%**	**1**	**100%**	**0**	**0%**	**2**	67%
Opposite same surface	1	100%	1	100%	0	0%	2	67%
Total	**1**	**33%**	**1**	**33%**	**1**	**33%**	**3**	100%

Table 27: Bipolar on anvil technique evidence among cores from the Mound 1 stratigraphy.

Bipolar cores are more numerous, considering the whole GOT-10 lithic assemblage (Appendix 1, supplementary table 15). In this case, most of the bipolar cores show the presence of two negative bulbs (67%) located opposite on the same surface (58%) (Figure 6: 1, 2, 4).

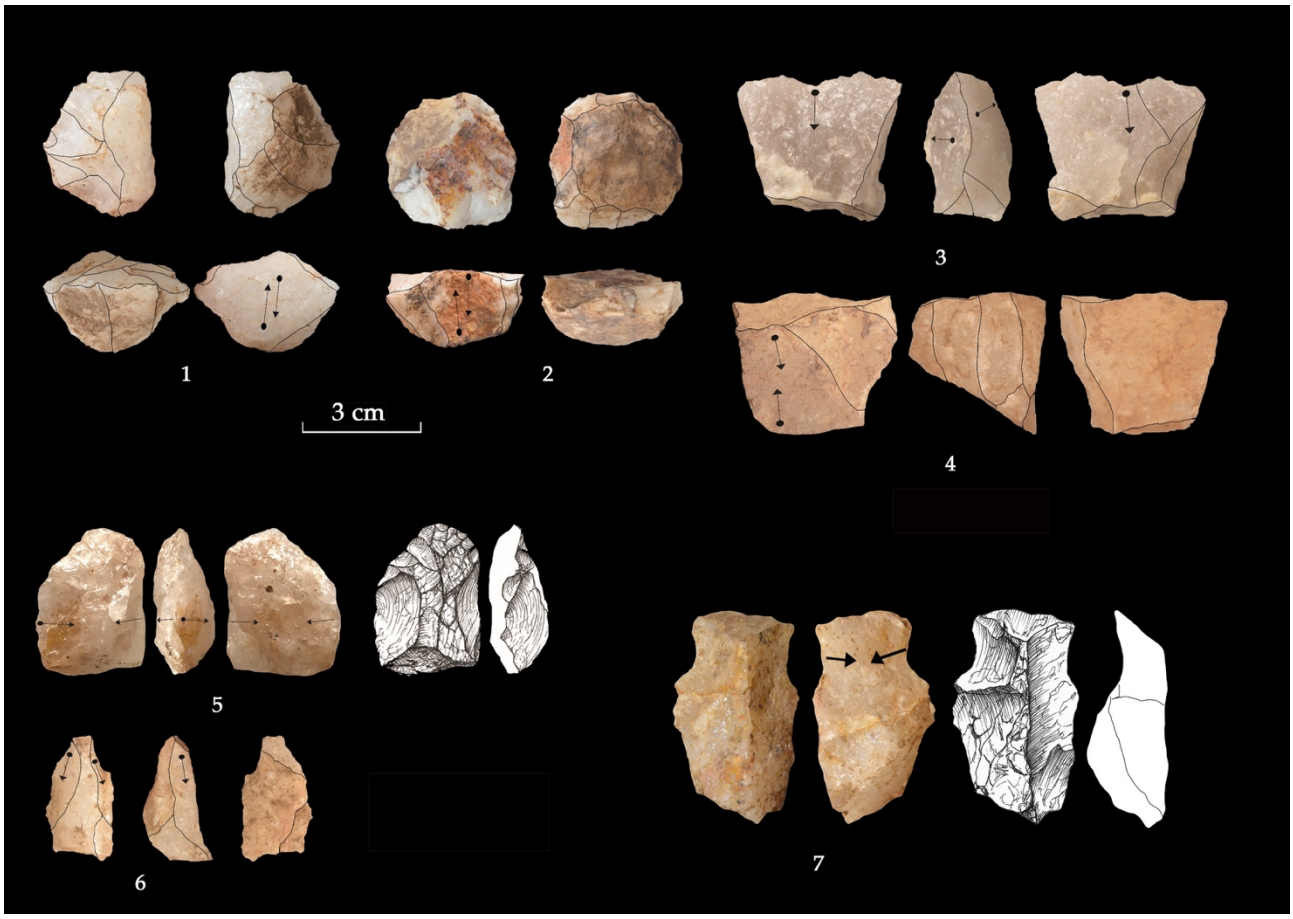


Figure 35: Artefacts from Gotera with Bipolar evidence. Levallois cores (1-2), volumetric bladelet core (4), irregular core (3), flakes (5-7), scaled piece (6) (drawings Dr. M.P. Maiorano).

3.4.10 Chaîne opératoire stages

The analysis of the *chaîne opératoire* stages (following Geneste, 1991), or reduction systems is a fundamental means to understand the presence of different knapping activities within a site, placing all the lithic objects within a technological process.

The analysis of the Mound 1 lithic assemblage shows the presence of procurement, production, exploitation, use and abandon phases. The Mound1 lithics show predominance of abandon phase (37%) due also to the number of broken tools found within the stratigraphic sequence. Abandon phase is followed by production and exploitation (both 29%), while use and procurement are very under-represented within the site, and it is confirmed by the low number of retouched tools and fully cortex flake/blades (Appendix 1, supplementary table 16).

The analysis of reduction stages shows the same pattern with the most represented phases being abandon and production (36%), while exploitation is represented by 24% of the assemblage. The procurement and use phases are the most under-represented, and they

made up respectively 1% and 4% of the whole assemblage (Appendix 1, supplementary table 17).

3.5 Discussion

The technological analysis conducted on the lithic industry from the GOT-10 site has revealed the presence of four distinct reduction strategies. These strategies are determined based on the examination of cores and flakes. Interestingly, these reduction strategies appear to be independent of the choice of raw materials, as they are observed in both quartz and basalt materials, with only one exception which is the use of the bipolar-on-anvil technique only on quartz.

The first reduction strategy involves the utilization of the bipolar-on-anvil technique in conjunction with other freehand debitage methods such as Levallois and laminar techniques. It is important to note that this reduction strategy is exclusively associated with the exploitation of quartz pebbles.

The second reduction strategy is characterized by a planimetric exploitation of raw material blocks, and it is observed in both quartz and basalt materials. This strategy is represented by the presence of Levallois and discoid flakes, which are indicative of specific flake production methods. The third reduction strategy is characterized by an intermediate exploitation of raw materials, encompassing both quartz and basalt. This strategy involves a combination of planimetric and volumetric exploitation of core convexities. It suggests a more versatile approach to core reduction, incorporating different methods depending on the desired outcome. The fourth and final reduction strategy identified is characterized by a volumetric exploitation of cores, resulting in the production of prismatic and cylindrical shape cores. This strategy highlights a distinct approach focused on the creation of specific core forms through volumetric reduction techniques.

Overall, these different reduction strategies provide insights into the variability of lithic production techniques employed at the GOT-10 site, with each strategy reflecting different approaches to raw material exploitation and core reduction, with the interchangeable feature of the production due to the debitage products that are not only exclusively of one reduction system (Figures 38 – 39 - 40).

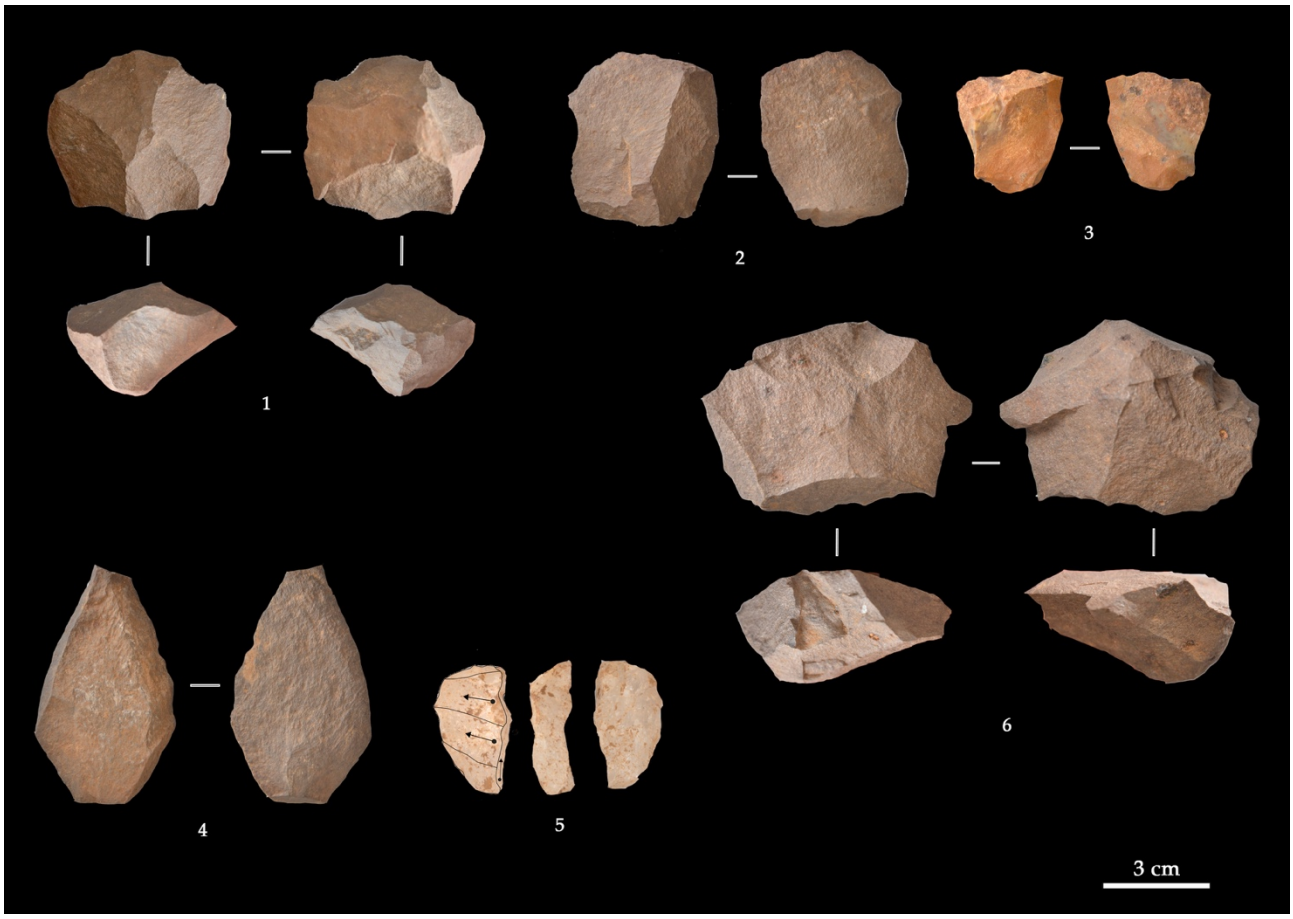


Figure 36: Artefacts from the GOT-10 site. Discoid core (1), ordinary flake on basalt (2), flake on chert (3), basalt point (4), quartz core on flake (5), planimetric core (6).

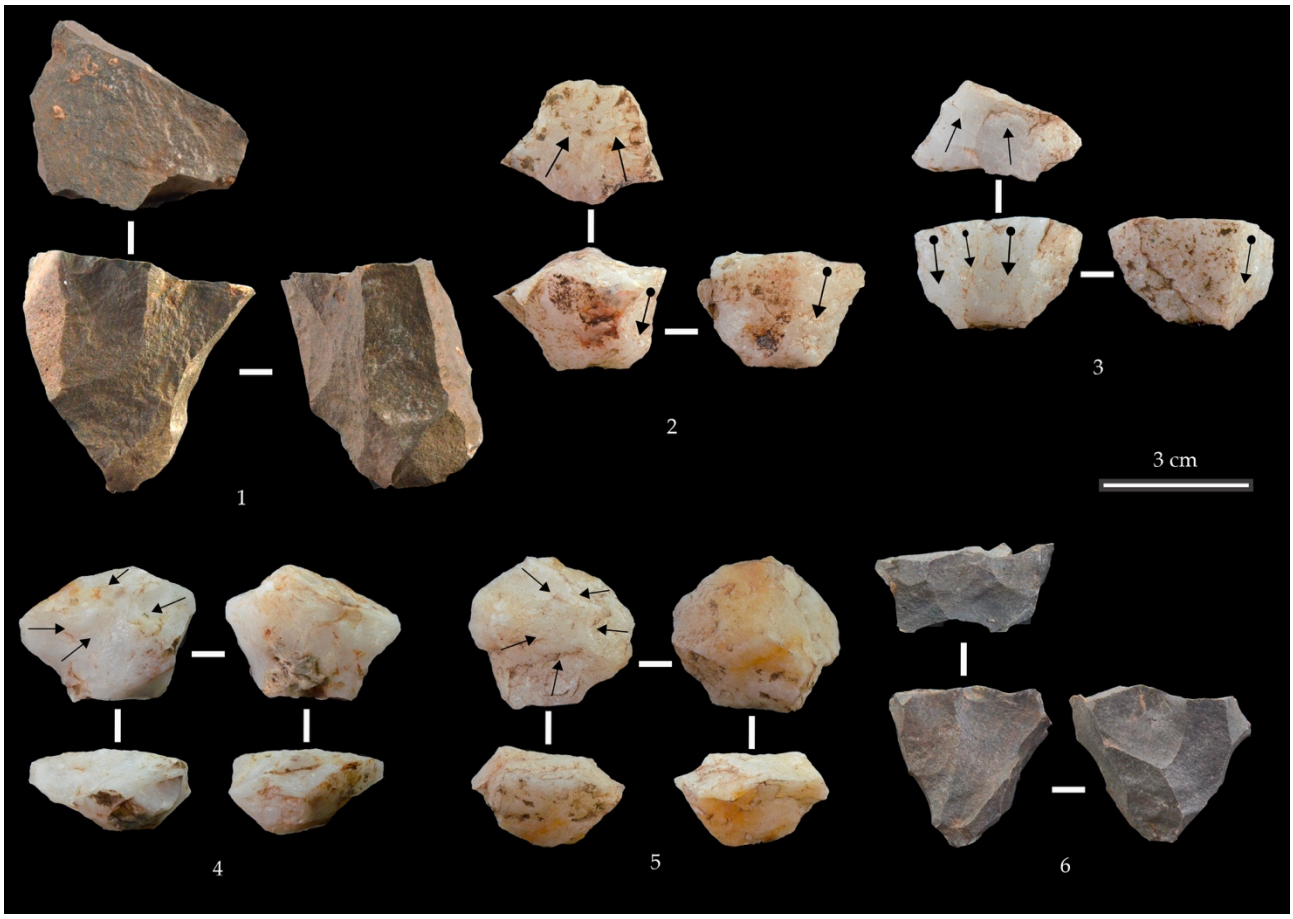


Figure 37: Artefacts from the GOT-10 site. Volumetric triangular core (1), intermediate core on quartz (2), volumetric semi-tournant core on quartz (3), planimetric Levallois core on quartz (4), planimetric discoid core on quartz (5), volumetric triangular core on basalt (double perpendicular platform) (6).

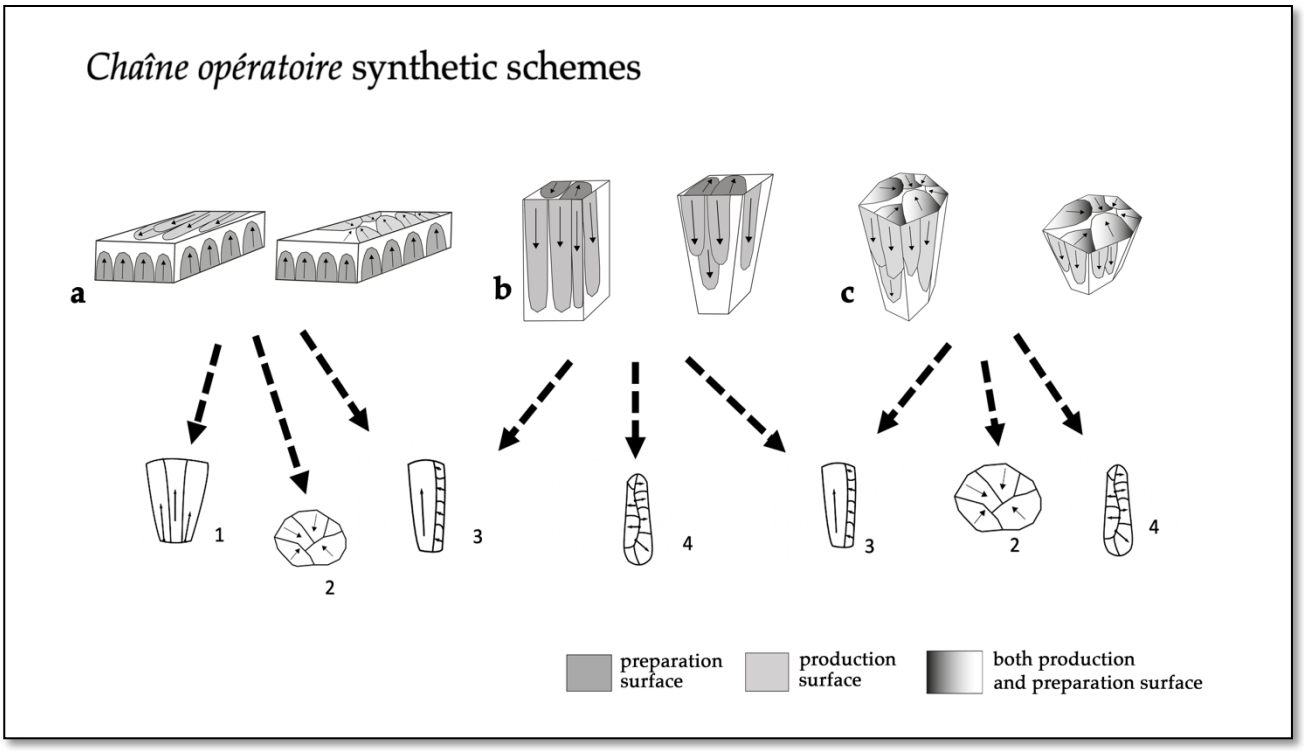


Figure 38: Schematic representations of the reduction sequences found at the GOT-10 site. A: planimetric reduction sequences; B volumetric; C: intermediate. 1: Levallois flakes; 2: centripetal/cordal flakes; 3: debordant flake/blade; 4: crested blade/bladelets.

3.5.1 Bipolar on anvil technique in the GOT10 lithic assemblage

The GOT-10 lithic assemblage shows evidence of the bipolar on-anvil technique. Evidence of this technique is present within the whole reduction process steps, with an emphasis on the initialization of small pebbles and recycling of cores. The bipolar technique at GOT-10 is always employed together with freehand exploitation of raw materials, planimetric (Figure 41) and volumetric (Figure 42). The use of the bipolar on anvil technique together freehand methods has already been found in the African stone age record (Nelson, 1973; Ranhorn et al.in press).

a) Raw materials

This technique is present exclusively for quartz exploitation. This evidence may be due to the small dimensions of quartz pebbles available around the site and within the whole Gotera area. This data is confirmed by the absence of bipolar evidence for basalt exploitation and among bigger quartz elements.

b) Core reduction strategy

The reduction sequence associated with the utilization of the bipolar-on-anvil technique at the GOT-10 site follows several steps. The process begins with the opening of small pebbles using the bipolar technique (Table 28). This technique involves placing a pebble on an anvil and striking it with a hammerstone, causing it to split into two or more halves along a flat plane. At the GOT-10 site, this created split halves that can be further reduced using freehand methods, such as Levallois or Laminar methods. These methods involve carefully removing flakes from the split halves to shape them into desired forms. This step in the reduction sequence allows for more controlled and precise flake production. The cores resulting from the freehand reduction methods are then further reduced according to the main reduction strategies observed at the site: planimetric reduction, which involves shaping the cores in a way that facilitates the production of triangular flakes, points (although rare), and centripetal flakes. This implies the removal of flakes from the surface of the core, resulting in triangular or centripetal-shaped flakes. The volumetric reduction, where the cores are shaped in a manner that allows the production of elongated blanks, involves reducing the core from multiple directions, resulting in elongated flakes or blanks with a more cylindrical or elongated shape. Furthermore, the bipolar on-anvil technique was employed at the GOT-10 site to recycle cores, facilitating the production of flakes through the reuse of cores. The products of this reduction scheme are generally small, with a mean length for flakes and blades of 3 cm and for bladelets of 2.7 cm (Table 28).

Bipolar on anvil							
		length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Flakes	81	32.88	9.60	25.40	6.91	12.61	4.42
Blades	7	33.93	9.59	20.86	4.04	10.69	2.00
Bladelets	4	27.60	6.21	14.21	1.85	6.86	0.86

Table 28: Distribution of blanks dimensions for the Bipolar on Anvil reduction system

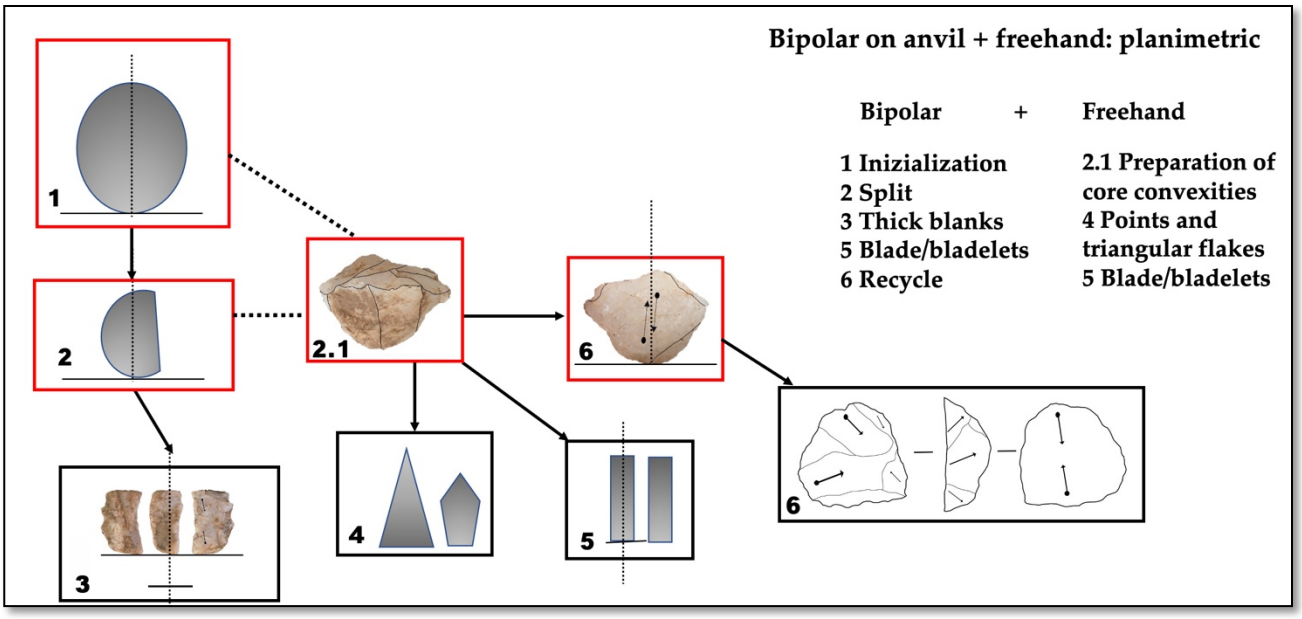


Figure 39: Operational schema of the use of bipolar-on-anvil technique in combination with planimetric exploitations.

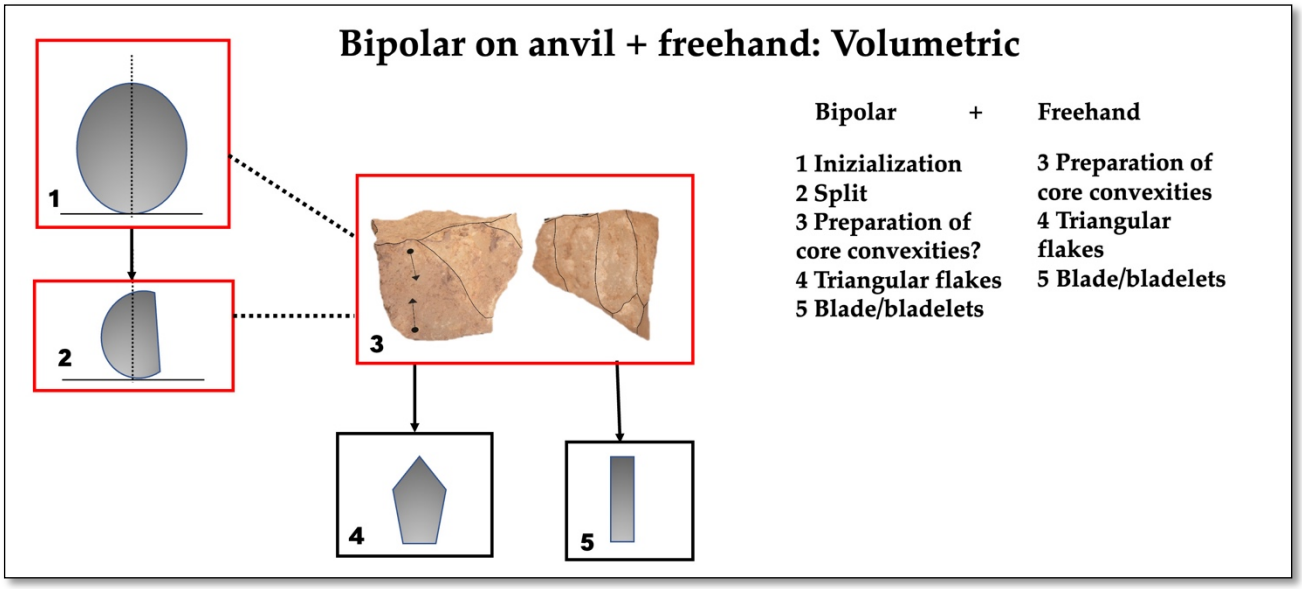


Figure 40: Operational schema of the use of bipolar-on-anvil technique in combination with volumetric exploitations.

3.5.2 Planimetric exploitation in the GOT10 lithic assemblage

The GOT-10 lithic assemblage shows strong evidence of planimetric exploitation of raw materials. Evidence of this reduction strategy is present both in quartz and basalt. This reduction strategy has been identified through the analysis of core reduction and its products.

The analysis reveals clear indications of planimetric exploitation of raw materials. This reduction strategy is observed in both quartz and basalt materials, suggesting its widespread use across the site.

The planimetric reduction strategy is based upon a specific debitage concept in which there is a two-dimensional core organization with one or few flakes of predetermined shapes produced from a single plane of intersection. At GOT-10 site, Levallois and discoid methods are included in this *débitage* concept.

The presence of planimetric reduction can be inferred from several characteristics observed in the lithic assemblage. These include the presence of triangular flakes, points (although rare), and centripetal flakes. These types of blanks are indicative of a reduction strategy that involves removing flakes from the surface of a core, resulting in flat or planar flakes with specific shapes. For the striking platform preparation, debordant flakes, as well as cordal flakes were removed to prepare the debitage plain.

The evidence of planimetric exploitation being present on both quartz and basalt materials suggests that this reduction strategy was not dependent on the raw material type but rather on the intended product, the desired shape of the flakes or the tools being produced.

a) Blank morphology

At the GOT-10 site, the planimetric conception of core reduction is primarily focused on the production of triangular and hexagonal flakes. These flakes exhibit a unipolar convergent and centripetal negatives organization, indicating a deliberate shaping of the flakes to achieve specific forms.

One of the main objectives of the planimetric reduction at the site was to produce ordinary flakes that have a plain platform. This means that the flakes were intentionally detached from cores without low preparation or modification of the platform area.

Regarding Levallois products, only a few Levallois flakes, *sensu stricto* (following Boëda, 1995), have been identified within the assemblage. The limited presence of these flakes despite the use of planimetric conception, indicates a minor utilization of this method at the site. However, it is worth noting that the majority of planimetric products identified at the site can be categorized within a specific technological variability of the African Middle Stone Age (MSA) Levallois, where lateral and distal convexities are often less prepared in comparison to the classic morphological definition of the European Middle Palaeolithic Levallois (Boëda, 1995). This "variant" is also aimed to produce predetermined blanks with a certain morphology, but it does take more advantage of the natural convexities of the

available raw materials. This suggests the need for further exploration and investigation to better understand this technological variability within the African MSA context in order to understand and categorize the Levallois methods in Africa.

The exploitation of discoid technology within the assemblage is characterized by both bifacial and unifacial flaking. At GOT-10 site, the discoid technology is recognised by the presence of blanks detached from a core having two asymmetric, secant and convex surfaces that define the plane of intersection, that is not hierarchical. Moreover, the reduction of the cores and the production of blanks is made with the striking platform oriented in the way that the two planes of intersection are perpendicular to the edge of the cores. Discoid products are represented in the assemblage. These products are characterized by a significant number of centripetal flakes, which exhibit plain and/or dihedral platforms, with wide platform angles. Moreover, cordal flakes, mostly on basalt, are present in the assemblage. These types of flakes are related to a specific discoid reduction that contributes to create a certain technological variability within the planimetric reduction concept at Gotera (Figure 43). Basalt flakes are slightly larger than quartz flakes (Table 29).

Planimetric flakes							
		length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Basalt	20	35.42	8.90	24.86	5.94	8.24	5.19
Quartz	50	29.60	6.74	24.28	5.63	24.28	5.63

Table 29: Distribution of blanks dimensions for the planimetric reduction systems

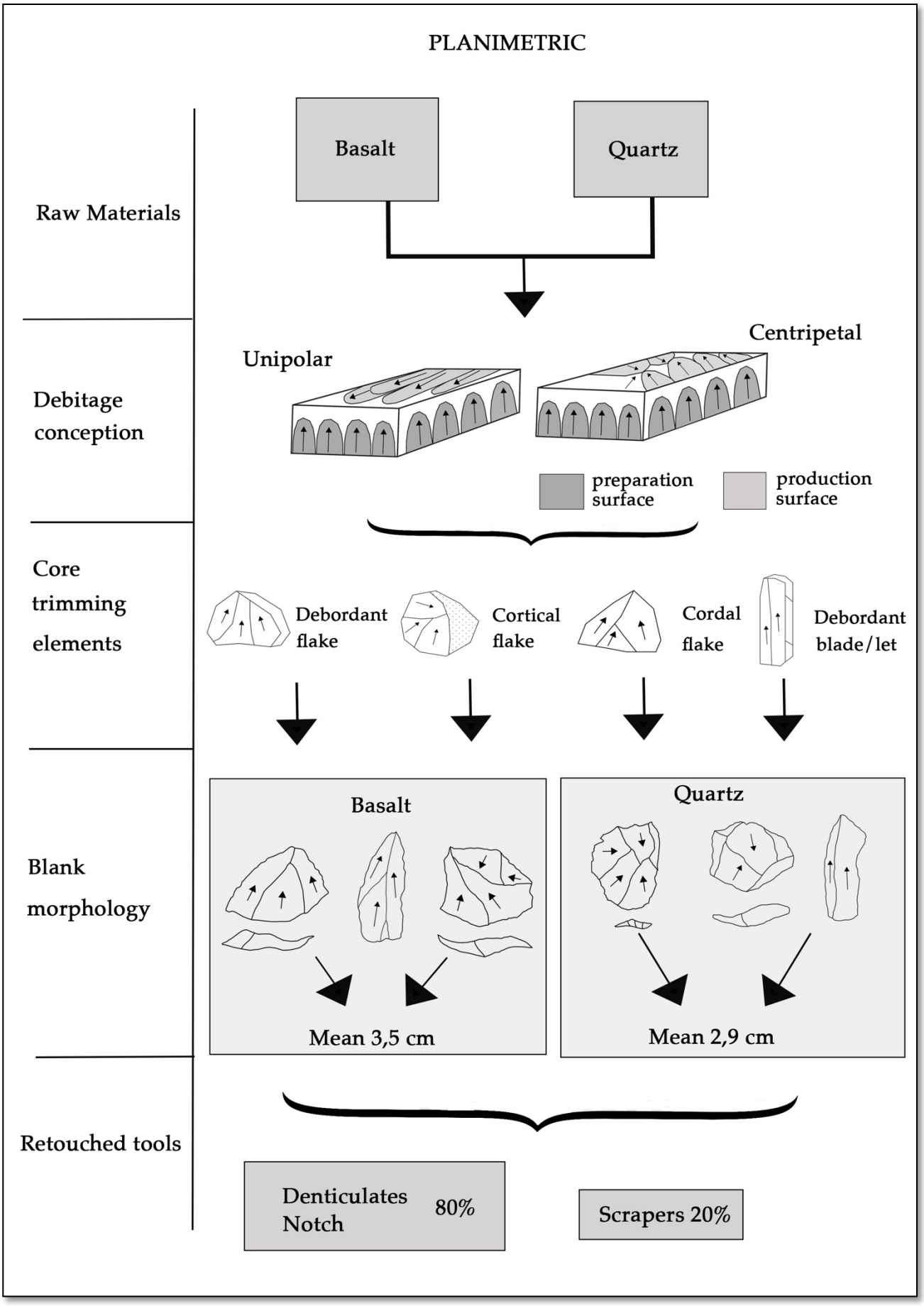


Figure 41: Schema of the debitage planimetric conception.

3.5.3 Volumetric exploitation in the GOT10 lithic assemblage

The GOT-10 lithic assemblage shows strong evidence of volumetric exploitation of raw materials. Evidence of this reduction strategy is present both in quartz and basalt and has been identified through the analysis of core reduction and its products.

The volumetric debitage conception can be summarized as follows: it involves a three-dimensional core organization with a very convex production surface that allows the continuous production of elongated blanks. There is an active surface of the core from which blanks are struck off, extending along most of the periphery of the cores, and they are not limited to one defined surface (Delagnes and Meignen, 2007).

Volumetric débitage systems show substantial technological variability, expressed by the core morphology (semi-rotating, rotating, prismatic, etc.) as well as by the number of striking platforms (one or two opposed).

The GOT-10 lithic assemblage is characterized by the presence of cylindrical, *semi-tournant* and triangular cores, which follows within the volumetric debitage conception. These cores were minimally prepared before the detachment of flakes, mostly elongated (blades and bladelets). Volumetric cores at the GOT-10 site are principally characterised by cores with no more than five or six detachment, and are mostly of tertiary secondary or tertiary exploitation.

The assemblage is composed of preparation stage elements such as elongated debordant flakes as well as crested blades and bladelets. In addition, ordinary blade and bladelets are present which are present as results of the volume exploitation of cores.

a) Blank morphology

At the GOT-10 site, the volumetric conception of core reduction primarily emphasizes the production of elongated blanks, specifically blades, and bladelets. These elongated blanks typically display a unipolar negative organization, although bipolar negatives are observed very rarely.

One of the key objectives of the volumetric reduction strategy employed at the site was to generate ordinary blades and bladelets This implies that the flakes were intentionally detached from the cores without extensive preparation or modification of the striking platform area.

The results of this approach in the lithic assemblage at the GOT-10 site primarily consists of elongated blades and bladelets. These artefacts were produced through the deliberate

detachment of flakes from cores without significant modification of the striking platform areas, resulting in the desired plain platforms and flat bulbs characteristic of the volumetric reduction strategy at the site (Figure 44).

Blank dimensions are characterised by slightly larger value for basalt flakes and blades while bladelet dimension are homogeneous both for quartz and basalt (Table 30).

Volumetric Flakes							
		length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Basalt	15	45.11	16.48	25.52	9.83	11.62	7.71
Quartz	11	29.75	8.19	20.91	7.06	8.63	2.86
Volumetric blade							
		length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Basalt	29	42.71	11.63	19.80	3.81	9.30	3.66
Quartz	23	36.24	6.86	19.64	3.37	9.87	2.80
Volumetric bladelet							
		length		**breadth**		**thickness**	
	N	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Basalt	52	26.95	7.67	12.30	3.30	4.88	1.88
Quartz	78	26.77	6.42	13.31	3.29	6.29	2.13

Table 30: Distribution of blanks dimensions for the volumetric reduction system

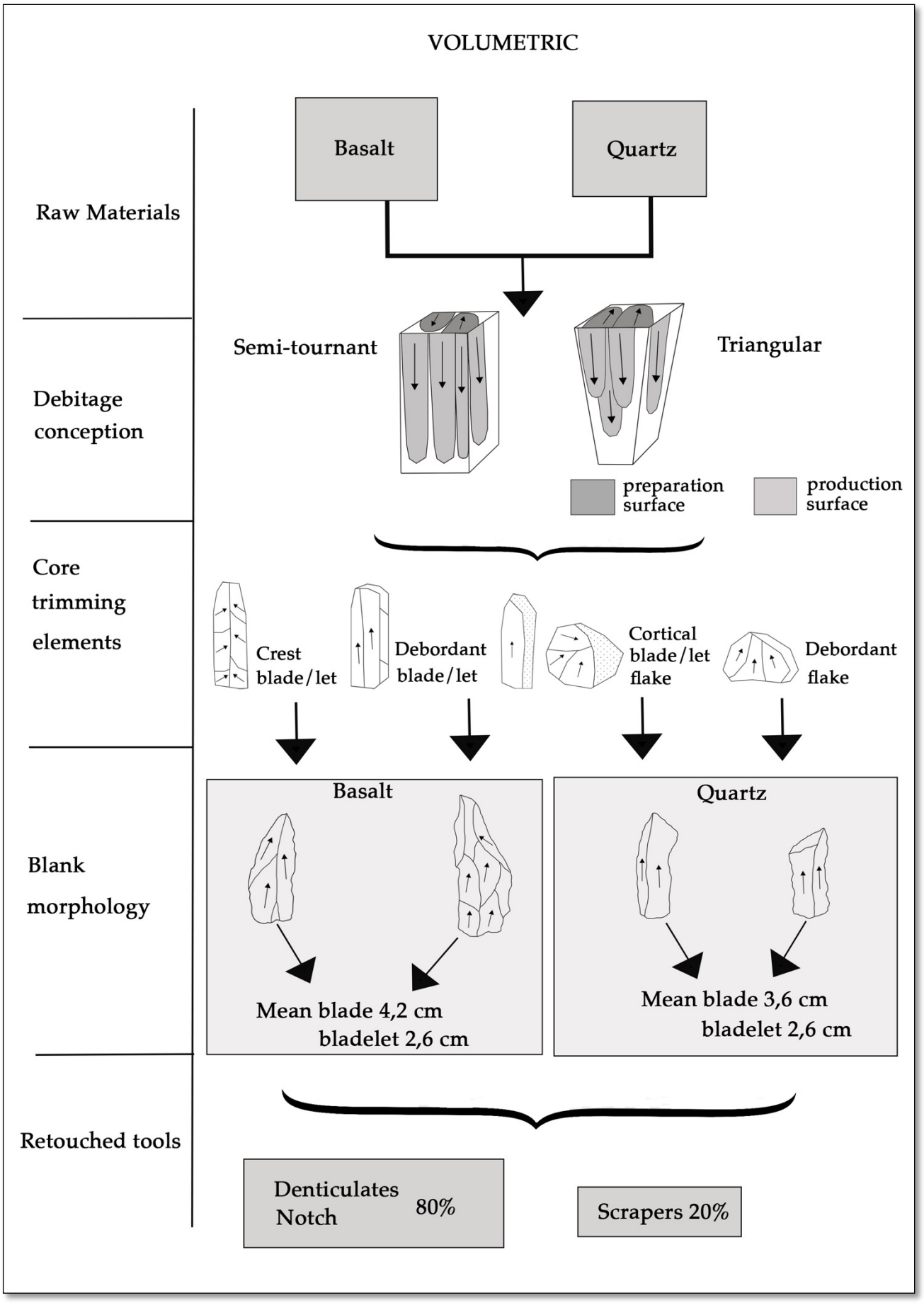


Figure 42: Schema of the debitage volumetric conception.

3.5.4 Intermediate exploitation in the GOT10 lithic assemblage

Interestingly, at the GOT-10 site, an intermediate reduction system has been identified, through the analysis of cores and blanks. This reduction system involves both basalt and quartz exploitation. It is characterized by a mixed volumetric and planimetric exploitation of cores. This conception results in a specific core morphology in which a planimetric striking platform (mostly centripetal) and volumetric three-dimensional convex surface are both used for flakes and elongated blanks production.
Intermediate cores are suited for centripetal planimetric products and elongated production. Generally, the cores are minimally prepared, with 2 or 3 detachments on the planimetric surface as well as on the volumetric surface.
Core trimming elements such as cordal flakes, but also debordant and crest blade and bladelets are correlated with this approach.

a) Blank morphology

The intermediate reduction system at GOT-10 site aims to produce both centripetal flakes and elongated blanks, resulting from the mixed planimetric and volumetric exploitation of cores. However, also crest blade and bladelets are present, as well as cordal flakes, resulting from the core reduction (both for the striking platform and the preparation surface).
Centripetal flakes, as well as elongated blanks (blade and bladelets) are the products of this conception (Figure 45).

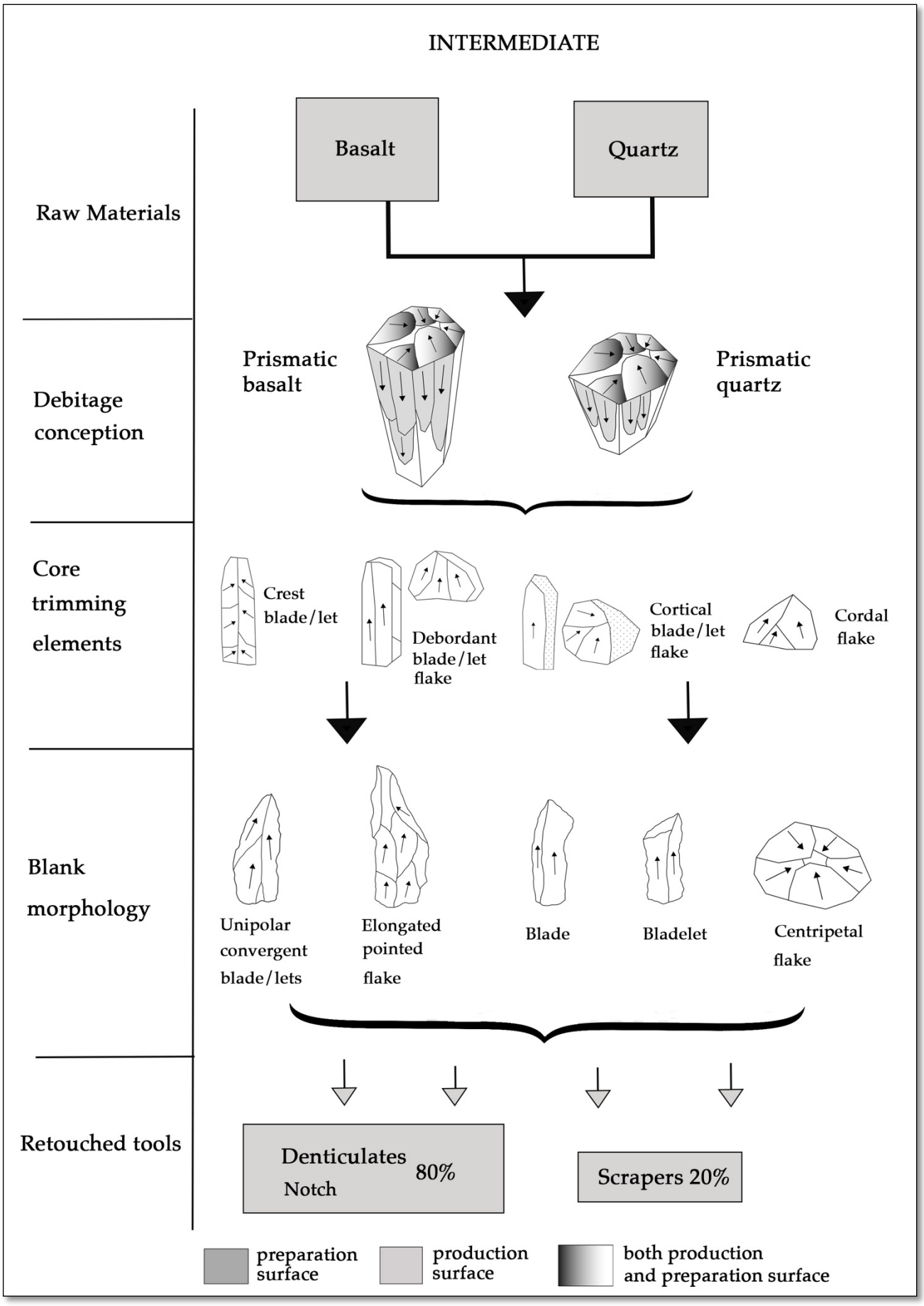


Figure 43: Schema of the debitage intermediate conception.

3.6 Intra-site comparative analysis of the GOT-10 lithic assemblages

In order to understand the relationships between surface assemblage (clusters and scatters) and those coming from the archaeological deposit, and to understand how many human occupations are reflected in the technological variability of the GOT-10 site, a comparative statistical analysis at the intra-site level has been conducted. Materials from the surface can be in fact the result of erosional processes that affected multiple layers (thus, different occupations and chronologies), while the Mound 1 archaeological deposit is probably referred to as a single occupation event. The result of this analysis allows us to determine whether lithic industries belong to a single techno-complex (and therefore can potentially be considered contemporaneous) or if technological differences suggest that they belong to different occupational periods, distinct groups, etc. Results from the analysis of lithics from *in situ* (Mound 1) and lithics from scatters (1, 2, 3, and 4) and clusters (A, H, L, M) can be compared in order to establish if there is a technological correlation and determine whether the GOT-10 assemblage is a single, whole techno complex.

3.7 Materials and methods of the intra-site comparative analysis

The comparative analysis was conducted using multivariate statistical methods. All the analyses were performed using the RStudio software (R Core Team 2023). The lithic assemblages from the GOT-10 site were divided into different groups based on their provenance:

1st group: lithics from the Mound 1 stratigraphic sequence divided by Sus.

2nd group: the clusters found at GOT-10 site (A, H, L, M).

3rd group: the scatters from the GOT-10 site (1,2,3,4).

Therefore, a further division of the assemblage was done based on the technological categorisation of artefacts: flakes and cores. This division was necessary to perform the analysis grouping the same class of artefact.

The methodology here applied for the comparative intra-site analysis consists of an attribute-based statistical approach that combines two quantitative and qualitative multivariate analyses: Principal Component Analysis (PCA) and Correspondence Analysis (CA). Numerical variables were analysed using PCA, while the analysis of categorical variables was performed using CA. These methods, when used in combination, have previously been applied to the analysis of lithic attributes, and are proven to generate insightful results for data comparison (Fusco et al. 2021; Scerri et al. 2014; 2016; Pargeter et al. 2023).

The reason for the selection of CA for categorical variables is that this technique is used to explore the relationships between categories of two or more qualitative variables (nominal or ordinal). The principal aims is to identify patterns of association between the categories of the analysed variables. It uses measures of similarity or dissimilarity between categories to build a structure of correspondences among them. The CA focuses on qualitative variables, it explores relationships between categories of qualitative variables, and it uses measures of association or dissimilarity between categories. Thus for the purpose of this thesis it is useful not only to identify pattern of similarities, like for example the Cluster Analayis, but also to identify differences within the dataset.

The reason why PCA was chosen as the statistical analysis of attributes on lithic industries is essentially the need to identify the main patterns of variation in the datasets. The PCA is a multivariate technique that aids in exploring specific patterns within the data, reducing a complex set of data to a smaller number of variables (components) for analysis. The principal components extracted from PCA can be interpreted as directions in the "variable space" that explain the maximum variance in the data. In fact, by examining the principal components and their corresponding loadings (weights), analysts can understand which variables contribute most to the variability in the data and how they are related to each other. This can help identify hidden relationships or trends in the data. Additionally, PCA is an analysis that reduces the dimensionality and complexity of the data while retaining the most significant information, which is very useful when analyzing datasets with a large number of variables. By reducing dimensionality, PCA facilitates data visualization in a two- or three-dimensional space, helping to better understand the data structure and the relationships between them.

This method has been chosen in order to explore the pattern of the lithic assemblages from Gotera, following the null hypothesis of substantial differences within the data. The reason behind the selction of this statistical analysis

A PCA on flakes has been performed, considering the number of flakes as cases and comprising values for six attributes (Table 31). Since "Raw Material" is not a quantitative attribute, I employed the function *as.factor*() from the R *Base* package to treat it as a categorical variable. This was done to prevent it from influencing the result and to use it for grouping the outcome.

Within the framework of the PCA, I extracted components using the R function *prcomp*() from the *FactoMineR* package (Lê et al. 2008), employing singular value decomposition of the rectangular data matrix. Before running the function, I standardized the values. This involves extracting vectors using a correlation matrix. The correlation matrix is the preferable choice when the variables are measured in different units and are deemed equally

important. In contrast, the covariance matrix would have retained the units of measurement and the differences in variance among the variables. Furthermore, when using the covariance matrix, the variables should have comparable variances; if not, the larger ones would dominate the results.
Before running the PCA, the function *scale()* from the *Base* R package has been used. This function allows the standardisation of the different datasets from the dimension point of view. Standardization is important in PCA because it ensures that all variables have the same scale and weight, preventing variables with larger ranges from dominating the analysis.

Flakes Analysis	
Technological Length	XTL
Technological Breadth	XTB
Maximum Thickness	XT
Elongation Index	EI
Flattening Index	FI
Number of scars	FR
Platform Thickness	PT
Platform Width	PW

Table 31:Variables used for PCA on flakes.

To perform the PCA on cores, I considered the number of cores as cases and comprising values for nine attributes (Table 32): five technological and four morphological.
Again, raw material was not considered as an active quantitative variable, as it could disrupt the results, thus it was considered a categorical variable using the function *as.factor()*. In order to describe size and shape, length, width, elongation index and thickness were considered.
The number of technological and morphological striking platforms and the number of major flakes detached from the core are two useful variables to investigate the process of reduction, thus they were considered into the analysis (Table 32).

Core Analysis	
Maximum Length	XTL
Maximum Breadth	XTB
Maximum Thickness	XT
Elongation index	EI
Flattening Index	FI
Number of Striking Platform (morphological)	NSP
Number of Striking Platform (technological)	NTSP
Number of negatives	CNFS

Table 32: Variables used for the PCA on cores.

To elaborate the PCA plots for blanks, cores, and retouched tools, indicating artefacts as specific cases along with the direction of variables on the principal components, grouped by site, the *fviz_pca_biplot()* function from the *FactoMineR* package was used.

Categorical variables for flakes and cores were explored using Correspondence Analysis (CA). In a similar way to the PCA, this multivariate analysis is an effective tool for summarising categorical data in a reduced number of dimensions. For the CA performed on flakes, four active categorical variables (percentage of cortex, platform type, dorsal scar pattern, bipolar on anvil presence), and two supplementary categorical variables (sites and raw materials) were considered (Table 33). The same variables have been considered also for the analysis of elongated blanks. For the core analysis (Table 34), five active categorical variables (percentage of cortex, core type, flake scar direction, degree of core reduction, and bipolar on anvil) and two supplementary variables (sites and raw materials) were considered.

Variables used in the CA for Flakes			
Active qualitative variables			
Cortex		Percentage of cortex	0 - 100%
Platform type		Abraded	PL_AB
		Cortical	PL_CTX
		Dihedral	PL_DH
		Facetted	PL_FC
		Linear	PL_LIN
		Plain	PL_PLA
		Punctiform	PL_PUN
		Missing	PL_MIS
Direction of scars pattern		Cortical	DSP_CTX
		Unipolar	DSP_UNI
		Unipolar Convergent	DSP_UNIC
		Bipolar	DSP_BIP
		Centripetal	DSP_CEN
		Bipolar on anvil	BIP
		Not visibile	N/A
Active supplementary variables			
Site			Moun1 SU6
			Mound1 SU7
			Scatter 1
			Scatter 2
			Scatter 3
			Scatter 4
			Cluste A
			Cluste H
			Cluster L
			Cluster M
Raw Materials		Basalt and quartz	BAS/QUA

Table 33: Variables used for the CA on flakes.

Variables used in the CA for cores			
Active qualitative variables			
Cortex		Percentage of cortex	0 - 100%
Core Type		Levallois Preferential	L_PREF_CL
		Levallois Preferential bipolar	L_PREF_BIP
		Levallois Recurrent bipolar	L_REC_BIP
		Levallois Recurrent unipolar	L_REC_UNI
		Levallois Recurrent centripetal	L_REC_CEN
		Polyhedral	POLY
		Triangular	TRIANG
		Core on flake	CORE_FL
		Disc	DISC
Flake Scar Direction		Bidirectional	BID
		Bidirectional Irregular	BID_IRR
		Centripetal	CENT
		Convergent	CONV
		Multidirectional	MULT
		Unidirectional	UNID
Degree of Core reduction		Primary	PRIM
		Secondary	SEC
		Tertiary	TER
		Exhausted	EXHA
Active supplementary variables			
Site			Mound1 SU6
			Mound1 SU7
			Scatter 1
			Scatter 2
			Scatter 3
			Scatter 4
			Cluster A
			Cluster H
			Cluster L
			Cluster M
Raw materials		Basalt and Quartz	BAS/QUA

Table 34: Variables used for the CA on cores.

CA was carried out using RStudio v. 1.4.1103 (R Core Team 2021), while the *FactoMineR* and *Factoshiny* packages (Vaissie et al. 2023) were used to conduct the analyses on flakes and cores, using the *CAshiny*() function. The selection of categorical variables was based on the traditional parameters used in lithic attribute analysis, along with the results of experimental studies and analyses already conducted on lithic assemblages (Fusco et al. 2021; Scerri 2016; Scerri et al. 2014). All the graphs were generated using the *ggplot2* package (Wickham 2016) and the *FactoMineR* package.

3.8 Results of the intra-site statistical comparative analysis

The results of the PCA performed on the unretouched flakes from the GOT-10 lithic assemblage are shown in Figure 46, a biplot that illustrates both individuals and variables on a single graph. The first two components of the PCA explain 67% of the overall variance. The primary variables influencing the first dimension include technological measurements such as maximum length, breadth, and thickness. The second dimension is most impacted by two indices: elongation and flattening. Given the positive scores of the loadings, moving upwards along the first two components corresponds to an increase in artefact size, platform angle, and longitudinal curvature from the platform. The results show that there is no clear pattern of differentiation between the contexts analysed at the GOT-10 site.

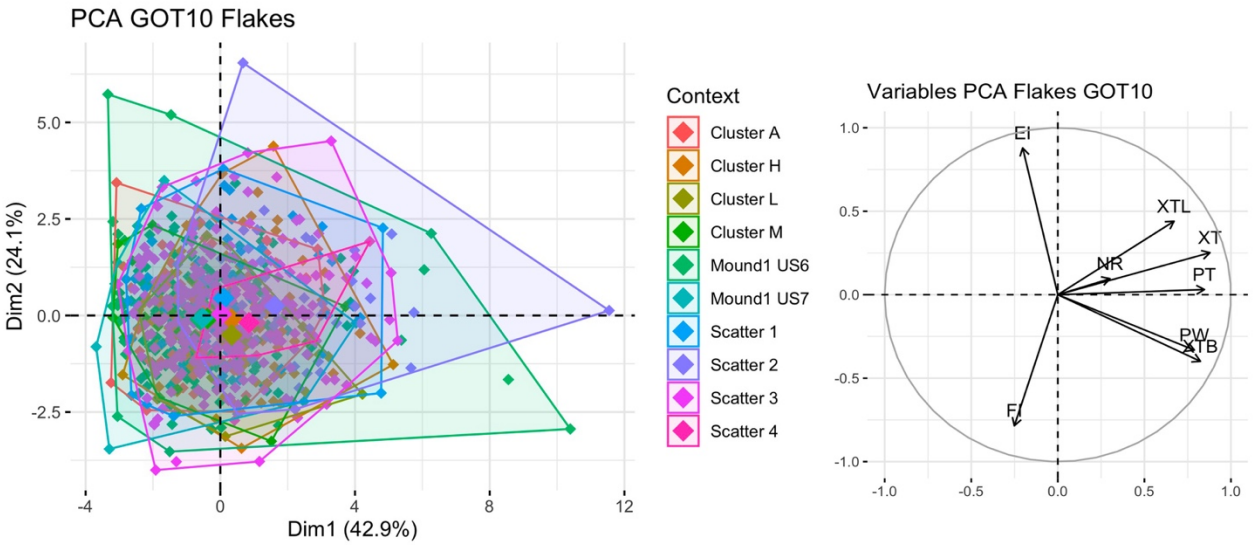


Figure 44: Plot with results of the PCA analysis on unretouched flakes from the GOT-10 site (left). Plot with variable directions (right).

The results are clearer for the PCA grouped by unretouched blanks in which flakes, blades, and bladelets are grouped according to their respective classifications (Figure 47). Thus,

there is no specific pattern of difference among blade, bladelets and flakes within scatters, clusters and the Mound1 at GOT-10 site.

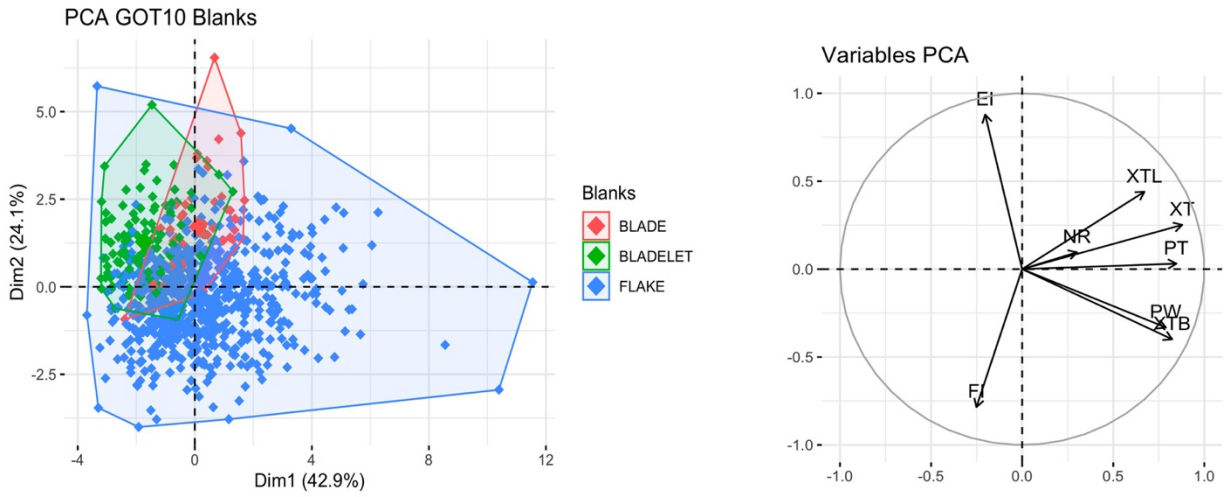


Figure 45: Plot showing results of the PCA analysis on unretouched blanks from GOT-10 site grouped by type of blank (left). Plot showing the variables direction (right)

The PCA for cores (Figure 48) shows the same pattern, demonstrating that there is no evidence for technological change within the lithic assemblage of the GOT-10 site.
The analysis of cores and unretouched blanks confirms the homogeneity of the technology and the integrity of the assemblages.

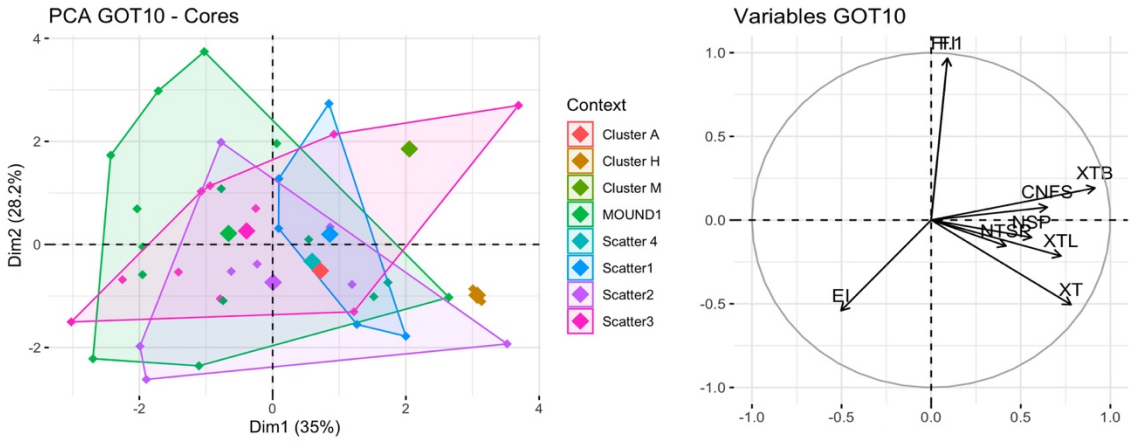


Figure 46: Plot with the results of the PCA on cores showing individuals (left) and variables (right).

Correspondence analysis (CA) of the GOT-10 flakes accounts for a total of 72.41% of the overall variance (Figure 49). In the first dimension, the majority of the data are clustered,

suggesting no significant differences between Mound 1, the Clusters, and Scatters 3 and 4. This dimension captures variables relating to raw materials, which are present uniformly across all assemblages, but also platform morphology and cortex percentages. The complete absence of cortex, the prevalence of plain platforms, and the centripetal and unipolar convergent scar patterns seem to be common across all contexts of the GOT-10 site. However, Mound 1 exhibits a higher presence of prepared platforms, such as facetted and dihedral types, which seems to account for some observed differences. Nevertheless, it does not deviate significantly from the cluster set. On the other hand, the second dimension captures the cortex percentage, which is higher at Scatters 1 and 2, as well as the orientation of unipolar negatives. Some degree of difference can probably be explained by the numerical heterogeneity of the assemblages; however, the overall pattern still shows a strong coherency.

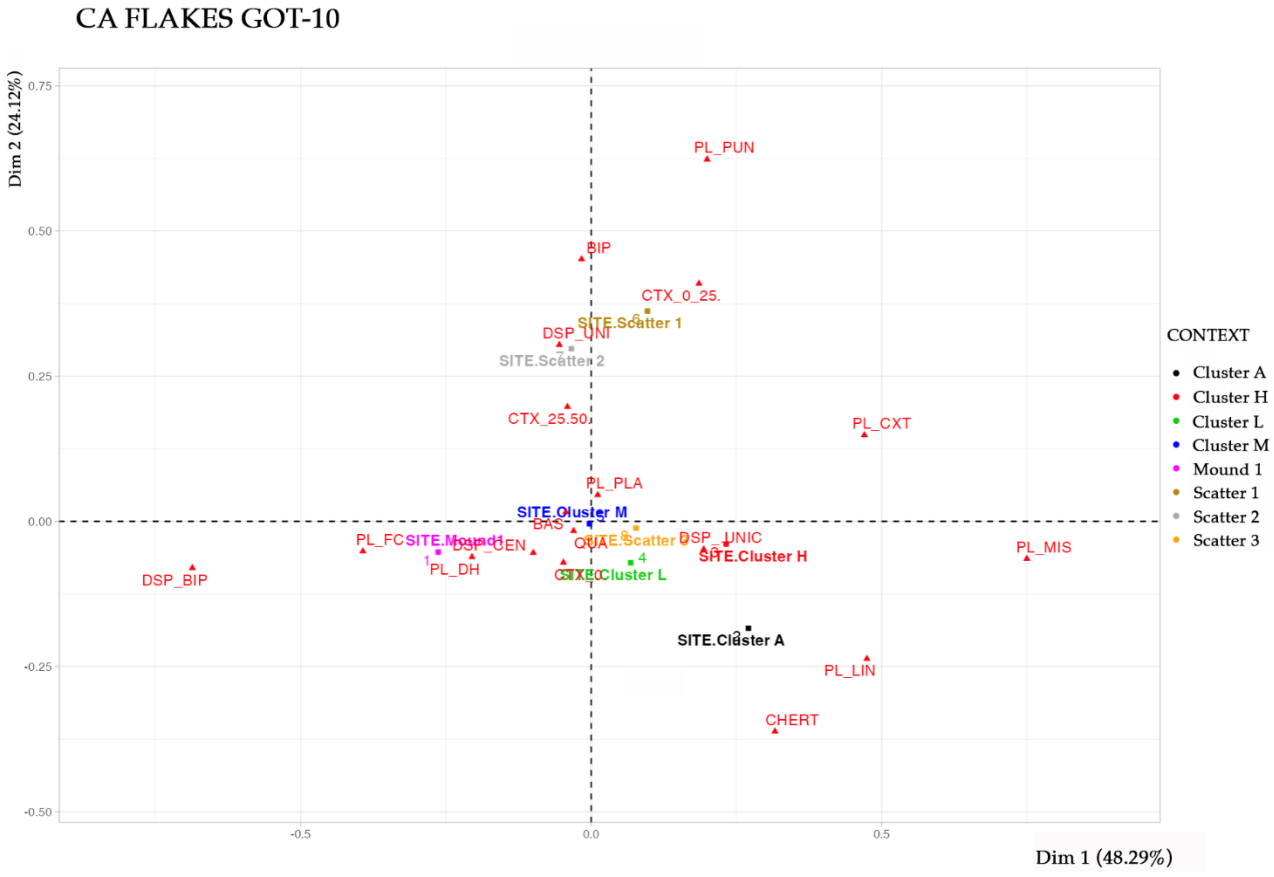


Figure 47: Plot showing the results of the CA on unretouched blanks from the GOT-10 site.

The qualitative variables analysed for GOT-10 cores show a similar pattern (Figure 50). In this case, the CA captures 64.65% of the total variance of the entire core assemblage. The first dimension, which accounts for 48.19%, reflects raw materials, once again uniformly present across all assemblages. Mound 1 cores are primarily regular (preferential Levallois,

discoid) and characterized by the absence of cortex; these are, in fact, tertiary cores. This data point aligns with Cluster H and Scatter 3, which also include some irregular cores. Slight deviations are observed in the data derived from Scatter 1, Cluster A, and M. However, it is important to reemphasize that most of the results are concentrated on the first dimension of the CA.

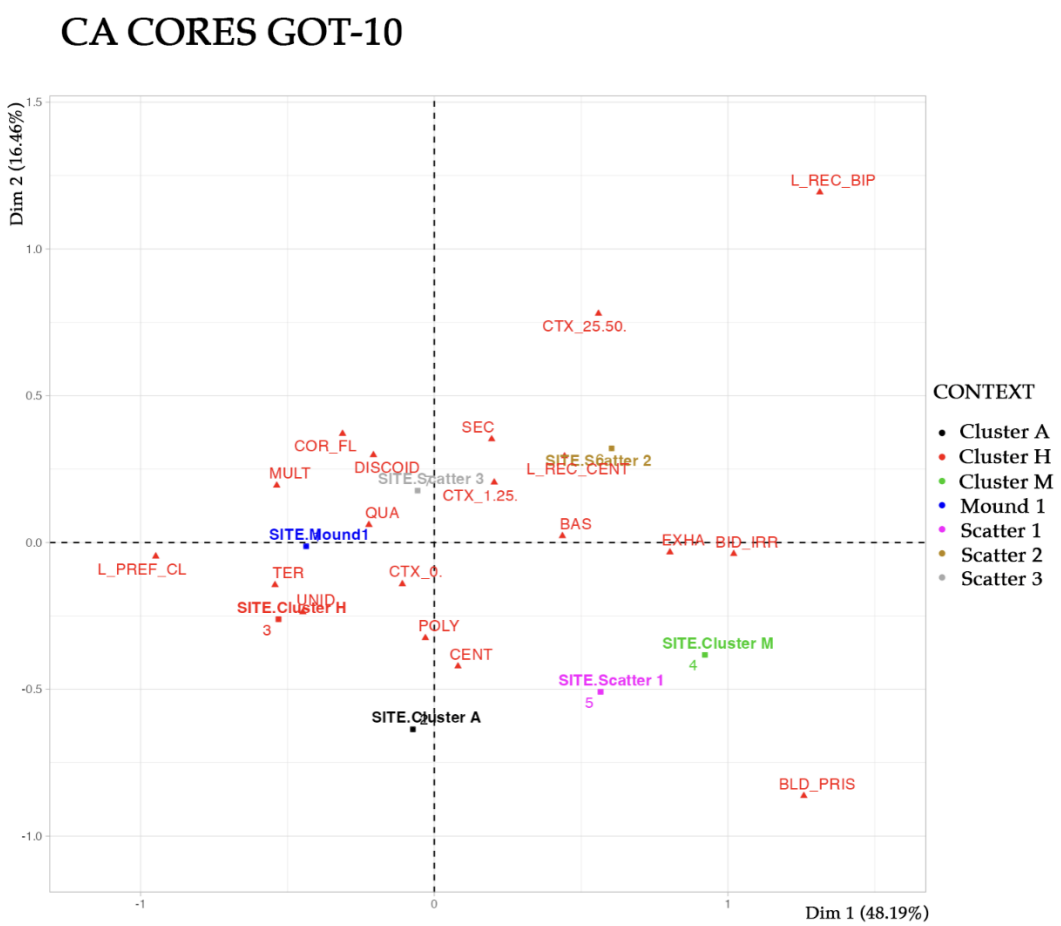


Figure 48: Plot showing results of the CA on cores from the GOT-10 site.

These results demonstrate that the assemblage from the GOT-10 site have no significant technological differences. Therefore, it can be considered a single cohesive technological complex for further statistical inter-site comparisons.

Chapter 4 – Comparative analysis of the Gotera area assemblages

4.1 Introduction

The local-level inter-site comparative analysis presented in this chapter serves several purposes:

1. To define any similarities and differences among the assemblages in order to evaluate the potential attribution of technological traits to the MSA and/or LSA, and to add more information regarding the technological variability of lithic industries during the Late Pleistocene in eastern Africa.
2. to clarify the nature of the Gotera area occupation and potentially its timing and duration with the identification of potential similar or different techno-complexes.

The Gotera lithic collections are the product of several research activities that have taken place within the area. Over the years, the Gotera area has been the subject of investigations by two separate research teams at different times, resulting in diverse findings (Chavaillon and Chavaillon, 1985; Fusco et al. 2021; Fusco et al. in press; Spinapolice et al. 2017). In his work, Chavaillon analysed and published aspects of the lithic industries discovered at nine locations (from I to IX) across the area (Chavaillon and Chavaillon, 1985).

Before running the statistical comparison of the assemblages, I will show the results of the technological analysis of lithic assemblages conducted on a small sample from the Chavaillon collection. I will then summarise the results of the technological analysis of the surface collection from GOT1-S (Main Site) recovered between 2016 and 2018.

4.2 Materials and methods of the comparative analysis

The materials used for the inter-site comparative analysis derive from two distinct data analyses on separate lithic artefact collections recovered from Gotera: a small sample from the lithic assemblages collected by Chavaillon during his research at Gotera (Chavaillon's sample) and the complete assemblage recovered from a surface collection in the Gotera area between 2016 and 2018 by the GOTAM team (GOT1-S assemblage) (Fusco et al. 2021; Spinapolice et al. 2017).

4.2.1 Chavaillon's sample

In order to standardise data collection and variables for statistical analysis, a subsample was selected from Chavaillon's lithic assemblage, preserved at the EHA in Addis Ababa. This sample was then studied using the same method employed for data collection and technological analysis of the lithic assemblage from GOT-10 (refer to Chapter 3).

To minimize any analytical and interpretation errors, it was necessary to collect data by measuring the same variables, using the same methodology, for both lithic collections. Thus, both numerical and categorical variables have undergone analysis using multivariate statistics. Additionally, considering the time that has passed since Chavaillon's analysis, it was deemed appropriate to re-examine a subsample of his lithic collection, to move beyond the mere typological comparison of the assemblages. Without collecting these specific lithic technological attributes (variables for statistical analyses), a typological comparison would have been the sole alternative to include material from the nine locations in Gotera discovered by Chavaillon.

The sample from Chavaillon's collection was analysed during the 2023 data collection season at the EHA in Addis Ababa. A total of 164 lithics were selected for analysis, using a random selection, encompassing cores (N=42), flakes (unretouched blanks, including blades and bladelets) (N=71), bipolar on anvil products (N=10), and retouched blanks (N=41) from all nine localities (Table 35).

Chavaillon's sample										
	Core		**Flake**		**Bipolar**		**Retouched Tools**		**Total**	
Sites	N	%	N	%	N	%	N	%	N	%
GOT I	25	60%	34	48%	3	30%	19	46%	81	49%
GOT II	1	2%	6	8%	0	0%	7	17%	14	9%
GOT III	1	2%	0	0%	0	0%	2	5%	3	2%
GOT IV	0	0%	3	4%	0	0%	1	2%	4	2%
GOT V	0	0%	3	4%	0	0%	0	0%	3	2%
GOT VI	0	0%	3	4%	0	0%	0	0%	3	2%
GOT VII	2	2%	2	3%	1	10%	2	5%	7	4%
GOT VIII	12	29%	6	8%	5	50%	5	12%	28	17%
GOT IX	1	2%	3	4%	1	10%	2	5%	7	4%
GOT X	0	0%	7	10%	0	0%	3	7%	10	6%
GOT RE	0	0%	4	6%	0	0%	0	0%	4	2%
Total	**42**	**26%**	**71**	**43%**	**10**	**6%**	**41**	**25%**	**164**	100%

Table 35: Distribution of lithic categories among the Chavaillon's sample

The sample from Chavaillon's excavation can be compared directly with the surface material collected at the GOT1-S site. The methods employed for data collection and attribute measurements are the same as those used for the analysis of the GOT-10 lithic assemblages (refer to Chapter 3).

4.2.2 GOT1-S lithic assemblage

The GOT1-S assemblage is the result of a surface collection that took place across approximately 2 km^2 of the Gotera area immediately south of the road that connects Konso to Yabello (Chapter 2). During this survey, collection activities focused on a specific location known as the GOT1-S Main Site. This locality is likely to be the same place where Chavaillon and his team concentrated their research activities (Fusco et al. 2021).
According to the way the materials were found, during the analysis, the overall collection of artefacts from the GOT1-S area has been categorized into two distinct groups. One group consists of all the lithic scatters, and the second group comprises all the isolated lithic finds (Table 36) that were documented and collected within the GOT1-S site and around the Main Site. This division serves a dual purpose: to organize the collected data and to analyse whether there are any differences and similarities between lithic concentrations throughout the surveyed area.
Around the GOT 1-S Main Site, the survey facilitated the identification and collection of several concentrations of archaeological artefacts. Lithic materials are associated with well-preserved faunal remains, mostly small herbivores, and these are currently under study by the PhD student Caterina Aureli, in the frame of her doctoral research at Sapienza University of Rome. The whole lithic assemblage is composed of 332 pieces, including cores (N=25), flakes (N=278), and retouched tools (N=29) (175 on basalt and 125 on quartz), excluding chunks and indeterminate fragments (N=23) (Table 36). No hammerstones were collected during the survey activities. The analysis of isolated findings reveals the technological similarities between the isolated finds and the lithic scatter analysis, indicating this is a coherent single assemblage that can be considered homogeneous. The detailed methods and results of the technological analysis have been the subject of two publications (Fusco and Spinapolice, under review; Fusco et al. 2021).

GOT1-S assemblage								
	Cores		Flakes		Tools		Total	
Contexts	N	%	N	%	N	%	N	%
Isolated Finds	9	36%	38	14%	6	21%	53	16%
EC14	0	0%	19	7%	1	3%	20	69%
EC22	11	44%	26	9%	12	41%	49	15%
MG32	3	12%	104	37%	3	10%	110	33%
Scatter1	2	8%	62	22%	7	24%	71	21%
Scatter IS	0	0%	29	10%	0	0%	29	9%
Total	25	8%	278	84%	29	9%	332	100%

Table 36: Distribution of lithic categories among the GOT1-S assemblage

4.3 Results of the Technological Analyses of the Chavaillon's sample

4.3.1 Chavaillons' sample

The lithic assemblages from the nine localities discovered by Chavaillon and his team was originally analysed and published in 1985 (Chavaillon and Chavaillon, 1985). Here I will briefly summarise his results.

The principal raw materials used were quartz and basalt. Numerous choppers, chopping tools, and flaked pebbles are present in the assemblages. Levallois recurrent cores as well as other planimetric cores (e.g. discoid) are predominant, but some prism-shaped or pyramidal cores suggest the production of elongated flakes with parallel edges. Retouched pieces are rare, with only a few scrapers, points, burins, and backed knives featuring edge modifications. According to the authors, at Gotera the presence of typological elements associated with the ESA, such as choppers and chopping tools, could be related both to their chronology (assemblages dating to the end of the Acheulean or the beginning of the MSA) and to a "constraint" imposed by the available raw materials (Chavaillon and Chavaillon, 1985). However, given the surface nature of the contexts, it was impossible to attribute a secure chronology to the sites and to attribute the assemblage to a specific chrono-cultural complex (Chavaillon and Chavaillon, 1985; Douze, 2011).

The sample from Chavaillon's collections has resulted in similar findings in the framework of the analysis presented here, with the exception that no elements clearly relating to the ESA or Early MSA have been found. Moreover, although some of these artefacts. were recovered by Chavaillon from excavation trenches, it is not possible to determine which of them were excavated, since no information is available about their specific provenance (in terms of trenches, depth below surface, layer, etc.). The only information relates to the general locality (e.g. GOTII, GOTIII, etc.) and year of recovery. Therefore, this sample was

considered conservatively, as a whole assemblage without attribution to an in situ or surface context. The following section describes the results derived from the re-analysis of this sample (Table 35).

4.3.2 Raw materials

The raw materials (Table 37) are consistent with those identified across the wider area and with the previous analysis conducted by Chavaillon, and confirms the use of local resources, particularly quartz (35%) and basalt (61%) (Fusco et al. 2021; Spinapolice et al. 2017). The use of chert is documented in a very low proportion (2%) and is only found at the GOTI and GOTIII localities. Phonolite is only present at GOTI (1%).
It is important to remember that the sample analysed here does not represent the entire lithic assemblage collected during the work at Gotera by Chavaillon. Therefore, the ratio between quartz and basalt, as well as other quantitative data from this technological analysis, may differ slightly from that identified if the whole assemblage were re-analysed.

Raw materials												
	Basalt		**Chert**		**Lava**		**Phonolite**		**Quartz**		**Total**	
Sites	N	%	N	%	N	%	N	%	N	%	N	%
GOT I	63	63%	3	75%	0	0%	1	100%	14	24%	81	49%
GOT II	2	2%	0	0%	0	0%	0	0%	12	21%	14	9%
GOT III	1	1%	1	25%	0	0%	0	0%	1	2%	3	2%
GOT IV	2	2%	0	0%	1	100%	0	0%	1	2%	4	2%
GOT V	3	3%	0	0%	0	0%	0	0%	0	0%	3	2%
GOT VI	1	1%	0	0%	0	0%	0	0%	2	3%	3	2%
GOT VII	1	1%	0	0%	0	0%	0	0%	6	10%	7	4%
GOT VIII	12	12%	0	0%	0	0%	0	0%	16	28%	28	17%
GOT IX	1	1%	0	0%	0	0%	0	0%	6	10%	7	4%
GOT X	10	10%	0	0%	0	0%	0	0%	0	0%	10	6%
GOT RE	4	4%	0	0%	0	0%	0	0%	0	0%	4	2%
Total	100	61%	4	2%	1	1%	1	1%	58	35%	164	100%

Table 37: Distribution of raw materials exploited in the analysed sample from Chavaillon's lithic assemblage.

4.3.3 Artefact condition analysis

A comprehensive analysis of artefact condition has been conducted. The analysis of the lithic assemblage from Chavaillon's sample indicates a low degree of post-depositional

surface alteration, with 58% of the assemblage considered fresh, 20% classified as slightly worn, and 14% as worn. This suggests that, despite the overall good state of preservation of lithic edges, roughly 48% of the assemblage classified here as not fresh likely relates to their collection from the modern land surface (Table 38).

	Fresh/Unworn		**Slightly-Worn**		**Worn**		**Highly-Worn**		**Total**	
Sites	N	%	N	%	N	%	N	%	N	%
GOT I	40	42%	23	70%	13	57%	5	38%	81	49%
GOT II	10	11%	2	6%	1	4%	1	8%	14	9%
GOT III	3	3%	0	0%	0	0%	0	0%	3	2%
GOT IV	3	3%	1	3%	0	0%	0	0%	4	2%
GOT V	0	0%	0	0%	2	9%	1	8%	3	2%
GOT VI	2	2%	0	0%	0	0%	1	8%	3	200%
GOT VII	5	5%	2	6%	0	0%	0	0%	7	4%
GOT VIII	18	19%	2	6%	4	17%	4	31%	28	17%
GOT IX	6	6%	0	0%	1	4%	0	0%	7	4%
GOT X	5	5%	3	9%	1	4%	1	8%	10	6%
GOT RE	3	3%	0	0%	1	4%	0	0%	4	2%
Total	**95**	**58%**	**33**	**20%**	**23**	**14%**	**13**	**8%**	**164**	**100%**

Table 38: Artefact condition in the analysed sample from Chavaillon's lithic assemblage.

Furthermore, the analysis of the likely cause of the post-depositional wear observed on the sample reveals that the majority is attributable to fluvial processes (35%) (Table 39).
The analysis of artefact patina (Table 40) indicates that they are most frequently just slightly patinated (60%), while patinated specimens account for 25% of the total. Fresh artefacts represent only 14%, suggesting that the analysed sample has been exposed to external factors, in correlation with their probably surface nature.

	Fresh		Rolled		Uncertain		Water-worn		Total	
Sites	N	%	N	%	N	%	N	%	N	%
GOT I	40	42%	0	0%	3	30%	38	66%	81	49%
GOT II	10	11%	0	0%	1	10%	3	5%	14	9%
GOT III	3	3%	0	0%	0	0%	0	0%	3	2%
GOT IV	3	3%	0	0%	0	0%	1	2%	4	2%
GOT V	0	0%	0	0%	0	0%	3	5%	3	2%
GOT VI	2	2%	0	0%	0	0%	1	2%	3	2%
GOT VII	5	5%	0	0%	1	10%	1	2%	7	4%
GOT VIII	18	19%	0	0%	5	50%	5	9%	28	17%
GOT IX	6	6%	1	100%	0	0%	0	0%	7	4%
GOT X	5	5%	0	0%	0	0%	5	9%	10	6%
GOT RE	3	3%	0	0%	0	0%	1	2%	4	2%
Total	**95**	**58%**	**1**	**1%**	**10**	**6%**	**58**	**35%**	**164**	**100%**

Table 39: Types and proportions of mechanical alteration in the analysed sample from Chavaillon's lithic assemblage.

Additionally, the analysis of the patina shows that the most prevalent colour is white (40%), followed by red (23%), and black/dark (20%) (Table 41). This evidence indicates a higher degree of post-depositional alteration when compared to the assemblages from the GOT-10 site and the GOT1-S collection (Fusco et al. 2021). Further analyses on the characterisation of taphonomic processes, as well as patina characterisation, will help clarify the depositional history of the Gotera area.

	Fresh		Slight-Patina		Patinated		Heavy-Patina		Total	
Sites	N	%	N	%	N	%	N	%	N	%
GOT I	17	74%	44	45%	20	49%	0	0%	81	49%
GOT II	0	0%	8	8%	6	15%	0	0%	14	9%
GOT III	1	4%	2	2%	0	0%	0	0%	3	2%
GOT IV	0	0%	3	3%	1	2%	0	0%	4	2%
GOT V	0	0%	3	3%	0	0%	0	0%	3	2%
GOT VI	1	4%	2	2%	0	0%	0	0%	3	2%
GOT VII	0	0%	5	5%	2	5%	0	0%	7	4%
GOT VIII	1	4%	17	17%	9	22%	1	50%	28	17%
GOT IX	0	0%	5	5%	1	2%	1	50%	7	4%
GOT X	1	4%	7	7%	2	5%	0	0%	10	6%
GOT RE	2	9%	2	2%	0	0%	0	0%	4	2%
Total	**23**	**14%**	**98**	**60%**	**41**	**25%**	**2**	**1%**	**164**	**100%**

Table 40: Types and proportions of patina in the analysed sample from Chavaillon's lithic assemblage.

Patina colour										
	Black/Dark		**Red**		**White**		**No Patina**		**Total**	
Sites	N	%	N	%	N	%	N	%	N	%
GOT I	11	33%	16	43%	34	52%	20	69%	81	49%
GOT II	2	6%	9	24%	2	3%	1	3%	14	9%
GOT III	0	0%	1	3%	0	0%	2	7%	3	2%
GOT IV	2	6%	0	0%	2	3%	0	0%	4	2%
GOT V	3	9%	0	0%	0	0%	0	0%	3	2%
GOT VI	0	0%	0	0%	2	3%	1	3%	3	2%
GOT VII	2	6%	3	8%	2	3%	0	0%	7	4%
GOT VIII	9	27%	6	16%	11	17%	2	7%	28	17%
GOT IX	3	9%	1	3%	3	5%	0	0%	7	4%
GOT X	0	0%	1	3%	8	12%	1	3%	10	6%
GOT RE	1	3%	0	0%	1	2%	2	7%	4	2%
Total	**33**	**20%**	**37**	**23%**	**65**	**40%**	**29**	**18%**	**164**	**100%**

Table 41: Proportions of patina colour on the analysed sample from Chavaillon's lithic assemblage.

The analysis of thermal alteration on the surfaces of lithics from Chavaillon's sample reveals a low occurrence (Table 42). Ninety-nine percent of the artefacts show no signs of burning, indicating that they have not been exposed to significant heat or fire-related processes.

	Not-burned		**Partially**		**Total**	
Sites	N	%	N	%	N	%
GOT I	80	49%	1	100%	81	49%
GOT II	14	9%	0	0%	14	9%
GOT III	3	2%	0	0%	3	2%
GOT IV	4	2%	0	0%	4	2%
GOT V	3	2%	0	0%	3	2%
GOT VI	3	2%	0	0%	3	2%
GOT VII	7	4%	0	0%	7	4%
GOT VIII	28	17%	0	0%	28	17%
GOT IX	7	4%	0	0%	7	4%
GOT X	10	6%	0	0%	10	6%
GOT RE	4	2%	0	0%	4	2%
Total	**163**	**99%**	**1**	**1%**	**164**	**100%**

Table 42: Observed thermal alteration on the analysed sample from Chavaillon's lithic assemblage.

4.3.4 Core analysis

In Chavaillon's sample selected for this comparative analysis, the core assemblage numbers 41 specimens. These cores have been thoroughly examined to understand their technological characteristics. Interestingly, despite their low occurrence, the analysis reveals significant technological variability in terms of reduction strategies, observed in both regular and irregular cores (Table 43).

Core Analysis						
	Irregular		**Regular**		**Total**	
Sites	N	%	N	%	N	%
GOT I	17	71%	7	41%	24	59%
GOT II	0	0%	1	6%	1	2%
GOT III	1	4%	0	0%	1	2%
GOT VII	1	4%	1	6%	2	5%
GOT VIII	4	17%	8	47%	12	29%
GOT IX	1	4%	0	0%	1	2%
Total	**24**	**59%**	**17**	**41%**	**41**	**100%**

Table 43: Regular and irregular cores in the analysed sample from Chavaillon's lithic assemblage.

Among the cores, irregular cores make up 63% of the sample, while regular cores constitute the remaining 37%. The regular cores are mostly represented by Levallois cores (24%), followed by Discoid (7%) and blade cores (2%) (Table 44). The irregular cores include cores-on-flakes, polyhedral cores, and triangular cores, with the most common type being triangular (27%), followed by polyhedral (24%), and then cores-on-flakes (10%).

	GOT I		**GOT II**		**GOT III**		**GOT VII**		**GOT VIII**		**GOT IX**		**Total**	
Core Type	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Irregular	**16**	**67%**	**0**	**0%**	**1**	**100%**	**1**	**50%**	**4**	**33%**	**1**	**100%**	**23**	**56%**
Core-on-flake	4	17%	0	0%	0	0%	0	0%	0	0%	0	0%	4	10%
Polyhedral	7	29%	0	0%	1	100%	1	50%	2	17%	0	0%	10	24%
Triangular	5	21%	0	0%	0	0%	0	0%	2	17%	1	100%	11	27%
Regular	**8**	**33%**	**1**	**100%**	**0**	**0%**	**1**	**50%**	**8**	**67%**	**0**	**0%**	**18**	**44%**
Blade	2	8%	0	0%	0	0%	0	0%	2	17%	0	0%	1	2%
Discoid	1	4%	0	0%	0	0%	1	50%	1	8%	0	0%	3	7%
Levallois	5	21%	1	100%	0	0%	0	0%	4	33%	0	0%	10	24%
Total	**24**	**59%**	**1**	**2%**	**1**	**2%**	**2**	**5%**	**12**	**29%**	**1**	**2%**	**41**	**100%**

Table 44: Core types in in the analysed sample from Chavaillon's lithic assemblage.

4.3.5 Regular cores

Levallois cores are made from both basalt and quartz. Within the assemblage, preferential, centripetal, and bipolar-recurrent variants are present, as well as Levallois point cores (Table 45). Basalt was frequently exploited for recurrent centripetal reduction, constituting 30% of all Levallois cores. Quartz exploitation for Levallois reduction shows a homogeneity of different types, spanning from preferential to point production and centripetal recurrent. This data shows that Levallois reduction strategies were regularly employed at Gotera, in all its variants. They were mainly used to produce preferential and centripetal flakes. The production of Levallois points is attested, but is very rare (Figure 51: 4).

Levallois Cores								
	GOT I		**GOT II**		**GOT VIII**		**Total**	
Core type	N	%	N	%	N	%	N	%
BASALT	**4**	**80%**	**0**	**0%**	**2**	**50%**	**6**	**60%**
Preferential-classical	0	0%	0	0%	1	25%	1	10%
Levallois Point	1	20%	0	0%	0	0%	1	10%
Recurrent-centripetal	2	40%	0	0%	1	25%	3	30%
UNCERTAIN	1	20%	0	0%	0	0%	1	10%
QUARTZ	**1**	**20%**	**1**	**100%**	**2**	**50%**	**4**	**30%**
Preferential-classical	0	0%	0	0%	1	25%	1	10%
Levallois Point	0	0%	0	0%	1	25%	1	10%
Recurrent-bipolar	1	20%	0	0%	0	0%	1	10%
Recurrent-centripetal	0	0%	1	100%	0	0%	1	10%
Total	5	50%	1	10%	4	40%	10	100%

Table 45: Levallois core frequency within Chavaillon's sample

Evidence for a regular laminar reduction system is represented in the collection by four blades cores found at the GOTI and GOTVIII localities (Table 46). They were produced from chert, basalt, and quartz, but the only types present in the sample are cylindrical blade core. These cores are characterised by the presence of a single striking platform, prepared by two or more detachments perpendicular to the direction of flake production. The exploitation of volume is conceived to produce elongated blanks, including blades and bladelets. The cylindrical cores at Gotera were principally exploited to produce small, elongated blanks (max length <6 cm) (Figure 1: 1-2).

Blade cores						
	GOT I		**GOT VIII**		**Total**	
Core Type	N	%	N	%	N	%
BASALT	**1**	**50%**	**0**	**0%**	**1**	**25%**
BLADE – Cylindrical	1	**50%**	**0**	**0%**	1	25%
CHERT	**1**	**50%**	**0**	**0%**	**1**	25%
BLADE - Cylindrical	**1**	**50%**	**0**	**0%**	1	25%
QUARTZ	**0**	**0%**	**2**	**100%**	**2**	**50%**
BLADE - Cylindrical	**0**	**0%**	2	100%	2	50%
Total	**2**	**50%**	**2**	**50%**	**4**	100%

Table 46: Blade core frequency within Chavaillon's sample

4.3.6 Irregular Cores

The irregular cores within Chavaillon's sample include cores-on-flakes, polyhedral, and triangular shaped cores. This data suggests an opportunistic exploitation of raw materials, in order to produce flakes and mostly elongated blanks. The cores-on-flakes are flakes that have been selected for additional exploitation aimed at the production of other flakes. In the case of the Gotera sample from Chavaillon's collections, this evidence is represented by one cortical basalt flake. One edge of this artefact has been exploited as a striking platform from which several small, elongated flakes have been detached. The other cores-on-flakes are mainly made on ordinary and triangular flakes, also used to remove elongated flakes. Irregular polyhedral cores in Chavaillon's Gotera collection are characterised by cores that usually have one striking platform, and do not follow a specific reduction system to produce elongated flakes. Usually, their surface convexities are minimally prepared to detach blade/bladelets, and often the same core was exploited for the production of both flakes and elongated flakes. Triangular cores follow the same concept as polyhedral ones, having typically triangular shapes, formed by the detachment of mostly elongated flakes. They show one or two striking platforms that usually not oriented in opposition. From the analysed sample, it is clear that the primary purpose of irregular core reduction was to produce elongated flakes.

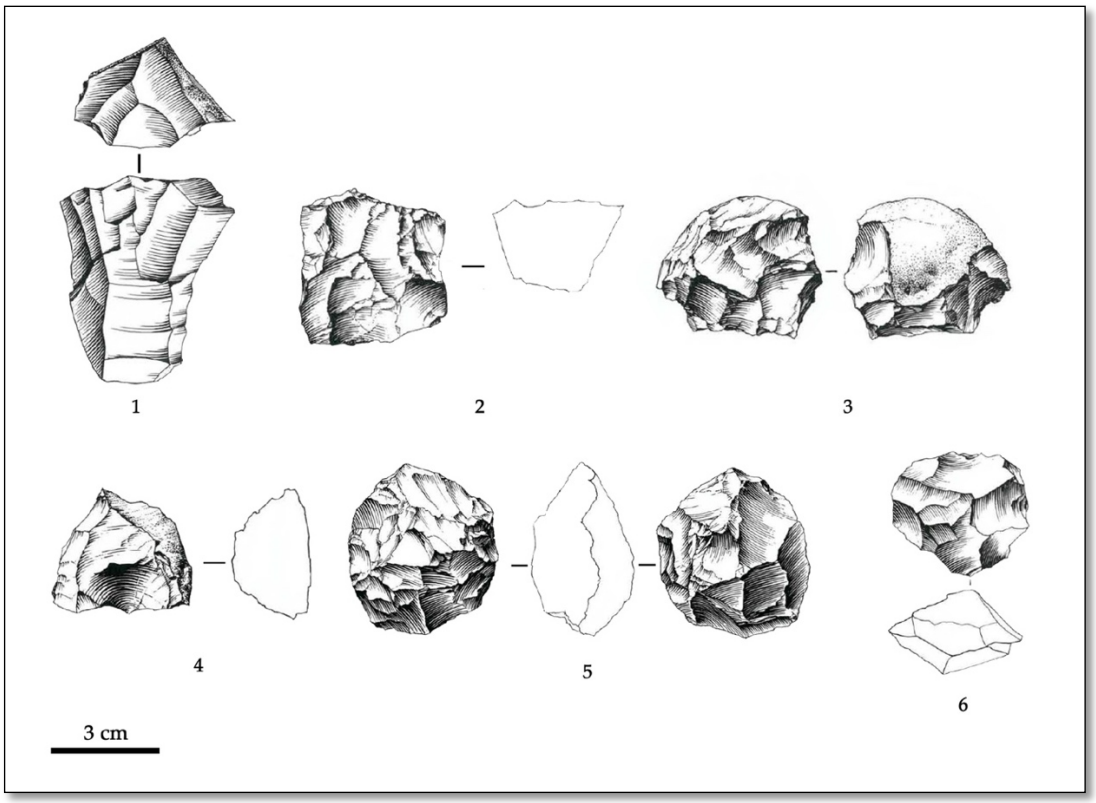


Figure 49: Core from Chavaillon's sample. Basalt (1-4); quartz (2-3-5-6). Cylindrical blade core (1), double platform cylindrical blade core (2); Centripetal secondary core (3); Levallois point core (4); Centripetal discoid core (5-6) (Modified after Chavaillon and Chavaillon, 1985).

4.3.7 Flake analysis

A comprehensive analysis of unretouched flakes has been conducted. Results from this analysis show that unretouched flakes comprise the largest proportion (44%) of the entire lithic assemblage.

To further categorize and understand the related knapping activities in the sample, flakes have been classified based on their place within the reduction scheme. This classification considers various technological criteria and characteristics, allowing for a more nuanced interpretation of the roles of flake production within the knapping process.

Analysis reveals that many flakes (N=27) belong to the earliest stage of lithic production, the preparation stage. This includes processes involving, for example, the removal of cortex or the creation of suitable platforms for flake detachment from cores.

Among the basalt preparation flakes, cortical flakes are the most frequently represented (52%) followed by debordant flakes (22%). Pseudolevallois points in basalt are only 7% while cortical blade/bladelets are 4%. Quartz preparation flakes are rare, and the different flake technological categories are equally represented (Appendix 2, supplementary table 1).

According to the information derived from this technological analysis, the production stage is represented in the assemblage by various flake types (Appendix 2, supplementary table 2) (Figure 52). The most common types for both basalt (32%) and quartz (11%) are ordinary flakes. These are classified as ordinary since they do not fit into any other specific technological flake category. They typically lack a dihedral or facetted platform and cannot therefore be classified as either Levallois or discoid flakes.

The second most frequently represented technological category among basalt specimens are the ordinary blade and bladelets, which comprise 8% and 5% of the sample, respectively. Basalt points such as volumetric and Levallois types represent 3% of the sample.

The exploitation of quartz shows a roughly equal representation of Levallois points and flakes (preferential, unipolar recurrent, and bipolar) as well as volumetric points. The presence of the Levallois reduction strategy is well represented in the analysed sample, and this observation will help integrate and compare Chavaillon's collection with the wider variability of the eastern Africa MSA. Moreover, the absence of typical Acheulean elements (bifaces, handaxes, cleavers, *façonnage* flakes) is likely indicating that this sample reflects relatively more recent chronology for hominin occupation, contradicting the Chavaillon's original proposed attribution to the late Acheulean or early MSA.

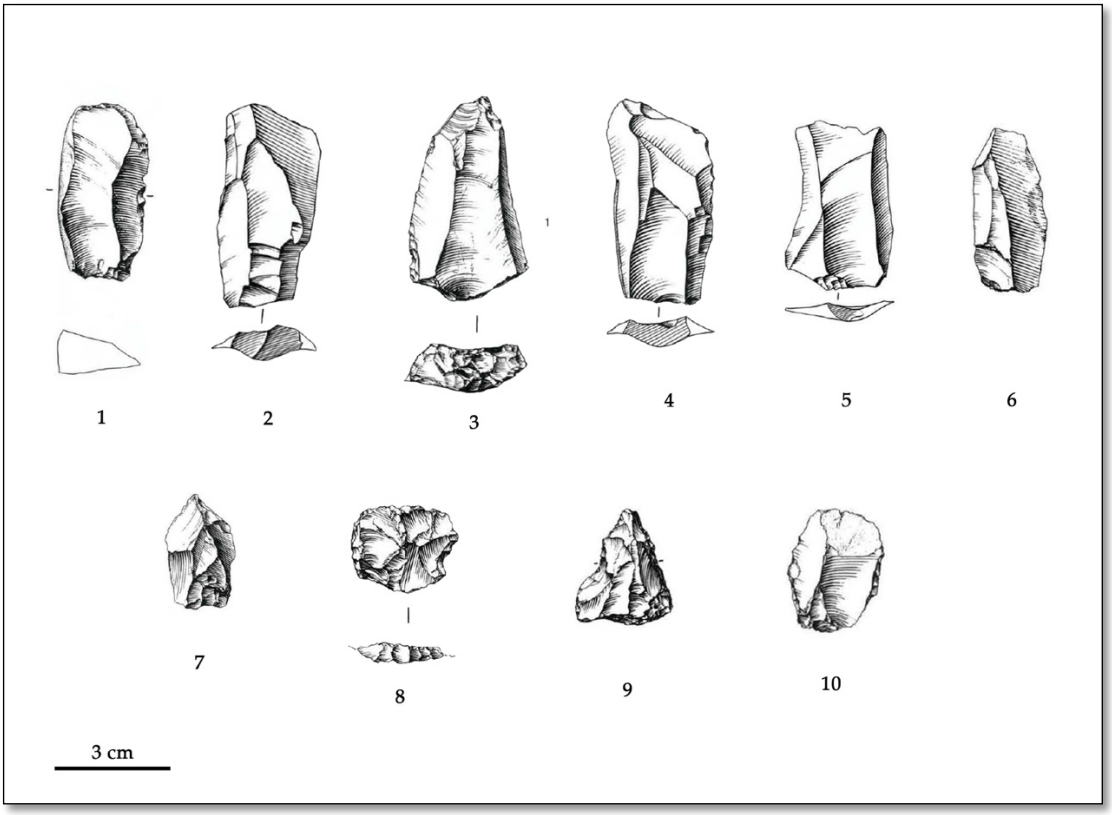


Figure 50: Flakes sample. Basalt (1-6), quartz (7-10). Cortical debordant blade (1), blade (2-4-5-6), point (3-9), Levallois flake (8), ordinary flakes (7-10) (Modified after Chavaillon and Chavaillon, 1985).

4.3.8 Technique

A comprehensive examination of platform and bulb morphology has been conducted In order to understand the techniques used to produce flakes, blanks, and tools at Gotera. The identified platform types include abraded, cortical, dihedral, facetted, linear, and plain (Appendix 2, supplementary table 3). Analysis reveals a clear predominance of plain platforms, both for basalt (49%) and quartz (12%) artefacts. The next most represented type is the dihedral platform, both for basalt (12%) and quartz (4%). By contrast, cortical, abraded, and facetted platform types are present but occur relatively rarely within the assemblage.

To summarize, the analysis indicates a clear predominance of non-prepared (plain) or minimally prepared (dihedral) platform types. This pattern is consistent across different raw materials.

An analysis bulb of percussion has also been conducted, which complements the study of flake platforms (Appendix 2, supplementary table 4). This analysis helps understanding the knapping techniques employed in the production of flakes, blanks, and retouched flakes. Chavaillon's sample exhibit clearly visible bulbs, along with impact points indicating direct percussion using hard and soft hammers. Analysis reveals a predominance of flat and normal bulbs for both basalt and quartz. Specifically, 49% of bulbs on basalt artefacts are normal, and for quartz 9% are normal. The presence of normal bulbs indicates that a substantial number of flakes, exhibit a more typical bulb morphology associated with direct percussion techniques. The second most represented category is flat bulbs, which occur 15% of basalt specimens and 4% of quartz pieces. This type of bulb is generally associated with volumetric/laminar production using direct percussion with a soft hammer. Furthermore, the presence of dihedral and negative bulbs is found on the lithics that show evidence of the bipolar-on-anvil technique. From this analysis it is clear that direct percussion was the primary mode for striking flakes, and that this involved both hard and soft hammers.

4.3.9 Retouched flakes

Retouched flakes are scarce within the sample (N=20). The classification of retouched flakes in this analysis follows the typology developed in 1966 by François Bordes for the Lower and Middle Palaeolithic. This typology provides a framework for categorising and identifying different types of retouched flakes based on their characteristics (see Chapter 2.). Among the frequent retouched flakes identified in the assemblages are denticulate, which

account for 20% of basalt flake tools, and 15% of quartz specimens (Appendix 2, supplementary table 5) (Figure 53). The other retouched flake types are represented by retouched Levallois points, scrapers, and backed pieces, however, there is no difference in their frequencies across the different raw material types. This pattern is generally seen in the lithics from Gotera area, where normally retouched tools are almost absent (Fusco et al. 2021).

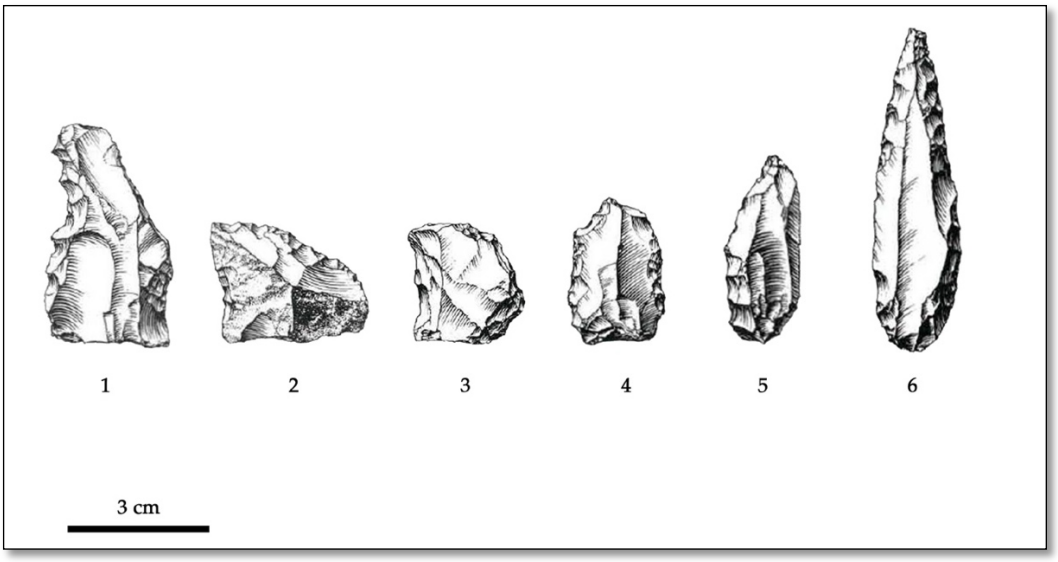


Figure 51: Retouched tools. Jasper (1-4), basalt (2-6), quartz (3-5). Denticulate (1, 3, 4), scraper (2, 4), retouched blade (6) (Modified after Chavaillon and Chavaillon, 1985).

4.3.10 Bipolar on anvil evidence

The presence of the bipolar on anvil technique is attested by the presence of cores and flakes with signs of the use of this technique.

The number of cores and flakes with bipolar on anvil evidence is not high (N=10) and it is attested only among quartz exploitation. However, the analysis of bulbs shows the presence of negative bulbs, between two and four bulbs present in opposite location on the same surface (Table 47).

	GOT I		**GOT VII**		**GOT VIII**		**GOT IX**		**Total**	
Negative Bulbs	N	%	N	%	N	%	N	%	N	%
2 Bulbs	**2**	**67%**	**1**	**100%**	**5**	**100%**	**1**	**100%**	**9**	90%
Opposite same surface	2	67%	1	100%	5	100%	1	100%	9	90%
4 Bulbs	**1**	**33%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	10%
Opposite same surface	1	33%	0	0%	0	0%	0	0%	1	10%
Total	**3**	**30%**	**1**	**10%**	**5**	**50%**	**1**	**10%**	**10**	100%

Table 47: Frequency of bipolar on anvil evidence within Chavaillon's sample.

Among the irregular cores, bipolar on anvil technique is attested for only six cores (Tab 67). Core-on-flakes and triangular cores are slightly more abundant within the sample, and they make both 33% of the sample (Table 48).

Irregular cores										
	GOT I		**GOT VII**		**GOT VIII**		**GOT IX**		**Total**	
Negative Bulbs	N	%	N	%	N	%	N	%	N	%
Anvil	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**100%**	**1**	17%
2 Bulbs	0	0%	0	0%	0	0%	1	100%	1	17%
Opposite same surface	0	0%	0	0%	0	0%	1	100%	1	17%
Core-on-flake	**2**	**100%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**2**	33%
2 Bulbs	1	50%	0	0%	0	0%	0	0%	1	17%
Opposite same surface	1	50%	0	0%	0	0%	0	0%	1	17%
4 Bulbs	1	50%	0	0%	0	0%	0	0%	1	17%
Opposite same surface	1	50%	0	0%	0	0%	0	0%	1	17%
Polyhedral	**0**	**0%**	**0**	**0%**	**1**	**50%**	**0**	**0%**	**1**	17%
2 Bulbs	0	0%	0	0%	1	50%	0	0%	1	17%
Opposite same surface	0	0%	0	0%	1	50%	0	0%	1	17%
Triangular	**0**	**0%**	**1**	**100%**	**1**	**50%**	**0**	**0%**	**2**	33%
2 Bulbs	0	0%	1	100%	1	50%	0	0%	2	33%
Opposite same surface	0	0%	1	100%	1	50%	0	0%	2	33%
Total	**2**	**33%**	**1**	**17%**	**2**	**33%**	**1**	**17%**	**6**	100%

Table 48: Frequency of bipolar on anvil evidence among irregular cores within Chavaillon's sample.

Regular cores with Bipolar on-anvil evidence are represented only by the presence of one Levallois core, with two negatives bulbs located in opposite position on the same surface (Table 49). The bipolar on anvil technique has been used here to recycle the core, in the same way as seen for the bipolar cores found within the GOT-10 assemblage.

Regular Cores						
	GOT VII		**GOT VIII**		**Total**	
Negative Bulbs	N	%	N	%	N	%
Levallois	**1**	**100%**	**1**	**100%**	**2**	100%
2 Bulbs	1	100%	1	100%	2	100%
Opposite same surface	1	100%	1	100%	2	100%
Total	**1**	**50%**	**1**	**50%**	**2**	100%

Table 49: Frequency of bipolar on anvil evidence among regular cores within Chavaillon's sample.

Among flakes, evidence of the bipolar on anvil technique is present only on two retouched flakes in quartz (Table 50).
The analysis of the use of this technique for Chavaillon's sample confirmed that in Gotera it is present only for quartz exploitation.

Retouched flakes						
	GOTI		**GOT VIII**		**Total**	
Negative Bulbs	N	%	N	%	N	%
Backed piece	**1**	**100%**	0	0%	**1**	**50%**
2 Bulbs	1	100%	0	0%	1	50%
Opposite same surface	1	100%	0	0%	1	50%
Notch	0	0%	**1**	**100%**	**1**	**50%**
2 Bulbs	0	0%	1	100%	1	50%
Opposite same surface	0	0%	1	100%	1	50%
Total	**1**	**50%**	**1**	**50%**	**2**	**100%**

Table 50: Frequency of bipolar on anvil evidence among retouched flakes within Chavaillon's sample.

4.3.11 Chaîne opératoire stages

The analysis of *chaîne opératoire* stages is a fundamental means to understand the presence of different knapping activities at a site, by considering all lithic pieces as part of a technological process.
Analysis of the sample shows that products of production, exploitation, use, and abandonment phases are all present. The most represented stage is that of abandonment (34%), followed by use (26%) and then exploitation (24%). Then finally the production phase is attested for 17% of the sample (Appendix 2, supplementary table 6).
It is however worth reiterating that this sample is not the entire collection recovered by Chavaillon and colleagues, and thus any interpretation regarding the sites' function/s, may be biased.

4.4 Discussion

The analysis of the lithic sample recovered by Chavaillon has yielded interesting results. In all the assemblages, the exploited raw materials collected from the surface or recovered *in situ* are the same. Local basalt and quartz predominate, while chert and phonolite were possibly brought to Gotera from unknown sources.

It is interesting that the degree of surface alteration seen on Chavaillon's sample is higher than that seen on other assemblages from Gotera. This is likely the result of post-depositional and/or taphonomic processes having affected some materials differently or for a longer period than some other artefacts collected on the surface. Regarding patina, although there is a slightly greater prevalence in Chavaillon's sample, the representation of the different types follows a similar overall pattern to other lithic assemblages from Gotera. From a technological perspective, the analysis of cores reveals the presence of reduction methods reflecting both regular and irregular patterns. Among the regular cores, the presence of the Levallois method and its preferential, pointed, centripetal, and bidirectional recurrent variants places Chavaillon's assemblage within the technological variability typical of the MSA. It is worth noting that the high variability in Levallois methods in this sample is unlike other assemblages from Gotera, where unidirectional convergent is the predominant Levallois pattern. However, it should be remembered that both Chavaillon's sample and the GOT1-S assemblage are derived from surface collections, however the comparative analysis with the other assemblages from Gotera may give new insight regarding its affinities to MSA and/or LSA traits. Furthermore, it is possible that in the Gotera area there could be evidence of earlier occupation than the one related to the Late Pleistocene of the GOT-10 deposit, thus more investigation is necessary to establish a more robust chronology.

Chavaillon's irregular cores are characterised by variability in both shape and volume exploitation type. They have been classified based on their shape as polyhedral and triangular, but cores-on-flakes also fall into this category. It seems that the main purpose of this opportunistic exploitation was to detach volumetric elongated blanks.

The analysis of flakes, the most common technological items found in Chavaillon's sample, shows the presence of elements related both to the initial stages of raw material reduction, and to the subsequent stages of the *debitage*.

Many preparation flakes are cortical (both dorsal surfaces and platforms). This suggests that the initial stages of flaking took place in the area and at the sites investigated by Chavaillon. There are also numerous flakes with various shapes, including both triangular and trapezoidal specimens. The presence of Levallois flakes and points further demonstrates the use of this method in lithic production at Gotera. The presence of volumetric flakes also indicates the exploitation of raw material according to a volumetric conception of their surfaces. This interpretation is also strongly supported by the analysed cores.

4.5 Results from the technological analysis of the GOT1-S surface collection

The surface collected materials are stored at the EHA in Addis Ababa and were analysed previously, in the context of my postgraduate studies in prehistoric archaeology, obtained in January 2019 (Fusco, 2019). The findings of this analysis were reported in 2021 (Fusco et al. 2021) and for the most detailed information, the reader is referred to that publication. However, a summary is provided here to give context to the results obtained from the technological analyses before the statistical comparison of the three assemblages is presented.

The analysis of raw materials demonstrates that quartz and basalt were the principal raw materials exploited at Gotera (Table 51). Both are of local origin and were frequently found during the 2017 survey. Basalt cobbles and pebbles are today found in the alluvial deposits around the Gotera depression. Quartz exists as both pebbles or cobbles and as outcrops. During surveys, a quartz outcrop was identified a few kilometres away from the GOT 1-S Main Site. Unfortunately, this location has recently been destroyed as part of construction work in the area. Thus, any potential future analyses investigating the origin of quartz from this source are therefore now impossible.

Raw materials								
	Basalt		**Quartz**		**Other**		**Total**	
Type	N	%	N	%	N	%	N	%
Cores	19	76%	6	24%	0	0%	25	7%
Flakes	154	55%	120	43%	4	2%	278	84%
Tools	21	73%	5	17%	3	10%	29	9%
Total	194	58%	131	40%	7	2%	332	100%

Table 51: Raw material frequencies at the GOT1-S site.

Generally, the degree of surface alteration observed on the assemblage is very low (Table 52); this means that the assemblage has been exposed to only mild post-depositional processes and transport. In addition, despite being a surface collection with a still active process of strong erosion, the integrity of the assemblage is supported by the presence of one refit from Scatter 1, located within the Main Site. Fresh lithic elements represent 79% of the assemblage, with only 13% of artefacts being slightly worn.

	Fresh		Slightly worn		Worn		Highly worn		Total	
Contexts	N	%	N	%	N	%	N	%	N	%
IS Finds BAS	**28**	**11%**	**4**	**10%**	**1**	**4%**	0	0%	34	10%
IS Finds QUA	**21**	**8%**	**6**	**14%**	1	4%	1	33%	30	9%
EC14	16	6%	3	7%	0	0%	1	33%	20	6%
EC22	7	3%	20	48%	21	84%	1	33%	49	15%
MG32	**101**	**39%**	**7**	**17%**	**2**	**8%**	0	0%	110	33%
Scatter1	69	26%	2	5%	0	0%	0	0%	71	21%
Scatter IS	29	11%	0	0%	0	0%	0	0%	29	9%
Total	**262**	**79%**	**42**	**13%**	**25**	**8%**	**3**	**1%**	**332**	100%

Table 52: Artefact condition frequencies at the GOT1-S site.

The analysis of patina shows that generally it is fresh, with a low cadence of this type of alteration (Table 53). Fresh artefacts account for 44% of the total, with an additional 44% showing only a slight patination. Patinated and heavily patinated items are very few, representing just 11% and 1% respectively. This data confirms the high degree of preservation of this surface collection.

	Fresh		Slightly patina		Patinated		Hightly patina		Total	
Contexts	N	%	N	%	N	%	N	%	N	%
IS Finds BAS	**16**	**11%**	**8**	**5%**	1	3%	0	0%	25	8%
IS Finds QUA	18	12%	6	4%	2	6%	2	100%	28	8%
EC14	5	3%	15	10%	0	0%	0	0%	20	6%
EC22	2	1%	28	19%	19	53%	0	0%	49	15%
MG32	52	35%	49	33%	9	25%	0	0%	110	33%
Scatter1	30	20%	36	24%	5	14%	0	0%	71	21%
Scatter IS	24	16%	5	3%	0	0%	0	0%	29	9%
Total	**147**	**44%**	**147**	**44%**	**36**	**11%**	**2**	**1%**	**332**	100%

Table 53: Frequency and degree of patination at the GOT1-S site.

4.5.1 Core analysis

The analysis of cores shows that there are many irregular cores (56%) in comparison to cores reflection regular reduction methods (44%) (Table 54) (Figures 54 and 56). Among the regular cores, the planimetric exploitation of raw material blocks and cobbles is registered, as it is for the other assemblages from the area.

Core analysis						
	Irregular		**Regular**		**Total**	
Contexts	N	%	N	%	N	%
Isolated Finds	7	50%	2	0%	9	36%
EC22	5	36%	6	55%	11	44%
MG32	1	7%	2	18%	3	12%
Scatter1	1	7%	1	9%	2	8%
Total	**14**	**56%**	**11**	**44%**	**25**	**100%**

Table 54: Frequency of regular and irregular cores at the GOT1-S site.

In the GOT1-S assemblage, this is evidenced by the presence of the Levallois concept, which is reflected in both cores and knapping products. These cores are mostly made of basalt (73%) (Table 55) and exhibit primarily a recurrent bipolar pattern of removals (40%) (Table 55). However, centripetal, unidirectional convergent reduction occurs as well (Table 55). The upper surfaces of Levallois cores at GOT 1-S were minimally prepared with no strong evidence of appropriate distal and lateral convexities for predetermined removals (Boëda *sensu stricto*). However, the flaking of the lower surface, allowed the shaping of the striking platform, meaning this type of core is classifiable within the Levallois concept, as defined by a hierarchy of planes. The preparation of the striking platform was carried out in such a way as to produce predetermined flakes, even if this is different from the Levallois concept as defined based on the analysis of lithic assemblages from the European Mousterian. Thus, the Levallois products at Gotera suffer sometimes from the absence of prepared platforms such as facetted and dihedral.

Levallois cores										
	EC22		**MG32**		**Scatter1**		**Isolated finds**		**Total**	
Levallois core type	N	%	N	%	N	%	N	%	N	%
BASALT	**6**	**100%**	**0**	**0%**	**1**	**100%**	**1**	**50%**	**8**	80%
Preferential-classical	1	17%	0	0%	0	0%	0	0%	1	10%
Recurrent-bipolar	3	50%	0	0%	1	100%	0	0%	4	40%
Recurrent-centripetal	1	17%	0	0%	0	0%	1	50%	2	20%
Recurrent-unipolar	1	17%	0	0%	0	0%	0	0%	1	10%
QUARTZ	**0**	**0%**	**1**	**100%**	0	0%	**1**	**50%**	**2**	20%
Recurrent-centripetal	0	0%	1	100%	0	0%	1	50%	2	20%
Total	**6**	**60%**	**1**	**10%**	**1**	**10%**	**2**	**20%**	**10**	100%

Table 55: Frequency of Levallois core types at the GOT1-S site.

Regular Cores										
	EC22		MG32		Scatter1		Isolated Finds		Total	
Core Type	N	%	N	%	N	%	N	%	N	%
BASALT	**6**	**100%**	**0**	**0%**	**1**	**100%**	**1**	**50%**	**8**	**73%**
LEVALLOIS	6	100%	0	0%	1	100%	1	50%	8	73%
QUARTZ	**0**	**0%**	**2**	**100%**	**0**	**0%**	**1**	**50%**	**3**	**27%**
BLADE	0	0%	1	50%	0	0%	0	0%	1	9%
LEVALLOIS	**0**	0%	1	50%	**0**	0%	1	50%	2	18%
Total	**6**	**55%**	**2**	**18%**	**1**	**9%**	**2**	**18%**	**11**	**100%**

Table 56: Frequency of regular core types at the GOT1-S site.

There is one semi-cylindrical bladelet core among the regular cores in the GOT1-S assemblage (Table 56). However, the volumetric exploitation of raw materials is well attested among the lithic product assemblage. The bladelet core is part of the MG32 scatter, and blades, crested blades, and bladelets are present here primarily in quartz.

4.5.2 Irregular cores

Irregular cores (56%) are overall more abundant than regular ones (44%) (Table 54) and are represented by cores-on-flakes, polyhedral and triangular cores with opportunistic and multidirectional exploitation of convexities, cores with multiple platforms, cores with a few removals, and centripetally exploited cores. The latter may be related to the initial phases of core exploitation. Irregular cores on basalt make up 79% of the cores (Table 57). Irregular products were found both within the scatter and as isolated finds. The presence of cortical basalt flakes with irregular or quadrangular shapes is also attested within the scatters. Evidence of irregular quartz products is limited compared to basalt products and consists mainly of cortical irregular shaped flakes, which may relate to the initial phase of regular core preparation in the area.

Irregular Cores										
	EC22		MG32		Scatter1		Isolated Finds		Total	
Core Types	N	%	N	%	N	%	N	%	N	%
BASALT	**5**	**100%**	**0**	**0%**	**1**	**100%**	**5**	**71%**	**11**	**79%**
Core-on-flake	1	20%	0	0%	0	0%	0	0%	1	7%
Disc	0	0%	0	0%	0	0%	3	43%	3	21%
Polyhedral	3	60%	0	0%	1	100%	1	14%	5	36%
Triangular	1	20%	0	0%	0	0%	1	14%	2	14%
QUARTZ	**0**	**0%**	**1**	**100%**	**0**	**0%**	**2**	**29%**	**3**	**21%**
Polyhedral	0	0%	1	100%	0	0%	2	29%	3	21%
Total	**5**	**36%**	**1**	**7%**	**1**	**7%**	**7**	**50%**	**14**	**100%**

Table 57: Frequency of irregular core types at the GOT1-S site.

4.5.3 Flake analysis

The lithic assemblage includes numerous *debitage* flakes from the early stages of production, as indicated by the occurrence of many cortical basalt flakes (38%) and the presence of preparation flakes to produce core convexities - such as debordant flakes – as well as core preparation flakes. However, there is only very rare evidence of striking platform preparation flakes, as well as crested blades and bladelets. This is also testified by the evidence on cores, where platform preparation appears to be very basic. The flake analysis shows a higher percentage of cortical basalt artefacts, but conversely, quartz flakes are characterised by a general lack of cortex (Appendix 2, supplementary table 7) (Figures 54 and 55).

Flake production includes the frequent use of the Levallois method on both basalt and quartz. Specifically, dorsal scar directions on basalt flakes show flake production involved Levallois preferential, unipolar convergent, and centripetal removal patterns. Levallois flake scar patterns are mainly unipolar convergent and centripetal, with a low occurrence of preferential products. This interpretation is based on the different dorsal scar patterns of Levallois flakes, and scar patterns on the upper surfaces of Levallois cores. Technological analysis of flake production on quartz shows the frequent use of the Levallois centripetal method. In addition to the Levallois method, elongated flakes with a wide platform angle were made through the volumetric exploitation of convexities. The presence of blades, crested blades, and bladelets - the latter especially on quartz - confirms the presence of the laminar reduction system (Appendix 2, supplementary table 8).

4.5.4 Retouched flakes

The presence of retouched flakes across the whole Gotera area is very limited. From technological analysis, every stage of the *chaîne opératoire* is present, but unretouched blanks represent the majority. Among the retouched flakes found at the GOT1-S site, there are retouched flakes and denticulates. Preparation flakes that show evidence of retouching are found mostly in the basalt assemblage (Appendix 2, supplementary table 9). Most of the retouched tools in basalt are made on cortical flakes (56%) and denticulates are the most frequent tool type (33%), while there is a similar frequency of all other basalt retouched tools. There is only one chert specimen among the retouched preparation blanks, which occurs in the form of a denticulate made on a crested bladelet. No retouched preparation blanks on quartz have been identified (Figure 54, 55 and 56).
Retouched flakes made on production stage items are also present both on basalt and quartz. Basalt retouched flakes are predominant (73%), while the quartz retouched tools on production flakes are only 21%. The most predominant blank used for retouching are ordinary flakes both for basalt (36%) and for quartz (7%). Among basalt exploitation, a bit more frequent are ordinary flakes with irregular retouch on the ventral face (7%), while the distribution of denticulate, Levallois retouched flakes are scanty and homogenous.
The quartz exploitation for retouched tools made on production stage items is scanty and constituted by 1 denticulate made on ordinary flake, 1 Levallois retouched point and 1 Levallois retouched unipolar recurrent flake.

4.5.5 Techniques

Technological analysis shows a predominance of plain platform types among both basalt (43%), and quartz (23%) artefacts, as well as those made from other raw materials (Appendix 2, supplementary table 10). Analysis also reveals evidence of different platform types, even if at much lower frequencies. These consist of dihedral, facetted, and cortical for basalt (4%, 5%, and 4% respectively), and dihedral and facetted for quartz (3% and 9% respectively) (Appendix 2, supplementary table 10).
Platform types also seem to vary according to raw materials. Cortical platforms only occur on basalt artefacts, and plain platforms in this raw material are dominant in the assemblage. Among quartz artefacts, prepared platforms are more abundant than for basalt.
The analysis of platforms on unretouched flakes and tools from both scatters and isolated finds shows substantial variability in technology and confirms the existence of two different reduction systems and multiple economies according to the raw materials exploited.

The GOT 1-S lithic assemblage is characterised by visible bulbs of percussion and impact points related to direct percussion with hard hammers. In the exploitation of basalt, flat bulbs are most frequent (29%) followed by normal bulbs (19%) (Appendix 2, supplementary table 11). The same pattern is visible in the exploitation of quartz, where flat bulbs make up 23% of the assemblage, while normal bulbs 16%. According to this bulb and platform analysis, the techniques used to produce flakes and tools were primarily direct percussion with hard hammer.

4.5.6 Chaîne opératoires stages

Analysis shows that the preparation, production, exploitation, use, and abandonment phases of lithic production are all present within the assemblage (Appendix 2, supplementary table 12). In general, the preparation and exploitation phases are more frequently represented. The first is reflected in the occurrence of a considerable number of cortical flakes, in the presence of convexity preparation flakes such as debordant flakes, and core platform preparation flakes, while the second is reflected in the presence of ordinary flakes and blades, Levallois products (blades, points, and flakes).

Among the basalt artefacts, the exploitation phase is the most frequently represented, making up 25% of the overall assemblage, followed by the preparation (18%), and subsequently the abandonment (9%), and use (6%) stages. The procurement phase is very poorly represented and even then, is only present among the basalt artefacts (1%).

Within the quartz assemblage, the exploitation phase is very well represented and makes up 30% of the overall lithic assemblage, followed by preparation (6%), abandon (3%), and use (1%) stages. In general, the use and abandonment phases are less common, both for quartz and basalt. The procurement phase is absent for quartz artefacts.

The technological analysis of flakes suggests differences in the production sequence according to the different raw materials that were exploited (Fusco et al. 2021). Basalt products appear to be more elongated in general, and their platforms are usually plain, thick, and large with a wide platform angle. On the other hand, quartz flake production seems to have had different knapping goals: quartz flakes are generally smaller with a high percentage of prepared platforms and a minor incidence of plain platforms, indicating a trend toward smaller and thinner products, characterised mostly by elongated small flakes, with plain, facetted, and dihedral platforms, as well as small triangular flakes.

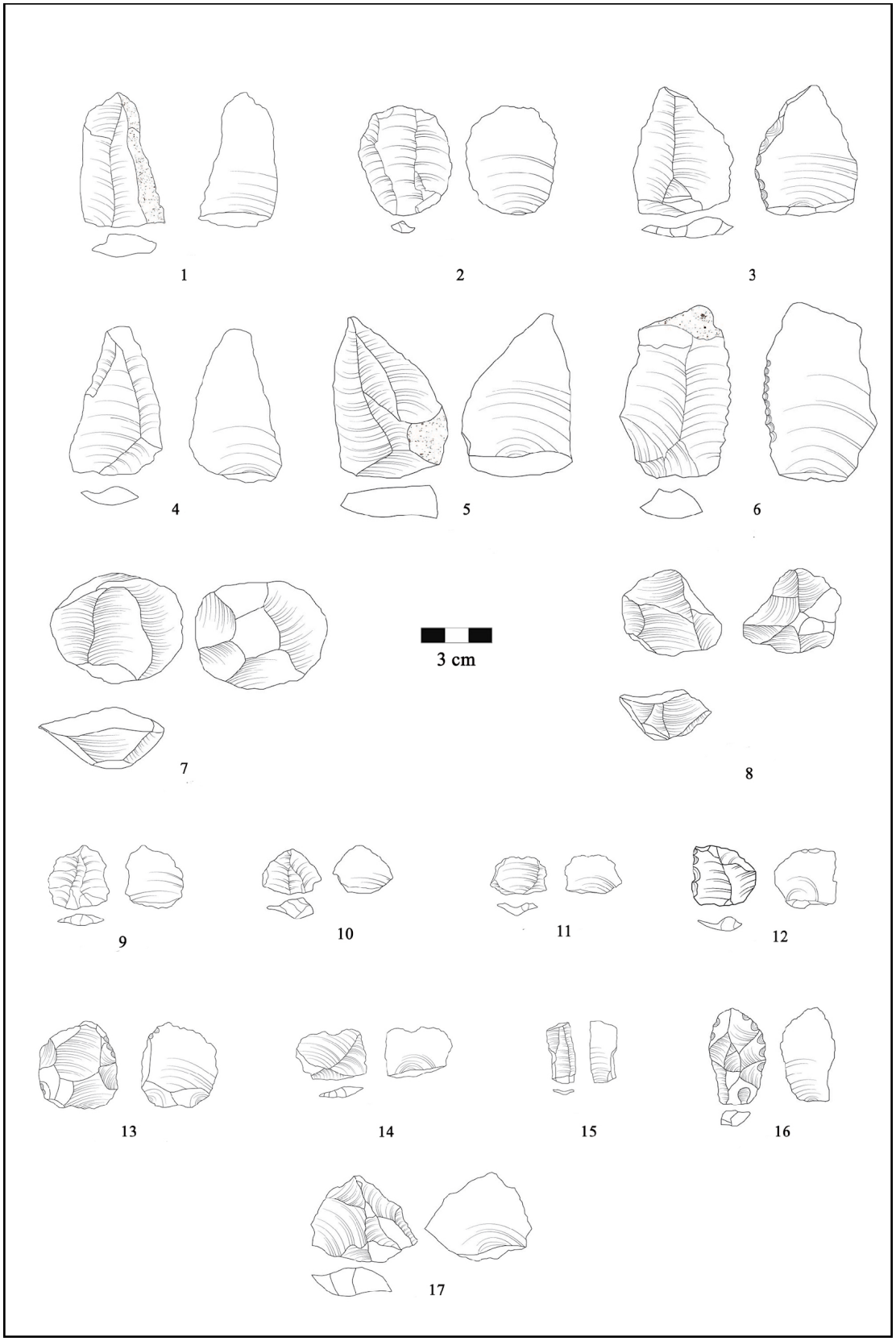


Figure 52: Lithic artefacts from GOT1-S surface collection. Basalt (1-7). Volumetric points (1, 4), Levallois flake (2) and Levallois retouched point (3), point (5), retouched flake (6), Levallois core (7). Quartz (8-17), Levallois flakes (9-14), discoid flake (17), bladelet (15), Levallois core (8) (Fusco et al. 2021).

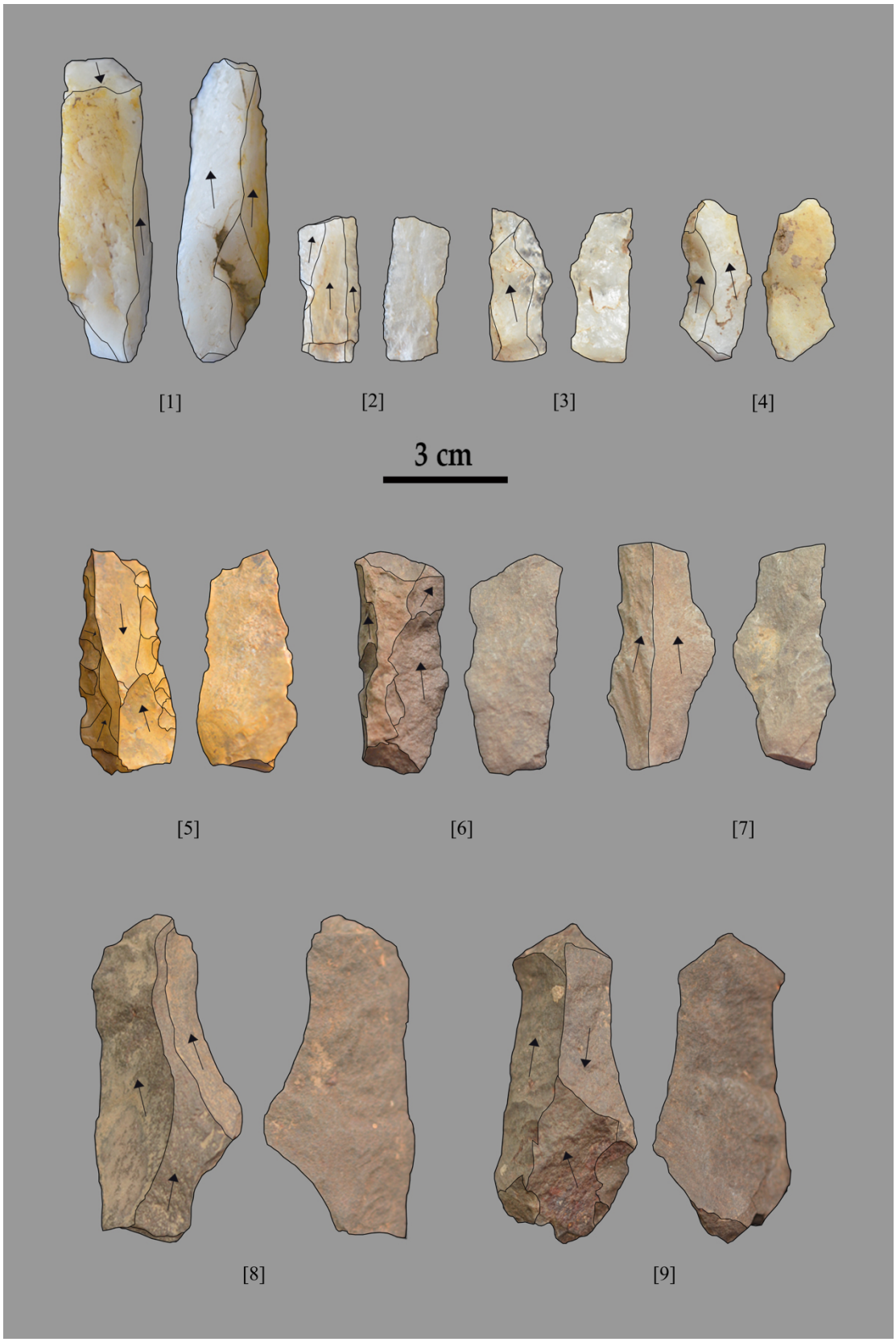


Figure 53: Lithic artefacts from GOT1-S: cortical blade (1), bladelets (2-4), crest retouched blade in chert (5), crest cortical bladelet in basalt (6), crest bladelet in basalt (7), debordant blade (8), crest blade (9).

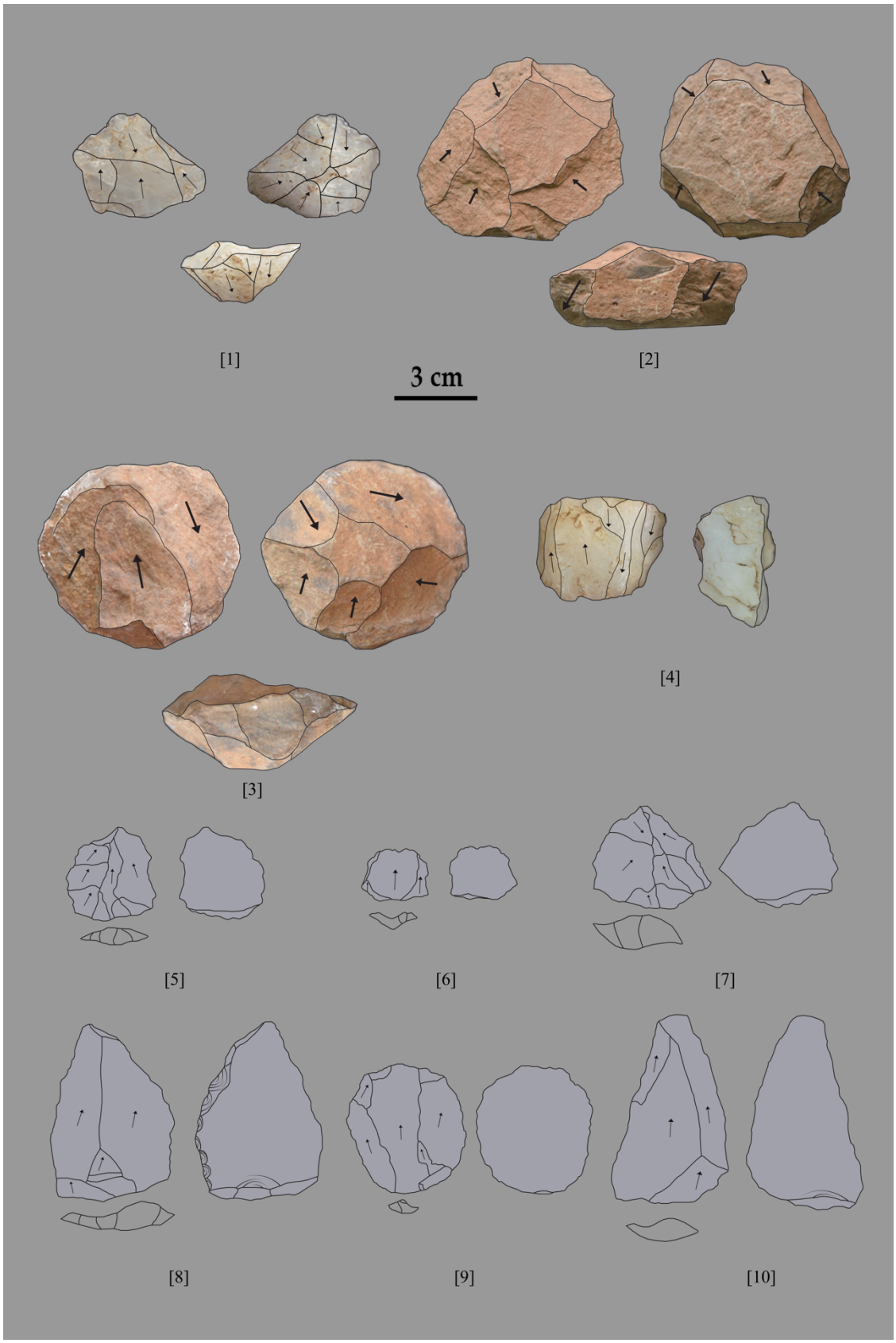


Figure 54: Lithics from GOT 1-S: Levallois cores (1-3), bladelet core (4), Levallois flakes in quartz (5-7), Levallois retouched point in basalt (8), Levallois preferential flake in basalt (9), volumetric point in basalt (10).

4.6 Discussion

The results obtained from the technological analysis of the GOT1-S lithic assemblage can be summarised as follows:

1) There is a low incidence of post-depositional alterations, reflecting a high-density dispersion of relatively fresh lithics and bones.

2) The predominant techniques used were direct percussion using hard and soft hammers.

3) The surfaces and percussion platforms of quartz core were extensively prepared to produce flakes and blanks of predetermined size and shape. By contrast, basalt exploitation seems to have focused on taking advantage of the natural convexities of cobbles, even for Levallois and the other *débitage* methods identified. Diverse strategies including Levallois and non-Levallois methods were employed for flake and blank production.

4) Generally, the raw material economy and production were adapted to three technological products: Levallois flakes, quartz and basalt blades, and quartz bladelet production.

The results confirm the affinity of this assemblage with the MSA. This is particularly thanks to the presence of Levallois and discoid reduction systems. The GOT1-S assemblage documents technological variability at a local scale since multiple core reduction strategies are evident. Big flakes and blades in basalt (mainly cortical and debordant with unprepared platforms) were one specific production goal at Gotera, together with smaller and more prepared *débitage* products on quartz. At Gotera, both Levallois and non-Levallois methods were used for flake production, based on the presence of Levallois and non-Levallois cores, as is common for MSA assemblages (Tryon and Faith 2013). Within the Levallois reduction, multiple strategies were employed, as is often the case in the MSA. This includes preferential, recurrent unipolar convergent, and recurrent centripetal approaches to produce flakes and blanks with different morphologies. Laminar production was also implemented at Gotera. According to the results of technological analysis, morphological characteristics linked to the laminar *débitage* are present in both quartz (bladelet production) and basalt (blade production). These characteristics appear together with other *débitage* methods.

The analytical results from GOT1-S reveal the presence of two different technical behaviours linked to different raw material choices. These distinct technological strategies are likely affected by raw material dimensions, quality, and abundance: raw materials were selected and then exploited using specific approaches. Quartz artefacts show strong technological affinities - careful core and platform preparation, size reduction, recurrence of Levallois and laminar methods, and other flake removal patterns (Figure 56). Conversely, basalt production shows a more opportunistic exploitation of cores and their natural convexities,

which is also the case for Levallois production. Basalt cores often retain a large percentage of cortex, suggesting they were exploited during the initial phase in the reduction process as part of a more opportunistic reduction strategy. This is contrasted with Levallois cores, which show preparation convexities but often also a large presence of cortex on the lower surface. This indicates basalt was abundant and available since the cores were not heavily exploited. Recurrency in regular, irregular, and multidirectional flake removal patterns is also evidenced, and produces substantial variability in basalt flake production.

In the Gotera assemblages, the Levallois method often occurs together with the volumetric exploitation of the natural convexities of basalt cobbles, which is also the case in the GOT-10 assemblage, with the additional identification there of an intermediate reduction system. This combined method contributes to the widespread and high proportion of flakes at the Gotera site that are curved, elongated, and often convergent and have plain, or sometimes dihedral platforms with a wide angle. Overall, the lithic assemblage is highly patterned according to size, shape, and technology. Technological differences between quartz and basalt lithics may reflect a difference in raw material procurement strategies and management or a selection of the raw material based on the desired morphologies and intended functions of the products. Moreover, results from the technological analysis of the lithic assemblage recovered *in situ* from Mound1 at the GOT10 site demonstrate that the exploitation of basalt and quartz together was integrated into one cohesive subsistence strategy. Thus, the difference in *chaînes opératoires* is the result of the intelligent management of the available resources because they have been found buried in the same level and clearly belong to the same occupational episode.

The differential use of quartz and basalt at Gotera is peculiar and sheds light on the management of environmental resources in this area during the Pleistocene. The exploitation of local raw materials reflects a well-developed adaptation to that specific landscape, which is also characterised by a lack of high-quality raw materials, such as obsidian. Obsidian is generally present at other Ethiopian MSA sites - such as Melka Kunture, Mochena Borago, or Gademotta-Kulkuletti formation (Brandt et al. 2012; Douze & Delagnes 2016; Mussi et al. 2014). The exploitation of chert is demonstrated by the presence of six artefacts, but there is no known origin, either local or distant, of this material. However, the exploitation of chert is well attested in the sites of the Omo Valley (Shea et al. 2007; Shea, 2008).

The GOT1-S assemblage confirms the regional character of the MSA, where human groups built lithic tradition upon strictly local conditions.

One potential limitation of Pleistocene archaeological sites and assemblages is the possibility that they represent time-averaged palimpsests (Binford 1981, 1987). It is possible

that the multiple reduction strategies identified could represent multiple separate occupations, or visits to the same locality for the same or different purposes over time (Binford, 1976, 1980; 1982; Inizan et al. 1999; Kuhn, 2020; 1994; Perlés, 1991; Soressi and Geneste 2011). It is therefore crucial to consider the distribution and chronology of the sites to extract information about landscape use and the exploitation of the surrounding areas. The Gotera lithic assemblages reveal a certain amount of technological variability, as shown by several knapping strategies, and confirmed by statistical analyses (Fusco et al. 2021). This variability in stone tool knapping and manufacturing provides a solid starting point from which elaborate future research lines. These should test the idea that multiple reduction strategies were part of a shared technological *répertoire* among human groups that were adapted to cope with local conditions, including the local availability of raw materials.

4.7 Inter-site comparative statistical analysis of the Gotera area

Once established the technological characteristics of the GOT1-S and Chavaillon's sample lithic assemblages, it can be possible to proceed with the comparative inter-site statistical analysis. Therefore, the same technological attributes from the three assemblages synthesised in the Figure 57 will be compared using the methodology outlined below.

Comparative regional analysis samples		
GOT-10	**GOT1-S**	**GOT-CH**
Mound1 (SUs)	Scatters	Chavaillon's sample
Clusters	Isolated Finds	(From Locality I to IX)
Scatters		

Figure 55: Schematic synthesis of the lithic assemblages' provenance considered in this comparative analysis.

4.8 Methods

The comparative analysis was conducted using multivariate statistical methods. All the analyses were performed using the RStudio software (R Core Team 2023). The three assemblages (GOT-10, GOT1-S and GOT-CH, Figure 57) have been categorised into four major groups based on the technological assessment of artefacts: cores, flakes, elongated blanks (blades and bladelets), and retouched flakes. Given the minimal representation of retouched tools within the three assemblages (and generally at Gotera, as noted in Fusco et al. 2021), only one tool type – the denticulate – could be considered for statistical comparison. This is because the limited number of retouched tools could potentially impact the results, introducing bias into the interpretation.

Each lithic category was subjected to the same statistical methods to ensure comparability. The attribute-based statistical approach used for the intra-site analysis (Chapter 3) has been also applied here, combining PCA and CA.
I ran the PCA on flakes, considering the number of flakes as cases and comprising values for six attributes (Table 58). Since "Raw Material" is not a quantitative attribute, I employed the function *as.factor*() from the R Base package to treat it as a categorical variable.

Flake Analysis	
Technological length	XTL
Technological bredth	XTB
Maximum thickness	XT
Elongation index	EI
Flattening index	FI
Number of scars	FR
Platform thickness	PT
Platform width	PW

Table 58: Variables used for PCA on flakes.

To perform the PCA on cores, I considered the number of cores as cases and comprising values for nine attributes (Table 59): five technological and four morphological.
Again, raw material was not considered as an active quantitative variable, as it could disrupt the results, thus it was considered a categorical variable using the function *as.factor()*. Length, width, elongation index and thickness were considered in order to describe size and shape.
The number of technological and morphological striking platforms and the number of major flakes detached from the core are two useful variables to investigate the process of reduction, thus they were considered into the analysis.

Core Analysis	
Maximum Length	XTL
Maximum Breadth	XTB
Maximum Thickness	XT
Elongation index	EI
Flattening Index	FI
Number of Striking Platform (morphological)	NSP
Number of Striking Platform (technological)	NTSP
Number of negatives	CNFS

Table 59: Variables used for the PCA on cores.

To visualise the results and especially any differences between cores, blades, bladelets, and flakes across the various datasets from Gotera, I used the function *grid.arrange*() from the *gridExtra* package (Baptiste Auguie, 2015) to create a multiplot that displays variation in size and shape of the lithic assemblages. To elaborate the PCA plots for blanks, cores, and retouched tools, indicating artefacts as specific cases along with the direction of variables on the principal components, grouped by site, the *fviz_pca_biplot()* function from the *FactoMineR* package was used.

Categorical variables for flakes and cores were explored using Correspondence Analysis (CA). For the CA performed on flakes, four active categorical variables (percentage of cortex, platform type, dorsal scar pattern, bipolar on anvil presence), and two supplementary categorical variables (sites and raw materials) were considered (Table 60). The same variables have been considered also for the analysis of elongated blanks. For the core analysis (Table 61), five active categorical variables (percentage of cortex, core type, flake scar direction, degree of core reduction, and bipolar on anvil) and two supplementary variables (sites and raw materials) were considered.

Variables used in the CA for Flakes			
Active qualitative variables			
Cortex		Percentage of cortex	0 - 100%
Platform type		Abraded	PL_AB
		Cortical	PL_CTX
		Dihedral	PL_DH
		Facetted	PL_FC
		Linear	PL_LIN
		Plain	PL_PLA
		Punctiform	PL_PUN
		Missing	PL_MIS
Direction of scars pattern		Cortical	DSP_CTX
		Unipolar	DSP_UNI
		Unipolar Convergent	DSP_UNIC
		Bipolar	DSP_BIP
		Centripetal	DSP_CEN
		Bipolar on anvil	BIP
		Not visibile	N/A
Active supplementary variables			
Site		GOT-10 site	GOT-10
		GOT1-S	GOT1-S
		Chavaillon's sample	GOT-CH
Raw Materials		Basalt and quartz	BAS/QUA

Table 60: Variables used for the CA on flakes.

Variables used in the CA for cores			
Active qualitative variables			
Cortex		Percentage of cortex	0 - 100%
Core Type		Levallois Preferential	L_PREF_CL
		Levallois Preferential bipolar	L_PREF_BIP
		Levallois Recurrent bipolar	L_REC_BIP
		Levallois Recurrent unipolar	L_REC_UNI
		Levallois Recurrent centripetal	L_REC_CEN
		Polyhedral	POLY
		Triangular	TRIANG
		Core on flake	CORE_FL
		Disc	DISC
Flake Scar Direction		Bidirectional	BID
		Bidirectional Irregular	BID_IRR
		Centripetal	CENT
		Convergent	CONV
		Multidirectional	MULT
		Unidirectional	UNID
Degree of Core reduction		Primary	PRIM
		Secondary	SEC
		Tertiary	TER
		Exhausted	EXHA
Bipolar on anvil			BIP
Active supplementary variables			
Site		GOT-10 site	GOT-10
		GOT1-S	GOT1-S
		Chavaillon's sample	GOT-CH
Raw materials		Basalt and Quartz	BAS/QUA

Table 61: Variables used for the CA on cores.

In the retouched tools analysis (Table 62), four active categorical variables (percentage of cortex, platform type, direction of scars pattern, retouch location) and two supplementary variables (sites and raw materials) were considered.

Variables used in the CA for Flakes			
Active qualitative variables			
Cortex		Percentage of cortex	0 - 100%
Platform type		Abraded	PL_AB
		Cortical	PL_CTX
		Dihedral	PL_DH
		Facetted	PL_FC
		Linear	PL_LIN
		Plain	PL_PLA
		Punctiform	PL_PUN
		Missing	PL_MIS
Direction of scars pattern		Cortical	DSP_CTX
		Unipolar	DSP_UNI
		Unipolar Convergent	DSP_UNIC
		Bipolar	DSP_BIP
		Centripetal	DSP_CEN
		Bipolar on anvil	BIP
		Not visibile	N/A
Retouch location		Dorsal retouch	D_RET
		Ventral retouch	V_RET
		Dorsal retouch on left edge	D_RET_SX
		Dorsal retouch on right edge	D_RET_DX
		Ventral retouch on left side	V_RET_SX
		Ventral retouch on right side	V_RET_DX
Active supplementary variables			
Site		GOT-10 site	GOT-10
		GOT1-S	GOT1-S
		Chavaillon's sample	GOT-CH
Raw Materials		Basalt and quartz	BAS/QUA

Table 62: Variables used for the CA on retouched blanks.

4.9 Results of the Gotera Area Comparative Analysis

4.9.1 Results of the comparative analysis of quantitative variables

The results of the PCA performed on the unretouched blanks (flakes) from the three lithic assemblages from Gotera are presented in Figure 58. The first two components capture 67% of the variance in the analysed data. The primary variables influencing the first dimension include technological measurements such as maximum length, breadth, and thickness. On the second dimension, the most impactful variables are the two indices of elongation and flattening. Given the positive scores of the loadings, moving upwards along the first two components corresponds to an increase in artefact size, platform angle, and longitudinal curvature. The PCA plot reveals discernible differences in shape and size among the assemblages. Notably, the GOT-10 flake assemblage preferentially occupies the extreme left part of the graph, indicating smaller items. In contrast, Chavaillon's assemblage appears to be positioned toward the centre and right side of the graph, where dimension values are greater. This trend is further emphasized by the variables on the second dimension that capture shape. The GOT-10 flake assemblage is mainly represented by smaller flakes and exhibits a homogeneous distribution of flakes that are either small, long, and thin, or small and thick. No apparent differences are observed between the GOT1-S and Chavaillon's flake assemblages. However, to enhance the visualization of the PCA results and facilitate the comparison of the three assemblages, the results are also shown in a single plot (Figure 59).

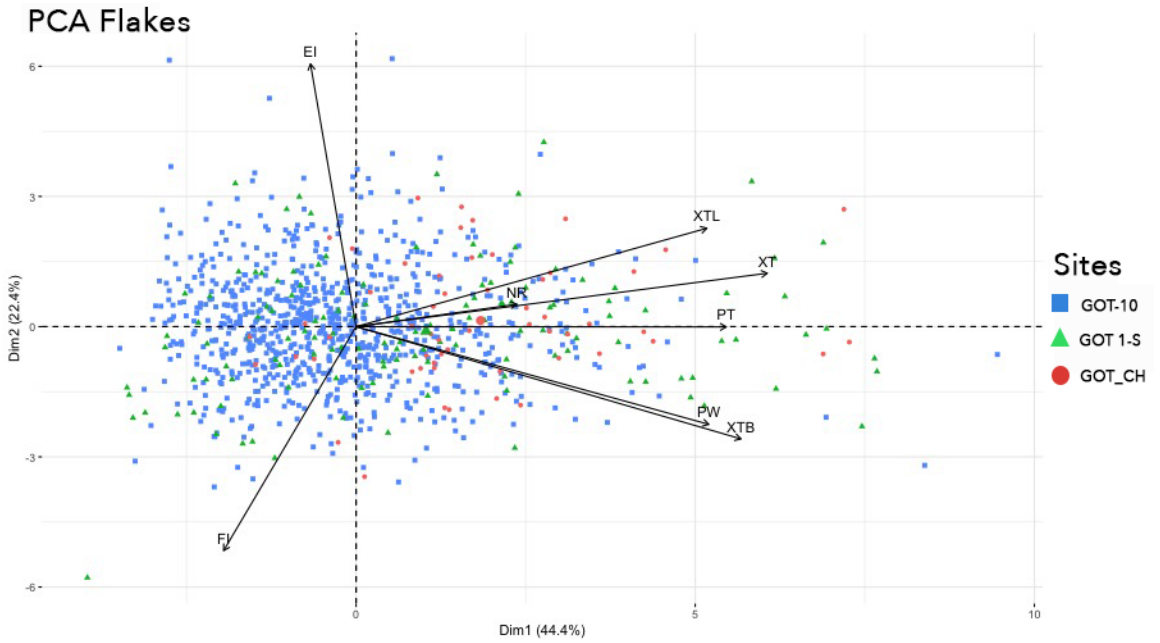


Figure 56: Biplot of the results of the PCA for unretouched flakes from GOT-10, GOT1-S, and GOT_CH, showing individuals distribution and variables.

To gain a better visualization to the differences between the sites, I have also grouped these results of the PCA by separating them into flakes, blades, and bladelets (Figure 59). The differences between the assemblages in terms of size and shape are evident, with flakes from the GOT-10 site positioned on the extreme right of the graph, corresponding to the smallest dimensions. In the middle, flakes from the GOT1-S assemblage appear to be mostly distributed in the centre and left part of the graph, indicating correspondence with an increase in the size of the artefacts. Furthermore, based on the variables of the second dimension, it seems that the flakes from GOT1-S are characterised by a substantial shape variability as they are as thick and short as they are thin and longer.
The flake assemblage from the Chavaillon's collection is almost entirely situated along the left side of the graph, where the dimension values are greater. Along the second dimension, the assemblage seems to exhibit shapes characterised by thicker elements.
The same pattern described for flakes appears to be valid for the blades and bladelets as well, where the GOT-10 assemblages are characterised by smaller, thinner, and relatively longer blanks, while the other two sites seem to have larger shapes and sizes.

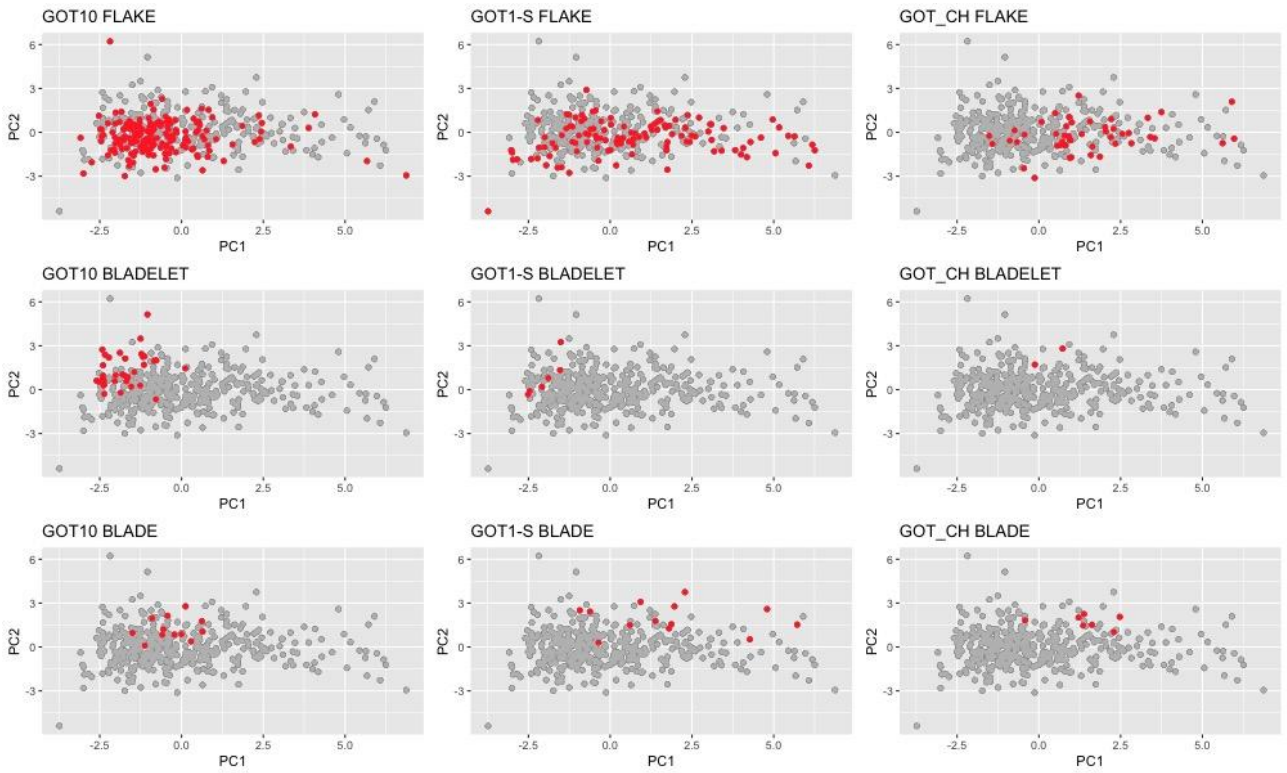


Figure 57: Multiplot showing results of the PCA on unretouched blanks from GOT-10, GOT1-S and GOT_CH divided by blank type.

To enhance our understanding of production dynamics in the Gotera area, it is also important to analyse the cores. The results of the PCA on cores are shown in Figure 60. The

first principal component explains 36.3% of the variance, and the second component explains 26.6%. Over 60% of the variation in the data is captured by these two components. The most influential variables that affect the first component are artefact measurements (length, breadth, and thickness), while the second component is mainly comprised by the number of striking platforms, together with the indices. The first component distinctly characterises aspects related to size variability, whereas the second one emphasizes shape and technology.

According to these results, the core assemblage from the GOT1-S site is positioned on the bottom right side of the graph (green in Figure 60). They appear to exhibit generally larger dimensions when compared to GOT-10 cores, which are situated on the left side of the graph. The number of striking platforms on cores is generally higher in the assemblages recovered from the GOT1-S sites and in Chavaillon's collection. However, for a clearer visualization, I have organized the results in a single plot, grouping the core assemblages by irregular and regular, for each site (Figure 61).

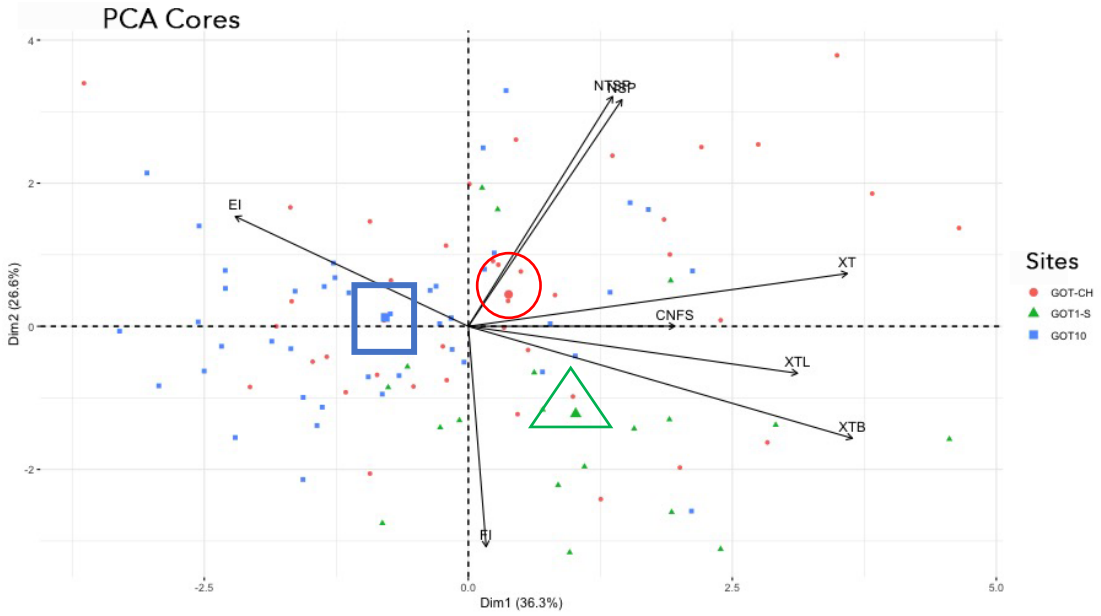


Figure 58: Biplot of the PCA results for cores from GOT-10, GOT1-S, and GOT_CH showing individuals and variables.

The results reveal a pattern in which GOT-10 irregular cores are situated on the left part of the graph, where the values represent smaller dimensions. It is also evident that irregular cores from GOT-10 exhibit a greater number of striking platforms compared to the assemblages from GOT1-S and that recovered by Chavaillon. The latter are positioned in the centre and left part of the graph and characterised by relatively larger dimensions. A similar pattern is observed in the regular cores, in which the assemblage from the GOT-10 site has generally smaller dimensions and a relatively greater number of striking platforms.

This might be attributed to the presence of multi-platform cores to produce bladelets, a trend absents in the other two assemblages.

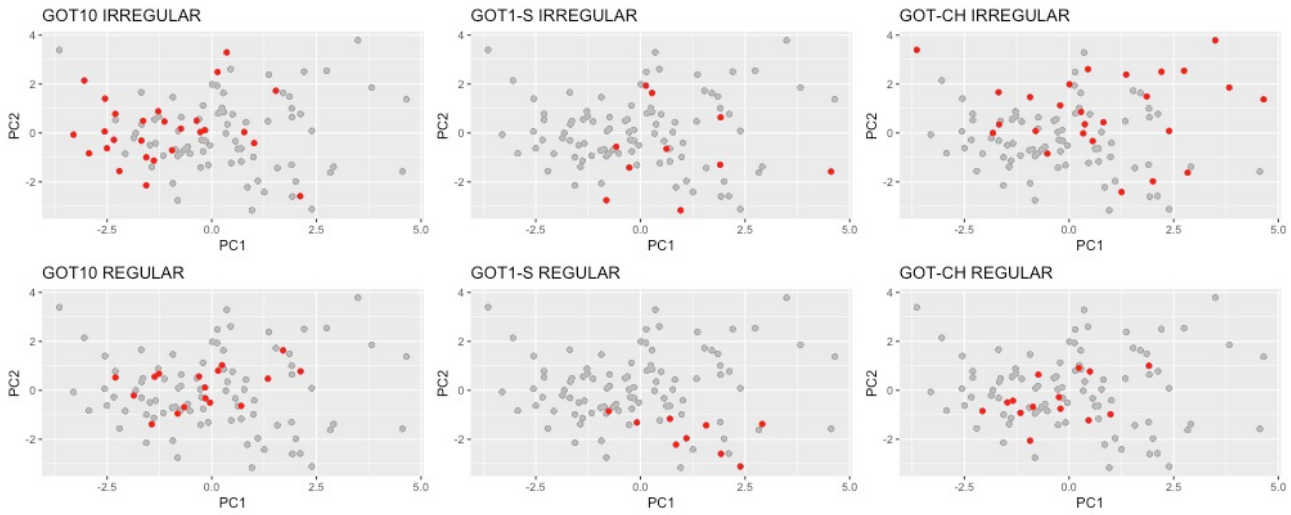


Figure 59: Multiplot showing results from the PCA on cores from GOT-10, GOT1-S and GOT_CH separated into regular and irregular cores.

The analysis of retouched tool, specifically denticulate, has been performed both for numerical and categorical variables. Figure 62 shows the results of this PCA on denticulates. The two dimensions respectively represent 40% (Dim 1) and 25% (Dim2) of the assemblage variance. The variable that is most influential on the first dimension is artefact measurements (length, thickness, and breadth) while the second dimension is mostly affected by the elongation index (EI) and platform width (PW).

Scores on the first dimension are positive, which means that the size of artefacts increases on the right part of the graph and decreases on the left side. The left side corresponds mostly to the GOT-10 denticulate assemblage, which appears to be smaller, thinner, and longer. This is confirmed by the technological analysis which has shown that most are made on quartz blades and bladelets.

The position of denticulates from GOT1-S and from Chavaillon's sample shows a different pattern compared to cores and flakes from these assemblages. These in fact are different from each other, but in this case, the artefacts from GOT1-S have bigger dimensions while those from Chavaillon's excavation stay almost in the middle.

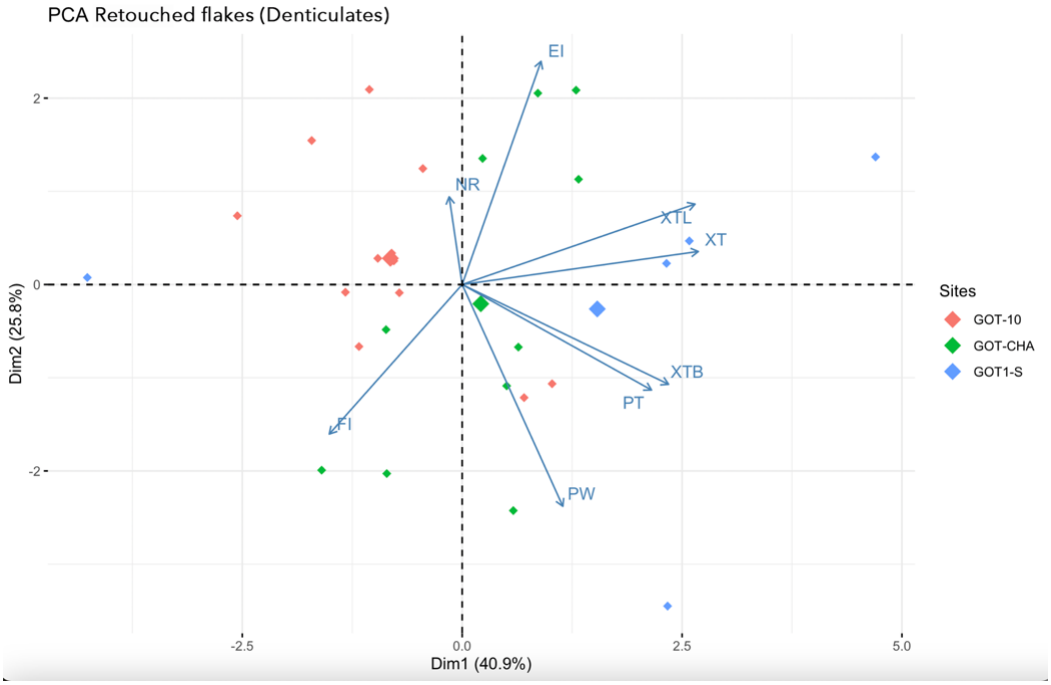


Figure 60: Biplot of the results from PCA for denticulate from GOT-10, GOT1-S, and GOT_CH showing individuals and variables.

Figure 63 helps to clarify the relative position of denticulates on flakes, blades, and bladelets from each site. At GOT-10 denticulates are made mostly on bladelets and small flakes, while at GOT1-S they are made on bigger flakes and blades. The Chavaillon sample shows the presence of denticulates on flakes with highly variable dimensions and shapes, (but generally larger than those from GOT-10) and on larger blades (more similar to GOT1-S than to GOT-10).

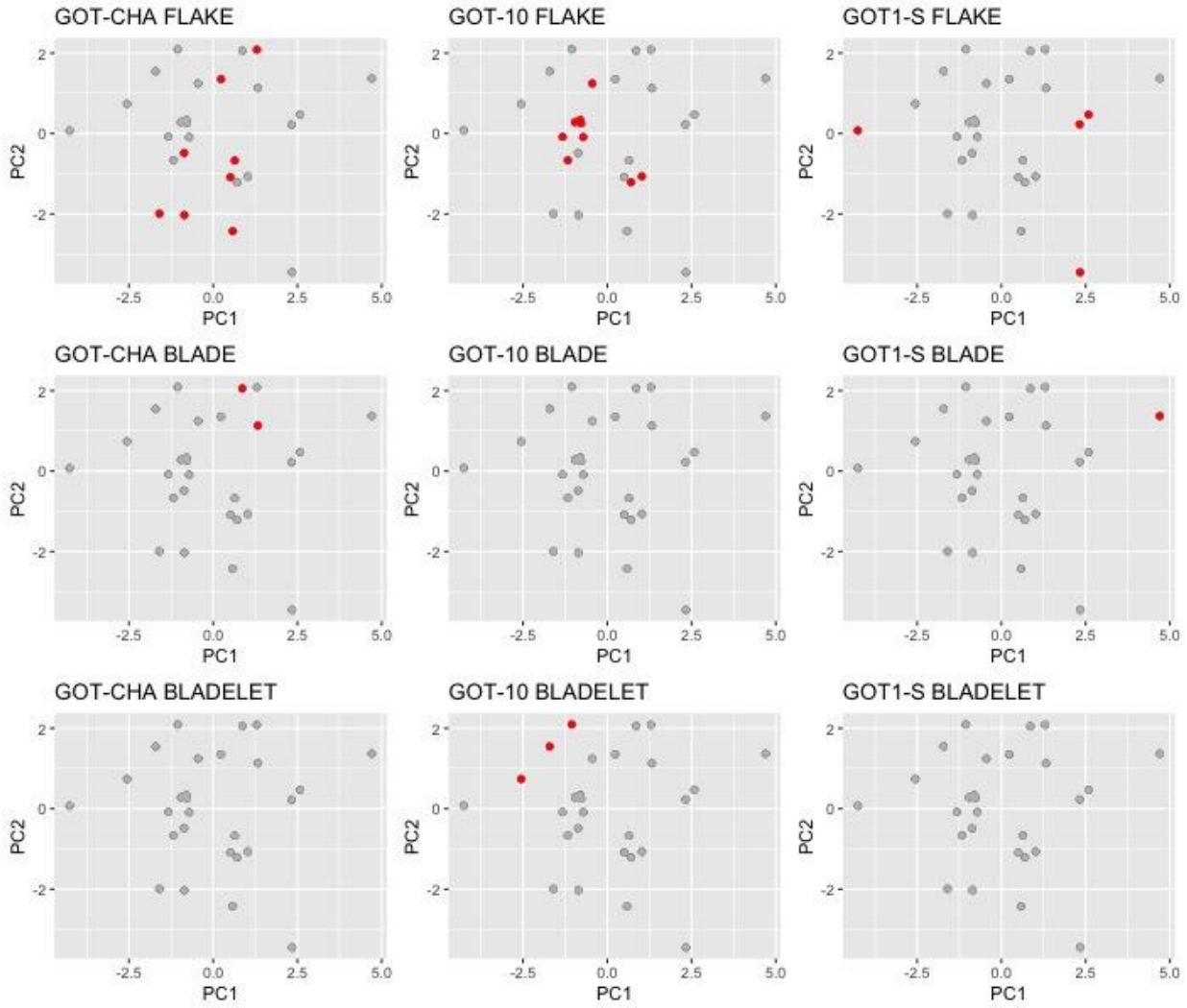


Figure 61: Multiplot showing results from the PCA on denticulate from GOT-10, GOT1-S, and GOT_CH divided by type of blank.

4.9.2 Results of the comparative analysis of categorical variables

For a more in-depth exploration of the technological characteristics of blanks and cores, categorical variables were explored by performing a correspondence analysis on the three lithic assemblages. Results of the CA for flakes are shown in Figure 64. This analysis includes two dimensions that represent the total overall variability within the flake assemblage. The first dimension includes 83.57% of the variance while the second reflects only the remaining 16.43%. Based on the analysis of the categorical variables, the three assemblages appear to be quite different from one another. The GOT-10 flake assemblage is characterised by the greater exploitation of quartz compared to the other two sites. It also exhibits a higher frequency of dihedral and punctiform platforms in contrast to GOT1-S and the Chavaillon assemblage. Moreover, the patterning of negatives on the flake dorsal faces are typically centripetal, a characteristic less regularly observed in the other two

assemblages. Conversely, at GOT1-S basalt is dominant along with facetted platforms and a higher presence of elements with high cortex coverage. Both assemblages, however, include the presence of flakes that lack cortex, have plain platforms, and show negative dorsal scar patterns reflecting bidirectional, unidirectional, and convergent knapping strategies.

The Chavaillon's assemblage, on the other hand, is characterised by a higher presence of linear and cortical platforms, as well as a greater occurrence of flakes with more than 50% of the surface covered by cortex. Despite the observed differences, the three assemblages share similarities, possibly stemming from common strategies in raw material exploitation. It appears in the surface assemblages that the basalt elements were less frequently prepared compared to the exploitation of quartz (Fusco et al. 2021).

Results for the CA for elongated blanks are shown in Figure 65. The analysis presents two dimensions that represent the total overall variability within the assemblage (100%). The first dimension captures 81.62% of the variance while the second reflects the remaining 18.38%. In this respect the three assemblages appear to be markedly different. The GOT-10 assemblage is characterised by the greater exploitation of quartz for elongated blanks, that usually lack cortex and have plain platforms. It is placed in the opposite position to the GOT1-S assemblage, which is primarily made up of cortical elongated elements. It is worth noting however that elongated blanks are not well represented in the GOT1-S assemblage, and that interpretations must remain speculative due to its surface exposure and collection.

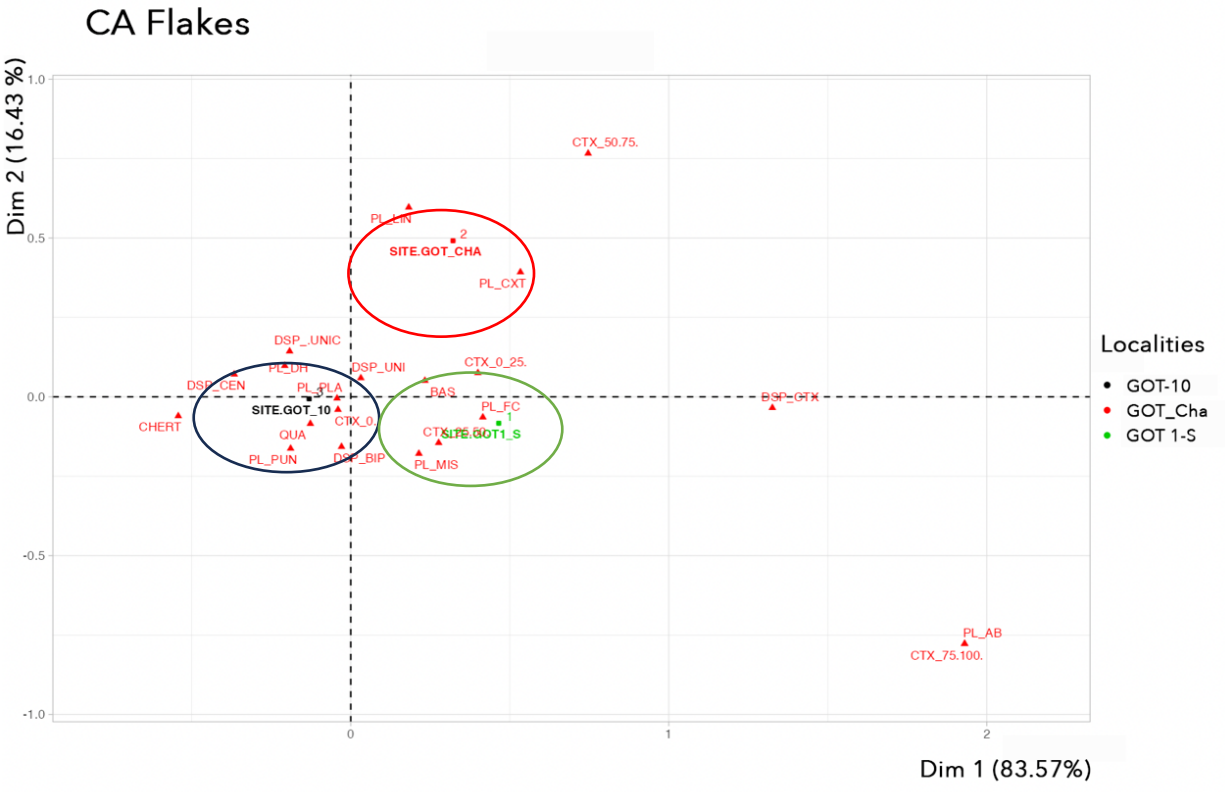


Figure 62: Plot showing results of the CA on unretouched flakes.

The sample from Chavaillon's excavation is characterised by elongated blanks mostly made on basalt and characterised by prepared platforms (both facetted and dihedral types). This is probably related to the presence of elongated blanks produced with planimetric exploitation of cores, while GOT1-S elongated blanks appear to be mostly related to laminar/volumetric reduction methods.

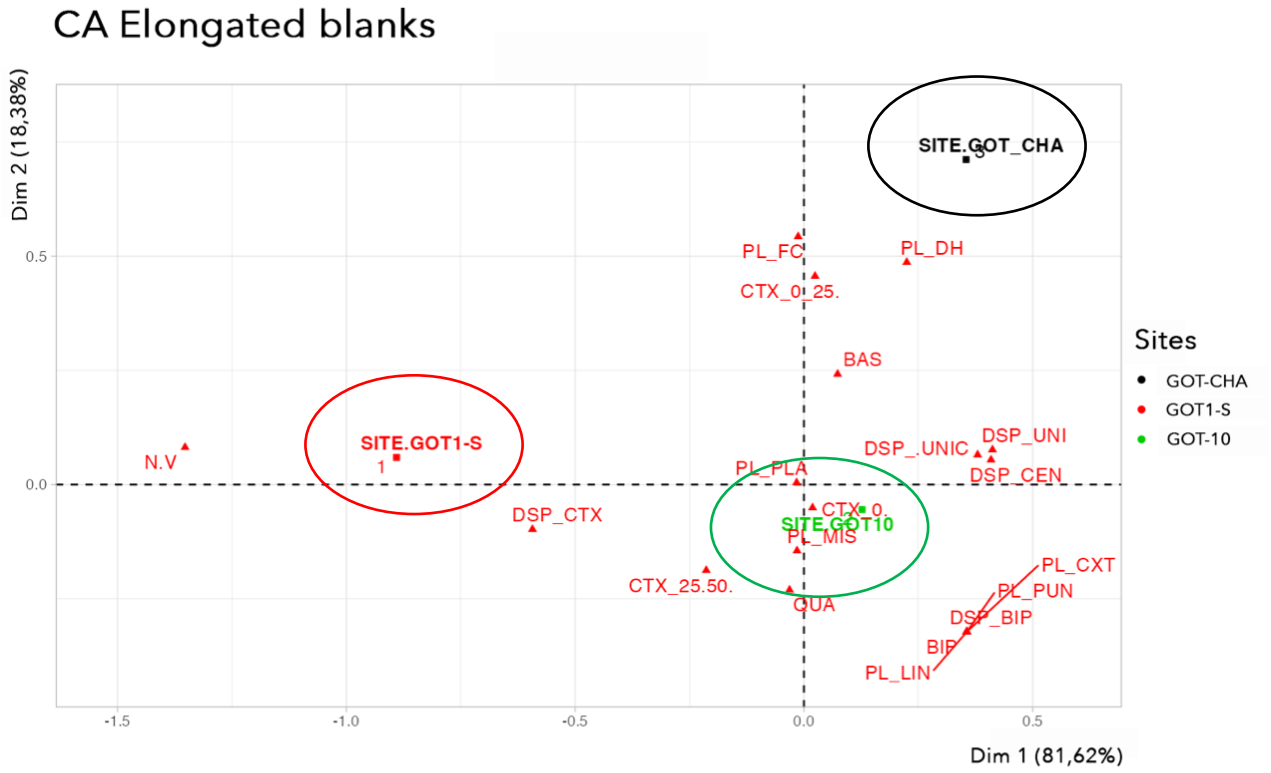


Figure 63: Plot showing results of the CA on elongated blanks.

Results of the CA on cores show that the first two components represent the total variance of the assemblage (Figure 66). The first dimension expresses 68.49% of the total assemblage variance while the second dimension explains 31.51% of the variance. The three assemblages are different. GOT-10 and GOT1-S are located at the two extremes of the first dimension. Cores in Chavaillon's sample instead seems to share more characteristics with GOT-10 than with GOT1-S cores.

The GOT1-S assemblage is characterised by Levallois recurrent bipolar cores and centripetal cores; secondary stage cores that exhibit at least 25% cortex on their surface. The cores are mostly made of basalt. The GOT-10 site assemblage, positioned on the left side of the graph in red, is characterised by greater variability in core reduction systems. Levallois centripetal, discoid, and blade cores (prismatic and semi-cylindrical) cores are registered, that are

mostly made of quartz and frequently almost exhausted. The presence of Irregular cores is greater at GOT-10. The sample from Chavaillon's excavation is characterised by irregular cores (multiplatform, double platform) as well as an intensive presence of Levallois preferential methods.

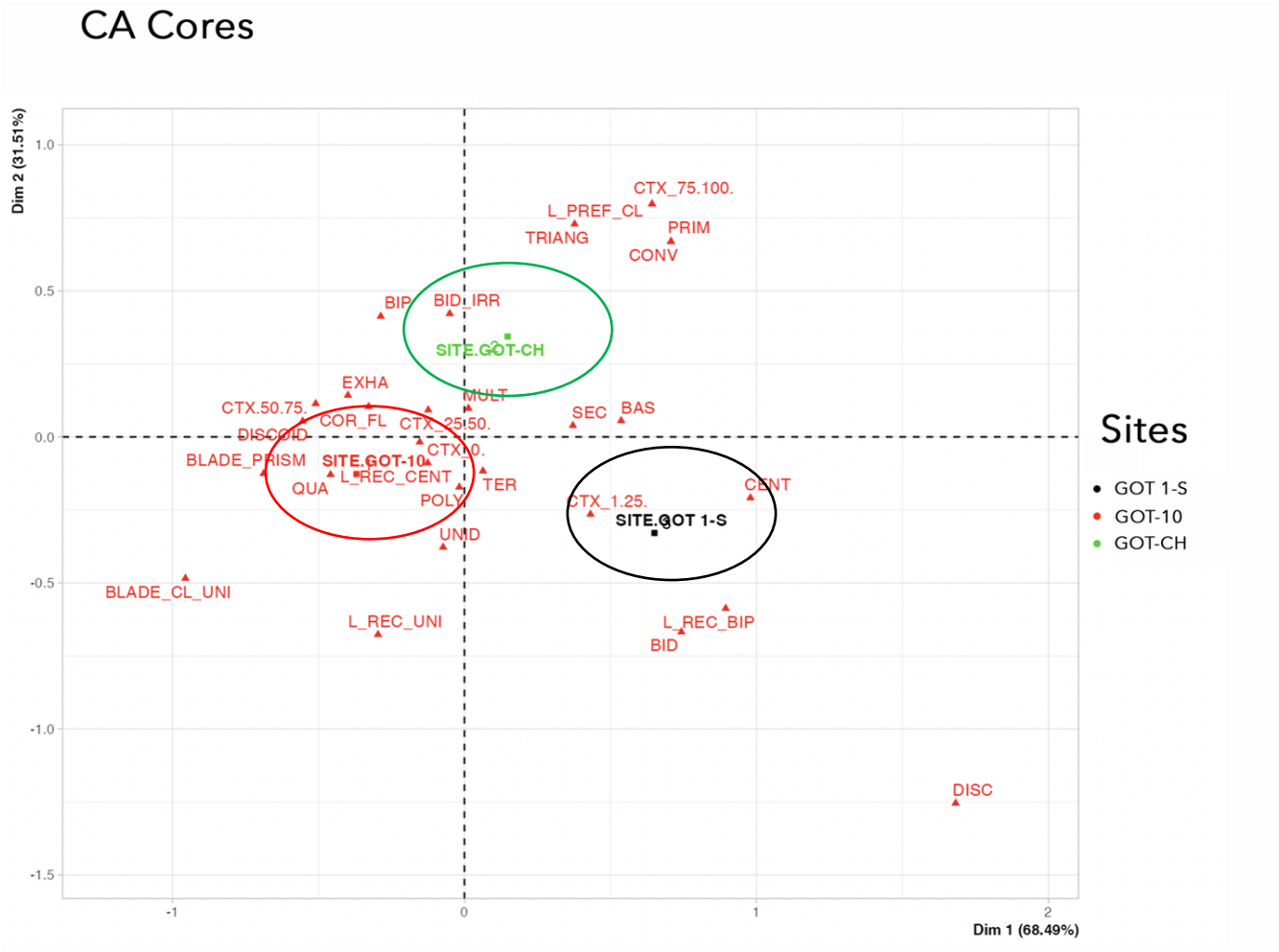


Figure 64: Plot showing results of the CA on cores.

The results of CA on retouched blanks (denticulates) show that the first two dimensions represent 94% of the total variance (Figure 67). The first dimension represents 73.97% of the variance. GOT-10 and the sample from Chavaillon's excavation are both located on the left side of the graph (in black and red), while GOT1-S is on theIte side, showing substantial differences with the other two assemblages.

The GOT-10 assemblage is characterised by mostly quartz elements with indirect retouch on their left edges, and showing a unidirectional and/or unidirectional convergent dorsal scar pattern. This is compatible with the presence of denticulates made mostly on bladelets blank. Chavaillon's sample and the GOT-10 assemblage are similar in the greater frequency of quartz denticulates, the absence of cortex, and the mostly unidirectional dorsal scar

pattern. However, Chavaillon's sample is also characterised by elements with dihedral platforms and dorsal retouch, both on the left and right edges.

The GOT1-S assemblage seems to be distinctive and is mostly represented by a higher frequency of cortical elements, plain platforms, and more cortical basalt elements.

Some features, like cortical platforms, increased cortex coverage (35-75%), and linear platform are shown here as outliers. This means that, since they reduced presence in the assemblage, they do not affect the variability of the assemblages.

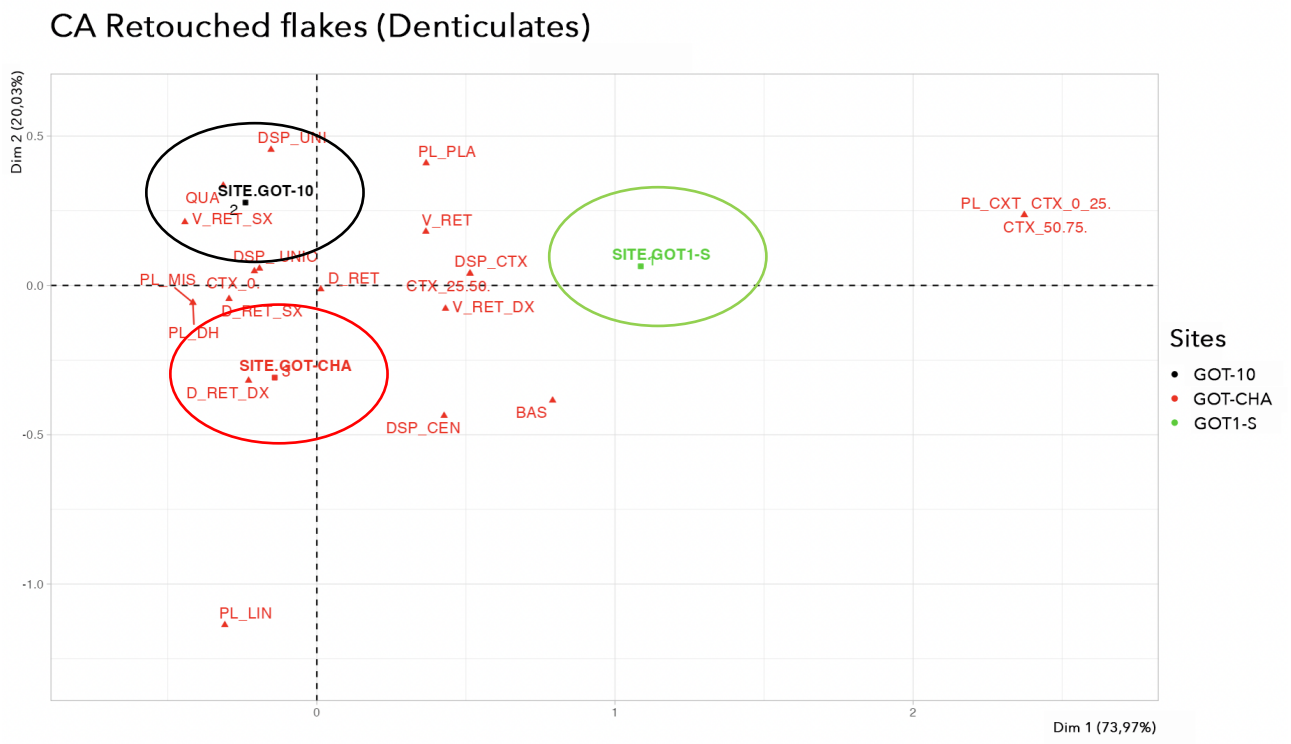


Figure 65: Plot showing results of the CA on denticulate.

4.10 Discussion

The results of this analysis demonstrate that lithic assemblages recovered to-date from the Gotera area are characterised by significant differences. The analysis of both unretouched blanks (blades, bladelets, and flakes) and cores reveals a noticeable difference in their sizes and shapes. The GOT-10 assemblage is characterised by significantly smaller dimensions compared to the surface assemblages of GOT1-S and the sample from Chavaillon's research. Both the unretouched flakes, the blades, and the bladelets (the latter in lower frequencies) appear to be smaller, thinner, and more elongated.

Furthermore, as demonstrated both by the technological and statistical analyses, the GOT-10 assemblage is oriented more towards the production of small, elongated blanks compared to the other two assemblages. This is attested by not only the presence of cores

with long and small detachments but also from the products struck from them. This is particularly evident in the presence of bladelets at GOT-10, which are more abundant than at the other locations. Not only that, but the choice of raw materials for the lithic production of small, elongated flakes also seems to differ at GOT-10. Here, quartz is not the only material used for small production (hominins probably took advantage of the naturally small size of the pebbles found near the site). Indeed, basalt is also used for producing small elongated (and-non) products. At the GOT-10 site, basalt cores are smaller, and more intensively prepared to obtain small flakes and small elongated blanks compared to GOT1-S for example. These characteristics show that some LSA schematic traits are present in the GOT-10 assemblage, such as smaller lithics and a different choice for raw material exploitation, while absent in the other two considered in the analyses.

From the results of the general Gotera assemblages, it is evident that one of the knappers main objectives was to create elongated blanks that were then subsequently rarely retouched. However, it is also important to note differences in the production of elongated blanks, especially bladelets, in the GOT-10, the Chavaillon sample, and the GOT1-S assemblages. In the GOT1-S assemblage, evidence of bladelet production is present only for quartz exploitation, and it is much less prominent compared to the other two assemblages, especially concerning basalt exploitation in the GOT-10 site. The Chavaillon's sample, on the other hand, seems to fall into the same category of lithic production as GOT-10, where evidence of volumetric exploitation (particularly evidenced by the presence of cores with bladelet detachments, which are notably different from bladelet cores) is prevalent, even for basalt. However, it is important to highlight that in the Chavaillon's sample, there are many artefacts with significantly larger dimensions (both flakes and cores). Typically, the cores in the Chavaillon's sample are large but show evidence of volumetric exploitation for the production of small elongated blanks. This is especially clear in irregular cores. This difference between cores and products may be influenced by the fact that these materials come from a surface context, where it is not possible to determine their chronology or material associations in the absence of refits, a possibility that has not yet been explored. Additionally, the materials recovered by Chavaillon seem to be slightly more altered than those found in the frame of the GOTAM project, and this information is also important to consider. However, it is worth remembering that this sample does not represent the entire collection of Chavaillon’s excavations.

Artefacts making up the GOT-10 assemblage are typically smaller. This is true for the reduction strategies used for both planimetric volume reduction and volumetric reduction. The intention was not just to create smaller objects, but to exploit basalt in a different way.

Blocks were reduced into small and well-prepared cores, that were used for the production of small and thin blanks, similar to those made from quartz.
Another important feature of these assemblages is the almost complete absence of retouched points and a very scanty presence of point.
Points and especially the retouched ones, are a distinctive feature in the overall context of the eastern Africa MSA (Basell, 2008; McBrearty and Brooks, 2000; Tryon and Faith, 2013; Scerri and Will, 2023). However, at Gotera, this characteristic is absent for retouched points and scarcely present for points. Furthermore, there is no evidence of the production of points in the analysis of cores from GOT-10 and GOT1-S, with a scantyevidence in the Chavaillon's sample. In general, this data can be interpreted both as evidence of the absence of this type of production (which would place the Gotera assemblages closer to the LSA) and as an absence due to the type of site and the specific behavior of the groups inhabiting the area: there are no points at Gotera because they were taken elsewhere away from the site. However, this latter hypothesis seems to be the unlikely, considering the results of the technological analysis which indicate a very limited presence of cores aimed at the production of points.
Through technological and comparative analysis, the GOT-10 assemblage can be considered a homogeneous assemblage reflecting the site's occupation; however, caution must be taken in assigning a chronological attribution to the surface sample since only a portion of GOT-10 comes from a secure and well-dated stratigraphic context. It is clearly also impossible to determine the absolute chronology of the two surface assemblages. Nevertheless, despite the potential bias in surface collection that could undoubtedly affect the results, during the systematic surveys in 2017 and 2018, no basalt bladelets were found anywhere around the GOT1-S site. This trend appears to reflect a real technological difference and behavioural pattern, potentially related to a different chronological origin of the assemblages.
The comparative analysis of the three assemblages at Gotera has revealed the presence of some important similarities, such as the general orientation towards the production of elongated blanks, but also, critical differences. Most notable is the size reduction observed at GOT-10, the different exploitation of basalt, and the tendency to more intensively prepared cores with the intent of obtaining more predetermined products. The data on size reduction is intriguing, especially because, at some eastern Africa sites, it has been associated with the emergence of the LSA.
The analysis of dimensions alone does not allow for the association of an assemblage with a particular techno-complex. However, the fact that these differences were identified through the comparison of GOT-10 with other Gotera area lithic assemblages might help to formulate hypotheses regarding the human occupation dynamics of the area.

These results lend weight to the hypothesis that the Gotera area may have been populated at different times during the Pleistocene and that its spatial occupation may have been much broader than detected by the survey (see Chapter 2). One possible explanatory mechanism is that the lithic assemblages show differences because Gotera was occupied over a long period of time, perhaps extending to both older and/or more recent periods than indicated by the only chronostratigraphic datapoint from the Mound1 deposit at GOT-10 (~42ka). This may reflect a multi-phase occupation of the area. This data is supported by the presence of typical MSA traits in all the assemblages (e.g. Levallois and discoid methods) as well as some typical LSA traits for GOT-10 assemblage (e.g. smaller artefact dimension, the use of bipolar on anvil technique, an orientation towards the production of small bladelets; the selection of both basalt and quartz to produce small, elongated products).

Future analysis of the area and the ancient basin from a geological and hydrological perspective could provide insights also into the seasonal dynamics of the Gotera basin, allowing for an examination of the potential patterns of multiple occupations in relation to seasonal variations in water availability.

The data on artefact size reduction could indicate a phenomenon of artefact miniaturisation, associated with the emergence of the LSA in some context or assemblages. It is plausible that at GOT-10, we are witnessing a lithic production trend moving in that direction.

Another hypothesis regarding the differences in lithic technology at Gotera involves the possibility that different groups occupied the same area and shared various technologies. This could have occurred in response to the spread and retraction of environments caused by climatic fluctuations during the Upper and Late Pleistocene. However, these hypotheses will need to be tested and supported by the collection of additional data to establish a longer chronological framework beyond the single dated deposit availability at the GOT-10 site.

Chapter 5 – Regional comparative analysis of MSA-LSA assemblages

5.1 Regional analysis: quantitative comparison of MSA-LSA lithic assemblages and paleoclimate data integration

5.2 Introduction

This concluding section aims to analyse the MSA-LSA transition from a strictly macro-regional perspective, offering a quantitative insight into the causes behind this phenomenon. Therefore, the metric and technological attributes of lithic artefacts from different assemblages at various sites provided me by the researchers that analysed the archaeological record, will be statistically analysed to identify potential technological changes in lithic production. Additionally, paleoclimatic data, including bioclimatic variables, will be integrated to assess the role of climate and environmental changes in the transition and to determine whether they could be the cause of hypothetical technical trajectories specific to the regional level (Scerri and Will, 2023; Clark, 1988).

Defining the correct approach for quantitatively analysing the MSA-LSA transition is crucial. This is because the definition of African lithic industries and/or techno complexes has often been influenced by different research traditions and the application of various analytical methodologies, making it challenging to proceed with comparisons between assemblages (Pargeter and Brandt, 2015; Will et al. 2019). Moreover, dealing with the development of continental-scale models of human behaviours and technical variability can be even more challenging, as much information may be misunderstood or lost due to the large dimensions of the African continent, characterised by greater bio-geographical variability. Thus, it is important to consider these aspects when we aim to reconstruct human behavioural dynamics on a continental scale. Therefore, an explicit geographical approach, developed on regional zones, has been proposed to study distinct regional trajectories (Clark, 1988; Tryon, 2019).

The geography of eastern Africa is among the most complex on the continent, encompassing the formation of the Rift, as well as different biomes such as deserts, tropical forests, highlands, and coastal environments (Lahr and Foley, 2016; Tryon, 2019). The development of a regional approach thus is useful for obtaining a broader understanding of hominin behaviors. This would consist of examining parts of the African continent that are of equivalent size to other areas with analogous archaeological records. This is why the regional comparative analysis presented here results from the examination of several sites located in a small part of eastern Africa: Ethiopia and Kenya.

The MSA-LSA transition in eastern Africa happened in the Late Pleistocene, between ~70 and 15ka ka (MIS 4-2) (Brandt, 1986; Leplongeon et al. 2020; Shipton et al. 2018; Tryon, 2019). The asynchronous nature of the emergence of the LSA across the African continent offers a great opportunity to investigate the drivers behind these changes. However, several challenges have prevented a unified view regarding the mode and tempo of this phenomenon (Leplongeon et al. 2020; 2023; Scerri and Will, 2023).

In the global literature, at least three hypotheses have been proposed to explain the shift from the MSA to the LSA. The first hypothesis suggests that this change may be the result from a genetic mutation in *Homo sapiens*, leading to rapid cognitive advancements, including the emergence of language and art (Klein, 2009). Others attribute the MSA-LSA transition to demographic shifts within *Homo sapiens* populations, resulting in larger and more interconnected communities conducive to the development and spread of new behaviors (Mackay et al. 2014; Tryon and Faith, 2016). Finally, the hypothesis that led the transition to technological and social adaptations to cope with environmental changes during the Late Pleistocene (Ambrose, 1998; 2002). However, direct evidence for these hypotheses in eastern Africa is scarce.

The general knowledge of Late Pleistocene archaeology in eastern Africa has focused mostly on the analysis of single, stratified contexts, making it extremely difficult to develop a broader model of these changes between MIS 4 and 2, even at a regional scale.

However, we are aware that some eastern Africa sites show evidence that includes an increase in small-sized tool productions and a different selection of finest-grained raw materials, which have been associated with the LSA (Blinkhorn and Grove, 2020; Shipton, 2023; Shipton et al. 2018; 2021). In other contexts, along with the technical changes in lithic assemblages, the hypothesis of increased population growth alongside decreased residential mobility has been tested in association with the environmental changes characterising the late Pleistocene (Tryon and Faith 2016). However, in these complex, multi-layered archaeological contexts, such patterns do not display a regional tendency and have been recognised exclusively when compared to the MSA levels in single-layer contexts. This is partially why there is no agreement on a unique definition for the transition from the MSA to the LSA and a unique hypothesis for such changes.

The analysis of material culture alone highlights past human choices and behavioural changes, but more is needed to identify the drivers behind them. To do so, it is necessary to look at regional-scale human behavioural dynamics, performing regional-scale comparative analyses on lithic assemblages and integrating different data (i.e. environmental, genetic, climatic) (Basell and Spinapolice, 2024). In fact, the explanation that the emergence of the LSA toolkit (e.g. small lithics and backed pieces) could be a response to changes in the

environmental conditions during the Late Pleistocene (Ambrose, 1998; 2002; Blinkhorn and Grove 2021; Leplongeon et al. 2020; Tryon and Faith 2016; Tryon 2019;) can be tested here using the archaeological and paleoclimate reconstructions. When dealing with such hypotheses, integrating archaeological and climatic data allows testing for the role of the environment in the observed changes (Shumon and Soressi, 2021), while other data reflecting evidence of population growth, demographic changes and social behaviours in eastern Africa are still unsatisfying for these kinds of analyses.

Environmental conditions, including temperature, precipitations, and the differential availability of natural resources, are likely to have played an important role in shaping how past societies behaved and adapted through time. For example, refugia, physical barriers, and corridors led to population bottlenecks and expansions. These phenomena are seen among the driving factors for the emerging, developing, and spread of past human behaviours and cultures (Basell 2008; Blinkhorn et al. 2022; Clark 1988).

Eastern Africa is particularly suitable for the integration of archaeological and paleoclimate data due to the presence of various habitats that might explain distinct regional traditions in lithic productions (Clark, 1988). From a climatic and paleoenvironmental perspective, between MIS 4 and MIS 1 in eastern Africa, the climate is mostly arid but includes significant climatic oscillations and humid episodes like MIS 4 and 3 (Blome et al. 2012). MIS 2 is marked by the so-called "Big Dry," corresponding to the Last Glacial Maximum (LGM), occurring around ~23-20 ka. Humid conditions are observed both before and after the LGM, i.e., before ~24 ka and after ~19-18 ka. MIS 1 includes the African Humid Period (AHP), dated between ~14ka and 5ka and characterised by increased precipitation in eastern Africa and improved environmental conditions, resulting in a more humid environment. While it seems that technological changes are evident during these periods of environmental fluctuations placing this phenomenon roughly between the end of MIS 3 and the beginning of MIS 2 (Leplongeon et al. 2023), it remains to be understood whether the transition from MSA technical traditions to LSA reflects cultural and behavioural adaptations to global climate changes and environments or responses to localised events and then spreads to larger areas (Figure 68).

The approach of integrating different data (i.e., lithic attributes, climate data, and paleoenvironmental data) has already given interesting results, showing a more complex scenario for human occupation and dispersal dynamics in North Africa during the MIS 5 (Scerri et al. 2014). However, this approach has never been tested in eastern Africa contexts.

Research questions	Hypothesis	Methods
What are the technological characteristics of lithic assemblages in the region under study during the MSA-LSA transition?	Trends in technology such as reduction in size; selection of finer-grain raw materials; major use of the bipolar on anvil technique	Statistical comparison of lithic attributes collected from several archaeological sites spanning the MIS4 and 2
Is it possible to identify phenomena of cultural transmission or convergent evolution within the technical systems of human groups during the MIS4-2?	Sharing of knowledge among groups (thus a phenomenon of technical innovation spreading across the region); individual manifestation due to environmental contraints (together with other factors)	Statistical comparison of lithic attributes collected from several archaeological sites spanning the MIS4 and 2; evaluation of sites chronology and occupations.
Lastly, what are the factors that influenced the technological changes characterizing the transition from MSA to LSA?	Response to climatic (and environmental) conditions?	Integration of paleoclimate data reconstruction within the results of the comparison between lithic assemblages

Figure 66: Schematic synthesis of the research questions at the basis of this chapter.

5.2.2 Sample selection

Among the reasons for the absence of a valid model concerning the factors influencing technological changes at the regional level in a slightly broader portion of the Horn of Africa, there is, on one hand, the limited number of archaeologically datable data from this chronological period. On the other hand, there is also a complete lack of a comparative analysis of lithic assemblages that goes beyond the mere typological classification of artefacts, potentially leading to interpretative errors (Will et al. 2019).

Based on the above statements, the sample selection for this analysis was based on two specific criteria:

1. Chronological; All the earliest MSA contexts or, in general those contexts that are too far in terms of chronology from the approximate date of the MSA-LSA transition were excluded from the selection. Therefore, sites classified as EMSA were not considered (e.g. Gademotta and Kulkuletti, Kapthurin, etc. for a complete list, see Chapter 1). Additionally, in order to integrate paleoclimatic data, the most important criterion is a sufficiently reliable chronology.
2. Analytical. This is a fundamental criterion used to select samples for analysis. As mentioned in the introduction of this chapter, it is crucial to avoid typological comparisons that might exclude information about the production of lithic artifacts. To be included in a statistical methodology that compares technological attributes (both qualitative and quantitative), the collections and datasets must be amenable to a piece-by-piece artefact analysis in which all critical variables can be measured and assessed. It is clear that the technological approach based on the analysis of lithic artefact attributes is not a new methodology, however some assemblages collected

and studied many years ago would require a full re-analysis to enable comparable data to be derived.

Based on the above criteria, in order to examine an archaeologically and chronologically significant sample, the sites of Goda Buticha, Porc Épic, Gotera, Deka Wede 4 in Ethiopia, and Enkapune ya Muto in Kenya were considered in this analysis (Figure 69). This section provides a comprehensive review of the sites analysed, along with the lithic assemblages' characteristics found in each layer.

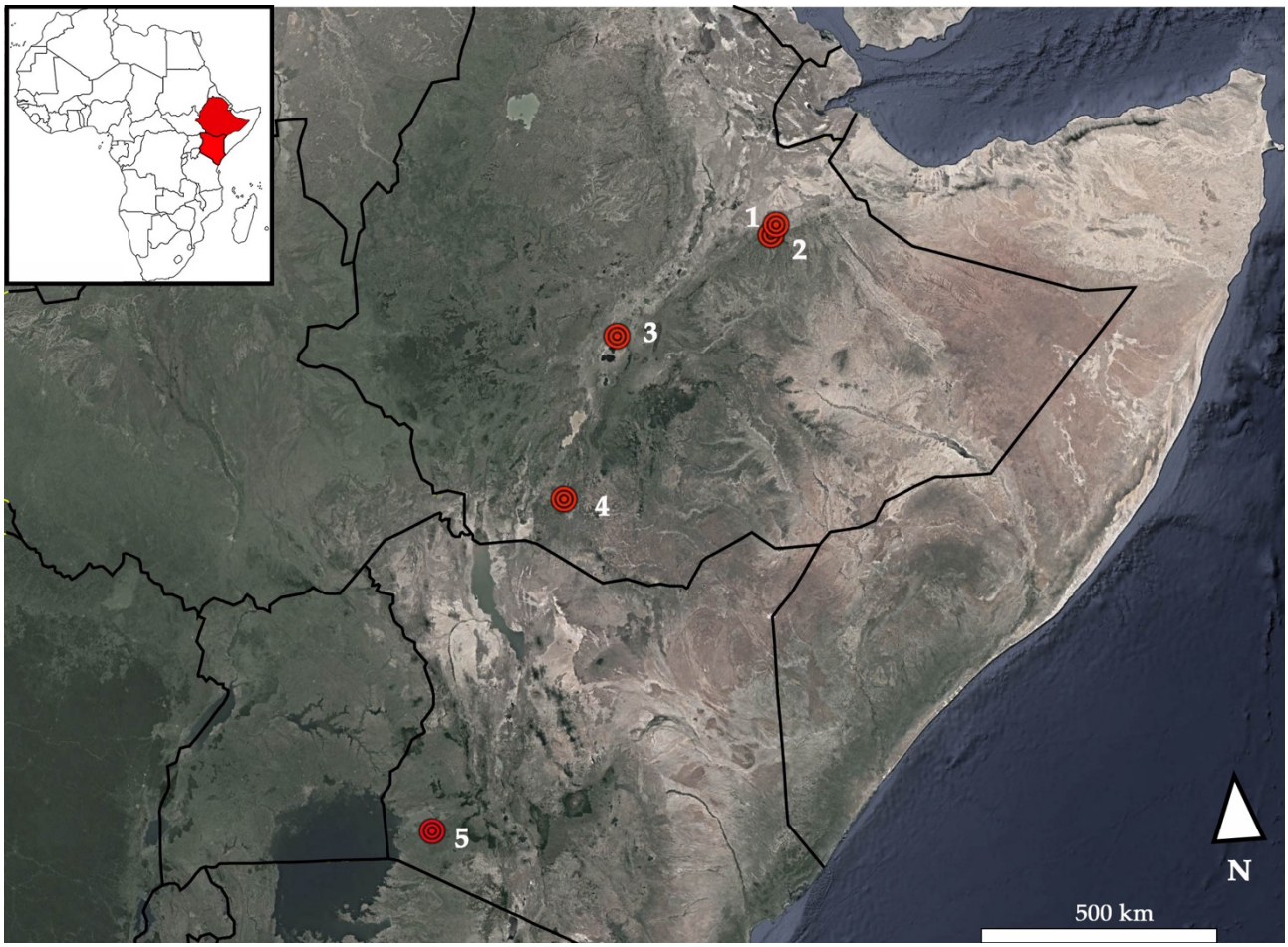


Figure 67: Location of the sites analysed in this research. 1: Goda Buticha; 2: Porc Épic; 3: Deka Wede 4; 4: Gotera; 5: Enkapune ya Muto. (Map created with © Google Earth).

5.2.3 Goda Buticha

Goda Buticha rock shelter, in the Dire Dawa area, was discovered in 2007, in the frame of the South-Eastern Ethiopia Cave Survey Project (SEECSP) (Assefa et al. 2014; Leplongeon et al. 2017). The site has a 2.3 m-deep stratigraphic sequence recording two phases of occupation, separated by a chronological *hiatus* between MIS 2 and the beginning of the

Holocene (Figure 70). This absence of data in the occupational history of the Horn is a common feature in all the archaeological sites of the region (Brandt, 1986; Leplongeon et al. 2017; 2020; 2023; Pleurdeau et al. 2023).

The site is located high on a cliff made of crystalline limestone of the Gebredare Series. The karst cave consists of three chambers with two mouths opening to NE and NW, joined by a third small SE-oriented chamber and it is the remaining of a larger cave system.

The main gallery faces northwest onto the slope. The north-eastern gallery houses small rock paintings in dark pigment. In contrast, the northwestern gallery contains all the *in situ* MSA and LSA lithic artefacts, faunal remains, human remains, and ornaments (Pleurdeau et al. 2023). Together with lithic assemblages, several animal remains (including small vertebrates), hominin remains and other evidence like ostrich eggshell beads as well as engraved fragments have been found within the sequence (Leplongeon et al. 2017).

The stratigraphic sequence of Goda Buticha cave has been divided into two main complexes (I and II) with a further subdivision into layers IIf-IIc (dated to ~63-24 ka) and layer IIc (dated ~7-6 ka), while Complex I is dated ~ 4-1 ka. All these complexes contain lithic artefacts (Figure 2). The lithic assemblage from Goda Buticha layers has both MSA and LSA technical characteristics, with the production of flakes and elongated blanks using different reduction methods (both Levallois and volumetric), and a toolkit in which retouched points, backed pieces, and (end)scrapers are well-represented. Multiple studies of the lithic assemblage clarify the dynamics of technical change and continuity throughout the sequence, in the context of the MSA-LSA transition (Leplongeon et al. 2017; Leplongeon, 2014; Pleurdeau et al. 2014).

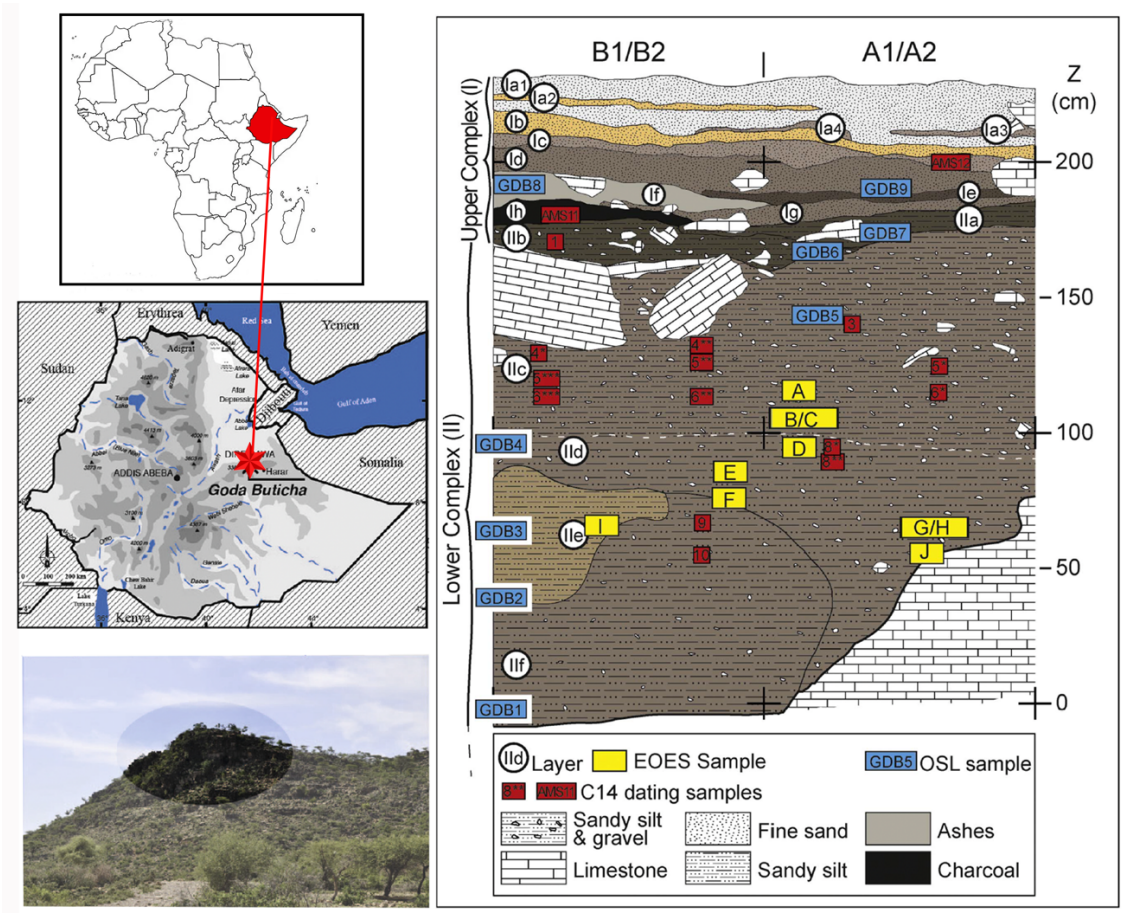


Figure 68: Location of the Goda Buticha cave (left) and stratigraphic description of the sequence (right). (Modified after Leplongeon et al. 2017 and Tribolo et al. 2017).

a) Stratigraphic description of the Complex I (upper complex)

A stratigraphic sequence of seven alternating layers of white, light pink, and black fine-grained silts, with a thickness ranging from 50-60 cm, underlies a more recent organic layer (10-30 cm thick) containing materials like straw and wood, where numerous hyena coprolites were discovered (Pleurdeau et al. 2023; Tribolo et al. 2017). This sequence is in line with human-made ash deposits from fireplaces. These sediments are abundant in fragments of long bone shafts. Micromammal remains were discovered across the ash layers, some of which were calcined and concentrated into dense pockets. At an elevation of 180-170 cm above the datum, a lone pottery piece was unearthed.

Within the Lower Complex, there is a distinct horizon, 10-20 cm thick, rich in micromammal remains and some artefacts.

Sediments of Complex II feature a diverse lithic collection, faunal remains, human remains, and numerous ostrich eggshell beads. Forty-four charcoal samples were gathered from in

situ contexts. Fourteen samples, all from the stratigraphic Lower Complex, underwent Accelerator Mass Spectrometry (AMS) radiocarbon dating.

b) Stratigraphic description of the Complex II (lower complex)

Under a 10 cm thick layer of brown clay (Layer IIa/b), there lies a deposit of light brown clay with a thickness of 170-180 cm. The increased presence of limestone clasts starting from an elevation of approximately 100 cm above the datum prompted the division of Complex II into two distinct layers (IIc and IId) (Figure 70).
The lower portion of Complex II exhibits substantial induration and concretion (IIf). Another indurated part with a distinct orange hue (IIe) is present. The formation of these concretions is likely post-depositional (Tribolo et al. 2017). Radiocarbon dating indicates episodes of human occupation in the late Upper Pleistocene, ranging from 42500 ± 1000 14C BP (46,273 ± 2084 cal BP) to 29680 ± 230 (33,843 ± 405 cal BP) in Layers IIf and IId. During the mid-Holocene, occupation dates range from 6920 ± 50 (7791 ± 126 cal BP) to 4130 ± 30 (4676 ± 144 cal BP) in layers IIc and IIb (Leplongeon et al. 2017).
However, the available radiocarbon dates imply a significant gap in the accumulation of fine-grained sediments within the Lower Complex (II). The top of Layer IId is dated to 29.5 ± 32 ka 14C BP (33.5 ± 36 ka cal BP), while the lower part of Layer IIc is dated to 5.5 ± 7 ka 14C BP (6.3 ± 7.8 ka cal BP). This hiatus corresponds to the sedimentological transition between Layer IId and Layer IIc (Leplongeon et al. 2017).

c) The lithic assemblages of Goda Buticha

The lithic assemblages from the Goda Buticha cave have been analysed in detail using two methodologies combined: the *chaîne opératoire* approach and the attribute analysis (Leplongeon et al. 2017).
Previous analysis of the Goda Buticha lithic assemblages was conducted in order to understand the technical behaviors and eventually technological trends within the assemblage recovered from the long sequence (Pleurdeau et al. 2014). The principal raw materials used are chert, obsidian, basalt, and quartzite. Flake production is predominant, with several Levallois cores with centripetal preparation and the unipolar recurrent method. Levallois products include flakes, blades, and points. Moreover, volumetric blade production is evident as well. Among the retouched tools, retouched points are present, as well as backed pieces, side-scrapers, and various retouched items. The interesting aspect is

that there are no abrupt typo-technological changes in the lithic assemblage throughout the sequence.

Obsidian frequency increases from the bottom to the top of the sequence, along with the frequency of backed microliths. The lithic assemblage exhibits a combination of typical LSA elements (e.g. backed pieces) with MSA elements (Levallois flakes and retouched points).

Chert, basalt, and quartzite at Goda Buticha are assumed to have a local origin, while obsidian, despite its high frequency, lacks a known nearby source (Leplongeon et al. 2017; Pleurdeau et al. 2014).

The lithic assemblages will be presented by dividing the results by layers, as published elsewhere (Leplongeon et al. 2017).

d) Goda Buticha IId-IIf, ~63-25ka

Layers IId-IIf at Goda Buticha are dated between 63±7 ka and 24.8±2.6 ka. A density peak is observed from layers dated between ~45 and 25 ka. The lithic assemblage exhibits consistency in the frequencies of major stone artefact categories. The lower part of Complex II (layers IId, IIe, and IIf) was presented as a homogeneous unit due to its uniformity (Figure 71) (Leplongeon et al. 2017).

The predominant characteristic of the assemblage is the orientation toward flake production. Cores also primarily show flake production, while there is no evidence of cores oriented to point production.

Levallois products and elongated blanks are frequent components of the lithic assemblage (Figure 71: 1-3; 9-14).

Among the Levallois cores, there is evidence of centripetal preparation for preferential flake removal, unipolar recurrent flaking, and centripetal recurrent flaking. The assemblage includes Levallois blanks, and retouched Levallois blanks, comprising four unifacial points, two retouched flakes, and one notched piece.

Levallois cores made on basalt are less frequent, suggesting possible off-site basalt Levallois production. The majority of Levallois products are flakes, and the use of the Levallois flaking system for elongated blank production is less attested. Products generally feature plain or faceted striking platforms with centripetal or bidirectional scar patterns, compatible with core observations.

Elongated products are primarily made on chert, with few on obsidian, basalt, and quartzite. Raw material frequencies for elongated blanks reflect those observed in all debitage, indicating no specific material selection for this type of production. Although

small, elongated artefacts are present, the distributions of size suggest a unified production system for both large and small items (Leplongeon et al. 2017).

Elongated cores with removal scars are present, including Levallois and non-Levallois planimetric debitage. Striking platforms are mainly faceted or plain, and elongated products display plain platforms, a high frequency of linear and punctiform platforms, dihedral, and faceted platforms. A significant percentage of prominent to very prominent bulbs, together with large platforms, suggests the use of direct percussion with hard hammer.

The direction of debitage on elongated products is mainly unipolar, with low frequencies of unipolar, orthogonal, bidirectional, or centripetal scar patterns. Elongated products exhibit thin profiles, flat to slightly curved longitudinal profiles, flat lateral profiles, and parallel edges or at least one distal convergent segment.

Overall, the data indicates that knapping at IId-IIf was oriented towards the production of relatively small, elongated products, with occasional use of the Levallois recurrent method or prismatic blade production. The production process seems to involve minimal preparation of core striking platforms and debitage surfaces, which appear relatively flat based on the profiles of blanks and debordant products.

Retouched tools in the IId-IIf lithic assemblage are made from elongated blanks. This percentage suggests a deliberate preference for this type of blank in the retouching process. Retouched blades made on obsidian are the most present category, alongside scrapers, unifacial and bifacial tools as well as retouched bladelets.

Thirty retouched points are counted in the IId-IIf assemblage. Six points are made on pointed flakes (including one Levallois point) and three on regular flakes. Raw material distribution for retouched points is the same for the overall assemblage, suggesting no selective preference for specific raw materials for point production.

Unifacial points are the most represented category, and the presence of only two partially bifacial, and eight bifacial points. The retouch is generally invasive, particularly for bifacial points, and most retouched points exhibit regularly convergent edges, starting convergence from the first half of the length (Figure 3, 5-7). The retouched points are relatively small and narrow. Only two microliths have been found in IId-IIf: one backed microlith and one retouched bladelet (Figure 71: 15-16).

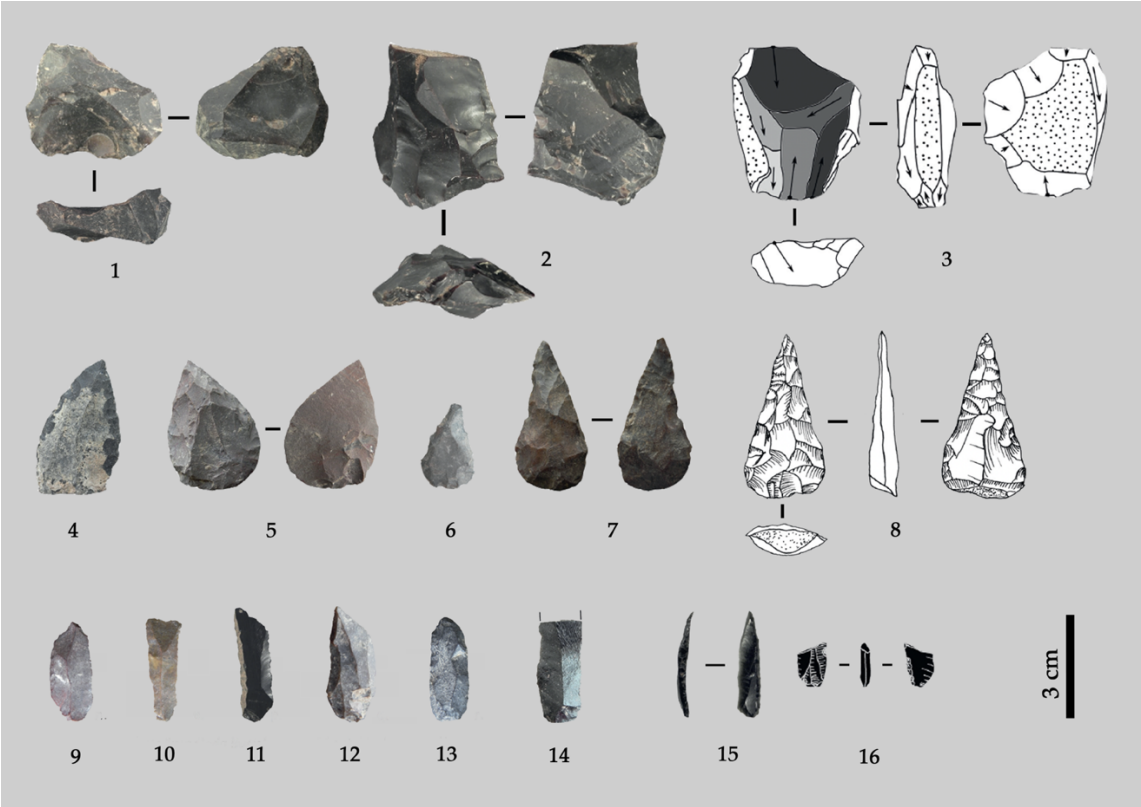


Figure 69: Lithic artefacts from layers IId-IIf of Goda Buticha. 1: Levallois core; 2-3: blade cores; 4-8: retouched points; 9-14: elongated blanks; 15-16: microliths. (Modified after Leplongeon et al. 2017).

e) Goda Buticha IIc, 8-6ka

The predominant focus of the assemblage in this layer towards flake production. The assemblage consists mainly of flakes, with few cores. Point production is minimal, with consistent evidence of elongated blanks (Figure 72).

Within the cores assemblage, the planimetric conception of debitage is prominent, and three cores are attributed to the Levallois flaking system. These three include two with centripetal preparation for the removal of a preferential flake and one with bipolar recurrent flaking (Figure 72: 1). Additionally, Levallois blades have been found, with two of these blanks exhibiting retouch. The predominant scar patterns on Levallois blanks are centripetal or bipolar.

The elongated blanks in this layer are made principally on chert, followed by obsidian and then basalt exploitation. The elongated products are relatively small. The ones made of obsidian tend to be smaller, possibly due to the preference for small obsidian nodules, indicating more intensive reduction or smaller nodules (Leplongeon et al. 2017).

Layer IIc yielded cores with elongated removal scars, categorised as bladelet cores. These cores, predominantly plain or dihedral, include both planimetric and volumetric (*semi-tournant*) conceptions. Striking platforms are mainly plain, followed by dihedral, cortical, and facetted. Additionally, core trimming elements associated with elongated blank production were found in Layer IIc.

The blades and bladelets from Layer IIc, have mainly plain platforms, followed by facetted and linear/punctiform platforms. Prominent bulbs, even with narrow platforms, suggest direct percussion with hard hammer, with the possibility of soft hammers due to the high frequency of linear/punctiform platforms. Most elongated blanks lack cortical surfaces. The direction of removal scars is mainly unipolar, differing between blades and bladelets, with blades showing a higher frequency of the "unipolar and lateral" and "bidirectional" scar patterns.

Most of the retouched tools in Layer IIc are made on blades and bladelets. This high frequency suggests a preferential selection of elongated blanks. Most retouched elongated blanks are on obsidian, indicating a preference for this raw material.

Layer IIc includes a single small core with a pointed flake removal scar, along with some pointed flakes, two of which are Levallois points. Some of the retouched points in Layer IIc include unifacial points, two partially bifacial, and three bifacial points. Covering retouch leads to a high frequency of undetermined blanks. Most of the retouched points are made on obsidian, showing a strong preference for this raw material.

Layer IIc has yielded microliths, consisting of retouched bladelets and backed microliths, including four geometric microliths (Leplongeon, 2014).

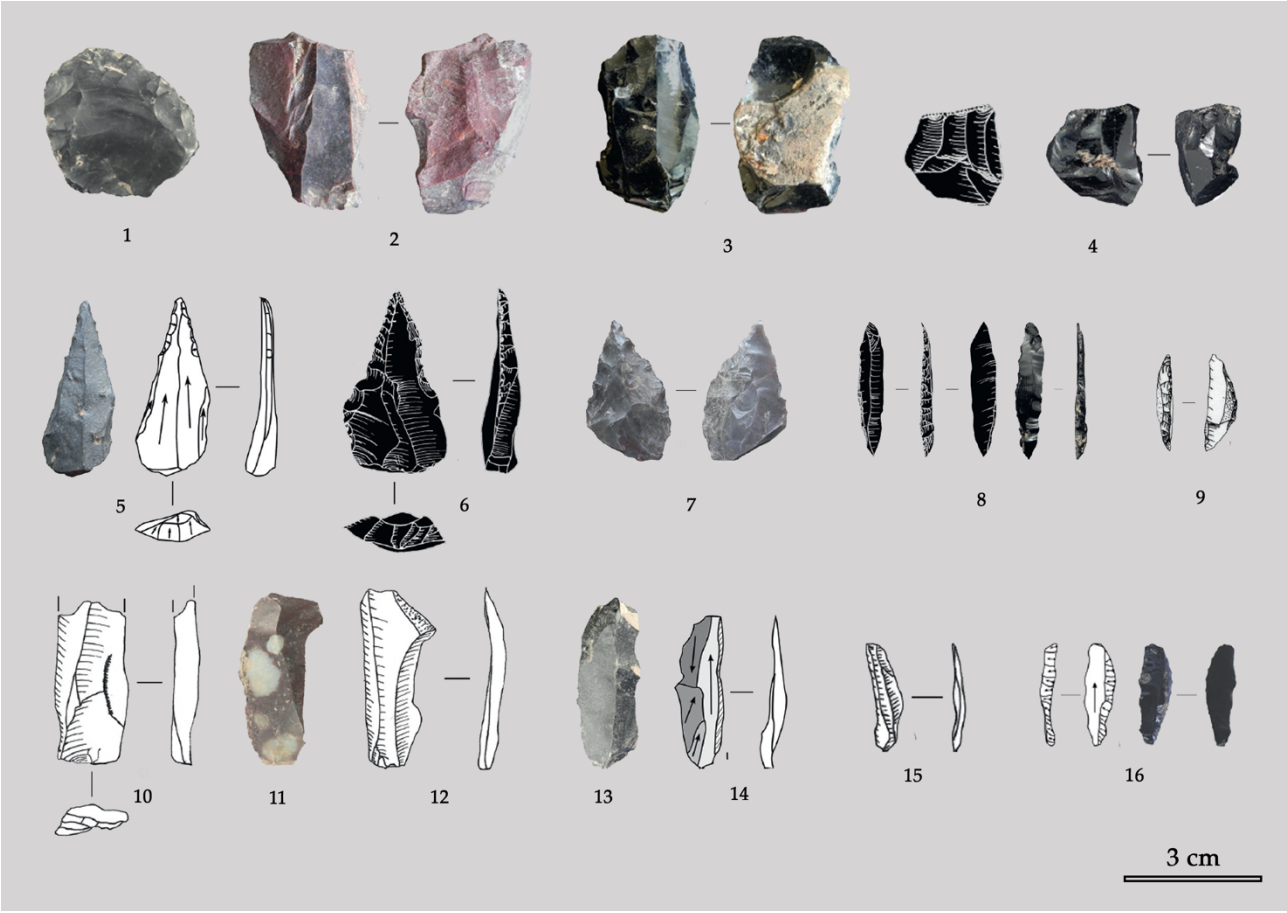


Figure 70: Lithic artefacts from layers IIc of Goda Buticha. 1: Levallois core; 2-3: blade cores; 4: bladelet core; 5-7: retouched points; 8: elongated backed point; 9: backed piece; 10-14: blades; 15: bladelet; 16: microlith. (Modified after Leplongeon et al. 2017).

f) Goda Buticha Complex I < 4 ka

The primary focus of the lithic production at Complex I at Goda Buticha, is the production of flakes (Figure 73). In fact, among the cores found in Complex I, the majority show flake removal scars. However, there is also evidence of cores displaying elongated flake removal scars. Planimetric debitage dominates the core assemblage. Two Levallois bipolar recurrent cores show flake and blade removals. A singular pyramidal core related to bladelet production is present. In this layer, there are no points present, and only two Levallois flakes are identified. Although elongated blanks are relatively frequent, they are less common compared to lower layers, with obsidian as the primary raw material. Levallois production plays a minor role here, with the presence of only two Levallois cores and two flakes.

Elongated blanks are mostly small and are all made of obsidian. Plain or faceted platforms dominate elongated products. Percussion bulbs are primarily prominent, indicative of percussion with hard hammer.

Half of the retouched tools from Complex I are made from elongated blanks. Thirteen retouched blade(let)s are made of obsidian. There is no evidence of point production or retouched points in Complex I. Microliths constitute the primary category of retouched tools here, comprising backed microliths, including geometric microliths (crescent shape), and retouched bladelets, detailed described elsewhere by Leplongeon (2014).

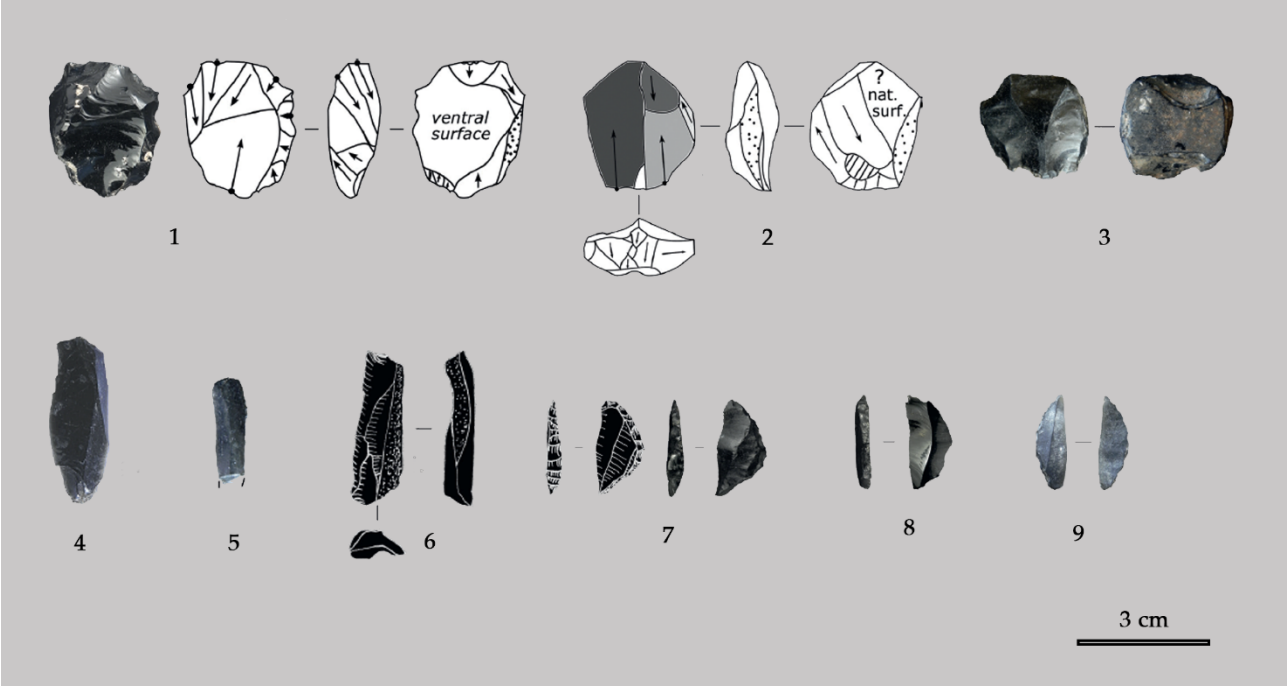


Figure 71: Lithic artefacts from layers I of Goda Buticha. 1: Levallois-like core; 2-3: cores for elongated blanks; 4-6: bladelets; 7-9: geometric microliths. (Modified after Leplongeon et al. 2017).

g) Discussion

The analysis of the Goda Buticha lithic assemblages shows that there are some similarities and differences among the archaeological layers described above.

The key similarities across all levels at Goda Buticha include the prevalent use of obsidian for retouched tools, a dominance of flake assemblages employing Levallois flaking systems, and relatively high frequencies of elongated blank production (Leplongeon et al. 2017; Pleurdeau, 2006). The elongated blanks share similar dimensions, featuring unidirectional scar patterns, plain platforms, and variability in morphology with parallel, rounded, and

convergent edges. However, there are also significant changes between levels. First, there is a shift in raw material procurement strategies, with increased obsidian use, particularly between layers IIc and I, while its use decreases between Layers IId-IIf and IIc. The preferential selection of obsidian for specific blank production or tool types is different across levels.

The frequency of Levallois methods, mainly for flake production, decreases from Layers IId-IIf to Complex I, while elongated blank production increases. Complex IIc has a notably higher percentage of elongated blank production, emphasizing *semi-tournant* or prismatic blade(let) production compared to other assemblages. Elongated blanks in IIc exhibit higher bidirectional scar pattern frequencies, particularly among blades. Furthermore, there is a general rise in bladelet frequencies from IId-IIf to IIc and to I, where bladelets become the primary focus of production. Technological characteristics of blades and bladelets suggest two distinct reduction sequences in IIc, a distinction not observed in IId-IIf.

Additional changes include the absence of retouched points in Complex I and the increased use of obsidian for retouched points in IIc. Microliths are nearly absent in layers IId-IIf but are frequent in Layer IIc and constitute the primary tool category in Complex I. While layer IIc features mainly retouched bladelets and non-geometric backed microliths, Complex I displays mainly geometric shapes (Leplongeon 2014). Unique typological features in GB IIc include elongated backed points, while obsidian unifacial or bifacial ovate tools are found in both GB IId-IIf and GB IIc.

5.2.4 Porc Épic

The Porc Épic site is a cave located at the southern entrance of the Afar Depression, approximately ~2 km south of Dire Dawa, a major city in Ethiopia located at the north-eastern end of the Chercher Highlands within the Harar Plateau and adjacent to the Rift Valley (Figure 74). Located 9 m below the ridge's top on a steep slope, Porc Épic Cave strategically overlooks the landscape, suggesting a good-looking point probably also for past human groups who inhabited the area (Pleurdeau, 2006).

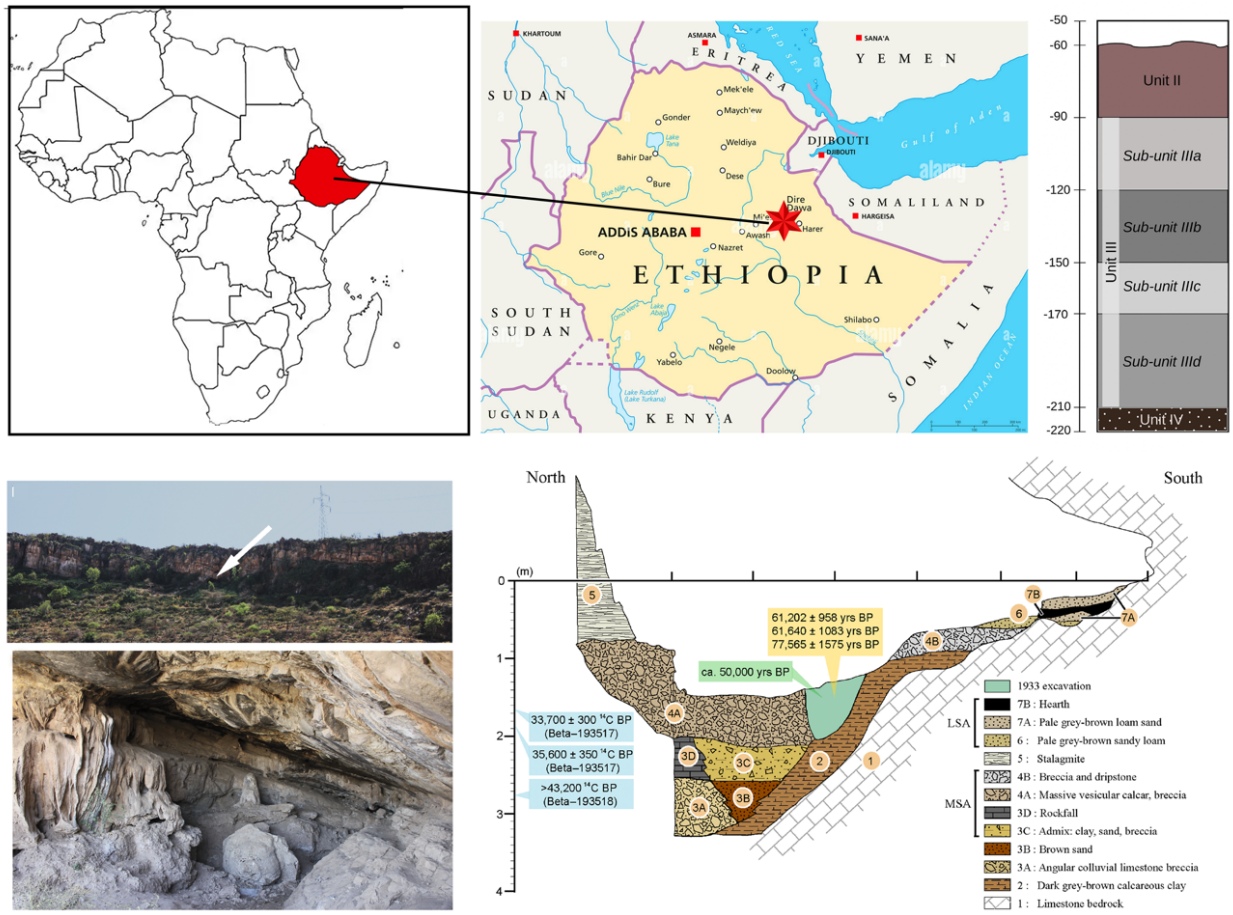


Figure 72: Location of the Porc Épic cave (upper left part) and stratigraphic sequence (bottom right). (Modified after Rosso et al. 2017).

From the ecological point of view, the site is located at an ecotone between two physiographic units—the south-eastern escarpments and the rift valley depression (Wolde-Mariam, 1972). Within a 15 km radius of the site, the elevation of the surrounding area varies from about 1000 to 2200 m. With a current average annual temperature of 24.8 °C, Dire Dawa is situated in one of the hottest regions of the country. The area is quite dry, receiving

rain in two seasons - July to September and March to May (Wolde-Mariam, 1972) - recording an average annual rainfall of 617 mm.

The cave was discovered in the late 1920s by H. De Monfried and P. Teilhard de Chardin, and the first excavation took place in 1933. The investigation was primarily focused on a significant portion of the cave entrance, and it was led by H. Breuil and P. Wernert from the French Muséum National d'Histoire Naturelle (MNHN) (Breuil et al. 1951). Subsequent excavation seasons were conducted by J. Desmond Clark in 1974 and K. D. Williamson in 1975–76, with a central trench of 6 m2 being dug in 1974 and comprehensive excavation of the cave undertaken in 1975–76. The area excavated in 1933 covered an estimated 57.5 m2. After a 40-year gap, in 1974, Clark and Williamson conducted a 1 × 6 m test excavation to clarify the sedimentary history of Porc Épic Cave and initiate a pilot study on archaeological remains. In subsequent years, Williamson led a comprehensive excavation covering over 50 m2, yielding a substantial collection of artefacts and faunal remains. Noteworthy discoveries from the 1933 excavation included a hominid mandible found in association with stone tools and vertebrate faunal remains. However, findings from this excavation phase lack detailed descriptions (Clark and Williamson, 1984).

The 1974 excavation at Porc Épic aimed to recover MSA artefacts and reconstruct the stratigraphic sequence to address concerns of possible intrusion and admixture of the overlying LSA sequence with the MSA sediment (Clark and Williamson, 1984; Clark, 1988). The sedimentary history involved the deposition of the MSA assemblage in the calcareous breccia layer, protected by a major dripstone (Assefa et al. 2006).

The stratigraphic layers at the eastern section of the 1974 excavation illustrate the MSA-bearing breccia layer sealed by a significant dripstone (Figure 74). Post-dripstone stream activity and erosion, especially toward the cave entrance, led to the removal of weakly consolidated deposits to about a meter's depth. Subsequent deposition of post-dripstone LSA and Neolithic sediments followed, unconformably overlaying the MSA deposits. The main MSA deposit, protected by the dripstone, is less susceptible to natural mixing with later deposits.

In 1998, a collaborative expedition involving the Authority for Research and Conservation of the Cultural Heritage (ARCCH) of Addis Ababa and the National Museum of Natural History in Paris aimed to establish stratigraphical correlations using the remaining sections to enhance the understanding of the cave's stratigraphy (Pleurdeau, 2004; 2005).

Their study affirmed the accuracy of the stratigraphical section created by J.D. Clark's team, displaying a succession of sandy-loam and clay layers indurated by cave breccias (Clark and Williamson, 1984). They identified four main stratigraphical units (further divided into layers): the two lowest units (IV and III) considered as MSA, unit II potentially mixed but

predominantly MSA, and unit I, a very thin brownish layer identified as LSA (Figure 74) (Clark and Williamson, 1984; Pleurdeau, 2004).
A microstratigraphic study in 2003 identified stratigraphic horizons and layers, matching those described by Clark and Williamson. Obsidian hydration dating provided MSA occupation ages of 61202 ± 958, 61640 ± 1083, and 77565 ± 1575 years BP. Accelerator mass spectrometry (AMS) analyses on gastropod shell fragments from three different layers yielded conventional radiocarbon ages of 33700 ± 300, 35600 ± 350, and >43200 years BP, aligning with the stratigraphic sequence. Despite disparities in results, the MSA occupation at Porc Épic is generally considered to date to the Last Glaciation (Assefa et al. 2006; Leplongeon, 2014; Pleurdeau 2006; 2008).

a) Chronology of the site

Nine obsidian artefacts from the 1933 excavation were dated through hydration dating. The results range from 61202±958 to 71565±1575 years BP. It's important to note that the hydration rate is influenced by temperature, and considering the likely lower temperatures during that period, the obtained dates are considered minimal (Michels and Marean, 1984). Consequently, the dating of the principal MSA occupation remains uncertain.
Contradictory dates arose from different dating methods: obsidian hydration dating on artefacts from the 1933 excavation (upper layers) yielded dates around 61-75 ka (Michels and Marean, 1984); high-resolution low background gamma-ray spectrometry directly applied to the 1933 mandible yielded a date of approximately 50 ka; shells from the 1975-1976 excavations (lower layers) sampled for radiocarbon dating produced dates around 35-40 ka BP (Assefa, 2006).
Numerous age measurements were conducted after the 1974 excavation. The stalagmite unit covering the breccia housing the primary Middle Stone Age (MSA) assemblage has been dated to 4590±60 and 6270±1020 years BP. However, these age estimates need to be approached with caution due to potential post-depositional physical and chemical alterations. As per Clark and Williamson (1984), these dates are not contemporaneous with the MSA occupation.
To resolve these conflicting dates, new samples for optically stimulated luminescence (OSL) dating were collected at Porc Épic in late 2012, and the samples are currently undergoing analysis at the IRAMAT laboratory at the University of Bordeaux, France. Preliminary results on OSL dating revealed an older date (Leplongeon et al. 2022; Tribolo et al. 2022).

b) Lithic assemblages from Porc Épic cave

A previous analysis made on the lithic assemblage from Porc Épic consisted of the entire 1933 excavation collection (~4000 artefacts) stored in Paris at the *Institut de Paléeontologie Humaine*, along with the material from three designated squares of the 1975–76 fieldwork stored at the National Museum of Addis Ababa (~8000 artefacts) and published in 2005 (Pleurdeau 2006) (Figure 75). The primary aim was to reconstruct the reduction schemes and to understand possible differences and similarities within the sequence.

The raw material used at Porc Épic Cave highlights the exploitation of various rock types, including chert, basalt, obsidian, and quartzite. The raw material sources differ for sedimentary and volcanic materials. Chert and quartzite seem to come from local sources, while basalt and obsidian originate from more distant locations, with obsidian sources identified around 100 to 250 km away.

The entire sequence at Porc Épic cave reveals four primary reduction schemes.

The first and second schemes, emphasizing surface exploitation, are the most significant, compared with the volumetric scheme. The third scheme represents an intermediate method between surface and volume reduction. The resulting blanks are diverse, with flakes being the most common. Blades and bladelets show the knappers' technical capabilities. These blanks, particularly obsidian ones, tend to be small, with core sizes averaging less than 4 cm.

In the first reduction scheme, blank production involves a knapping axis parallel to the intersecting plane of two core faces, resembling the Levallois method. It enables the production of various products like flakes, blades, bladelets, and points. Typical cores exhibit round shapes with two opposing surfaces, one preserving radial negative scars and the other as the "preparation surface of the striking platform." This surface, often highly convex, may show negative invasive removals, indicating prior use as a production surface. The first scheme encompasses two distinct methods: one with a preferential flake and the other with recurrent flaking, extracting a series of products in the same productive phase. In both methods, backed products (debordants) maintain optimal convexity for restarting production.

The resulting debitage products from the first method exhibit distinctive characteristics. They are typically thin, mainly round, and sometimes quadrangular. The majority often displays centripetal removals, indicative of a meticulously prepared flaking surface. The platform is frequently facetted, confirming the intensive preparation of the striking platform.

Cores related to the second method show two distinct surfaces with a succession of unidirectional, orthogonal, or radial removals. Convergent unidirectional removals in certain cases appear to have allowed the extraction of pointed flakes, identified as Levallois points.

The second reduction scheme, less common than the first, is characterized by one or two highly convex flaking surfaces. Cores consistently have two distinct surfaces and are exploited along a non-parallel direction to the intersecting plane between these surfaces. The debitage products seem less extensive than in the first scheme, which is dominated by flakes. While the first scheme could be associated with Levallois debitage, this one is connected to discoidal debitage, well-known in the MSA and Middle Palaeolithic assemblages.

The third reduction scheme, although rare with only nine cores, occurs across several stratigraphic levels. It appears as an intermediate form between the standard exploitation of a Levallois surface and a standard volumetric blade reduction as in the Upper Palaeolithic (Figure 75: 1). The specific debitage products are challenging to recognize, but the aim was likely to produce elongated artefacts, mainly blades and small bladelets. Two methods are distinguished within this scheme: one exclusively recurrent with a series of blades/bladelet production, and a second marked by the final extraction of a large invasive removal.

The last reduction scheme involves a volumetric exploitation of the core, producing blades and bladelets without revealing any opposition between the two surfaces. Cores are mainly prismatic, with unidirectional and bi-directional scars, indicating a *semi-tournant* recurrent reduction (Figure 75: 2). Certain blade products, such as crested ones, seem to be exclusive to this scheme, revealing a long sequence of blade debitage as the primary objective of the production.

These reduction schemes exhibit relative stability in their technical characteristics and numeric representation of the cores throughout the sequence, with no discernible change or transition between the MSA and LSA from a technical perspective.

The operational sequence of obsidian appears unique. While there is no apparent differential exploitation of the raw material for flake and blade production, the frequency of obsidian for bladelets/small blades is higher than that for any other type of blank. This indicates that the exploitation of this non-local raw material took place on smaller nodules and was more intensive.

The tool production at Porc Épic is consistent, with points representing the most frequently retouched among debitage products, followed by scrapers and notched tools (Figure 7, 6-9) (Pleurdeau, 2006; Pleurdeau et al. 2023). Retouched points fall into two main categories: unifacial (Figure 75: 6 and 8) and bifacial (Figure 75: 7 and 9).

Unifacial points, often triangular, exhibit unilateral or bilateral retouch, with some showing retouch on the proximal edge, creating an oval form. Bifacial points tend to have slimmer morphologies, with a round retouched proximal edge. The lower face may be entirely covered by invasive retouch, sometimes thick or very fine, indicating the potential use of a soft hammer. These bifacial points may also display only proximal retouch with simple thinning of bulb and butt.

In all stratigraphic units, several scrapers are present, ranging from simple to double or triple forms, constituting the most frequent tools after points. These scrapers are mainly made from flakes and feature direct retouch on one or both lateral edges. End-scrapers are rare and small. Notched tools, including notches, denticulates, and *becs*, are less common, often retouched on one of the lateral edges, and made from thicker and larger flakes than scrapers. The assemblage also includes backed bladelets or geometric tools. Produced by backing bladelets or flake segments, these tools span all stratigraphic levels except the lower unit IV. Half of them is made from obsidian, with backing achieved through short and abrupt retouch, imparting a slightly convex form to the edge. In some cases, the backing results in a grossly curved edge, producing a crescent shape.

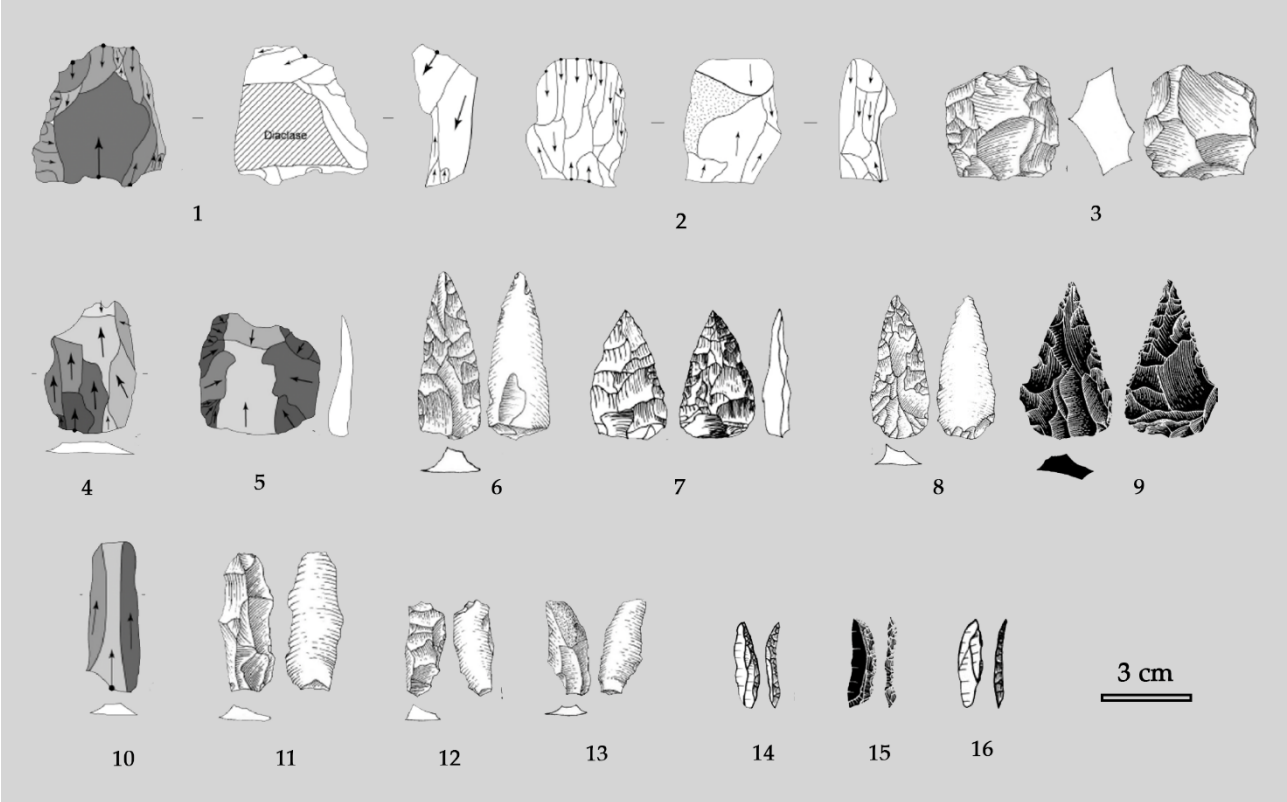


Figure 73: Lithic artefacts from Porc Épic cave. 1: Intermediate reduction core; 2: *semi-tournant* debitage core; 3: flake core; 4-5: Levallois flakes; 6-9: Retouched points; 10-11: Blades; 12-13: Bladelets; 14-16: Backed bladelets. (Modified after Leplongeon, 2014 and Pleurdeau, 2006).

5.2.5 Deka Wede4

The Deka Wede4 (DW4) site is located in the Ziway Sahla basin area and was identified as part of the Ziway Sahla project conducted by François Bon and Asamerew Dessie starting in 2007 (Ménard and Bon, 2023) (Figure 76).

The Ziway-Shala basin is a significant source of paleoenvironmental data. It has undergone extensive investigation over the past 50 years, revealing that it was characterized by important water-level fluctuations during the Upper Pleistocene and Holocene.

The basin, divided now into four lakes, in the late Quaternary was constituted by a larger single basin. Its sensitivity to rainfall variations on adjacent plateaus, influenced by its location at the floor of a narrow portion of the MER, suggests that climate change plays a crucial role in its water balance dynamics (Ménard and Bon, 2023; Ménard et al. 2014).

Deposits along the Bulbula River, spanning approximately the last 100 thousand years, primarily consist of lacustrine and volcanic origins. Over the last 50 thousand years, the river's course has witnessed frequent changes due to dramatic water-level fluctuations, leading to the cutting and filling of sedimentary deposits. The Deka Wede tributary, revealing irregular topographies beneath unconformities, offers a glimpse into this complex sedimentation history. Geologists have meticulously recorded and dated evidence of changes in the basin's water level, over the past five decades. Recent efforts aim to refine the chronological framework using various dating methods such as radiocarbon, argon–argon, and optically stimulated luminescence, seeking to understand the forces driving discreet local variations.

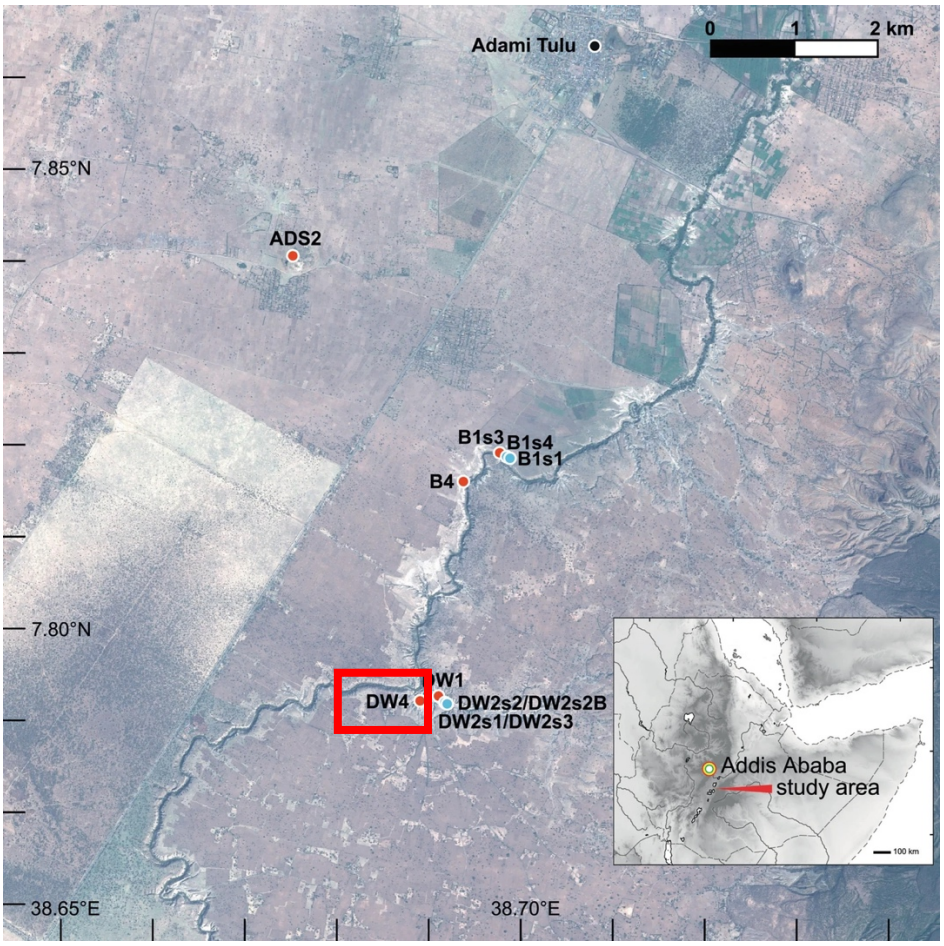


Figure 74: Location of the Deka Wede4 site within the Ziway Sahla basin area (Ménard and Bon, 2023).

Among the oldest sites investigated, there is DW4, and it is dated to the late MIS 3 period (approximately ~34 ka). However, the site is difficult to reach because of the presence of a high pendency slope. Thus, it has not been possible to directly date the sediments. The age of the site has been provided through the correlation of the same deposits at Deka Wede1 (DW1) site.

This timeframe corresponds to a phase of landscape stability, leading to the formation of paleosols across the plain. The paleosol identified at DW1 is rich in lithic artefacts, indicating a notable human presence in the region. DW1, the only directly dated site, is positioned at the base of thick and unstable exposures, hindering further excavation.

a) *Lithic assemblages from the MIS 3 sites in the Ziway Sahla basin*

The lithic assemblage found at DW4 is still under study and has not been published yet. Therefore, this section of the thesis will describe the general characteristics of the assemblages analysed in the DW1 site, nearby of DW4, dated to the MIS 3 (Ménard and Bon,

2023). For a detailed description of the assemblage, we refer to future publications by the current research team.
During the MIS 3 period at the examined sites, the focus of production was on elongated blanks derived from surface cores, particularly utilizing Levallois bidirectional methods. The resulting blanks exhibited diverse morphologies, including thin and pointed products from the center of the flaking surface and thick, asymmetric products from the junction of the core's sides (debordant products, crested blades). All products underwent preparation of the striking platform, involving faceting. Additionally, evidence suggests the production of smaller elongated blanks (bladelet size, approximately 50–20 mm long) from dorsal ridges of large flakes (core-on-flakes), utilizing one or two inverse truncations as striking platforms. The tool assemblage comprises a limited number of shaped tools such as convergent sidescrapers, unifacial points, and endscrapers. Some blanks also display inverse proximal thinning retouch. The scarcity of retouched artefacts implies that a significant portion of the products was likely utilized without further modification.
The artefacts from DW4 are all made of obsidian.

5.2.6 Enkapune ya Muto

Enkapune Ya Muto (EYM), also known as Twilight Cave or GtJi 12, is a rock shelter situated on the Mau Escarpment above the Naivasha basin in Kenya's Central Rift Valley (Figure 77). Initial excavations by Stanley Ambrose in 1982 uncovered deposits from the LSA to the MSA, leading to further investigations in 1987 (Marean, 1992). located in the central Rift Valley of Kenya, is characterized by a 5.6-meter deep archaeological sequence spanning significant periods of the Later Holocene and the middle of the Upper Pleistocene (Ambrose, 2002). Initially excavated in 1982, the site aimed to fulfill objectives such as finding archaeological occurrences from the Middle Holocene dry phase, testing a model of forest-savanna ecotone preference for Holocene hunter-gatherers, and documenting the transition to food production during the later Middle Holocene. These objectives were successfully achieved, revealing new MSA and early LSA lithic industries beneath an erosional unconformity. Subsequent excavations in 1987 aimed to obtain a more complete Late Pleistocene cultural sequence and accurate dates for the MSA-LSA transition.
Radiocarbon and obsidian hydration dates suggest the transition may have occurred around 50 ka. The younger early LSA industry, associated with evidence of ostrich eggshell bead manufacture, is dated to ~39 ka.

The site is near major obsidian sources in the Naivasha basin, and most flaked stone artefacts were made from this material. The stratigraphical description is provided in the right side of Figure 77.

The long stratigraphic sequence has been described in detail (Ambrose, 1998; Marean, 1992) and reported here for only the most ancient layers, excluding Iron Age occupations.

The layer RBL1 comprises approximately 10 cm of light red-brown fine silts, dated to 3390 BP. It yields a high concentration of Eburran lithic artefacts and bone remains, but there is no pottery evidence.

A blue-grey Volcanic Ash (VA1), up to 53 cm thick and dated to 3125 BP, seals the underlying layers.

The layer RBL2 consists of a layer of hearths and wood ash, divided into three main strata. The presence of fauna consists of wild herbivores from grassland, woodland, bush, and forest habitats, indicating proximity to the ecotone between montane forest and savanna grasslands (Ambrose, 1998; Marean, 1992).

The third subunit of RBL2.1, dated to 3990 BP, includes caprines (Marean, 1992), the oldest domestic animal at the site.

RBL2.2 and RBL2.3, dated to 5265 and 5365 BP respectively, contain well-preserved layers of uncarbonized to partly carbonized fine grasses, likely used as bedding. These strata exhibit extremely high species and habitat diversity (Marean, 1992).

RBL1 and RBL2 indicate an exceptionally intense occupation of the rock shelter during a climate like or slightly more humid than the present, with the forest/savanna ecotone nearby (Ambrose, 1998).

The coarse Dark Brown Sand and silt (DBS1) layer, dated to 5220, 5470, and 5785 BP sees a decrease in artefact densities. Microfauna, rodent burrows, and rolled artefacts from the underlying deposit increase with depth, reflecting intense vertical mixing due to rodent bioturbation. The faunal assemblage includes more species adapted to closed habitats (Marean, 1992; Marean, Mudida & Reed, 1994). The site was occupied less intensively as closed habitats encroached (Ambrose, 1998).

The second Volcanic Ash (VA2) seals RBL3, a coarse, sandy, Red-Brown Loamy gravel lag deposit, featuring heavily abraded obsidian artefacts and undamaged Eburran Phase 4 artefacts (Ambrose, 1998). Closed habitat species predominate, suggesting a nearby forest (Marean, 1992; Marean, Mudida & Reed, 1994). This lag deposit likely formed when the shelter's dripline was active during the early Holocene wet phase. A date of 6350 BP, from an undisturbed hearth beneath VA2, marks the ashfall and cessation of erosion. Closed habitats surrounded the site during RBL3 formation, and occupation intensity increased through DBS1 as rainfall decreased and the forest ecotone approached.

The third Volcanic Ash (VA3) is dense, protecting underlying deposits from erosion.
The Dark Brown gritty Loam (DBL1) contains extremely high artefact densities and a faunal assemblage heavily fragmented by trampling and compaction. The associated Sakutiek Industry is dominated by typical LSA tool types (Ambrose, 1998). Ostrich eggshells are abundant, and radiocarbon dates from DBL1 reflect high-intensity occupation, including on-site manufacture of ostrich eggshell beads, likely during a warm phase of marine oxygen isotope stage 3 (Ambrose, 1998).
The underlying Grey Gravels (GG1, GG2) with intercalated layers of Orange gravelly Loamy sand (OL) have low artefact and bone densities. The Nasampolai Industry, a blade-based LSA lithic industry, dominates GG/OL. It represents a very long period of ephemeral occupation earlier than 40000 BP.
The basal horizon, a dark red-brown to dark brown gritty Loam (RBL4), has low densities of bone and flaked stone. The flake-based MSA lithic industry, named the Endingi Industry, indicates sparse occupation of the rock shelter during early MIS 3 or 4 (Ambrose, 1998).

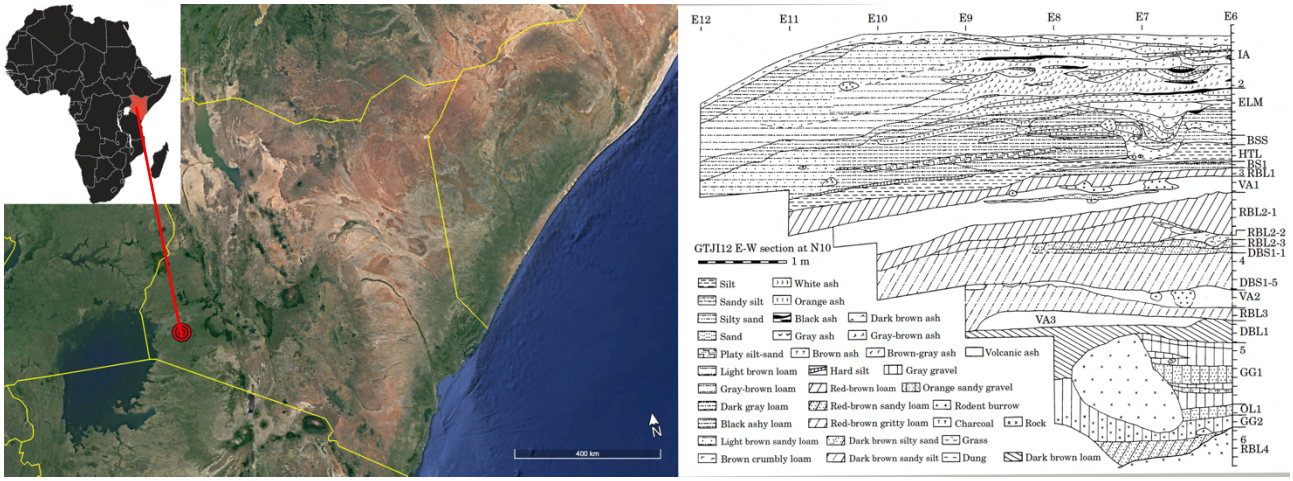


Figure 75: Location of the site (left) and description of the stratigraphic sequence (right). (Modified after Ambrose, 1998).

In summary, the three Late Pleistocene levels are the following:
(1) RBL4 stratum with sparse MSA material (Endingi industry).
(2) GG and OL strata with low densities of one of the earliest known LSA (Nasampolai) industries (>50ka).
(3) DBL stratum with abundant early LSA (Sakutiek) industry artefacts (ca 35-40ka). Ambrose (1998) previously noted that the later Sakutiek industry exhibits more "transitional" characteristics than the early LSA Nasampolai industry, suggesting a non-linear change from the MSA to the LSA in this context (Ambrose, 1998).

b) Lithic assemblage from EYM

The lithic assemblage discovered during the excavations at EYM, both LSA and MSA, has been studied as part of a recent Marie Curie project but has not yet been published (Leplongeon, 2016).

The assemblage has been studied according to two methodologies: the *chaîne opératoire* concept combined with an attribute analysis approach. Each category of artefact analysed (flakes/blade(let)s, core trimming elements (CTE's), cores, retouched tools) records specific attributes to reconstruct and quantify differences between the assemblages for each step of the *chaîne opératoire* (conception of debitage, percussion technique, preparation of striking platforms and flaking surfaces, modification of blanks by retouch, etc.) (Figure 78).

The lithic assemblage from Enkapune Ya Muto is mostly made of obsidian. Results indicate a significant technological shift between the MSA level, characterized by an assemblage focused on producing faceted-platform flakes and, to a lesser extent, pointed blanks, and the two LSA levels, which feature blade(let)-based assemblages. Despite numerical differences in lithic counts between the two LSA levels, the analysis reveals that the early LSA assemblage (*Nasampolai*) is characterized by a few volumetric blade cores, a high number of CTE's, and retouched tools, including large, backed segments. In contrast, the later LSA assemblage (*Sakutiek*) is defined by numerous cores-on-flakes/blades for bladelet production, few CTE's, and rare retouched tools, including end-scrapers, scaled pieces, and few geometrics. Large flakes with faceted platforms were also observed, though no core could be associated with this production.

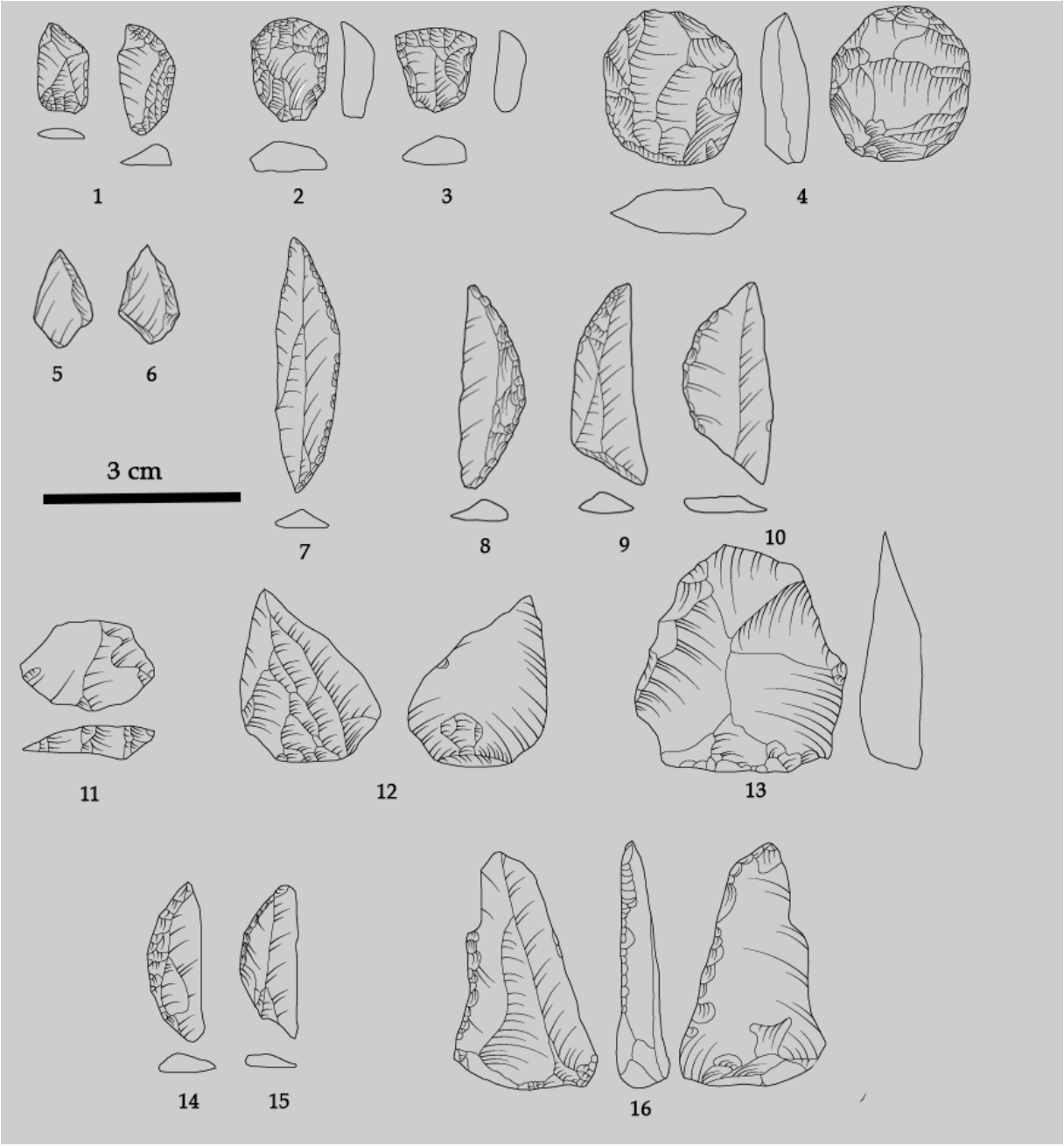


Figure 76: Lithic artefacts from EYM (Modified after Ambrose, 1998).

5.3 Materials and Methods

In this section, a detailed explanation of the materials and methods used for the comparative analysis at a regional level is provided. For the comparison of lithic assemblages, several metric and technological attributes have been collected from databases provided by scholars who worked on the assemblages described above.
Lithic attributes from Goda Buticha, Porc Épic and Enkapune ya Muto have been provided by Dr. Alice Leplongeon (University KULeuven) while data from Deka Wede4 has been provided by Dr. Clément Ménard (CNRS – Museum of Tautavel), Dr. Behailu Habte (Ethiopian Heritage Authority, Addis Ababa) and Dr. Katja Douze (University of Geneve).

5.3.1 Lithic category

Elongated unretouched blanks (named blades and bladelets according to the common terminology for lithic categorisation) from the archaeological sites described above, spanning stratigraphic sequences from MIS 4 to MIS 1 have been considered for this analysis.
I specifically chose to focus on unretouched and complete blades and bladelets because their presence seems to increase during the LSA (Blinkhorn and Grove, 2020; Leplongeon 2014). Moreover, they are the type of blank for which the most data were available for the sites of interest, which allows to increase in the chronological and geographical scale of the analysis. Each lithic in the dataset has been associated with a dated layer and a cultural phase. Cultural phases have been attributed in accordance with the publication related to the contexts analysed. Accordingly, the assemblage have been classified belonging to the Middle Stone Age (MSA) dated between ~80 and 63 ka; the Late Middle Stone Age (LMSA) between ~48 and 31 ka; the Late Stone Age (LSA) dated to ~24 ka; and the Late Holocene LSA (Late Hol LSA), from 9 ka (Fusco et al. in press; Fusco et al. 2021; Leplongeon et al. 2017; Leplongeon 2014; Ménard et al. 2014; Ménard and Bon, 2023; Pleurdeau 2005; Spinapolice et al. 2017).
It is important to highlight that these data have been collected by different researchers from various research traditions, each with distinct objectives. This led to great variability in the metrics considered, the categories analysed, and other technical choices that can highly impact our analyses. It must also be noted that, regarding metrics and technological attributes, caution must be given when merging different sets of data (Pargeter et al. 2023; Will et al. 2019). Following the approach designed by Pargeter and colleagues (2023), we focused on specific metrics and technological attributes that are most suitable for statistical

analyses of data collected by different individuals or research groups. These include technological measurements (maximum length, width, and thickness), the number of dorsal scars, blank completeness, elongated index (ratio between length and width), and flattening index (ratio between width and thickness) (Table 63). I analysed these attributes from the five different datasets related to the sites mentioned above (Table 64)

The lithic metric and technological attributes were organised into a new database, together with other relevant information for the analyses. Thus, the database was composed of the following columns: ID artefact, Site name, layer, and artificial cut (in order to have specific chronological information for each lithic assemblage), cultural phase, and chronology.

Lithic attributes	
Maximum length	XTL
Maximum bredth	XTB
Maximum width	XT
Elongation index	EI
Flattening index	FI
Number of scars	NR

Table 63: List of lithic attributes considered in the analysis.

Site	**Layer**	**Chronology**	**Cultural Phase**
Goda Buticha	IIdIIf (030-000)	63ka	MSA
Goda Buticha	IIdIIf(100-030)	44-31 ka	LMSA
Goda Buticha	Iic (110-100)	24ka	LSA
Goda Buticha	Iic (160-110)	7-4 ka	Late Holocene LSA
Goda Buticha	I (190-160)	3 ka - 700ya	Late Holocene LSA
Porc Épic	IIId-II	end MIS5 (~80ka)	MSA
Gotera	SU6 - SU7	43-42 ka	LMSA
Daka Weke4	1500	31ka	LMSA
Enkapune ya Muto	RBL4	42ka	LMSA
Enkapune ya Muto	GG1.2-3-4-5-7	46ka	LSA
Enkapune ya Muto	DBL1.3	38ka	LSA
Enkapune ya Muto	DBL1.2	35ka	LSA

Table 64: list of sites considered in the analysis with the identification of chronology and cultural attribution.

5.3.2 Statistical analyses

In order to further evaluate the most suitable variables for the analysis and, importantly, that were consistent with the data collected by other researchers, a series of exploratory analyses have been done. A first data exploration via PCA was performed using the following variables: maximum length, maximum width, maximum thickness, number of dorsal scars, elongation and flattening indices, and platform measurements. However, the latter posed a challenge as not all databases I collected contained information on platforms. It was decided to proceed by considering two approaches:
1. conducting a PCA with all variables only for the data that had all of them, and
2. PCA excluding the platform measures data.
In the PCA that includes platform measurements, databases related to Enkapune ya Muto and Deka Wede were excluded because these datasets did not contain the necessary information. In the PCA without platform measurements, on the other hand, all data from all databases were included. However, to find a way to include as much data as possible—otherwise, testing a model regarding the transition from the MSA to the LSA would have been even more challenging—a correlation analysis was conducted to determine if it was possible to exclude platform measurements and thus include all datasets. To perform the correlation, the R package *PerformanceAnalytics* (Peterson 2020) was used, and then the function *chart.Correlation()* was used. This function allows for the execution and visualization of a correlation matrix of the data to assess the correlation coefficients between two or more variables. The correlation matrix is a square table (i.e., with the same number of rows and columns) that lists in the row and column headers the variables for which the correlation is to be evaluated.

a) Principal Component Analysis

A Principal Component Analysis on lithic attributes using the *FactoMinerR* package (Lê et al. 2008) and its *prcomp()* function was performed. Cultural phases, chronology, and raw materials were chosen as variables for grouping the PCA results and the two principal components. This was done to evaluate the results of the PCA based on different archaeological questions.
Furthermore, to better visualise how the individuals (artefacts) related to different cultural phases are distributed in the PCA space, I calculated the centroids (the mean of PC1 and PC2) to show a single mid-point for each archaeological layer and site. The mean was calculated using the function *colMeans()* from the *base* package. Then a dataset was created

with the mean values of PC1 and PC2 using the function *as.data.frame()* from the *base* package. This allowed us to create a matrix with the mean values of PC1 and PC2.

b) Paleoclimate data exploration

The R package *pastclim* (Leonardi et al. 2023) was used to access the paleoclimate reconstructions (Beyer et al. 2020). The dataset includes 18 bioclimatic variables spanning from 120000 years ago to the present, with time intervals of 1000/2000 years. Since a regional analysis has been conducted, the function *"location_slice()"* from *pastclim* was used, to associate each dated layer and archaeological site with the climate variables reconstructed for their spatial coordinates and age, namely annual mean temperature (BIO01), temperature seasonality (BIO04), minimum annual temperature (BIO05), maximum annual temperature (BIO06), temperature annual range (BIO07), annual precipitation (BIO12), altitude and rugosity.
These variables have been tested to understand which of them are most likely to explain the pattern observed in principal components by testing for each layer the value of PC1 and PC2 for the associated centroids versus climatic and environmental variables reconstructed for its location and time.
A scatter plot with the results of the correlation between variables and PCs was created using the *"ggarrange()"* function from the *ggpubr* R package (Kassambara, 2023).
All graphic representations were generated using the *ggplot2* R package (Wickham 2016).

5.4 Results

Before running the PCA, the correlation matrix was calculated to define the variables to use for the PCA and evaluate if platform measurements were necessary variables or if they could have been excluded. Therefore, the correlation matrix was calculated, including all the variables considered for the PCA, including the platform measurement data.
Results are shown in figure 79. The individual cells within the table indicate the specific bivariate correlation coefficients.

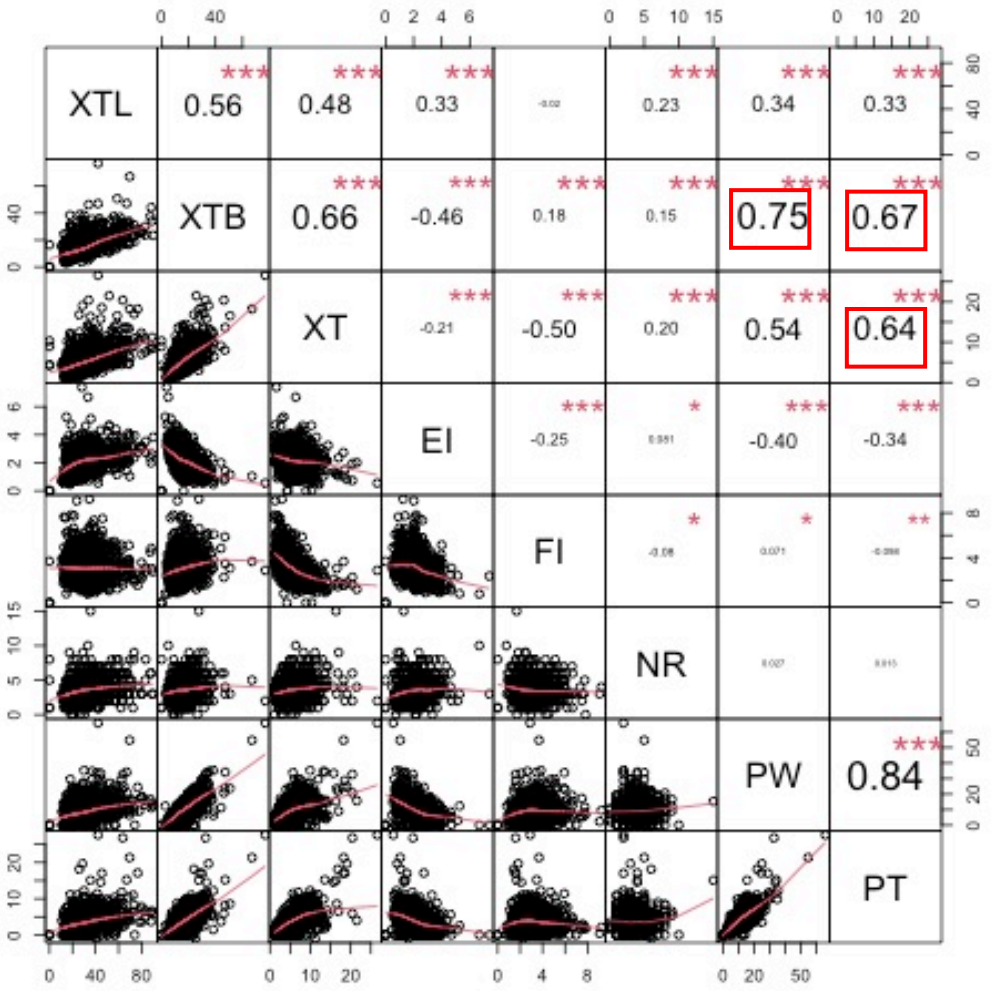


Figure 77: Correlation chart of platform measurements and size measurements. In red are shown the statistically significant correlation values.

The result obtained from the correlation matrix indicates a statistically valid correlation between the variables of maximum width (XTB) and platform width (PW) (0.75%), maximum width and platform thickness (PT) (0.67%), and maximum thickness (XT) and platform thickness (0.64%). Consequently, it was clear that the exclusion of data on platform measurements would not have influenced the result, as PW and PT are strongly correlated with the measurements of the width and thickness of the artefacts.

Therefore, the PCA was performed using the multiple measurements dataset, the number of scars, and the size and shape indexes. Results show that in the PCA, the two first principal components accounted for 68.3% of the overall variance.

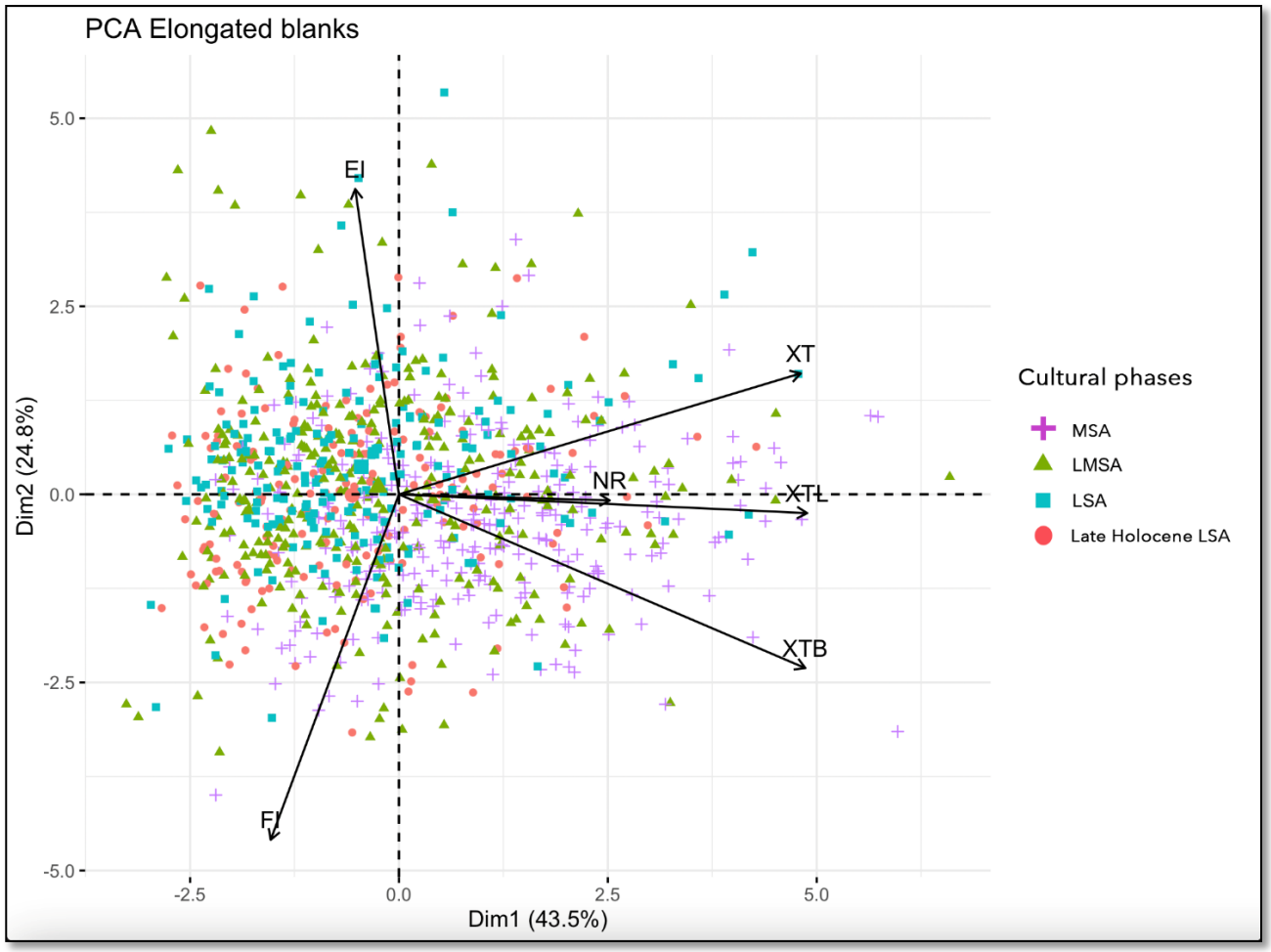


Figure 78: PCA results showing individuals grouped by cultural phases.

Component 1 captured the size as it is mostly influenced by dimension variables: maximum length (XTL), maximum breadth (XTB), and maximum thickness (XT), while Component 2 captured the shape since it is primarily influenced by the elongation index (EI) and flattening index (FI) (Figure 80).

However, as seen in the PCA plot displaying individuals' and variables' directions, the result is not very clear. Therefore, the result of calculating the centroids (means) of the principal components grouped based on the cultural phase variable associated with different archaeological levels in the analysed sites has been presented below.

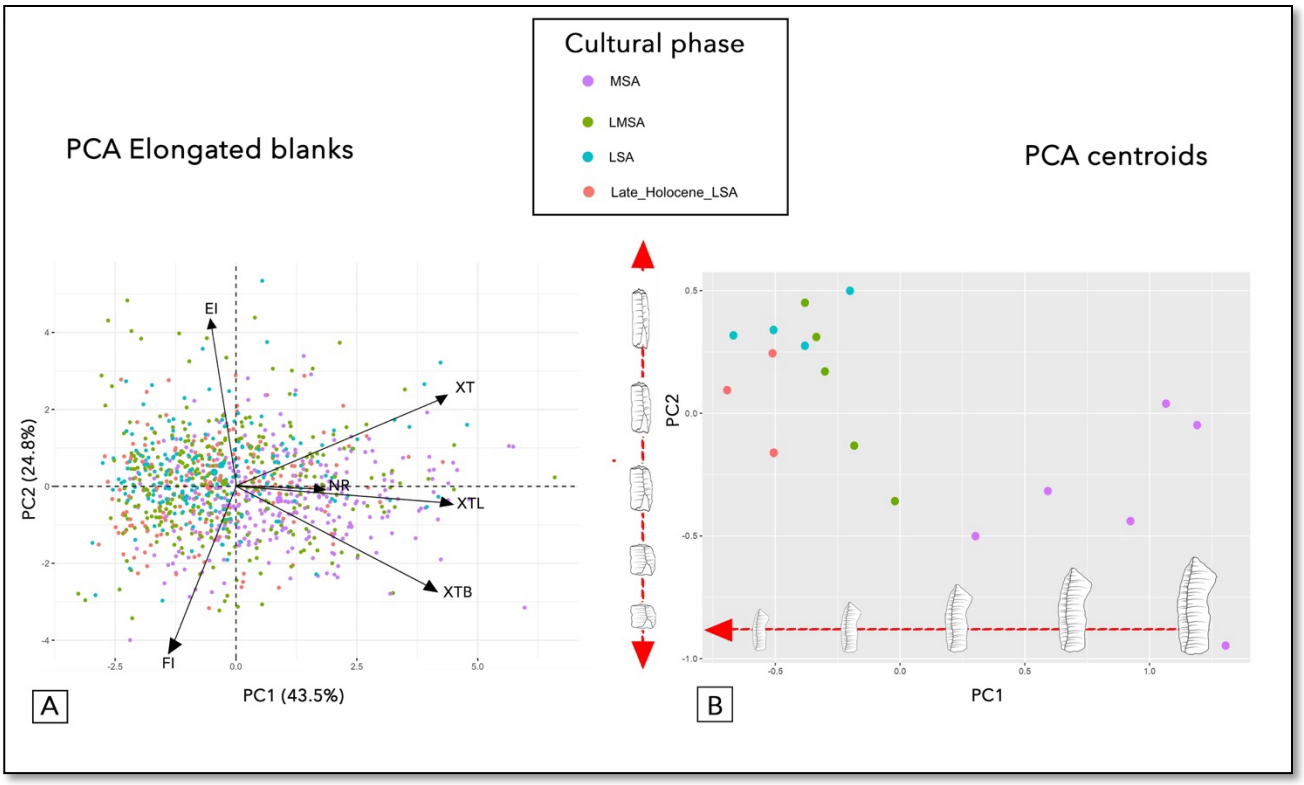


Figure 79: PCA results showing the position of the individuals (A) and the centroids (B) calculated for PC1 and PC2 grouped by cultural phases and showing how artefacts change along the two axes.

As shown in the figure, the result appears much clearer. The earlier phases of the MSA (MSA cultural phase) are separated from the rest in the extreme right part of the plot (Figure 81). Then, the presence of the late MSA phase (LMSA) is noticeable, followed by the LSA and late Holocene LSA. In this plot, the separation between cultural phases (and consequently between archaeological levels), at least regarding the MSA and LMSA, appears evident.

Furthermore, based on the direction of the variables along the axes of the two components, it can be stated that along the axis of the first component, the dimensions decrease as individuals move toward the left side of the plot, as the loadings in this case express negative values. In the second component, influenced by shape variables, the elongated blanks present in the upper part of the graph are characterized to be thinner and longer, while the individuals disposed in the lower part of the graph are the ones to be shorter and thicker (Figure 81: B).

The results of the PCA demonstrate a progressive reduction in the size of elongated blanks in the analysed assemblages. The assemblages of Porc Épic and the 63ka layers of Goda Buticha (in purple in Figure 81) are the ones that have larger dimensions. In contrast, Gotera, Deka Wede4, LMSA layers of Goda Buticha, and the MSA layer of Enkapune Ya Muto appear on the left side of the graph with artefacts of smaller dimensions (in green in Figure

81). The LSA layers of Enkapune Ya Muto and the LSA of Goda Buticha (in blue in Figure 81) show smaller dimensions than the LMSA artefacts. However, there is an evident superimposition of these data in the PCA, reflecting the blurry boundaries between the LMSA and the beginning of the LSA in the region. Finally, the late Holocene LSA layers of Goda Buticha (in red in Figure 81) are placed at the extreme left of the graph, demonstrating the smallest dimensions of the assemblages. Below is a summary of the main results:

- PC1 in the results clearly distinguishes between the MSA, LMSA, LSA, and Holocene LSA data with a phenomenon of progressive reduction in sizes from ~80 ka to the Holocene in the studied contexts.
- However, PC2 does not seem to be correlated with chronology, thus a further exploration of cultural and environmental factors has been done in order to answer the first and third research questions (Figure 1).

To explain the pattern identified in the PCA, cultural and environmental factors were explored. Among the most cited behavioural aspects for technological changes is raw material selection (Blinkhorn and Grove 2021; Shipton et al. 2018). In this regard, I tested the role of raw materials within the assemblages analysed, exploring their relationship with the two principal components. The results revealed a diverse pattern, highlighting a notable absence of a clear link between the technological changes during the late Pleistocene and Holocene and the selection of different raw materials within the contexts examined in this study (Figure 82). This is particularly evident when individuals grouped by raw materials are shown with confidence ellipses representing confidence regions within the assemblage (Figure 82: B).

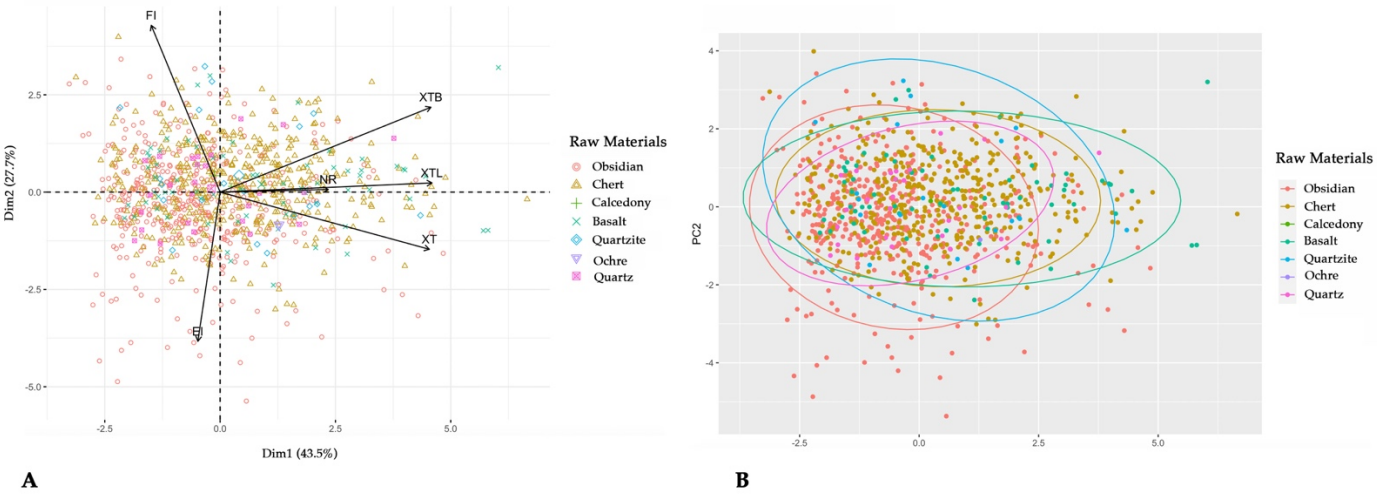


Figure 80: PCA results grouping individuals by raw materials (A); PCA showing individuals and confidence ellipses (B).

Then it has been tested the hypothesis of paleoclimate as a potential factor for technological changes by correlating the PCA results with climate variables. We extracted climatic variables for each assemblage from paleoclimate reconstructions based on the Had-CM3 model (Beyer et al. 2020) as available in the *pastclim* package (Leonardi et al. 2023) in R. The two principal components were then correlated with the climatic variables listed in the methods.

The results of the correlation between the two components and Time, BIO05, and BIO06 are shown in the figure below (Figure 83). In box A the results of the correlation between PC1 and "time" are displayed, while in box B, the variable time has been correlated with PC2. This information is intriguing because it confirms what was already observed in the PCA regarding the correlation of variables related to dimensions (expressed by PC1) and time as a chronological sequence. We observed that the first component of the analysis indicates a reduction in dimensions along the first axis, which is evident in chronological order from the oldest assemblages (MSA levels of Goda Buticha and Porc Épic) to the more recent ones (Holocene levels of Goda Buticha). On the other hand, the second component, as noted in the PCA, does not exhibit any correlation with the time variable. Thus, the data on the shapes (expressed by PC2) is not related to differentiation in time and the chronology did not affect it in terms of changes in technology. In boxes C and D, the results of the correlation between PC1 and the minimum annual temperature are presented. Box C displays the correlation results between PC1 and the minimum annual temperature, while in box D, the variable minimum annual temperature has been correlated with PC2.

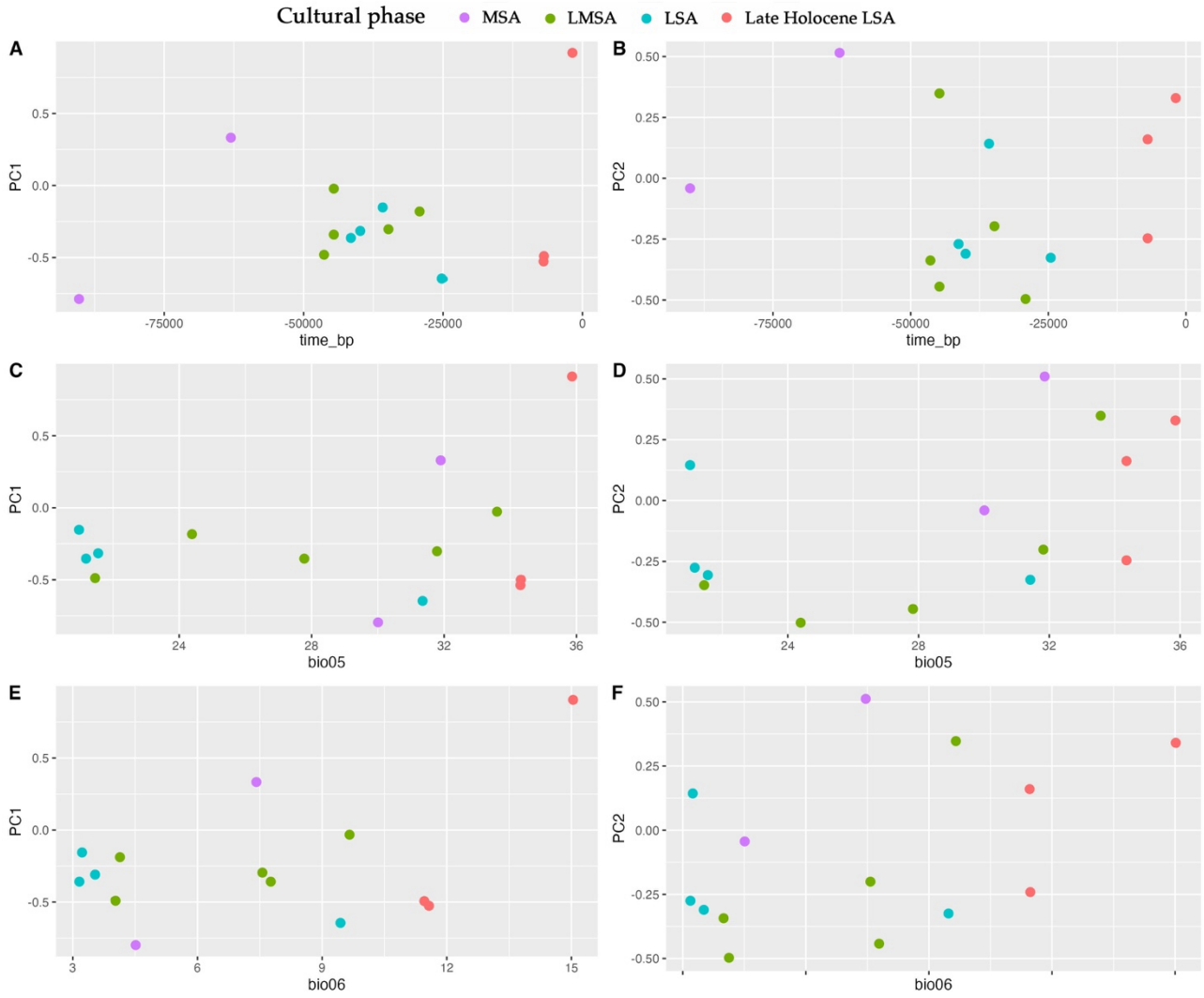


Figure 81: results of correlation between PC1 and PC2 and chronology (time_bp) and bioclimatic variables (BIO05 and BIO06).

It is clear from the graph that there is no correlation between the two components of the PCA and the bioclimatic variable associated with the minimum annual temperature. Consequently, we had to reject the hypothesis that the data on the analyzed lithic industries show a correlation with the minimum annual temperature, particularly ruling it out for the aspect represented by PC2 and proceed with the investigation. In this regard, the two components have been related to the bioclimatic variable concerning the maximum annual temperature (BIO06). In box E, the correlation result with PC1 is expressed, and in box F, the correlation with PC2 is shown. Once again, no correlation is demonstrated between the two components and the variable under consideration. Therefore, the hypothesis of a connection between the maximum annual temperature and variations in the shape and dimensions of elongated flakes in the considered contexts can be ruled out.

The results of the correlation between the two components and the topographic variable of altitude and rugosity are shown in the figure below (Figure 84). The data on roughness refers to a specific measurement that calculates small-scale variations in the amplitude of a surface. In this case, it can be useful to compare to indicate the potential variations of the amount of habitat availability in correlation with variation in lithic technology and data on cultural variability.

In boxes A and B of figure 84, the results of the correlation between the two components and altitude are presented. Box A displays the correlation results between PC1 and altitude, while in box B, the variable altitude has been correlated with PC2. However, as demonstrated by the displayed graph, there is no correlation between the two components and this topographic variable. This demonstrates the absence of a connection between the PCA data and, consequently, the variation in lithic technology across the investigated contexts and the variation in altitude. Similarly, as shown in boxes C and D, where the two components have been related to the roughness variable, there is no valid correlation between these variables. Therefore, changes in technology cannot be explained by a correlation between cultural aspects and the data on the surface variation and habitat availability.

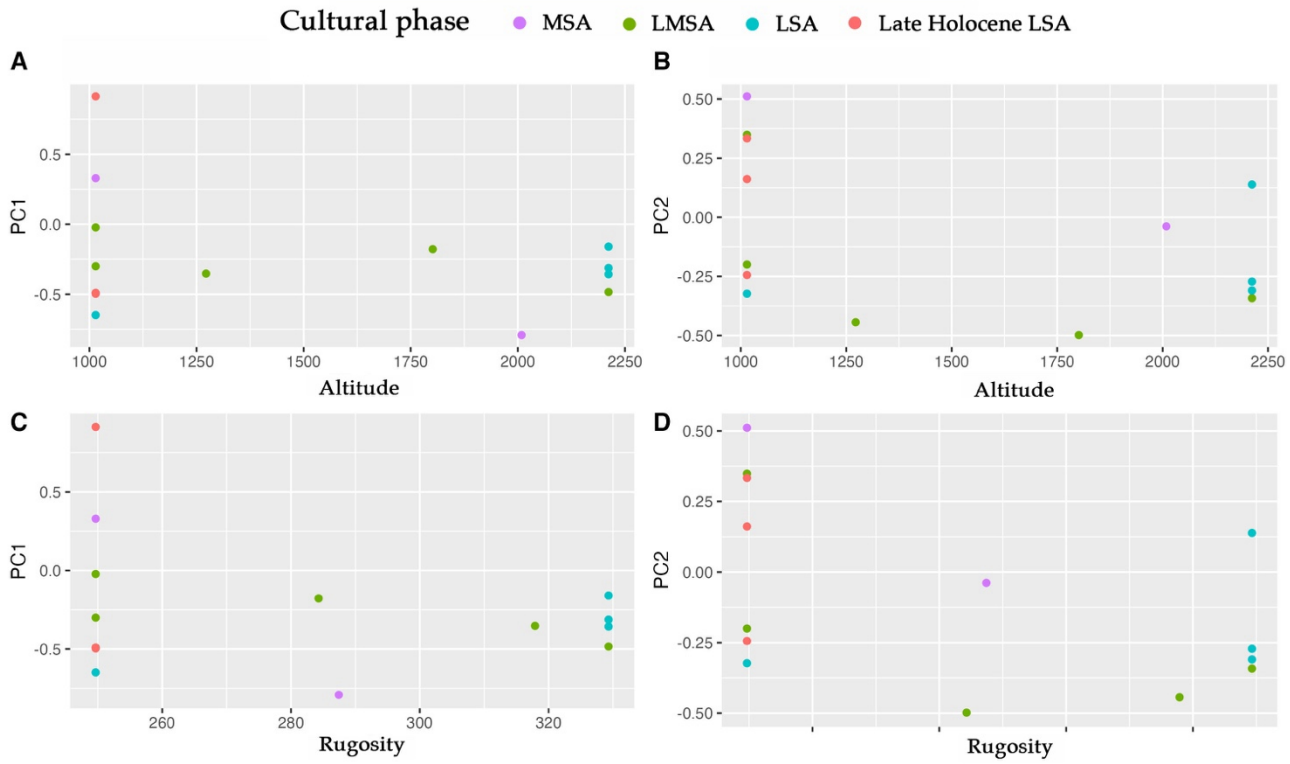


Figure 82: results of correlation between PC1 and PC2 and altitude and rugosity.

Then the variables related to the temperature seasonality (BIO04), the temperature annual range (BIO07), and the annual mean temperature (BIO01) have been compared with the two principal components (Figure 85).

In boxes A and B, the results of the correlation between PCA and the bioclimatic variable of temperature seasonality are displayed. As shown in box A, there is no correlation between PC1 and BIO04. What appears to be interesting, however, is the result of the correlation between PC2 and BIO04. From the graph, it is evident that a valid correlation exists between the two data sets. Therefore, PC2, which expresses changes in the shape of the analyzed blades and flakes, is strongly correlated with the data on temperature seasonality.

A significant correlation was found also between the data on the shape and the temperature annual range. This result is expressed in box D, while in box C is expressed the result of correlation between PC1 and BIO07. This latter has shown no correlation.

Finally, boxes E and F show that there is no correlation between the bioclimatic variable BIO01 and both PC1 and PC2.

What is evident from the analysis of climate variables in correlation with the PCA data is that component 1 has an almost perfect relationship with the chronology (time_bp, Figure 83: A), while component 2 is associated with the climatic variable related to the temperature annual range (BIO07) and the temperature seasonality (BIO04) (Figure 85: B and D).

In the context of our PCA, it has been observed that elements with a higher flattening index correspond to a higher value, whereas conversely, elements with a higher elongation index correspond to a lower value on the graph of BIO04 and BIO07 (Figure 85: B and Figure 85: D).

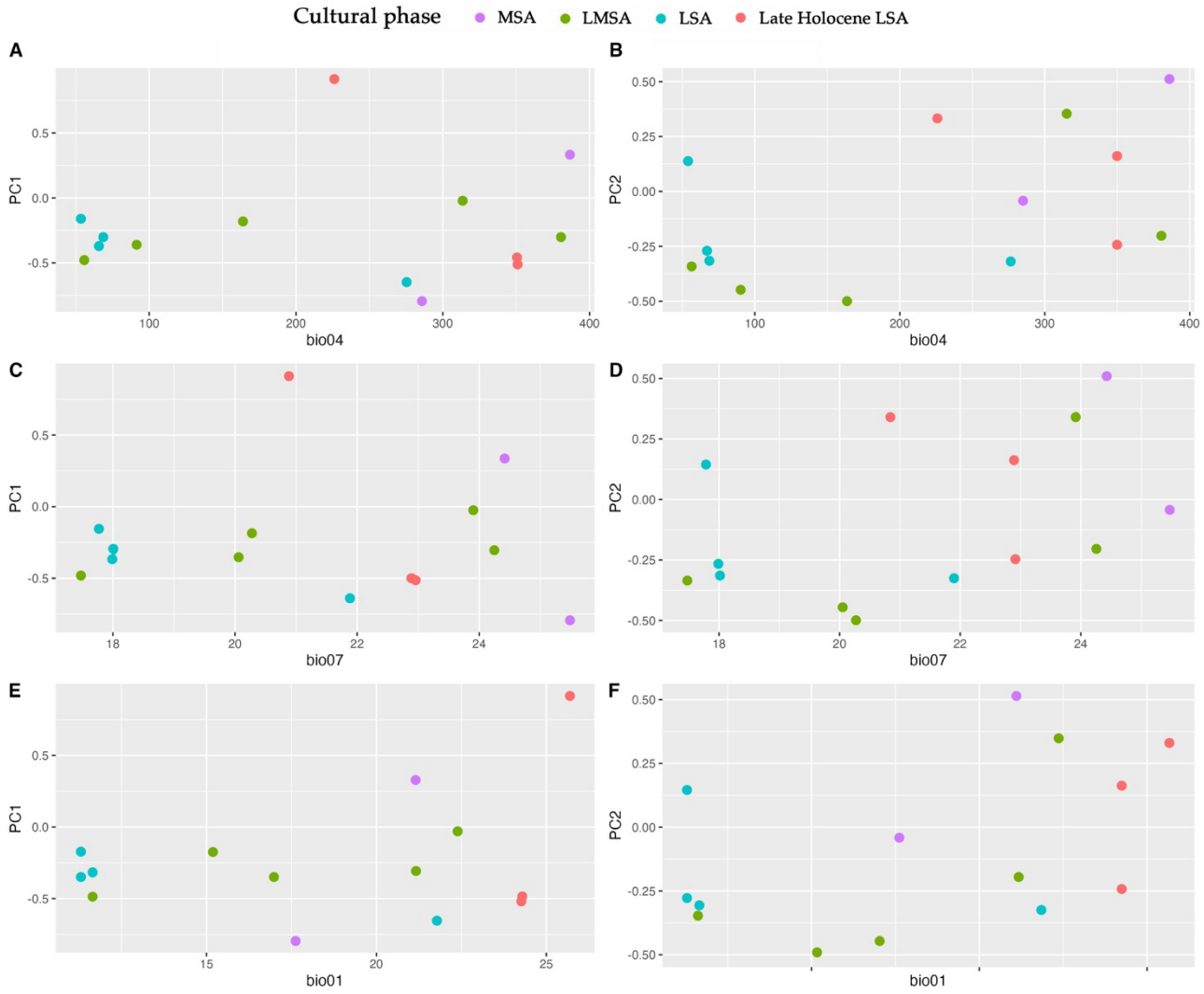


Figure 83: results of correlation between PC1 and PC2 and bioclimatic variables (BIO04, BIO07 and BIO01).

The temperature annual range represents the difference between the maximum and minimum annual temperatures (Beyer et al. 2020). On a scale from 18 to 24 degrees (see Figure 85: D), the higher the value, the greater the difference between the maximum temperatures. The other climatic variables analysed, on the other hand, do not show any correlation with either component 1 or component 2.

In order to validate the data, a correlation analysis has been performed on the data between PCA and time and PCA with BIO07 and BIO01 (in order to show differences between a correlated variable (BIO07) and an uncorrelated variable (BIO01) (Figure 86).

The figure below validates the statistically high significance of the correlation since the p-value appears to be extremely low for the results on the correlation between PC1 and time (p-value<1.8e-05), the correlation between PC2 and the temperature annual range (BIO07) (p-value 0.0021).

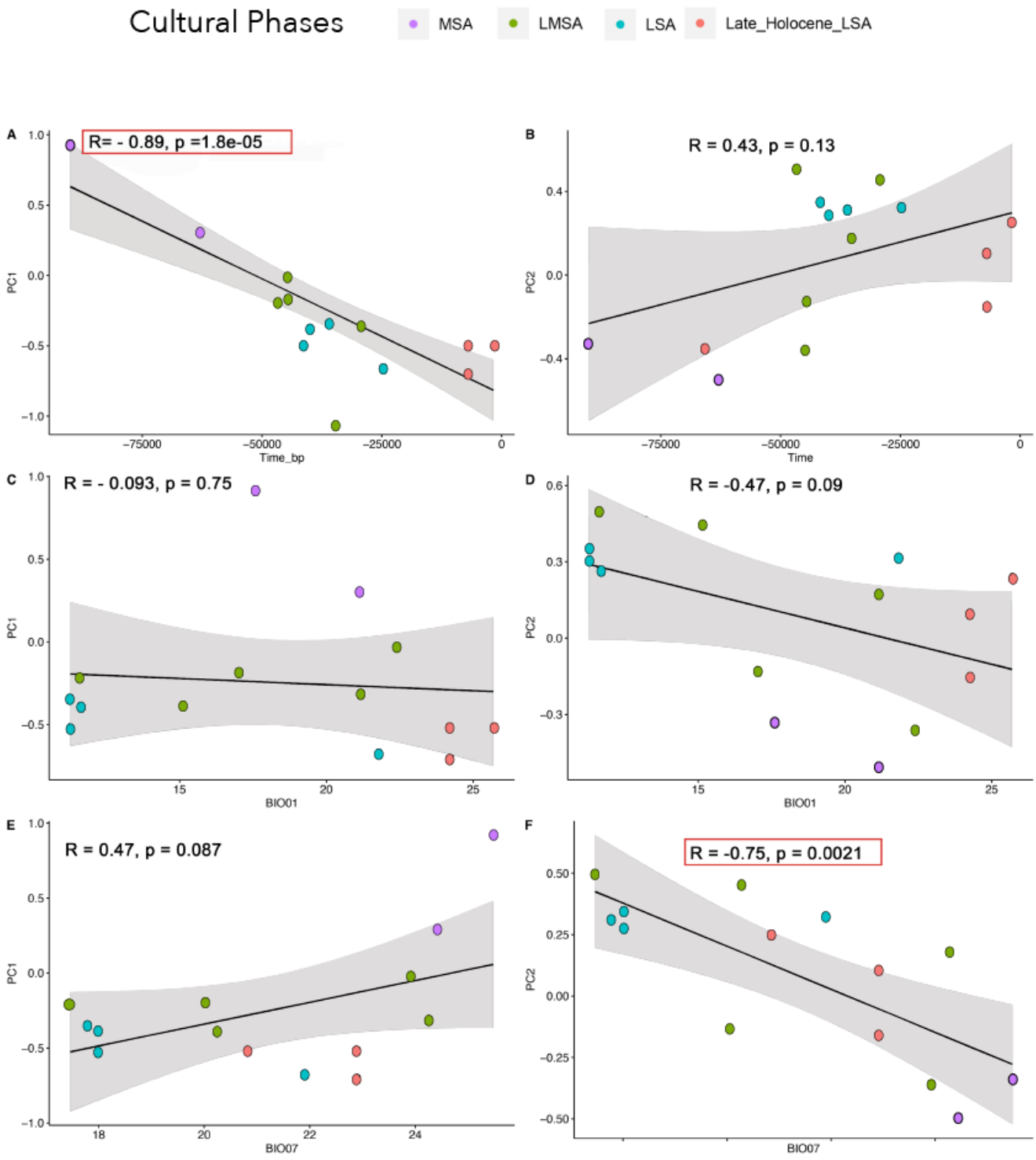


Figure 84: multiplot showing the statistical significance of the correlation between PC1 and chronology (time_bp) and PC2 and bioclimatic variable BIO07.

5.5 Discussion

The results of our PCA demonstrate a clear trend toward the reduction in the size of elongated blanks in the sites analysed.

The question regarding the decrease in the dimensions of blanks, cores, and tools in late Pleistocene lithic assemblages associated with specific cultural choices is a highly debated topic (Leplongeon et al. 2023; Pargeter and Shea 2018; Shipton 2023). In some contexts, it has been associated with the transition from the MSA to the LSA. In the past, size reduction, in fact, became one of the characteristics that defined the LSA and differentiated it from the MSA (Ambrose, 1998; Grove and Blinkhorn, 2020; Pargeter, 2016; Pargeter and Shea, 2018; Shipton et al. 2018; Shipton, 2023). However, now it is recognised that data on small size alone is not satisfactory to categorise an assemblage exclusively as LSA (Leplongeon et al. 2023). In fact, it has also been asserted that the presence of small-sized artefacts (<30-50 mm) has been documented in even earlier archaeological contexts (for example, small bifacial handaxes have been found in Olduvai in Africa, as well as evidence of small Levallois cores in the European and Levantine Middle Palaeolithic (Elston and Kuhn, 2002; Pargeter, 2016; Pargeter and Shea 2018).

In eastern Africa, assemblages with small-sized elements are present in various contexts and at different times, such as at Omo Kibish, Herto/Aduma, as well as at Panga ya Saidi (Shea 2008; Yellen et al. 2005; Shipton et al. 2018; 2021). In South Africa, evidence of small flakes and blades is present as early as the MSA, sometimes associated with the Howiesons Poort industry. The latter characterised by small geometric tools used probably as insets in multi-component tools (Pargeter and Shea 2018; Porraz et al. 2013; Soriano et al. 2007; Wurz 2013).

Therefore, it is well known that small-sized lithics are present in both the Pleistocene and Holocene African archaeological records, even if in different proportions across regions, in different periods, linked to different technical features, and in different periods and that it is not easy to associate this characteristic with a specific cultural techno-complexes (Pargeter and Shea 2018). It is important to note that historically, there has been a distinction in the definitions of microliths and assemblages containing microliths (Leplongeon 2014; Hiscock et al. 2011; Pargeter and Shea 2018). In the context of this analysis, it was not our intention to provide a new definition for terms such as 'microliths' as it fell outside the scope of our study. However, what is evident is an objective trend of progressive size reduction in both blades and bladelets within the contexts spanning from the MSA to the Holocene LSA.

The challenge arises when attempting to explain the reasons for these changes on a broader scale. Various hypotheses have been proposed regarding the shifts in artefact sizes, accompanied by ethnographic analyses in contexts from both North America and Australia

(Pargeter and Shea, 2018; Hiscock et al. 2011). These hypotheses encompass symbolic aspects related to the miniaturisation of flakes and blanks in general (Shipton, 2023; Hiscock et al. 2011). Additionally, they consider factors associated with raw material economics within contexts characterised by demographic growth, reduced residential mobility, and the cost-benefit analysis of maximising the quantity of produced objects by focusing on smaller sizes (Hiscock et al. 2011; Elston and Kuhn, 2002; Pargeter and Shea 2018).

In lithic production, raw material selection has played a significant role. One possible explanation for the reduction of lithic dimension could have been the different raw materials used through time and space. Pargeter and Shea (2018), in fact, argue that certain raw materials, such as quartz, are easier to manipulate to produce smaller-sized artefacts. Indeed, a significant observation of technological changes in the Late Pleistocene and early Holocene lithic industries in eastern Africa is the exploitation of different raw materials (Shipton et al. 2018; 2021). Generally, the trend of selecting fine-grain raw materials, better suited for small tools, has been proposed as a characteristic of the transition from the MSA to the LSA (Shipton et al. 2018; Grove and Blinkhorn, 2020). However, this pattern may be relevant for interpreting single sites where this evidence has been tested (Shipton et al. 2018). Indeed, this assumption regarding a general trend of fine-grain raw material selection in the LSA needs to be tested to a large-scale dimension, both geographical and chronological. Consequently, the correlation between the choice of distinct raw materials and technological and behavioural changes associated with the emergence and diffusion of traits categorised as LSA should be further substantiated through comprehensive analyses encompassing a wider range of contexts featuring extended chronologies.

Extensive discussions have taken place regarding ecological and environmental aspects to explain the phenomenon of lithic miniaturisation and, in general, phenomena regarding technological changes in stone tools' use and production (Ambrose 2002; Pargeter and Shea, 2018).

Like all species, humans faced the consequences of climatic fluctuations, especially during the eastern African Late Pleistocene, where environmental changes led to oscillations between arid and humid periods (Basell, 2008; Blome et al. 2012; Leplongeon et al.2023). It's evident that this should not be considered the only triggering factor, as we still have limited data available. However, it represents an important element that needs to be considered when discussing technological and economic changes in prehistoric societies.

In particular, the seasonality of resource acquisition is a key aspect of hunter-gatherer subsistence behaviour and social and economic organisations (Bleed, 1986).

Reconstructing behavioural aspects related to seasonality is challenging, especially when site-specific paleoenvironmental reconstructions are scarce, and understanding them is complex due to the varying modes of seasonal changes.

In our results, the correlation between the shape of blades and bladelets (i.e. elongation and flattening) and temperature annual range suggests adaptive strategies in response to different levels of seasonality. It is widely accepted that resources predictability (a consequence of more stable environments) has impacted hunter-gatherers behavioural dynamics, in terms of subsistence, settlement, and mobility strategies (Bleed, 1986; Jones, 2013; Grove, 2009; Nelson, 1991). Resource predictability is considered an important variable for understanding technological production and organisation. For example, it has been proposed that the way to exploit and knap raw materials to anticipate inadequate conditions is one of the features that differentiates the concept of curation from the one of expediency (Nelson, 1991). Going beyond the multiple definitions of curation and expediency concepts (Bamforth, 1986; Binford, 1979; 1980; 1991; Parry and Kelly, 1987; Shott, 1989; 1996), it was proposed that curated objects fall within those patterns where the need to cope with unpredictable environmental conditions leads to an anticipated preparation and exploitation of raw materials. Objects were curated because there was no guarantee of always having the necessary raw materials available, in this way time was invested in advance (Ebert, 1979; 1986; Kelly, 1983; Torrence, 1983). Conversely, in favourable conditions, this anticipation may have been not necessary with no necessary time invested in advance. The concept of expediency indeed refers to a minimal technological effort in object production, reflecting favourable and highly predictable external conditions in terms of resource availability (Bleed, 1986; Shott, 1989; Torrence, 1983).

However, it is still not clear whether and how seasonal variations and resource predictability could have influenced stone tools production and functions, although some hypotheses on older periods have been advanced (Clark and Linares Matàs, 2023; Linares-Matàs and Clark, 2022).

Based on these results, the hypothesis is that in periods of mild variations between the cold and warm seasons, the prevalence of longer and thinner elongated blanks could be linked to predictable resource availability. In regions with relatively stable environmental conditions, we expect that animal resources would be available for the whole year. In such a scenario, hunter-gatherer groups would have the opportunity to rely on a stable toolkit to focus on activities such as hunting and fishing for the whole year, an activity that would require more homogeneous, longer, and thinner blades, and may be linked to logistic camps.

On the other hand, a preference for more variable, shorter, and thicker blades may be a response to an environment where resource availability is relatively unpredictable. In such environments, hunter-gatherer groups would be less specialized in their hunting or foraging strategies, and more versatile to cope with the unpredictable fluctuations in food resources (Binford, 1980; 1991; Bleed, 1986; Shott, 1989; Kuhn, 1989). Thicker blades can be used for a larger set of activities and may caracterise more residential sites. Human response to climatic changes and environmental conditions during the Pleistocene is reflected in their ability to adapt and live in different ecologies while habitats expand or shrink. The diversity in lithic production and the different outcomes of technical evolution within these groups likely result from a modification and/or adaptation of hunting, butchering, animal processing strategies, and other subsistence practices based on the surrounding environment. The results obtained through the comparative analysis of lithic assemblages and the integration of paleoclimatic data show a high correlation between the shape of the elongated blanks analysed and temperature seasonality.

This suggested relationship between technological and, consequently, cultural aspects and environmental factors can help in understanding and further exploring the concept of adaptation and change over time. Our results suggest a link between how objects were produced (and, so, possibly, their function) and changes in vegetation and wood cover within different environmental contexts during various periods of the Late Pleistocene and early Holocene.

Chapter 6 – General discussion

This thesis is the result of an analysis intended to address a specific question that developed during archaeological work at Mound 1 of the GOT-10 site. After realising that the site was chronologically placed within the MIS 3, I began to consider the behavioural dynamics that underlie the archaeological record at Gotera. The significant technological changes observed during MIS 3 in the Horn of Africa in general (as extensively discussed throughout the five chapters of this thesis) led to the exploration of this particular aspect of behaviour. Hence, I began to question whether this site is best considered MSA or LSA. While acknowledging the limitations of these monolithic nomenclatures (MSA or LSA) they can be useful definitions for the sake of clarity.

When I began this doctoral research, I had some limited memory of the lithic assemblages recovered during the 2018 excavation (before the COVID-19 pandemic). However, upon initial examination, the material was distinct from that previously collected from the surface of the Gotera area.

Returning to the genesis of this doctoral research, once the site's chronology was established, the question became more precise: to explore the behavioural dynamics of human groups during the MSA-LSA transition in the Horn of Africa through the lithic analysis of the assemblages.

As outlined in Chapter 1, building a solid model regarding this issue is exceptionally challenging not only due to the scarcity of archaeological evidence but also because some of the existing contexts were excavated in prior decades and without chrono-stratigraphic control, resulting in the mere acquisition of archaeological data without a robust temporal framework. This observation becomes more evident when considering the record at the sub-regional level, for example across only Ethiopia (Leplongeon et al. 2020), but even more clear at the macro-regional level, when contexts across a very large portion of the continent are considered (such as the whole of eastern Africa) (Tryon, 2019).

In Chapter 1, I provided a summary of the technological and behavioural characteristics of the MSA cultural complexes (from the earliest contexts to the more recent times), which highlighted that there is a consistent variability that challenges any easy definition of this long period of African prehistory. There are clearly some general features that we find in most contexts, but there are no clear boundaries (temporally or spatially), and this is also expected and understandable because:

1. we are talking about a very large area (an entire continent!).
2. the MSA covers a large chronological span (more than 250000 years!).

3. there is an overall low density of data available.
4. human behavioural dynamics (and likely their technological adaptations), may not have followed a specific pattern.

Beyond the difficulty of definition, in eastern Africa there are very few systematically dated MSA contexts (relative to the size of the region), that have been excavated using high-resolution techniques. At the same time, it is also clear that the an absence of a clear and comprehensive definition for the LSA at a broader scale in the analysis and interpretation of archaeological contexts. The fragmented nature, both spatially and temporally, of what is considered distinctive in the emergence of the LSA questioned not only the concept itself, but also the idea of a real transition from the MSA to the LSA during the Late Pleistocene. Therefore, it is crucial to acknowledge the widespread presence of often inadequate terminologies and, most importantly, to consider the possibility that the classification conducted by archaeologists may have potentially resulted in misunderstandings regarding past phenomena. Moreover, contexts featuring both MSA and LSA horizons within the same stratigraphic sequence that could allow the investigation of the nature and processes underpinning this technological shift, are extremely rare.

As explained in the introduction, to ensure a meaningful and objective comparative analysis, it was not possible to consider sites in both Ethiopia and, for example, in Tanzania, which are thousands of kilometres apart and have very different environmental characteristics. Therefore, the attempt at this macro-region comparative analysis seemed quite complex. However, at the same time, a comparative analysis of lithic assemblages in this area and on this scale has never been fully developed, at least from the point of view of quantitative analysis of lithic attributes (and not just on the presence/absence of tool types). Having defined this doctoral path and hypotheses, the technological analysis of the lithic industries collected at the GOT-10 site from 2018 to 2022 began in earnest. As described in Chapter 3, I personally analysed all the lithic industries, including those from the stratigraphic sequence of Mound 1, those found on the surface but directly associated with the dissolution of the archaeological levels of Mound 1 defined as Clusters, and those scattered on the surface, defined as Scatters.

Chapter 2 has highlighted the complex nature of the Gotera archaeological area, both from a geomorphological perspective (in part due to the intense erosion that affects the area) and in terms of reconstructing the temporal patterns of the area's occupation. In fact, this open-air context has a high density of occupation (considering the spatial area surveyed and across which archaeological materials were found), especially given the presence of a spatially restricted locality with a stratigraphic sequence that yielded more than 2000 lithic artefacts. This provides a chronological baseline (with an exceptional level of preservation

for an open-air site in arid savannah environment, including the presence of multiple hearths and animal bones) for the interpretation of Gotera occupation. Understanding the occupation dynamics of an open area can be much more challenging compared to the analysis of occupation dynamics in a closed context such as a cave or a rock shelter (this is without considering the mobility aspects of human groups and the catchment areas that may be much larger than the single cave context). Moreover, it is also crucial to understand these dynamics in relation to the broader topic of the MSA-LSA transition in the region since the chronology of GOT-10 (MIS 3) placed it in the time frame where this phenomenon started to be seen (Leplongeon et al. 2023).

This analysis required the development and implementation of a specific methodology that began with the analysis at a local scale (the GOT-10 site), and gradually expanded to include surface collections from the Gotera area, and ultimately to encompass a general comparative analysis at a macro-regional level, with the inclusion of other sites across the Horn of Africa. From this technological analysis, four operational schemes have been identified within the lithic assemblages: three that exploit both basalt and quartz (the main raw materials found at Gotera (Fusco et al. 2021) and one that exclusively uses quartz (see Chapter 3).

The first operational scheme falls within a planimetric concept of raw material exploitation, where both the Levallois (traditional and MSA) and the discoid methods emerge. The second operational scheme, on the other hand, falls within a concept of volume exploitation, in which laminar cores are represented (mainly *semi-tournant* for bladelet production, but also triangular blade cores for blades and bladelet production). The third, defined here as an intermediate scheme, combines both the first and second schemes and involves cores that are prepared and show a volumetric preparation surface (which is also exploited for bladelet production) and a planimetric striking surface (e.g. standard Levallois and discoid surface). The fourth scheme involved the use of the bipolar-on-anvil technique, and exclusively involved the exploitation of quartz. This technique, used at various stages of the operational chain for working small quartz pebbles, was also used alongside freehand methods (e.g. Levallois, laminar), demonstrating a certain complexity of the stone tool-makers groups at Gotera, and excellent management of raw materials such as quartz. Some recycled Levallois cores with traces of the bipolar technique are present within the assemblage, as are a few Levallois flakes with traces of bipolar, but also open pebbles with bipolar traces and then subsequently prepared to become Levallois cores are also well represented.

Based on the intra-site statistical analyses, the lithic assemblages of GOT-10 can be regarded as a single, homogeneous techno-complex, with statistically significant affinities established between the clusters, scatters, and the stratigraphic units of the Mound 1 (see Chapter 3: 3.5).

The GOT-10 site and specifically the stratigraphic deposit of Mound 1 provide a chronological anchor from which to further explore, at an inter-site level, the technological variability of lithic industries found on the surface, as well as those collected by Chavaillon during his fieldwork at Gotera, in order to identify potential reconnections with either the MSA and the LSA. Through comparative statistical analyses, it is clear that observed differences and similarities between the assemblages are a reflection of the behaviour human groups at Gotera and are essential for the reconstruction of the area's occupation dynamics during the Late Pleistocene (see Chapter 4).

The analysis of Chavaillon's lithic sample reveals interesting results. The predominant raw materials are local basalt and quartz. However, chert and phonolite are present in low proportions and seem to have been sourced from unknown locations.

Technologically, the analysis of cores indicates a variety of reduction methods, including both regular and irregular patterns. While regular cores show a prevalence of Levallois methods characterized by recurrent variants, irregular cores demonstrate variability in their shape and volume exploitation type, suggesting opportunistic exploitation to detach volumetric elongated blanks.

Flake analysis, being the most common technological item in Chavaillon's sample, reveals elements related to both initial raw material reduction and subsequent *debitage* stages. Many preparation flakes exhibit cortical surfaces, indicating the presence of initial flaking activities. Additionally, the presence of variously shaped flakes, including Levallois flakes and points, suggests the utilization of different flaking methods at Gotera, supported by the presence of volumetric flakes in the assemblage.

The analysis of GOT1-S surface collection yielded the following key results:

1. Post-depositional alterations are low, indicating a probably recent dispersion of relatively fresh lithics.
2. The predominant techniques used were direct percussion using hard and soft hammers.
3. Quartz cores were extensively prepared to produce flakes and blanks of predetermined size and shape, while basalt exploitation focused on the natural convexities of cobbles, even for Levallois and other *débitage* methods. Various strategies, including Levallois and non-Levallois methods, were employed for flake and blank production.
4. raw material economy and production were adapted to three main technological products: Levallois flakes, quartz and basalt blades, and quartz bladelet production.

The assemblage demonstrates the affinities with the MSA, particularly through the presence of Levallois and discoid reduction methods and the absence of backed pieces and bipolar-on-anvil technique.

The analysis also reveals differences in technological behaviour linked to local raw material exploitation. Quartz was used more for prepared products and cores, while basalt production involved more opportunistic exploitation of the raw material's natural convexities. The use of different raw materials sheds light on the management of environmental resources during the Pleistocene in the Gotera area.

The inter-site comparative analysis performed between the GOT-10 lithic assemblages, the GOT1-S surface collection, and Chavaillon's sample reveals significant differences in lithic assemblages recovered from the whole Gotera area. Both unretouched blanks (blades, bladelets, and flakes) and cores display noticeable variations in size and shape. The GOT-10 assemblage exhibits significantly smaller dimensions compared to surface collections from GOT1-S and Chavaillon's sample. Blades, bladelets (albeit in lower frequencies), and unretouched flakes at GOT-10 appear smaller, thinner, and more elongated.

Technological and statistical analyses demonstrate that the GOT-10 assemblage exhibits a focus more on producing small, elongated blanks compared to the other two assemblages. This is evident from the presence of cores with small detachments and the products struck from them, particularly bladelets, which are more abundant at GOT-10. Additionally, there is a homogeneity in the raw material selection at GOT-10, where both basalt and quartz were used for producing small elongated products. This evidence is in contrast to previous analyses performed on the GOT1-S surface assemblage (Fusco et al. 2021) as well as Chavaillon's analyses (Chavaillon and Chavaillon, 1985; Douze, 2011).

Overall, the assemblages at Gotera emphasize the production of elongated blanks, especially bladelets, with differences observed in production techniques and material selection between the three assemblages. The technological differences, particularly the size reduction at GOT-10, suggest potential shifts in lithic production trends, possibly associated with changes in human behaviour over time.

However, caution is needed in assigning precise chronologies to the samples, as only a portion of GOT-10 comes from a securely dated context. The differences identified through comparative analyses may offer insights into the occupation dynamics and behaviours of the area, suggesting a densely populated and spatially extensive occupation during the Pleistocene.

Further analysis, including geological and hydrological perspectives, could shed light on the seasonal dynamics of the Gotera basin and patterns of multiple occupations in response to environmental fluctuations. The phenomenon of artefact size reduction may indicate

miniaturisation associated with the emergence of an early LSA or changing technological trends at Gotera. However, these hypotheses require additional data to establish a longer chronological framework beyond the single dated deposit at GOT-10, given the results of the analysis of the Gotera three lithic assemblages.

It is important to remember, as previously emphasized, that the Gotera area represents a very extensive occupational context, which could be characterised by repeated, albeit short-lived, occupations over time (likely in connection with the fluctuations of the basin during the Pleistocene). While we have the chronological reference of GOT-10, it represents a spatially restricted location that must be placed within a larger territory that was certainly exploited on a broad spectrum.

The technological and statistical inter-site analysis of the Gotera area lithic assemblages demonstrates the presence of technological traits typical of the MSA in all three samples, as summarised in Figure 85. However, at the same time, there are also technological characteristics that are linked to the definition of the LSA, especially at GOT-10(where the LSA components are more evident). Comparison with other Late Pleistocene sites in the Horn of Africa shows that this period is indeed characterized by the beginning of technological change in the archaeological record, but it is also characterized by variability consisting of a set of features (discontinuous in space and time) that make the definition and identification of the MSA-LSA transition as well as the analysis of past human dynamics more complex. In this regard, doubts about the existence of a true transition are strengthened since there is neither a clear transition from one thing to another, nor the possibility of a clear terminological distinction of these assemblages. Thus, the Gotera area appears to be a relevant example.

Schematic MSA-LSA traits							
MSA	**Sites**			**LSA**	**Sites**		
	GOT-10	GOT1-S	GOT-CH		GOT-10	GOT1-S	GOT-CH
Levallois methods	✓	✓	✓	Bipolar on anvil	✓	✗	✓
Discoid methods	✓	✓	✓	Blades / Bladelets	✓	✓	✓
Retouched Points*	✗	✗	✗	Smaller artefacts	✓	✗	✗
				Backed pieces	✓	✗	✗
				Raw material selection	✓**	✗	✗
				Personal ornaments	✗	✗	✗

Figure 85: Scematic synthesis of the MSA and LSA traits present within the three assemblages. * Retouched points are absent from Gotera, while a small amount of point is present. In this context only retouched points have been indicated as schematic features of the MSA since this is an important trait used to distinguish the MSA from other cultural complexes. **The raw materials used in all the assemblages are always quartz and basalt. However, in GOT-10 a different management of quartz and basalt is seen, both oriented to the production of small (mostly elongated) products. This is absent in the other assemblages.

The data from the Gotera area thus represents an important improvement in the general knowledge of human occupation dynamics in the Horn of Africa region. This is especially the case regarding the data derived from the GOT-10 site, since it is the only open-air site with evidence of animal bones, and a lithic assemblage in association with fireplace, that has been systematically investigated and dated to the Late Pleistocene. The association of the surface materials with a single occupation is challenging, but comparison with other MSA sites and contexts could help to better explore the significance of this area and place it within the general pattern of the Pleistocene occupation in Ethiopia. I will now reprise the chronological division provided in Chapter 1: EMSA contexts (190-80 ka) and LMSA contexts (79-29 ka).

The main early MSA sites dated to MIS 6-5 (190-80 ka) in Ethiopia are Gademotta and Kulkuletti, Omo Kibish, Herto, and Aduma, while the most important late MSA sites dating to MIS 4-3 (70-29 ka) are Mochena Borago, Fincha Habera, and Goda Buticha. Porc Épic has been included in the LMSA list, however, recent OSL dating has revealed a different outcome.

Gademotta and Kulkuletti (GK), are characterized by the presence of uni-bifacial retouched points and a marked tradition of convergent tool production, mostly using obsidian (Douze, 2014; Douze and Delagnes 2016). However, while at both Gotera and GK sites the Levallois method for blank production is present, at Gotera points (and especially retouched examples) are extremely rare, with only one core-on-flake found at GOT-10 used for point production. At GK sites, convergent tool production is an important feature and three different technological changes in point retouching have been identified between 280 and 100 ka (Douze and Delagnes 2016). This is a marked difference given that the point presence is typical of the GK lithic assemblage, as well as the changes in its technology over time. The Omo Kibish lithic assemblage is dominated by Levallois centripetal cores and products, foliate bifaces, handaxes, picks, and lanceolates on chert, while retouched tools are rare (McDougall et al. 2005; Sisk and Shea, 2008). This is also the case for the Middle Awash Herto assemblages, where handaxes and picks are associated with the presence of centripetal Levallois cores and their products (Clark et al 2003; White et al 2003). While at Gotera the Levallois unipolar convergent method is strongly attested, there is a total absence of handaxes and picks, revealing strong differences with both Omo Kibish and Herto Bouri sites.

One of the Ethiopian late MSA sites dated to MIS 4-3 is the Mochena Borago rock shelter, whose occupation has been dated to early MIS 3 (~53 - 38 ka) (Brandt et al. 2012; 2017; 2023). The paleoenvironmental history of the site reveals that the human population experienced

several frequent changes in living conditions, triggered by local and regional changes in volcanism, hydrology, and climate. Tephra analysis attests to several periodic volcanic events that must have had dramatic consequences for human occupation of the area (Brandt et al. 2012).

The Mochena Borago lithic record consists mainly of obsidian artefacts, while the exploitation of other volcanic raw materials (basalt and rhyolite) is rare. Lithic analysis has suggested that the earliest occupants of the shelter were maintaining a distinctive lithic industry. They used direct percussion to produce elongated flakes from small tabular-shaped and minimally prepared single to multi-platform (SDM) obsidian cores. Radial cores were present but rarely registered. Prismatic pyramidal blade cores are absent from undisturbed context, suggesting that blade and bladelets were produced using SDM cores. Unifacial and bifacial points dominate the shaped tools. The presence of radial technology with the occurrence of shaped and retouched points, led the researchers to include the industry within the MSA of eastern Africa. Industries with small, backed pieces, usually defined as Later Stone Age (LSA) first appeared at Mochena Borago in assemblages showing strong technological continuity with earlier layers, with no evident changes as seen in the MSA-LSA transition seen at other African sites (Brandt et al 2017). Moreover, in the late Pleistocene layers, the bipolar technique is also attested (Brandt et al. 2017).

Comparison between the Mochena Borago rock shelter and Gotera lithic assemblages reveals clear differences. The latter is characterized by the frequent use of prepared cores and a lack of backed pieces, which are frequently found in the LSA. They are similar in the presence of bladelets and laminar technology. The Goda Buticha MSA assemblage is characterized by typical MSA elements including an emphasis on flake production, the presence of Levallois reduction methods, and a dominance of uni- and bifacial points in the formal tool category. Microliths are absent, while there is a high frequency of elongated blanks (Leplongeon, 2014; Leplongeon et al. 2017; Pleurdeau et al 2014).

Fincha Habera, located in the Ethiopian Bale mountains, is characterized by features typical of MSA lithic assemblages, such as the use of Levallois methods, unifacial points, blades, and bladelets, mostly on obsidian and chert. There is evidence of a unipolar exploitation of cores with two opposite platforms as well as the bipolar technique on anvil (Ossendorf et al. 2019).

Porc Épic lithic assemblages come from different layers. They appear to be homogeneous, and the production of blades and flakes is evident throughout the sequence. The production of points is not well represented but there is a wide variety of retouched points. The MSA levels are dated to ~77-60 ka, but the chronology at this site is complicated and not well understood, and they may be much older (Leplongeon et al. 2020; 2022; Tribolo et al. 2022).

The lithic assemblage is composed of Levallois cores and a series of retouched triangular flakes and foliate points. Moreover, burins are frequent within the assemblage, heavy bifacial cutting tools are very rare, and large triangular Levallois flakes appear to have been used as blanks to produce foliate points (Clark et al. 1984; Leplongeon, 2014; Pleurdeau, 2005). Moreover, the assemblage is characterized by four reduction schemes, and this data exhibits similarities with the GOT-10 assemblage. However, the GOT-10 assemblage is oriented mostly toward the production of small and elongated products, with almost no evidence of points (retouched and non-retouched). Moreover, at Porc Épic there is no evidence for the use of bipolar-on-anvil technique, and the most exploited reduction scheme is the planimetric approach, while GOT-10 it seems show the opposite, with a predominance of volumetric and intermediate methods (in order to produce small, elongated blanks).

From the point of view of lithic technology, there are clear differences between Gotera and the EMSA sites such as Gademotta and Kulkuletti, Omo Kibish, and Aduma. A clear difference is seen in the absence of retouched points at Gotera, especially a strong tradition of synchronic point production in several different ways as is seen at Gademotta. The absence of Acheulean elements such as LCT or biface components makes clear the difference between Gotera and older MSA sites.

LMSA sites such as Porc Épic, Fincha Habera, Mochena Borago, and Goda Buticha share some more similarities with the Gotera lithic assemblage. However, the absence of retouched points, as well as the predominance of denticulates at Gotera, indicates a more local identity for the Gotera assemblage, where the flake and elongated blank-oriented production of artefacts was a specific adaptation of the human population who exploited the area during the Pleistocene.

Additionally, the Gotera area is characterized by a homogeneity in raw material exploitation, with exotic raw material circulation almost absent in the area, and an exclusive preference for the local basalt and quartz. Obsidian, which is present at almost all Ethiopian sites, is absent at Gotera, while quartz and basalt are the preferred choices. Quartz is exploited at Goda Buticha and Porc Épic in low frequencies, while at Fincha Habera, scarce evidence of quartz, since it is a non-local raw material, seems to reflect people's movements towards highlands during arid periods (Ossendorf et al. 2019).

Iit is true, on the one hand, that across the Horn of Africa during the Late Pleistocene, lithic sites and industries exhibited a strong technological variability (Leplongeon et al. 2020; 2023), which is evident in the list of archaeological evidence provided here and in the first chapter. Gotera indeed fits into this pattern, with the presence of various reduction schemes and the exploitation of local raw materials generating a strong technological variability. Moreover, it is even more clear that despite the inter-site differences seen across the Gotera

area, excluding the dated deposit of Mound 1, it is impossible to establish a chronological succession of the assemblages found in the area (and consequently if there are any specific technological characteristics related to different chronologies).

However, it is also clear that some features that characterise the LSA are evident at GOT-10, such as artefact size reduction, the presence of bipolar-on-anvil technique, and the near absence of retouched and non-retouched points. Despite the difficulty in defining the transition, the assemblage from the GOT-10 site seems to have more affinities with the LSA than with the MSA, placing it probably within the variability of an early LSA tradition. Additionally, we have also seen how some MSA traits persist even into the Holocene (Leplongeon et al. 2017), thus it is not difficult to believe the use of the Levallois and discoid method within a context that shows technical characteristics going toward a different techno-complex. However, to better explore this debate, it is necessary to resume the comparative analysis at a regional level.

As seen in Chapter 5, the comparative statistical analysis between the blade and bladelets from Gotera and those from Goda Buticha, Porc Épic, Deka Wede4, and Enkapune ya Muto reveal a clear trend towards a reduction in the size of elongated blanks, with no evidence of any return to the production of larger pieces. We have seen that the debate surrounding the decrease in blank, core, and tool dimensions in Late Pleistocene lithic assemblages, associated with specific cultural preferences, is extensively discussed in the literature (Leplongeon et al. 2023; Pargeter and Shea 2019; Shipton 2023). This is because small-sized artefacts have been found in earlier archaeological contexts as well, challenging previous definitions for them to be attributed specifically to the MSA-LSA transition (Elston and Kuhn, 2002; Pargeter, 2016; Pargeter and Shea 2019).

In eastern Africa, small-sized elements are present in various contexts and times, such as at Omo Kibish, Herto/Aduma, and Panga ya Saidi. South Africa also revealed evidence of small flakes and blades as early as the MSA, which are sometimes associated with the Howiesons Poort industry (Pargeter and Shea 2019; Porraz et al. 2013; Soriano et al. 2007; Wurz 2013). Therefore, small-sized lithics are present in both Pleistocene and Holocene African records, albeit in varying proportions across regions and periods, and may be tied to different technical features and cultural complexes (Pargeter and Shea 2019; Spinapolice, 2020).

The reduction in lithic size may be influenced by factors such as raw material selection. Certain raw materials, like quartz, are easier to manipulate into smaller artefacts (Pargeter and Shea 2019). In eastern Africa, Late Pleistocene and early Holocene lithic industries show changes in raw material exploitation (Shipton et al. 2018; 2021). However, the general trend

towards the selection of fine-grained raw materials needs further investigation across broader geographical and chronological scales.

Various hypotheses have been proposed to explain changes in artefact sizes, including symbolic and economic factors (Shipton 2023; Hiscock et al. 2011). Additionally, ecological, and environmental factors, such as climatic fluctuations, may have influenced lithic miniaturization (Ambrose 2002; Pargeter and Shea, 2019).

The results provided in this doctoral dissertation, especially those integrating paleoclimate data and archaeological material, show that the shape of blades and bladelets is statistically highly correlated with annual temperature range. This bioclimatic variable is strictly linked to seasonality since it explains the difference between the maximum temperature in wet and dry seasons. The correlation between the shape of blades and bladelets and annual temperature range probably implies adaptive strategies in response to varying levels of seasonality. It is widely acknowledged that the predictability of resources (a consequence of more stable environments) has influenced the behavioural dynamics of hunter-gatherers concerning subsistence, settlement, and mobility strategies (Grove, 2009; Jones, 2013). During periods of mild fluctuations between cold and warm seasons, the prevalence of longer and thinner elongated blanks could be associated with predictable resource availability. In regions with relatively stable environmental conditions, animal resources would be expected to be accessible throughout the year. In such circumstances, hunter-gatherer groups would likely rely on a consistent toolkit to engage in activities such as hunting and fishing year-round; activities that may necessitate more uniform, longer, and thinner blades, potentially connected to logistical camps.

Conversely, a preference for more variable, shorter, and thicker blades may arise in response to environments where resource availability is relatively unpredictable. In such settings, hunter-gatherer groups might adopt less specialized hunting or foraging strategies and instead demonstrate greater versatility to manage erratic fluctuations in food resources (Binford, 1980; 1991; Bleed, 1986; Shott, 1989; Kuhn, 1989). Thicker blades can serve a broader range of functions and are characteristic of more permanent residential sites. Human responses to climatic changes and environmental conditions during the Pleistocene are reflected in their capacity to adapt and inhabit diverse ecologies as habitats expand or contract. The diversity in lithic production and the various outcomes of technical evolution within these groups likely stem from adjustments and/or adaptations in hunting, butchering, animal processing strategies, and other subsistence practices based on the surrounding environment. The results derived from the comparative analysis of lithic assemblages and the incorporation of paleoclimatic data reveal a significant correlation between the shape of the elongated blanks examined and temperature seasonality.

It is likely that the environment played a key role in shaping some lithic aspects that are the expression of past human behaviours. However, it is still challenging to construct robust behavioural models, because these hypotheses need to be tested using well-structured archaeological data.

6.1 Future perspectives

At a local level, there is still much work to be done in the Gotera area. While the technological characteristics of the lithic assemblages of the GOT-10 site have been defined, the duration of occupation has not yet been determined. It is likely to represent multiple occupations over time, but this hypothesis still lacks a firm chronological framework.
Additionally, it is still necessary to analyse the spatial pattern of the archaeological record at a site- specific level (both the Mound 1 deposit and the cluster and scatter materials from the whole GOT-10 site) in order to detect possible differences in the site function, as well as the relationship between the lithics, the animal bones and the fireplaces (through also the refits analysis of both lithics and bones).
Furthermore, although the high-resolution investigation of the GOT-10 site allow for the analysis of specific elements such as site seasonality, the lack of other stratigraphic deposits in the area still challenges the development of a comprehensive model that can reconstruct the occupation dynamics of an entire open-air area. Moreover, the mobility pattern of these groups is still not clear. Ninety percent of the lithic artefacts at Gotera are made of the local raw materials basalt and quartz. However, the evidence of the exploitation of non-local raw material, even if scant, shows a more complex mobility pattern that needs to be explored further.
Current analysis of GOT-10 archaeological record such as faunal remains, stable isotopes (undertaken by Seminew Asrat, PhD student at Sapienza University of Rome), pollen (undertaken by Prof. Donatella Magri and Dr. Juan Ochando Tomàs, Sapienza University of Rome), geology, micromorphology, refits on lithics in order to further explore the correlation between surface and stratigraphic materials, but also spatial analyses to understand landscape patterns promise further high-resolution data for the reconstruction of the area's occupation dynamics.
In addition to these aspects, samples for lithic residue and use-wear analyses have been collected from the GOT-10 lithic assemblage and are currently being processed by Prof. Cristina Lemorini at Sapienza University of Rome. Indeed, understanding how these tools were used during the Pleistocene occupation is crucial, as it provides direct insights into the

hunter-gatherer activity patterns, how these stone objects were used, and how/if their function changed over time and space. This is one of the most urgently needed pieces of information at many Palaeolithic archaeological contexts across Africa. These analyses are still underestimated, especially in African prehistory, where we observe a higher frequency of surface lithic assemblages compared to archaeological materials preserved in stratigraphic deposits, complex deposition due to erosion activities or post-depositional events, which can make it extremely challenging to reading of the stratigraphic record.

As already mentioned in Chapter 1, there is still very limited evidence available for stone tool use, especially compared to data on lithic technological aspects.

This problem is also clear from the results of the regional comparative analysis. In fact, the correlation of elongation and flattening indexes with the annual temperature range suggests that there is a connection with the environment. However, it is still not possible to provide a secure explanation for this, since the types of tool use activities are not known. The technological and functional change in these objects were likely interrelated. Therefore, there is a serious need to explore the functional aspects of lithic objects produced during prehistory. It is crucial to investigate why lithic tools were produced in specific ways and also their intended purposes, especially considering the relationship between technological aspects and the surrounding environment, as demonstrated here by the regional comparative analysis.

However, while the current available data are still poor to provide a model for human occupation that explore all the possible explanations behind cultural changes during the MIS4-2, it is notable that this thesis provide additional data to the debate. It is evident in fact that the analysis of the lithic assemblages shows a blurry pattern between what is classified as MSA and what is LSA. This led to questioning the definition and the existence of the MSA-LSA transition. In this context, while the analysis of technology shows this pattern, in addition with the integration of the paleoclimate reconstructions that demonstrates how the seasonal variations are correlated with blade and bladelets shape through the MIS 4 and 2 in the region, we lack the information from other aspect and the integration of other data such as spatial pattern, lithic refits, functional analyses on lithics etc.

The functional aspects of lithics may be relevant to exploring several research issues, such as the nature of cultural transitions (or changes), and also adaptative dynamics.

Analysing functional aspects in addition to technological features of lithic assemblages could provide direct information regarding the lifeways of hunter-gatherers at the end of the Pleistocene. It would therefore be complementary to the study of lithic technology (i.e., how a tool is made, and how the way of producing tools changed over time and space) with that of the functional aspects (i.e., what it is a tool used for and how the function changes

over space and time). These are two aspects of the analysis of human behaviour that must go hand in hand; only in this way will we have the opportunity to develop more solid models regarding how these human groups lived during prehistory.

Furthermore, by harnessing functional approaches it is possible to understand whether a tool was hafted or not. Backed pieces, for example, have been generally interpreted as hafted implements linked to composite tool technologies, and their production is associated with the development of prehistoric weapon systems. However, hafting is a highly debated issue, especially regarding the MSA-LSA transition (but also for the definition of the MSA itself, which can also be characterized by a shift to hafted tools (McBrearty and Tryon 2006; McBrearty and Brooks, 2000) and additionally unbacked artefacts were also hafted and used as projectiles as early as ~500 ka in South Africa and ~279 ka in the Horn of Africa (e.g. Sahle et al. 2013; Wilkins et al. 2012). Moreover, it has been shown that backed pieces could have been also used in activities other than hunting (e.g., as multifunctional tools and as sickles, both in Africa and the Near East, (Honegger, 2009; Hilbert et al. 2023). Moreover, the increase in the presence of backed pieces is considered characteristic of the emergence of the LSA. Nevertheless, studies on the technology of backed pieces during the LSA have revealed a great variability among those pieces. However, very few studies, almost all of them related to South African contexts, have attempted use-wear analyses on these tools.

What emerges is that studies are needed that couple technological and functional analyses on the backed pieces in order to understand whether changes in technology are linked to changes in their use. Therefore, it is extremely useful to explore the transition from the functional point of view, and to have an insight into the specific pattern of activities among past human groups. Changes in lifeways and activities have always been influenced by the environment, as is likely shown here in the regional comparative analysis with climatic variables. However, information about how environmental instability or changes have influenced humans is still not clear. Therefore, it important to look at these behavioural issues by integrating data from multiple different sources of information.

The results provided here show that there is a growing need for continuous comparative analyses of lithic attributes and data integration, to expand these data sets. This need is evident not only from this research but also from other contexts where more complex cultural patterns have been highlighted (e.g. Scerri et al. 2014). There is a need also for a large-scale framework that encompasses more extensive human behavioural dynamics across various spatial and temporal dimensions. More contexts are needed in order to build a solid narrative of past human behaviours, but also more caution is required in the selection of samples and in the way archaeological data are manipulated and interpreted. We still need to be cautious with the combination and use of archaeological data for large

comparative analyses, especially when manipulating data on lithic technologies. There is a need for a very deep understanding of these materials, the way they have been produced, and the implications of technologies for the reconstruction of past human behaviour.
Additionally, this analysis highlights an increasing need to standardise data collection for lithic industries and to establish a list of mandatory attributes to record for each assemblage and for all the object categories. It is desirable in fact to proceed with a comparison of all the lithic categories (cores, flakes, etc.) present within an assemblage. This standardisation may facilitate the comparison not only for morphometric attributes but also technological traits, including reduction methods, techniques, etc.

6.2 Conclusion

In conclusion, results from the analysis of lithic assemblages from the Gotera area, particularly the GOT-10 site, present an intriguing mix of MSA and LSA technological traits, suggesting a dynamic cultural landscape. The comparative analysis of the Gotera area with surface assemblages defined as MSA by previous analyses (Fusco et al. 2021 and Chavaillon and Chavaillon, 1985) confirmed indeed that there are significant differences between the technological aspects of the assemblages and this can be linked to the hypothesis that the area was characterised by multiple occupations over the time.
Further exploration of the entire area may provide additional insights into this hypothesis, offering a more comprehensive understanding of its archaeological significance. Moreover, the presence of mixed MSA and LSA traits in the Gotera area challenges conventional notions of an MSA-LSA transition, shedding light on the technological variability of Late Pleistocene lithic assemblages and questioning the value of the MSA and LSA labels in itself.
Additionally, the results of the comparative analysis of the sites from the region shed light on the role of the environment in shaping past human group behaviors, enriching our understanding of prehistoric dynamics in the Horn of Africa during the Late Pleistocene.
In conclusion, this doctoral thesis represents a significant contribution to our understanding of prehistoric dynamics in the Horn of Africa during the Late Pleistocene and it represents a crucial step towards unraveling the complexities of prehistoric human activities in the region and underscores the importance of continued interdisciplinary investigations in archaeological research.
Despite the challenges and limitations described in the availability of data, this thesis underscores the importance of systematically analysing lithic attributes for a quantitative understanding of past human behaviours. The exploration of lithic technology at the GOT-

10 site and comparative analyses with other sites in the region has revealed both similarities and differences, and provided insights into regional dynamics during MIS 4-2.

The applied research methodology, ranging from site-specific investigation to broader comparative analyses, has allowed for a comprehensive examination of lithic assemblages and their contextual significance. By establishing a chronological baseline and exploring inter-site technological variability, this thesis contributes to our understanding of occupation dynamics and behavioural adaptations in the region.

Furthermore, the results obtained by the comparative regional analysis highlight the importance of integrating different data to combining a broader model for past human behaviours. In order to find more complete answers, it would be ideal to integrate functional analyses of lithic artefacts to gain insights into past human activities. But not only that.

It will be necessary to combine different data (e.g. zooarchaeology, micromorphology, pollen analysis, isotopes, etc.) using different approaches (quantitative analyses, proteomics, ancient DNA, fieldwork) to explore past human behaviour at a broader scale.

Looking ahead, future research in lithic studies should prioritize establishing comprehensive chronological frameworks, investigating mobility patterns, conducting functional analyses, integrating different data, and standardising data collection procedures. By addressing these key areas, researchers can continue to unravel the complexities of prehistoric human societies and their interactions and adaptative dynamics in relation to the environment.

Although explanations for the MSA-LSA transition are still challenging to unravel, especially due to several weaknesses in available data, it is likely that environmental factors were critically influential and acted as drivers for the observed changes. It is essential to remain persistent in testing these hypotheses through quantitative analysis and data integration.

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Appendices

Appendix 1 - Chapter 3

1.1 Artefact condition analysis at GOT-10

Supplementary Table 1

	Mound 1											
	Fresh/unworn		**Highly-worn**		**Slightly-worn**		**Uncertain**		**Worn**		**Total**	
SU	N	%	N	%	N	%	N	%	N	%	N	%
SU10	9	2%	0	0%	0	0%	0	0%	0	0%	9	2%
SU11	48	8%	0	0%	2	12%	0	0%	0	0%	50	8%
SU12	34	6%	0	0%	2	12%	0	0%	1	33%	37	6%
SU18	1	0%	0	0%	0	0%	0	0%	0	0%	1	1%
SU19	6	1%	0	0%	1	6%	0	0%	0	0%	7	1%
SU2	2	0%	0	0%	0	0%	0	0%	0	0%	2	1%
SU4	38	7%	0	0%	1	6%	0	0%	1	33%	40	7%
SU6	224	39%	0	0%	7	41%	2	100%	1	33%	234	38%
SU7	50	9%	0	0%	1	6%	0	0%	0	0%	51	9%
SU8	1	0%	1	100%	0	0%	0	0%	0	0%	2	1%
SU9	60	10%	0	0%	2	12%	0	0%	0	0%	62	10%
SUY	20	3%	0	0%	0	0%	0	0%	0	0%	20	3%
SUZ	84	15%	0	0%	1	6%	0	0%	0	0%	85	13%
Total	**577**	**96%**	**1**	**0%**	**17**	**3%**	**2**	**0%**	**3**	**1%**	**600**	**100%**

Table 65: alteration distribution within lithic assemblage from Mound 1

Supplementary table 2

	Fresh/Unworn		Highly-Worn		Slightly-Worn		Uncertain		Worn		Total	
Context	N	%	N	%	N	%	N	%	N	%	N	%
Mound1	585	96%	1	0%	17	3%	2	0%	3	0%	608	36%
Cluster A	186	97%	0	0%	2	1%	1	1%	2	1%	191	10%
Cluster H	235	99%	0	0%	3	1%	0	0%	0	0%	237	12%
Cluster L	68	97%	0	0%	0	0%	1	1%	1	1%	70	4%
Cluster M	44	98%	0	0%	0	0%	1	2%	0	0%	45	2%
Scatter 4	25	96%	0	0%	0	0%	1	4%	0	0%	26	1%
Scatter1	110	99%	0	0%	1	1%	0	0%	0	0%	111	6%
Scatter2	110	98%	0	0%	2	2%	0	0%	0	0%	112	6%
Scatter3	506	95%	0	0%	17	3%	4	1%	3	1%	530	32%
Surface	8	73%	0	0%	2	18%	0	0%	1	9%	11	1%
Total	**1877**	**97%**	**1**	**0%**	**44**	**2%**	**10**	**1%**	**10**	**1%**	**1942**	**100%**

Table 66: Alteration distribution within lithic assemblage from the GOT-10 site.

Supplementary table 3

	Mound 1											
	Fresh		Slightly-Patinated		Patinated		Heavly-Patinated		Uncertain		Total	
SU	N	%	N	%	N	%	N	%	N	%	N	%
SU10	1	1%	8	2%	0	0%	0	0%	0	0%	9	2%
SU11	16	17%	31	7%	3	4%	0	0%	0	0%	50	8%
SU12	3	3%	25	6%	8	12%	0	0%	1	33%	37	6%
SU18	0	0%	1	0%	0	0%	0	0%	0	0%	1	1%
SU19	0	0%	5	1%	2	3%	0	0%	0	0%	7	1%
SU2	0	0%	2	0%	0	0%	0	0%	0	0%	2	0%
SU4	8	9%	27	6%	5	7%	0	0%	0	0%	40	7%
SU6	15	16%	185	44%	27	39%	6	43%	1	33%	234	38%
SU7	0	0%	28	7%	16	23%	7	50%	0	0%	51	9%
SU8	0	0%	0	0%	1	1%	1	7%	0	0%	2	1%
SU9	16	17%	43	10%	2	3%	0	0%	1	33%	62	10%
SUY	7	8%	13	0%	0	0%	0	0%	0	0%	20	3%
SUZ	26	28%	54	13%	5	7%	0	0%	0	0%	85	14%
Total	**92**	**15%**	**422**	**70%**	**69**	**12%**	**14**	**2%**	**3**	**1%**	**600**	**100%**

Table 67: Patina distribution within lithic assemblage from Mound 1

Supplementary table 4

	Fresh		Slightly-patinated		Patinated		Heavily-patinated		Uncertain		Total	
Context	N	%	N	%	N	%	N	%	N	%	N	%
Cluster A	37	7%	142	12%	11	6%	0	0%	1	6%	191	10%
Cluster H	72	14%	148	12%	17	10%	0	0%	1	6%	238	12%
Cluster L	30	6%	36	3%	1	1%	0	0%	3	17%	70	4%
Cluster M	21	4%	21	2%	3	2%	0	0%	0	0%	45	2%
Mound 1	95	18%	424	35%	71	41%	15	63%	3	17%	608	31%
Scatter 4	10	2%	14	1%	2	1%	0	0%	0	0%	26	1%
Scatter1	49	9%	53	4%	8	5%	1	4%	0	0%	111	6%
Scatter2	28	5%	66	5%	15	9%	2	8%	1	6%	112	6%
Scatter3	179	34%	293	24%	43	25%	6	25%	9	50%	530	27%
Surface	5	1%	5	0%	1	1%	0	0%	0	0%	11	1%
Total	**526**	**27%**	**1203**	**62%**	**172**	**9%**	**24**	**1%**	**18**	**1%**	**1942**	**100%**

Table 68: Alteration distribution within lithic assemblage from the GOT-10 site

Supplementary table 5

Mound 1										
	Not-burned		Partially		Totally		Calcinated		Total	
SU	N	%	N	%	N	%	N	%	N	%
SU10	9	2%	0	0%	0	0%	0	0%	9	2%
SU11	49	9%	0	0%	1	10%	0	0%	50	8%
SU12	33	6%	4	11%	0	0%	0	0%	37	6%
SU18	1	0%	0	0%	0	0%	0	0%	1	1%
SU19	6	1%	0	0%	1	10%	0	0%	7	1%
SU2	2	0%	0	0%	0	0%	0	0%	2	0%
SU4	36	6%	3	9%	1	10%	0	0%	40	7%
SU6	211	38%	18	51%	4	40%	1	100%	234	38%
SU7	48	9%	3	9%	0	0%	0	0%	51	9%
SU8	2	0%	0	0%	0	0%	0	0%	2	1%
SU9	59	11%	2	6%	1	10%	0	0%	62	10%
SUY	18	3%	1	3%	1	10%	0	0%	20	3%
SUZ	80	14%	4	11%	1	10%	0	0%	85	14%
Total	**554**	**92%**	**35**	**6%**	**10**	**2%**	**1**	**0%**	**600**	**100%**

Table 69: Burning alteration distribution within lithic assemblage from Mound 1

Supplementary table 6

	Cluster A		**Cluster H**		**Cluster M**		**Mound1**		**Scatter1**		**Scatter2**		**Scatter3**		**Scatter 4**		**Total**	
Cores	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Regular	**1**	**100%**	**1**	**50%**	0	0%	**4**	**25%**	**3**	**60%**	**5**	**63%**	**4**	**40%**	**1**	**100%**	**19**	**43%**
Blade	0	0%	0	0%	0	0%	1	6%	2	0%	1	13%	0	0%	0	0%	2	5%
Discoid	1	**100%**	1	50%	0	0%	1	6%	0	0%	1	13%	2	20%	1	100%	7	16%
Levallois	0	0%	0	0%	0	0%	2	13%	1	20%	3	38%	2	20%	0	0%	8	18%
Irregular	0	0%	**1**	**50%**	**1**	100%	**12**	**75%**	**2**	**40%**	**3**	**38%**	**6**	**60%**	0	0%	**25**	**57%**
Core on flakes	0	0%	0	0%	0	0%	6	38%	0	0%	2	25%	3	30%	0	0%	11	25%
Polyedral	0	0%	1	50%	1	100%	5	31%	2	40%	1	13%	2	20%	0	0%	12	27%
Triangular	0	0%	0	0%	0	0%	0	0%	0	40%	0	0%	1	10%	0	0%	1	2%
Uncertain	0	0%	0	0%	0	0%	**1**	**6%**	0	0%	0	0%	0	0%	0	0%	**1**	**2%**
Total	**1**	**2%**	**2**	**5%**	**1**	**2%**	**16**	**36%**	**5**	**11%**	**8**	**18%**	**10**	**23%**	**1**	**100%**	**44**	**100%**

Table 70: Core type distribution within the GOT-10 site.

Supplementary table 7

Preparation stage																				
	Cluster A		**Cluster H**		**Cluster L**		**Cluster M**		**Mound1**		**Scatter1**		**Scatter2**		**Scatter3**		**Scatter4**		**Total**	
Flake type	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Cortical bl/blt	0	0%	4	5%	0	0%	0	0%	6	4%	2	5%	3	9%	8	4%	0	0%	23	4%
Cortical flake	2	6%	2	2%	0	0%	2	12%	6	4%	4	9%	7	21%	5	3%	0	0%	28	5%
Debordant bl/blt	9	26%	12	15%	5	28%	5	29%	23	15%	3	7%	4	12%	25	14%	0	0%	86	15%
Debordant flake	11	32%	31	38%	4	22%	4	24%	57	36%	18	42%	14	41%	74	41%	2	67%	215	38%
LSPP	1	3%	1	1%	0	0%	0	0%	2	1%	0	0%	0	0%	9	5%	0	0%	13	2%
SPP	2	6%	5	6%	3	17%	2	12%	18	11%	10	23%	2	6%	33	18%	0	0%	75	13%
Pseudolev point	1	3%	15	18%	3	17%	0	0%	7	4%	2	5%	0	0%	8	4%	0	0%	36	6%
Crest bl/blt	7	21%	8	10%	2	11%	4	24%	24	15%	3	7%	2	6%	20	11%	1	34%	71	12%
Cordal flake	1	3%	4	5%	1	6%	0	0%	14	9%	1	2%	2	6%	0	0%	0	0%	23	4%
Total	**34**	**6%**	**82**	**14%**	**18**	**3%**	**17**	**3%**	**157**	**28%**	**43**	**8%**	**34**	**0,06**	**182**	**32%**	**3**	**1%**	**570**	**100%**

Table 71: Preparation stage product distribution within the GOT-10 site. Legend: LSPP (Levallois striking platform preparation flake); SPP (Striking platform preparation flake).

Supplementary table 8

Production stage																				
	Cluster A		**Cluster H**		**Cluster L**		**Cluster M**		**Mound1**		**Scatter1**		**Scatter2**		**Scatter3**		**Scatter4**		**Total**	
Flake type	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Ordinary flake	11	46%	13	48%	4	29%	4	50%	93	58%	3	15%	15	47%	45	43%	2	33%	190	48%
Ordinary blade	2	8%	0	0%	0	0%	1	13%	3	2%	3	15%	1	3%	2	2%	1	17%	13	3%
Ordinary bladelet	1	4%	1	4%	1	7%	0	0%	21	13%	3	15%	1	3%	5	5%	0	0%	33	8%
Ordinary flake w/ cortex	0	0%	0	0%	1	7%	0	0%	1	1%	1	5%	1	3%	7	7%	0	0%	11	3%
Ordinary blade w/cortex	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%	0	0%	0	0%	1	0%
Levallois point	3	13%	2	7%	2	14%	0	0%	7	4%	3	15%	1	3%	6	6%	0	0%	24	6%
Levallois preferential	0	0%	0	0%	1	7%	0	0%	1	1%	0	0%	0	0%	0	0%	0	0%	2	1%
Unipolar Lev recurrent	1	4%	0	0%	0	0%	0	0%	4	3%	1	5%	1	3%	14	13%	0	0%	21	5%
Bipolar Lev recurrent	1	4%	0	0%	0	0%	0	0%	0	0%	1	5%	0	0%	1	1%	1	17%	4	1%
Centripetal Levallois	0	0%	0	0%	0	0%	0	0%	10	6%	2	10%	0	0%	7	7%	0	0%	19	5%
Volumetric point	3	13%	0	0%	1	7%	0	0%	4	3%	1	5%	2	6%	7	7%	0	0%	18	5%
Point	2	8%	5	19%	1	7%	2	25%	11	7%	0	0%	0	0%	0	0%	1	17%	22	6%
Centripetal flake	0	0%	6	22%	2	14%	0	0%	5	3%	0	0%	7	22%	6	6%	1	17%	27	7%
Unipolar flake	0	0%	0	0%	1	7%	1	13%	0	0%	2	10%	2	6%	5	5%	0	0%	11	3%
Total	**24**	**6%**	**27**	**7%**	**14**	**4%**	**8**	**2%**	**160**	**40%**	**20**	**5%**	**32**	**8%**	**105**	**26%**	**6**	**2%**	**396**	**100%**

Table 72: Production stage product distribution within the GOT-10 site.

1.4 Technique at GOT-10

Supplementary table 9

Platform Analysis of GOT-10																		
	Abraded		**Cortical**		**Dihedral**		**Facetted**		**Linear**		**Plain**		**Punctiform**		**Uncertain**		**Total**	
Contexts	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Not-Ret	**1**	**100%**	**21**	**95%**	**156**	**95%**	**61**	**97%**	**12**	**100%**	**810**	**96%**	**14**	**93%**	**87**	**95%**	**1162**	**96%**
Basalt	**0**	**0%**	**10**	**45%**	**50**	**30%**	**15**	**24%**	**3**	**25%**	**332**	**39%**	**3**	**20%**	**19**	**21%**	**432**	**36%**
Cluster A	0	0%	0	0%	2	1%	2	3%	0	0%	21	2%	0	0%	0	0%	25	2%
Cluster H	0	0%	3	14%	7	4%	1	2%	0	0%	44	5%	0	0%	1	1%	56	5%
Cluster L	0	0%	0	0%	0	0%	1	2%	0	0%	8	1%	0	0%	0	0%	9	1%
Cluster M	0	0%	0	0%	1	1%	0	0%	1	8%	17	2%	0	0%	0	0%	19	2%
Mound 1	0	0%	2	9%	22	13%	4	6%	0	0%	110	13%	2	13%	11	12%	151	12%
Scatter 4	0	0%	0	0%	0	0%	0	0%	0	0%	3	0%	0	0%	0	0%	3	0%
Scatter1	0	0%	1	5%	0	0%	0	0%	0	0%	21	2%	0	0%	0	0%	22	2%
Scatter2	0	0%	0	0%	4	2%	3	5%	0	0%	22	3%	0	0%	0	0%	29	2%
Scatter3	0	0%	4	18%	14	9%	4	6%	2	17%	86	10%	1	7%	7	8%	118	10%
Chert	**0**	**0%**	**1**	**5%**	**6**	**4%**	**2**	**3%**	**0**	**0%**	**14**	**2%**	**0**	**0%**	**0**	**0%**	**23**	**2%**
Cluster A	0	0%	0	0%	0	0%	0	0%	0	0%	4	0%	0	0%	0	0%	4	0%
Cluster H	0	0%	1	5%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	2	0%
Cluster L	0	0%	0	0%	1	1%	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%
Mound1	0	0%	0	0%	2	1%	0	0%	0	0%	2	0%	0	0%	0	0%	4	0%
Scatter2	0	0%	0	0%	0	0%	1	2%	0	0%	0	0%	0	0%	0	0%	1	0%
Scatter3	0	0%	0	0%	3	2%	1	2%	0	0%	7	1%	0	0%	0	0%	11	1%
Obsidian	0	0%	0	0%	0	0%	0	0%	0	0%	**1**	**0%**	0	0%	0	0%	**1**	**0%**
Surface	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	1	0%
Quartz	**1**	**100%**	**10**	**45%**	**100**	**61%**	**44**	**70%**	**9**	**75%**	**463**	**55%**	**11**	**73%**	**68**	**74%**	**705**	**58%**
Cluster A	0	0%	0	0%	3	2%	1	2%	1	8%	44	5%	1	7%	9	10%	59	5%
Cluster H	0	0%	2	9%	5	3%	0	0%	1	8%	48	6%	1	7%	12	13%	69	6%
Cluster L	0	0%	0	0%	3	2%	1	2%	1	8%	21	2%	0	0%	1	1%	27	2%
Cluster M	0	0%	0	0%	3	2%	2	3%	0	0%	5	1%	1	7%	0	0%	11	1%
Mound1	1	100%	2	9%	37	23%	24	38%	0	0%	143	17%	0	0%	26	28%	233	19%
Scatter 4	0	0%	0	0%	0	0%	1	2%	0	0%	4	0%	0	0%	2	2%	7	1%
Scatter1	0	0%	1	5%	4	2%	1	2%	0	0%	32	4%	4	27%	1	1%	43	4%
Scatter2	0	0%	2	9%	4	2%	0	0%	0	0%	40	5%	1	7%	2	2%	49	4%
Scatter3	0	0%	3	14%	39	24%	13	21%	6	50%	121	14%	3	20%	15	16%	200	17%
Surface	0	0%	0	0%	2	1%	1	2%	0	0%	4	0%	0	0%	0	0%	7	1%
Retouched	0	0%	**1**	**5%**	**8**	**5%**	**2**	**3%**	0	0%	**31**	**4%**	**1**	**7%**	**5**	**5%**	**48**	**4%**
Basalt	**0**	**0%**	**1**	**5%**	**3**	**2%**	**1**	**2%**	**0**	**0%**	**7**	**1%**	**0**	**0%**	**0**	**0%**	**12**	**1%**

Cluster A	0	0%	1	5%	0	0%	0	0%	0	0%	2	0%	0	0%	0	0%	3	0%
Scatter1	0	0%	0	0%	1	1%	1	2%	0	0%	2	0%	0	0%	0	0%	4	0%
Scatter2	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	1	0%
Scatter3	0	0%	0	0%	2	1%	0	0%	0	0%	2	0%	0	0%	0	0%	4	0%
Quartz	**0**	**0%**	**0**	**0%**	**5**	**3%**	**1**	**2%**	0	0%	**24**	**3%**	**1**	**7%**	**5**	**5%**	**36**	**3%**
Cluster A	0	0%	0	0%	0	0%	0	0%	0	0%	3	0%	0	0%	0	0%	3	0%
Cluster H	0	0%	0	0%	0	0%	0	0%	0	0%	5	1%	0	0%	0	0%	5	0%
Cluster L	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	1	0%
Mound1	0	0%	0	0%	3	2%	1	2%	0	0%	7	1%	0	0%	2	2%	13	1%
Scatter1	0	0%	0	0%	0	0%	0	0%	0	0%	4	0%	1	7%	1	1%	6	0%
Scatter3	0	0%	0	0%	2	1%	0	0%	0	0%	3	0%	0	0%	2	2%	7	1%
Surface	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	1	0%
Total	**1**	**0%**	**22**	**2%**	**164**	**14%**	**63**	**5%**	**12**	**1%**	**841**	**70%**	**15**	**1%**	**92**	**8%**	**1209**	**100%**

Table 73: Platform type distribution within the GOT-10 site.

Supplementary table 10

Platform Analysis of Mound 1																
	Abraded		**Cortical**		**Dyhedral**		**Facetted**		**Plain**		**Punctiform**		**Uncertain**		**Total**	
Stratigraphic Unit	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Not-Retouched	**1**	**100%**	**4**	**100%**	**61**	**95%**	**27**	**96%**	**253**	**97%**	**2**	**100%**	**36**	**95%**	**384**	**97%**
BASALT	**0**	**0%**	**2**	**50%**	**22**	**34%**	**4**	**14%**	**109**	**42%**	**2**	**100%**	**11**	**29%**	**150**	**38%**
SU10	0	0%	0	0%	0	0%	0	0%	4	2%	0	0%	0	0%	4	1%
SU11	0	0%	0	0%	2	3%	0	0%	18	7%	0	0%	0	0%	20	5%
SU12	0	0%	0	0%	1	2%	0	0%	3	1%	1	50%	0	0%	5	1%
SU19	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	1	0%
SU4	0	0%	0	0%	0	0%	0	0%	4	2%	0	0%	0	0%	4	1%
SU6	0	0%	2	50%	11	17%	3	11%	24	9%	0	0%	6	16%	46	12%
SU7	0	0%	0	0%	2	3%	0	0%	14	5%	0	0%	2	5%	18	5%
SU9	0	0%	0	0%	2	3%	1	4%	7	3%	1	50%	0	0%	11	3%
SUY	0	0%	0	0%	2	3%	0	0%	15	6%	0	0%	1	3%	18	5%
SUZ	0	0%	0	0%	2	3%	0	0%	19	7%	0	0%	2	5%	23	6%
CHERT	**0**	**0%**	**0**	**0%**	**2**	**3%**	**0**	**0%**	**2**	**1%**	**0**	**0%**	**0**	**0%**	**4**	**1%**
SU12	0	0%	0	0%	0	0%	0	0%	2	1%	0	0%	0	0%	2	1%
SUZ	0	0%	0	0%	2	3%	0	0%	0	0%	0	0%	0	0%	2	1%
QUARTZ	**1**	**100%**	**2**	**50%**	**37**	**58%**	**23**	**82%**	**142**	**55%**	0	0%	**25**	**66%**	**230**	**58%**
SU10	0	0%	0	0%	0	0%	1	4%	1	0%	0	0%	0	0%	2	1%
SU11	0	0%	1	25%	1	2%	2	7%	8	3%	0	0%	6	16%	18	5%
SU12	0	0%	0	0%	0	0%	1	4%	13	5%	0	0%	0	0%	14	4%
SU18	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	1	0%
SU19	0	0%	0	0%	0	0%	0	0%	2	1%	0	0%	0	0%	2	1%
SU2	0	0%	0	0%	0	0%	0	0%	2	1%	0	0%	0	0%	2	1%
SU4	0	0%	0	0%	2	3%	0	0%	8	3%	0	0%	5	13%	15	4%
SU6	1	**100%**	0	0%	24	38%	14	50%	57	22%	0	0%	7	18%	103	26%
SU7	0	0%	0	0%	2	3%	3	11%	15	6%	0	0%	0	0%	20	5%
SU8	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	1	0%
SU9	0	0%	0	0%	3	5%	0	0%	23	9%	0	0%	5	13%	31	8%
SUY	0	0%	0	0%	0	0%	0	0%			0	0%	1	3%	1	0%
SUZ	0	0%	1	25%	5	8%	2	7%	11	4%	0	0%	1	3%	20	5%
Retouched	**0**	**0%**	**0**	**0%**	**3**	**5%**	**1**	**4%**	**7**	**3%**	**0**	**0%**	**2**	**5%**	**13**	**3%**
QUARTZ	**0**	**0%**	0	0%	**3**	**5%**	**1**	**4%**	**7**	**3%**	**0**	**0%**	**2**	**5%**	**13**	**3%**
SU11	0	0%	0	0%	0	0%	0	0%	3	1%	0	0%	0	0%	3	1%
SU12	0	0%	0	0%	0	0%	0	0%	2	1%	0	0%	0	0%	2	1%
SU4	0	0%	0	0%	1	2%	0	0%			0	0%	1	3%	2	1%
SU6	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	1	3%	2	1%
SU7	0	0%	0	0%	1	2%	1	4%	1	0%	0	0%	0	0%	3	1%
SU9	0	0%	0	0%	1	2%	0	0%			0	0%	0	0%	1	0%
Total	**1**	**0%**	**4**	**1%**	**64**	**16%**	**28**	**7%**	**260**	**65%**	**2**	**1%**	**38**	**10%**	**397**	**100%**

Table 74: Platform type distribution within the Mound 1.

Supplementary table 11

Bulb morphology from GOT-10 site																		
	Dihedral		**Flat**		**Missing**		**Negative**		**Normal**		**Prominent**		**Removed**		**Uncertain**		**Total**	
Contexts	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Not retouched	**14**	**93%**	**589**	**95%**	**59**	**92%**	**99**	**97%**	**602**	**96%**	**4**	**100%**	0	0%	**179**	**96%**	**1545**	96%
Cluster A	1	7%	46	7%	2	3%	3	3%	53	8%	0	0%	0	0%	20	11%	126	8%
Cluster H	4	27%	78	13%	0	0%	5	5%	64	10%	0	0%	0	0%	20	11%	171	11%
Cluster L	0	0%	11	2%	0	0%	4	4%	26	4%	0	0%	0	0%	10	5%	51	3%
Cluster M	1	7%	16	3%	0	0%	4	4%	13	2%	0	0%	0	0%	2	1%	36	2%
Mound 1	7	47%	214	35%	34	53%	14	14%	188	30%	0	0%	0	0%	44	24%	501	31%
Scatter 4	0	0%	5	1%	0	0%	4	4%	4	1%	0	0%	0	0%	5	3%	18	1%
Scatter1	1	7%	35	6%	11	17%	13	13%	30	5%	0	0%	0	0%	1	1%	91	6%
Scatter2	0	0%	33	5%	6	9%	25	25%	38	6%	0	0%	0	0%	1	1%	103	6%
Scatter3	0	0%	150	24%	6	9%	24	24%	180	29%	4	100%	0	0%	76	41%	440	27%
Surface	0	0%	0	0%	0	0%	3	3%	5	1%	0	0%	0	0%	0	0%	8	0%
Retouched	**1**	**7%**	**29**	**5%**	**5**	**8%**	**3**	**3%**	**23**	**4%**	0	0%	**1**	**100%**	**7**	**4%**	**69**	4%
Cluster A	0	0%	3	0%	0	0%	1	1%	3	0%	0	0%	0	0%	1	1%	8	0%
Cluster H	0	0%	6	2%	0	0%	0	0%	2	1%	0	0%	0	0%	1	1%	9	0%
Cluster L	0	0%	1	0%	0	0%	0	0%	1	0%	0	0%	1	100%	0	0%	3	0%
Mound1	1	7%	7	1%	3	5%	1	1%	6	1%	0	0%	0	0%	1	1%	19	1%
Scatter1	0	0%	4	1%	1	2%	1	1%	5	1%	0	0%	0	0%	0	0%	11	1%
Scatter2	0	0%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	0	0%	1	0%
Scatter3	0	0%	7	1%	0	0%	0	0%	5	1%	0	0%	0	0%	3	2%	15	1%
Surface	0	0%	1	0%	1	2%	0	0%	0	0%	0	0%	0	0%	1	1%	3	0%
Total	**15**	**1%**	**618**	**38%**	**64**	**4%**	**102**	**6%**	**625**	**39%**	**4**	**0%**	**1**	**0%**	**186**	**12%**	**1614**	**100%**

Table 75: Bulb type distribution within the GOT-10 site.

Supplementary table 12

Mound 1 Bulb Morphology														
	Dihedral		Flat		Missing		Negative		Normal		Uncertain		Total	
Stratigraphic Unit	N	%	N	%	N	%	N	%	N	%	N	%	N	%
SU10	**0**	**0%**	**4**	**2%**	0	0%	0	0%	**2**	**1%**	0	0%	**6**	**1%**
Not-retouched	0	0%	4	2%	0	0%	0	0%	2	1%	0	0%	6	1%
SU11	**4**	**50%**	**31**	**14%**	0	0%	**2**	**13%**	**8**	**4%**	**2**	**4%**	**47**	**9%**
Not-retouched	3	38%	29	13%	0	0%	2	13%	8	4%	2	4%	44	9%
Retouched	1	13%	2	1%	0	0%	0	0%	0	0%	0	0%	3	**1%**
SU12	0	0%	**15**	**7%**	**1**	**3%**	**1**	**7%**	**12**	**6%**	**2**	**4%**	**31**	6%
Not-retouched	0	0%	13	6%	1	3%	1	7%	11	6%	2	4%	28	5%
Retouched	0	0%	2	1%	0	0%	0	0%	1	1%	0	0%	3	**1%**
SU18	0	0%	**1**	**0%**	0	0%	0	0%	0	0%	0	0%	**1**	0%
Not-retouched	0	0%	1	0%	0	0%	0	0%	0	0%	0	0%	1	0%
SU19	0	0%	**1**	**0%**	0	0%	0	0%	**3**	**2%**	0	0%	**4**	**1%**
Not-retouched	0	0%	1	0%	0	0%	0	0%	3	2%	0	0%	4	1%
SU2	0	0%	0	0%	0	0%	0	0%	**2**	**1%**	0	0%	**2**	**0%**
Not-retouched	0	0%	0	0%	0	0%	0	0%	2	1%	0	0%	2	0%
SU4	0	0%	**12**	**5%**	**6**	**16%**	**3**	**20%**	**8**	**4%**	0	0%	**29**	**6%**
Not-retouched	0	0%	10	5%	6	16%	3	20%	8	4%	0	0%	27	5%
Retouched	0	0%	2	1%	0	0%	0	0%	0	0%	0	0%	2	**0%**
SU6	**1**	**13%**	**62**	**28%**	**24**	**65%**	**8**	**53%**	**91**	**48%**	**13**	**29%**	**199**	39%
Not-retouched	1	13%	62	28%	22	59%	7	47%	90	47%	13	29%	195	38%
Retouched	0	0%	0	0%	2	5%	1	7%	1	1%	0	0%	4	**1%**
SU7	0	0%	**15**	**7%**	**6**	**16%**	0	0%	**27**	**14%**	0	0%	**48**	9%
Not-retouched	0	0%	15	7%	5	14%	0	0%	24	13%	0	0%	44	9%
Retouched	0	0%	0	0%	1	3%	0	0%	3	2%	0	0%	4	**1%**
SU8	0	0%	**1**	**0%**	0	0%	0	0%	0	0%	**1**	**2%**	**2**	0%
Not-retouched	0	0%	1	0%	0	0%	0	0%	0	0%	1	2%	2	0%
SU9	**1**	**13%**	**41**	**19%**	0	0%	0	0%	**6**	**3%**	**7**	**16%**	**55**	**11%**
Not-retouched	1	13%	40	18%	0	0%	0	0%	6	3%	6	13%	53	10%
Retouched	0	0%	1	0%	0	0%	0	0%	0	0%	1	2%	2	**0%**
SUY	0	0%	**12**	**5%**	0	0%	0	0%	**7**	**4%**	**1**	**2%**	**20**	4%
Not-retouched	0	0%	12	5%	0	0%	0	0%	7	4%	1	2%	20	4%
SUZ	**2**	**25%**	**24**	**11%**	0	0%	**1**	**7%**	**24**	**13%**	**19**	**42%**	**70**	**14%**
Not-retouched	2	25%	24	11%	0	0%	1	7%	23	12%	19	42%	69	13%
Retouched	0	0%	0	0%	0	0%	0	0%	1	1%	0	0%	1	**0%**
Total	**8**	**2%**	**219**	**43%**	**37**	**7%**	**15**	**3%**	**190**	**37%**	**45**	**9%**	**514**	100%

Table 76: Bulb type distribution within Mound 1.

1.5 Bipolar on anvil at GOT-10

Supplementary table 13

	Cluster A		Cluster H		Cluster L		Cluster M		Mound1		Scatter1		Scatter2		Scatter3		Scatter 4		Total	
Negatives bulbs	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1 Bulb	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**3**	**25%**	**1**	**14%**	**7**	**41%**	**8**	**50%**	**0**	**0%**	**19**	**29%**
Single	0	0%	0	0%	0	0%	0	0%	3	25%	0	0%	6	35%	8	50%	0	0%	17	26%
Single Biface	0	0%	0	0%	0	0%	0	0%	0	0%	1	14%	1	6%	0	0%	0	0%	2	3%
2 Bulbs	**3**	**100%**	**3**	**75%**	**2**	**67%**	**1**	**100%**	**8**	**67%**	**6**	**86%**	**8**	**47%**	**7**	**44%**	**2**	**100%**	**40**	**62%**
Opposite different surface	0	0%	0	0%	0	0%	0	0%	1	8%	0	0%	1	6%	0	0%	0	0%	2	3%
Opposite same surface	2	67%	3	75%	0	0%	1	100%	6	50%	6	86%	6	35%	5	31%	1	50%	30	46%
Orthogonal same surface	1	33%	0	0%	2	67%	0	0%	1	8%	0	0%	1	6%	0	0%	1	50%	6	9%
Single biface	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	13%	0	0%	2	3%
3 Bulbs	**0**	**0%**	**1**	**25%**	**1**	**33%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**6%**	**0**	**0%**	**3**	**5%**
Multiple	0	0%	1	25%	1	33%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	3%
Opposite same surface	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	6%	0	0%	1	2%
4 Bulbs	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**8%**	**0**	**0%**	**2**	**12%**	**0**	**0%**	**0**	**0%**	**3**	**5%**
Opposite different surface	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	6%	0	0%	0	0%	1	2%
Opposite same surface	0	0%	0	0%	0	0%	0	0%	1	8%	0	0%	1	6%	0	0%	0	0%	2	3%
Total	**3**	**5%**	**4**	**6%**	**3**	**5%**	**1**	**2%**	**12**	**18%**	**7**	**11%**	**17**	**26%**	**16**	**25%**	**2**	**3%**	**65**	**100%**

Table 77: Bipolar on anvil technique evidence among flakes from the GOT-10 assemblage.

Supplementary table 14

	Cluster A		Cluster M		Mound1		Scatter1		Scatter2		Scatter3		Scatter 4		Total	
Negative bulbs	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1 Bulb	**0**	**0%**	**0**	**0%**	**1**	**33%**	**0**	**0%**	**1**	**13%**	**2**	**50%**	**0**	**0%**	**4**	17%
Single	0	0%	0	0%	1	33%	0	0%	1	13%	2	50%	0	0%	4	17%
2 Bulbs	**1**	**100%**	**1**	**100%**	**2**	**67%**	**5**	**83%**	**4**	**50%**	**2**	**50%**	**1**	**100%**	**16**	67%
Opposite same surface	0	0%	1	100%	2	67%	5	83%	3	38%	2	50%	1	100%	14	58%
Orthogonal diff surface	0	0%	0	0%	0	0%	0	0%	1	13%	0	0%	0	0%	1	4%
Orthogonal same surface	1	100%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	4%
3 Bulbs	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**17%**	**2**	**25%**	**0**	**0%**	**0**	**0%**	**3**	13%
Opposite diff surface	0	0%	0	0%	0	0%	0	0%	1	13%	0	0%	0	0%	1	4%
Orthogonal diff surface	0	0%	0	0%	0	0%	1	17%	0	0%	0	0%	0	0%	1	4%
Orthogonal same surface	0	0%	0	0%	0	0%	0	0%	1	13%	0	0%	0	0%	1	4%
4 Bulbs	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**13%**	**0**	**0%**	**0**	**0%**	**1**	4%
Opposite diff surface	0	0%	0	0%	0	0%	0	0%	1	13%	0	0%	0	0%	1	4%
Total	**1**	**4%**	**1**	**4%**	**3**	**13%**	**6**	**25%**	**8**	**33%**	**4**	**17%**	**1**	**4%**	**24**	100%

Table 78: Bipolar on anvil technique evidence among cores from the GOT-10 assemblage.

1.6 Operational stages at GOT-10

Supplementary table 15

MOUND1												
	Procurement		**Production**		**Exploitation**		**Use**		**Abandon**		**Total**	
SU	N	%	N	%	N	%	N	%	N	%	N	%
SU10	1	20%	4	3%	1	1%	0	0%	1	1%	7	1%
SU11	0	0%	25	16%	11	7%	3	15%	9	5%	48	9%
SU12	0	0%	10	6%	3	2%	2	10%	16	8%	31	6%
SU18	0	0%	1	1%	0	0%	0	0%	0	0%	1	0%
SU19	0	0%	2	1%	1	1%	0	0%	2	1%	5	1%
SU2	0	0%	1	1%	1	1%	0	0%	0	0%	2	0%
SU4	0	0%	3	2%	13	8%	4	20%	11	6%	31	6%
SU6	0	0%	45	29%	76	49%	5	25%	77	39%	203	38%
SU7	0	0%	6	4%	27	17%	4	20%	13	7%	50	9%
SU8	0	0%	0	0%	1	1%	0	0%	1	1%	2	0%
SU9	0	0%	18	12%	9	6%	1	5%	28	14%	56	11%
SUY	2	40%	8	5%	8	5%	0	0%	2	1%	20	4%
SUZ	2	40%	33	21%	4	3%	1	5%	35	18%	75	14%
Total	**5**	**1%**	**156**	**29%**	**155**	**29%**	**20**	**4%**	**195**	**37%**	**531**	**100%**

Table 79: Chaîne opératoire stages distribution within the Mound 1.

Appendix 2 – Chapter 4

2.1 Flake analysis at Chavaillon's sample

Supplementary table 1

Preparation stage																				
	GOT I		**GOT II**		**GOT IV**		**GOT V**		**GOT VI**		**GOT VIII**		**GOT IX**		**GOT X**		**GOT RE**		**Total**	
Flake type	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%
BASALT	**11**	**100 %**	0	0%	**3**	**100 %**	**1**	**100 %**	0	0%	**2**	**100 %**	0	0%	**4**	**100 %**	**2**	**100 %**	**22**	81%
Cortical bl/flake	0	0%	0	0%	1	33%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	**1**	4%
Non standard Cortical flake	7	64%	0	0%	0	0%	0	0%	0	0%	2	100 %	0	0%	3	90%	2	100 %	14	52%
Debordant flake	4	36%	0	0%	1	33%	1	100 %	0	0%	0	0%	0	0%	0	0%	0	0%	6	22%
PseudoLevallois Point	0	0%	0	0%	1	33%	0	0%	0	0%	0	0%	0	0%	1	10%	0	0%	2	7%
QUARTZ	0	0%	**1**	**100 %**	0	0%	0	0%	**2**	**100 %**	0	0%	**1**	**100 %**	0	0%	0	0%	**4**	15%
Non standard Cortical flake	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	100 %	0	0%	0	0%	1	4%
Debordant flake	0	0%	1	100 %	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	4%
Striking Platform prep Flake	0	0%	0	0%	0	0%	0	0%	1	50%	0	0%	0	0%	0	0%	0	0%	1	4%
PseudoLevallois Point	0	0%	0	0%	0	0%	0	0%	1	50%	0	0%	0	0%	0	0%	0	0%	1	4%
Total	**11**	**41%**	**1**	**4%**	**3**	**11%**	**1**	**4%**	**2**	**7%**	**2**	**7%**	**1**	**4%**	**4**	**15%**	**2**	**7%**	**27**	100 %

Table 80: Preparation stage product frequencies within Chavaillon's sample

Supplementary table 2

Production stage																		
	GOT I		**GOT II**		**GOT V**		**GOT VII**		**GOT VIII**		**GOT IX**		**GOT X**		**GOT RE**		**Total**	
Flake type	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
BASALT	**16**	**64%**	**1**	**25%**	**2**	**100%**	**1**	**50%**	0	0%	0	0%	**3**	**100%**	**2**	**100%**	**25**	68%
Ordinary Flake	8	32%	0	0%	1	50%	0	0%	0	0%	0	0%	1	33%	2	100%	12	32%
Centripetal Levallois	1	4%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
Levallois Point	1	4%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
Ordinary Blade	2	8%	1	25%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	3	8%
Ordinary Blade w/cortex	2	8%	0	0%	1	50%	0	0%	0	0%	0	0%	0	0%	0	0%	3	8%
Ordinary Bladelet	1	4%	0	0%	0	0%	1	50%	0	0%	0	0%	0	0%	0	0%	2	5%
Volumetric Point	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	33%	0	0%	1	3%
Point	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	33%	0	0%	1	3%
Levallois Unipolar recurrent	1	4%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
PHONOLITE	**1**	**4%**	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	**1**	3%
Levallois Point	1	4%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
QUARTZ	**7**	**28%**	**3**	**75%**	0	0%	**1**	**50%**	**2**	**100%**	**1**	**100%**	0	0%	0	0%	**11**	30%
Ordinary Flake	2	8%	1	25%	0	0%	0	0%	1	50%	1	100%	0	0%	0	0%	4	11%
Levallois Point	0	0%	0	0%	0	0%	0	0%	1	50%	0	0%	0	0%	0	0%	1	3%
Volumetric Point	2	8%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	5%
Levallois Preferential	1	4%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
Levallois Unipolar recurrent	1	4%	1	25%	0	0%	1	50%	0	0%	0	0%	0	0%	0	0%	2	5%
Levallois Bipolar	1	4%	1	25%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
Total	**25**	**68%**	**4**	**11%**	**2**	**5%**	**2**	**5%**	**2**	**5%**	**1**	**3%**	**3**	**8%**	**2**	**5%**	**37**	**100%**

Table 81: Frequency of production stage products within Chavaillon's sample

Supplementary table 3

Platform Analysis																						
	GOT I		**GOT II**		**GOT IV**		**GOT V**		**GOT VI**		**GOT VII**		**GOT VIII**		**GOT IX**		**GOT X**		**GOT RE**		**Total**	
Platform Type	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Basalt	**29**	**85 %**	**1**	**20 %**	**2**	**67 %**	**1**	**100 %**	**1**	**33 %**	**1**	**50 %**	**4**	**57 %**			**7**	**100 %**	**4**	**100 %**	**50**	**72 %**
Cortex	2	6%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	50 %	4	6%
Dyhedral	5	15 %	0	0%	1	33 %	0	0%	0	0%	1	50 %	0	0%	0	0%	0	0%	1	25 %	8	12 %
Facetted	2	6%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	3%
Linear	1	3%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	14 %	0	0%	2	3%
Plain	19	56 %	1	20 %	1	33 %	1	100 %	1	33 %	0	0%	4	57 %	0	0%	6	86 %	1	25 %	34	49 %
Lava	**0**	**0%**	**0**	**0%**	**1**	**33 %**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**1%**
Plain	0	0%	0	0%	1	33 %	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	1%
Phonolite	**1**	**3%**	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	**1**	**1%**
Facetted	1	3%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	1%
Quartz	**4**	**12 %**	**4**	**80 %**	**0**	**0%**	**0**	**0%**	**2**	**67 %**	**1**	**50 %**	**3**	**43 %**	**3**	**100 %**	**0**	**0%**	**0**	**0%**	**17**	**25 %**
Cortex	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	14 %	0	0%	0	0%	0	0%	1	1%
Dyhedral	1	3%	2	40 %	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	3	4%
Facetted	1	3%	0	0%	0	0%	0	0%	1	33 %	1	50 %	0	0%	0	0%	0	0%	0	0%	3	4%
Plain	0	0%	2	40 %	0	0%	0	0%	1	33 %	0	0%	2	29 %	3	100 %	0	0%	0	0%	8	12 %
Uncertain	2	6%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	3%
Total	**34**	**49 %**	**5**	**7%**	**3**	**4%**	**1**	**1%**	**3**	**4%**	**2**	**3%**	**7**	**10 %**	**3**	**100 %**	**7**	**10 %**	**4**	**6%**	**69**	**100 %**

Table 82: Platform type frequencies within Chavaillon's sample.

Supplementary table 4

Bulb Analysis																						
	GOT I		**GOT II**		**GOT IV**		**GOT V**		**GOT VI**		**GOT VII**		**GOT VIII**		**GOT IX**		**GOT X**		**GOT RE**		**Total**	
Bulb Type	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Basalt	**30**	**81 %**	**1**	**17 %**	**2**	**67 %**	**3**	**100 %**	**1**	**33 %**	**1**	**33 %**	**4**	**40 %**			**7**	**100 %**	**4**	**100 %**	**53**	**66 %**
Flat	4	11 %	0	0%	0	0%	2	90 %	0	0%	1	33 %	1	10 %	0	0%	3	43 %	1	25 %	12	15 %
Negative	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	25 %	1	1%
Normal	26	70 %	1	17 %	2	67 %	1	10 %	1	33 %	0	0%	3	30 %	0	0%	4	57 %	1	25 %	39	49 %
Prominent	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	25 %	1	1%
Lava	**0**	**0 %**	**0**	**0 %**	**1**	**33 %**	**0**	**0%**	**0**	**0 %**	**0**	**0 %**	**0**	**0 %**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**1%**
Flat	0	0%	0	0%	1	33 %	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	1%
Phonolite	**1**	**3 %**	**0**	**0 %**	**0**	**0 %**	**0**	**0%**	**0**	**0 %**	**0**	**0 %**	**0**	**0 %**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**1%**
Normal	1	3%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	1%
Quartz	**6**	**16 %**	**5**	**83 %**	0	0%	0	0%	**2**	**67 %**	**2**	**67 %**	**6**	**60 %**	**4**	**100 %**	**0**	**0%**	**0**	**0%**	**25**	**31 %**
Flat	0	0%	0	0%	0	0%	0	0%	1	33 %	0	0%	0	0%	2	50 %	0	0%	0	0%	3	4%
Negative	2	5%	0	0%	0	0%	0	0%	0	0%	1	33 %	3	30 %	1	25 %	0	0%	0	0%	7	9%
Normal	4	11 %	5	83 %	0	0%	0	0%	1	33 %	1	33 %	2	20 %	1	25 %	0	0%	0	0%	14	1%
Uncertain	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	10 %	0	0%	0	0%	0	0%	1	1%
Total	**37**	**46 %**	**6**	**8 %**	**3**	**4 %**	**3**	**4%**	**3**	**4 %**	**3**	**4 %**	**10**	**13 %**	**4**	**5%**	**7**	**9%**	**4**	**5%**	**80**	**100 %**

Table 83: Frequency of bulb morphology types within Chavaillon's sample.

2.3 Retouched flakes at Chavaillon's sample

Supplementary table 5

Retouched Flakes																		
	GOT I		**GOT II**		**GOT III**		**GOT IV**		**GOT IX**		**GOT VII**		**GOT VIII**		**GOT X**		**Total**	
Tool Type	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
BASALT	**13**	**65%**	**1**	**14 %**	0	0%	0	0%	0	0%	0	0%	**4**	**67 %**	**3**	**100 %**	**22**	55%
Retouched Levallois Point	2	10%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	5%
Single Straight Scraper	3	15%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	3	8%
Single Convex Scraper	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	17%	0	0%	1	3%
Straight Transverse Scraper	1	5%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
Convex Transverse Scraper	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	10%	1	3%
Backed piece	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	17%	0	0%	1	3%
Mousterian Tranchet	3	15%	1	14%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	4	10%
Denticulate	4	20%	0	0%	0	0%	0	0%	0	0%	0	0%	2	33%	2	90%	8	20%
CHERT	**2**	**10%**	0	0%	**1**	**50 %**	0	0%	0	0%	0	0%	0	0%	0	0%	**3**	8%
Retouched Levallois Point	2	10%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	2	5%
Notch	0	0%	0	0%	1	50%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
QUARTZ	**5**	**25%**	**6**	**86 %**	**1**	**50 %**	**1**	**100 %**	**1**	**100 %**	**2**	**100 %**	**2**	**33 %**	0	0%	**18**	45%
Retouched Levallois Point	2	10%	1	14%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	3	8%
Pseudolevallois Point	0	0%	1	14%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
Single Convex Scraper	0	0%	1	14%	0	0%	0	0%	1	100%	0	0%	0	0%	0	0%	2	5%
Double Straight Scraper	1	5%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%
Backed piece	1	5%	0	0%	0	0%	1	100%	0	0%	0	0%	0	0%	0	0%	2	5%
Notch	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	17%	0	0%	1	3%
Denticulate	1	5%	2	29%	1	50%	0	0%	0	0%	2	100%	0	0%	0	0%	6	15%
Total	**20**	**50%**	**7**	**18 %**	**2**	**5%**	**1**	**3%**	**1**	**3%**	**2**	**5%**	**6**	**15 %**	**3**	**8%**	**40**	100 %

Table 84: Frequency of retouched flake types within Chavaillon's sample.

2.4 Operational stages at Chavaillon's sample

Supplementary table 6

Chaîne opératoire stages										
	Production		**Exploitation**		**Use**		**Abandon**		**Total**	
Sites	N	%	N	%	N	%	N	%	N	%
GOT I	12	43%	22	56%	18	43%	29	53%	81	49%
GOT II	1	4%	4	10%	6	14%	3	5%	14	9%
GOT III	0	0%	0	0%	2	5%	1	2%	3	2%
GOT IV	3	11%	0	0%	1	2%	0	0%	4	2%
GOT V	1	4%	2	5%	0	0%	0	0%	3	2%
GOT VI	1	4%	0	0%	0	0%	2	4%	3	2%
GOT VII	0	0%	2	5%	2	5%	3	5%	7	4%
GOT VIII	3	11%	3	8%	7	17%	15	27%	28	17%
GOT IX	1	4%	1	3%	3	7%	2	4%	7	4%
GOT X	4	14%	3	8%	3	7%	0	0%	10	6%
GOT RE	2	7%	2	5%	0	0%	0	0%	4	2%
Total	**28**	**17%**	**39**	**24%**	**42**	**26%**	**55**	**34%**	**164**	**100%**

Table 85: Chaîne opératoire stages identified within Chavaillon's sample.

Supplementary table 7

Preparation Stage														
	EC14		**EC22**		**MG32**		**Scatter1**		**Scatter IS**		**Isolated Finds**		**Total**	
Flake Type	N	%	N	%	N	%	N	%	N	%	N	%	N	%
BASALT	**12**	**100%**	**13**	**100%**	**0**	**0%**	**33**	**97%**	**12**	**100%**	**8**	**100%**	**78**	**76%**
Cortical Flake	5	42%	9	69%	0	0%	15	44%	7	58%	3	38%	39	38%
Fully Cortex Flake	2	17%	0	0%	0	0%	1	3%	0	0%	0	0%	3	3%
Debordant Flake	2	17%	3	23%	0	0%	10	29%	3	25%	3	38%	21	20%
Pseudolevallois point	0	0%	0	0%	0	0%	3	9%	0	0%	0	0%	3	3%
Debordant blade	3	25%	0	0%	0	0%	2	6%	1	8%	1	13%	7	7%
Levallois stricking platform Prep	0	0%	0	0%	0	0%	0	0%	1	8%	1	13%	2	2%
Crest blade/bladelet	0	0%	1	8%	0	0%	2	6%	0	0%	0	0%	3	3%
QUARTZ	**0**	**0%**	**0**	**0%**	**24**	**100%**	**1**	**3%**	**0**	**0%**	**0**	**0%**	**25**	**24%**
Cortical Flake	0	0%	0	0%	0	0%	1	3%	0	0%	0	0%	1	1%
Debordant blade	0	0%	0	0%	4	17%	0	0%	0	0%	0	0%	4	4%
Levallois stricking platform Prep	0	0%	0	0%	2	8%	0	0%	0	0%	0	0%	2	2%
Debordant Flake	0	0%	0	0%	12	50%	0	0%	0	0%	0	0%	12	12%
Striking platform prep	0	0%	0	0%	1	4%	0	0%	0	0%	0	0%	1	1%
Crest blade/bladelet	0	0%	0	0%	5	21%	0	0%	0	0%	0	0%	5	5%
Total	**12**	**12%**	**13**	**13%**	**24**	**23%**	**34**	**33%**	**12**	**12%**	**8**	**8%**	**103**	**100%**

Table 86: Frequency of preparation flake types at the GOT1-S site.

Supplementary table 8

Production stage														
	EC14		**EC22**		**MG32**		**Scatter1**		**Scatter IS**		**Isolated Finds**		**Total**	
Flake type	N	%	N	%	N	%	N	%	N	%	N	%	N	%
BASALT	**8**	**100%**	**15**	**100%**	0	0%	**32**	**100%**	**10**	**100%**	**6**	**33%**	**71**	45%
Ordinary Flake	2	25%	4	27%	0	0%	11	34%	2	20%	2	11%	21	13%
Levallois centripetal flake	1	13%	1	7%	0	0%	1	3%	0	0%	0	0%	4	3%
Point	0	0%	0	0%	0	0%	1	3%	0	0%	0	0%	1	1%
Levallois Blade	0	0%	1	7%	0	0%	0	0%	1	10%	0	0%	2	1%
Unipolar Flake	0	0%	0	0%	0	0%	2	6%	3	30%	1	6%	6	4%
Ordinary Blade	0	0%	1	7%	0	0%	1	3%	0	0%	1	6%	3	2%
Ordinary Blade with cortex	0	0%	0	0%	0	0%	1	3%	0	0%	0	0%	1	1%
Blade fragment	1	13%	1	7%	0	0%	8	25%	0	0%	0	0%	10	6%
Volumetric point	2	25%	0	0%	0	0%	1	3%	2	20%	0	0%	5	3%
Ordinary flake with cortex	0	0%	1	7%	0	0%	0	0%	0	0%	0	0%	1	1%
Unipolar flake with cortex	0	0%	0	0%	0	0%	1	3%	0	0%	0	0%	1	1%
Centripetal flake	1	13%	1	7%	0	0%	2	6%	1	10%	0	0%	5	3%
Centripetal flake with cortex	0	0%	0	0%	0	0%	1	3%	0	0%	0	0%	1	1%
Preferential Levallois flake	0	0%	1	7%	0	0%	0	0%	0	0%	0	0%	1	1%
Unipolar Levallois recurrent	0	0%	2	13%	0	0%	2	6%	1	10%	1	6%	6	4%
Bipolar Levallois recurrent	1	13%	2	13%	0	0%	0	0%	0	0%	0	0%	3	2%
CHERT	0	0%	0	0%	0	0%	0	0%	0	0%	**2**	**11%**	**2**	1%
Ordinary Flake	0	0%	0	0%	0	0%	0	0%	0	0%	1	6%	1	1%
Unipolar Levallois recurrent	0	0%	0	0%	0	0%	0	0%	0	0%	1	6%	1	1%
OBSIDIAN	0	0%	0	0%	0	0%	0	0%	0	0%	**1**	**6%**	**1**	1%
Unipolar Levallois recurrent	0	0%	0	0%	0	0%	0	0%	0	0%	1	6%	1	1%
QUARTZ	0	0%	0	0%	**75**	**100%**	0	0%	0	0%	**9**	**50%**	**84**	53%
Ordinary Flake	0	0%	0	0%	35	47%	0	0%	0	0%	2	11%	37	23%
Levallois centripetal flake	0	0%	0	0%	0	0%	0	0%	0	0%	1	6%	1	1%
Unipolar Flake	0	0%	0	0%	2	3%	0	0%	0	0%	5	28%	7	4%
Ordinary Blade with cortex	0	0%	0	0%	1	1%	0	0%	0	0%	0	0%	1	1%
Ordinary bladelet	0	0%	0	0%	9	12%	0	0%	0	0%	0	0%	9	6%
Ordinary bladelet with cortex	0	0%	0	0%	2	3%	0	0%	0	0%	0	0%	2	1%
Blade fragment	0	0%	0	0%	8	11%	0	0%	0	0%	0	0%	8	5%
Volumetric point	0	0%	0	0%	3	4%	0	0%	0	0%	0	0%	3	2%
Ordinary flake with cortex	0	0%	0	0%	7	9%	0	0%	0	0%	0	0%	7	4%
Unipolar flake with cortex	0	0%	0	0%	1	1%	0	0%	0	0%	0	0%	1	1%
Centripetal flake	0	0%	0	0%	0	0%	0	0%	0	0%	1	6%	1	1%
Unipolar Levallois recurrent	0	0%	0	0%	5	7%	0	0%	0	0%	0	0%	5	3%
Bipolar Levallois recurrent	0	0%	0	0%	2	3%	0	0%	0	0%	0	0%	2	1%
Total	**8**	**5%**	**15**	**9%**	**75**	**47%**	**32**	**20%**	**10**	**6%**	**18**	**11%**	**158**	100%

Table 87: Frequency of production flake types at the GOT1-S site.

2.6 Retouched flakes at GOT1-S

Supplementary table 9

Retouched flake on preparation blanks										
	EC14		**EC22**		**Scatter1**		**Isolated Finds**		**Total**	
Tool Type	N	%	N	%	N	%	N	%	N	%
BASALT	**1**	**100%**	**2**	**100%**	**4**	**80%**	**1**	**100%**	**8**	89%
Cortical Flake	**1**	**100%**	**1**	**50%**	**2**	**40%**	**1**	**100%**	**5**	56%
Denticulate	1	100%	0	0%	1	20%	1	100%	3	33%
Irregular Retouch on Interior	0	0%	0	0%	1	20%	0	0%	1	11%
Abrupt Alternating Retouch	0	0%	1	50%	0	0%	0	0%	1	11%
Scraper on Interior Surface	0	0%	0	0%	1	20%	0	0%	1	11%
Debordant Flake	0	0%	0	0%	**1**	**20%**	0	0%	**1**	11%
Irregular Retouch on Interior	0	0%	0	0%	1	20%	0	0%	1	11%
Crest blade/bladelet	0	0%	**1**	**50%**	0	0%	0	0%	**1**	11%
Denticulate	0	0%	1	50%	0	0%	0	0%	1	11%
CHERT	**0**	**0%**	**0**	**0%**	**1**	**20%**	**0**	**0%**	**1**	11%
Crest blade/bladelet	0	0%	0	0%	**1**	**20%**	0	0%	**1**	11%
Denticulate	0	0%	0	0%	1	20%	0	0%	1	11%
Total	**1**	**11%**	**2**	**22%**	**5**	**56%**	**1**	**11%**	**9**	100%

Table 88: Frequency of retouched flakes made on preparation blanks at the GOT1-S site.

Supplementary table 10

Retouched Flakes on production blanks										
	EC22		**MG32**		**Scatter1**		**Isolated finds**		**Total**	
Tool Type	N	%	N	%	N	%	N	%	N	%
BASALT	**8**	**100%**	**0**	**0%**	**1**	**100%**	**2**	**100%**	**11**	**79%**
Ordinary flake	**4**	**50%**	**0**	**0%**	**0**	**0%**	**1**	**50%**	**5**	**36%**
Denticulate	0	0%	0	0%	0	0%	1	50%	1	7%
Irregular Ret on ventral face	3	38%	0	0%	0	0%	0	0%	3	21%
Alternating Ret	1	13%	0	0%	0	0%	0	0%	1	7%
Levallois Point	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**50%**	**1**	**7%**
Retouched Levallois Point	0	0%	0	0%	0	0%	1	50%	1	7%
Unipolar flake	**1**	**13%**	0	0%	0	0%	0	0%	**1**	7%
Alternating Ret	1	13%	0	0%	0	0%	0	0%	1	7%
Ordinary blade	**2**	**25%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**2**	**14%**
Irregular Ret on ventral face	1	13%	0	0%	0	0%	0	0%	1	7%
Alternating Ret	1	13%	0	0%	0	0%	0	0%	1	7%
Ordinary blade with cortex	**0**	**0%**	**0**	**0%**	**1**	**100%**	**0**	**0%**	**1**	**7%**
Denticulate	0	0%	0	0%	1	100%	0	0%	1	7%
Blade fragment	**1**	**13%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**7%**
Alternate Scraper	1	13%	0	0%	0	0%	0	0%	1	7%
QUARTZ	**0**	**0%**	**3**	**100%**	**0**	**0%**	**0**	**0%**	**3**	**21%**
Ordinary flake	**0**	**0%**	**1**	**33%**	**0**	**0%**	**0**	**0%**	**1**	**7%**
Denticulate	0	0%	1	33%	0	0%	0	0%	1	7%
Levallois Point	**0**	**0%**	**1**	**33%**	**0**	**0%**	**0**	**0%**	**1**	**7%**
Retouched Levallois Point	0	0%	1	33%	0	0%	0	0%	1	7%
Unipolar Levallois recurrent	**0**	**0%**	**1**	**33%**	**0**	**0%**	**0**	**0%**	**1**	**7%**
Retouched Levallois Flake	0	0%	1	33%	0	0%	0	0%	1	7%
Total	**8**	**57%**	**3**	**21%**	**1**	**7%**	**2**	**14%**	**14**	100%

Table 89: Frequency of retouched flakes made on production blanks at the GOT1-S site.

Supplementary table 11

	EC14		EC22		MG32		Scatter1		Scatter IS		Isolated Finds		Total	
Platform types	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Basalt	**16**	**100%**	**31**	**100%**	**1**	**1%**	**48**	**96%**	**21**	**100%**	**14**	**54%**	**132**	**59%**
Abraded	1	6%	1	3%	0	0%	1	2%	0	0%	0	0%	3	1%
Cortex	0	0%	2	6%	0	0%	6	12%	1	5%	0	0%	9	4%
Dyhedral	1	6%	1	3%	1	1%	4	8%	3	14%	0	0%	10	4%
Facetted	1	6%	5	16%	0	0%	4	8%	1	5%	1	4%	12	5%
Linear	1	6%	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%
Plain	12	75%	22	71%	0	0%	33	66%	16	76%	14	54%	97	43%
Chert	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**2%**	**0**	**0%**	**4**	**15%**	**5**	**2%**
Abraded	0	0%	0	0%	0	0%	0	0%	0	0%	1	4%	1	0%
Dyhedral	0	0%	0	0%	0	0%	1	2%	0	0%	1	4%	2	1%
Plain	0	0%	0	0%	0	0%	0	0%	0	0%	2	8%	2	1%
Obsidian	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**4%**	**1**	**0%**
Plain	0	0%	0	0%	0	0%	0	0%	0	0%	1	4%	1	0%
Quartz	**0**	**0%**	**0**	**0%**	**68**	**99%**	**1**	**2%**	**0**	**0%**	**16**	**62%**	**85**	**38%**
Abraded	0	0%	0	0%	2	3%	0	0%	0	0%	0	0%	2	1%
Dyhedral	0	0%	0	0%	6	9%	0	0%	0	0%	**1**	**4%**	7	3%
Facetted	0	0%	0	0%	14	20%	0	0%	0	0%	7	27%	21	9%
Linear	0	0%	0	0%	0	0%	0	0%	0	0%	**1**	**4%**	1	0%
Plain	0	0%	0	0%	44	64%	1	2%	0	0%	7	27%	52	23%
Punctiform	0	0%	0	0%	2	3%	0	0%	0	0%	0	0%	2	1%
Total	**16**	**7%**	**31**	**14%**	**69**	**31%**	**50**	**22%**	**21**	**9%**	**26**	**12%**	**223**	**100%**

Table 90: Frequency of platform types at the GOT1-S site.

Supplementary table 12

	EC14		EC22		MG32		Scatter1		Scatter IS		Isolated Finds		Total	
Bulb Type	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Basalt	**18**	**100%**	**36**	**97%**	**3**	**3%**	**53**	**96%**	**23**	**100%**	**18**	**55%**	**151**	**56%**
Dyhedral	0	0%	0	0%	0	0%	1	2%	0	0%	0	0%	1	0%
Flat	8	44%	23	62%	0	0%	33	60%	10	43%	5	15%	79	29%
Missing	0	0%	1	3%	2	2%	3	5%	2	9%	2	6%	10	4%
Negative	1	6%	2	5%	0	0%	2	4%	1	4%	0	0%	6	2%
Normal	9	50%	9	24%	1	1%	11	20%	9	39%	11	33%	50	19%
Prominent	0	0%	1	3%	0	0%	1	2%	1	4%	0	0%	3	1%
Removed	0	0%	0	0%	0	0%	1	2%	0	0%	0	0%	1	0%
Chert	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**2%**	**0**	**0%**	**4**	**12%**	**5**	**2%**
Flat	0	0%	0	0%	0	0%	1	2%	0	0%	1	3%	2	1%
Normal	0	0%	0	0%	0	0%	0	0%	0	0%	3	9%	3	1%
Obsidian	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**3%**	**1**	**0%**
Normal	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%	1	0%
Quartz	**0**	**0%**	**0**	**0%**	**96**	**97%**	**1**	**2%**	**0**	**0%**	**20**	**61%**	**117**	**43%**
Flat	0	0%	0	0%	57	58%	0	0%	0	0%	6	18%	63	23%
Missing	0	0%	0	0%	5	5%	0	0%	0	0%	**2**	**6%**	7	3%
Negative	0	0%	0	0%	2	2%	0	0%	0	0%	0	0%	2	1%
Normal	0	0%	0	0%	32	32%	1	2%	0	0%	**11**	**33%**	44	16%
Removed	0	0%	0	0%	0	0%	0	0%	0	0%	1	3%	1	0%
Total	**18**	**7%**	**37**	**14%**	**99**	**37%**	**55**	**20%**	**23**	**9%**	**33**	**12%**	**269**	100%

Table 91: Frequency of bulb types at the GOT1-S site.

2.8 Operational stages at GOT1-S

Supplementary table 13

Chaine opératoire stages														
	EC14		EC22		MG32		Scatter1		Scatter IS		Isolated Finds		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Basalt	**20**	**100%**	**48**	**98%**	**3**	**3%**	**69**	**97%**	**29**	**100%**	**25**	**47%**	**194**	**58%**
Procurement	2	10%	0	0%	0	0%	0	0%	0	0%	0	0%	2	1%
Preparation	11	55%	11	22%	0	0%	20	28%	11	38%	7	13%	60	18%
Exploitation	6	30%	16	33%	0	0%	38	54%	14	48%	8	15%	82	25%
Use	1	5%	10	20%	0	0%	6	8%	0	0%	2	4%	19	6%
Abandon	0	0%	11	22%	3	3%	5	7%	4	14%	8	15%	31	9%
Chert	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**1%**	**0**	**0%**	**4**	**8%**	**5**	**2%**
Exploitation	0	0%	0	0%	0	0%	0	0%	0	0%	4	8%	4	1%
Use	0	0%	0	0%	0	0%	1	1%	0	0%	1	2%	2	1%
Obsidian	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**2%**	**1**	**0%**
Exploitation	0	0%	0	0%	0	0%	0	0%	0	0%	1	2%	1	0%
Quartz	**0**	**0%**	**0**	**0%**	**107**	**97%**	**1**	**1%**	**0**	**0%**	**23**	**43%**	**131**	**39%**
Preparation	0	0%	0	0%	14	13%	1	1%	0	0%	5	9%	20	6%
Exploitation	0	0%	0	0%	87	79%	0	0%	0	0%	13	25%	100	30%
Abandon	0	0%	1	2%	5	5%	0	0%	0	0%	3	6%	9	3%
Use	0	0%	1	2%	1	1%	0	0%	0	0%	2	4%	4	1%
Total	**20**	**6%**	**49**	**15%**	**110**	**33%**	**71**	**21%**	**29**	**9%**	**53**	**16%**	**332**	**100%**

Table 92: Frequency of Chaîne opératoires stages represented at the GOT1-S site.

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