Journal of Archaeological Science: Reports 67 (2025) 105423

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Lithic technology from level 22 at Nasera (Tanzania): The Kisele industry revisited

Irene Solano-Megías [a,b,*], José Manuel Maíllo-Fernández [c,d], Juan Marín [c,e,f], David M. Martín-Perea [d,e,g], Agness Gidna [h], Audax Z.P. Mabulla [i]

[a] Inter-University Graduate School of Human Evolution, University of Burgos, Burgos, Spain
[b] National Centre for Research On Human Evolution (CENIEH), Burgos, Spain
[c] Dpt. Prehistory and Archaeology, Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain
[d] Institute of Evolution in Africa (IDEA), University of Alcalá de Henares, Madrid, Spain
[e] Institut Català de Paleoecologia Humana I Evolució Social (IPHES), Tarragona, Spain
[f] Histoire naturelle de l'Homme préhistorique (HNHP, UMR 7194), MNHN/CNRS/UPVD, Musée de l'Homme, París, France
[g] Department of Geodynamics, Statigraphy and Palaeontology, Faculty of Geological Sciences, Complutense University of Madrid, Madrid, Spain
[h] Department of Cultural Heritage, Ngorongoro Conservation Area, Arusha, Tanzania
[i] Department of Archaeology and Heritage Studies, University of Dar es Salaam, Dar es Salaam, Tanzania

ARTICLE INFO

Keywords:
Nasera
Kisele industry
Middle Stone Age
Lithic technology
Tanzania

ABSTRACT

This study presents a techno-typological analysis of level 22 at the site of Nasera (northern Tanzania), shedding new light on the Kisele industry (Middle Stone Age) in the region. The lithic assemblage is predominantly characterized by discoid methods and the use of sidescrapers and points, both bifacial and unifacial. The raw materials used are primarily local in origin, including quartz and chert from Olduvai. However, the presence of a small number of obsidian pieces originating from Lake Naivasha basin suggests long-distance contact between MSA groups.

In addition to the discoid methods, other operational schemes, such as the Levallois or the single platform, have been identified in smaller numbers, with higher-quality materials such as chert used in the Levallois. This indicates a greater variability in the number of production methods used than that previously identified for the Kisele industry.

Comparisons with other regional industries, such as the older Sanzako, or contemporaneous ones like VCS and DGS at Olduvai or Loiyangalani in the Serengeti, show techno-typological differences that present a scenario of greater technological complexity and diversity than previously known for northern Tanzania.

1. Introduction

The Middle Stone Age (MSA) is a chronocultural period first defined by Goodwin and van Riet Lowe (1929) to distinguish it from the Earlier and Later Stone Age. It is generally dated to between ~300 ka and ~50–40 ka in Africa, although chronological boundaries vary regionally (Clark, 1988; McBrearty and Brooks, 2000; Henshilwood and Marean, 2003; Shea, 2008, 2011; Basell, 2008; Tryon and Faith, 2013; Hublin et al., 2017; Richter et al., 2017; Blinkhorn and Grove, 2018; Will et al., 2019; Boisard and Ben Arous, 2024; Rosas et al., 2025). This period is characterized by a rise in symbolic behavior, alongside the use of pigments, the preparation of cores prior to knapping, long-distance material exchanges, and even hafting, all linked to the emergence of *Homo sapiens* as a species (McBrearty and Brooks, 2000; Hublin et al., 2017; Brooks et al., 2018; Will et al., 2019; Scerri et al., 2021; Vidal et al., 2022). Despite the growing number of MSA sites studied across Africa, research intensity remains uneven, with some regions (e.g., parts of Central and West Africa) still underrepresented (Mitchell et al., 2024). In contrast, East Africa—together with southern Africa—has received sustained research attention and remains a key area for understanding human origins, the emergence of *Homo sapiens*, and associated behavioral developments (Day, 1969; White et al., 2003; Clark et al., 2003; McDougall et al., 2005; Fleagle et al., 2008; Brown et al., 2012; Vidal et al., 2022).

In recent decades, interest in the MSA has grown, and some researchers have proposed subdividing it into two subperiods: the Early

* Corresponding author at: Inter-University Graduate School of Human Evolution, University of Burgos, Burgos, Spain.
E-mail addresses: ism0029@alu.ubu.es, irene.solanome@gmail.com (I. Solano-Megías).

https://doi.org/10.1016/j.jasrep.2025.105423
Received 4 October 2024; Received in revised form 12 September 2025; Accepted 20 September 2025
Available online 29 September 2025
2352-409X/

Middle Stone Age (EMSA, ~300–130 ka) and the Later Middle Stone Age (LMSA, ~130–40 ka) (McBrearty and Tryon, 2005). During this time, technological changes reflect the development of new subsistence strategies and resource exploitation by human groups (Wurz, 2013; Chazan et al., 2020). During the LMSA, *Homo sapiens* increasingly used rockshelters and caves, alternating occupations between open-air sites and enclosed spaces (Clark, 1988; Tryon and Faith, 2013; Blinkhorn and Grove, 2021). Studies of MSA sites in rockshelters or caves are more common (Pleurdeau, 2003, 2004, 2005; Tryon and Faith, 2016; Ossendorf et al., 2019; Solano-Megías et al., 2020) than those of open-air sites (Wendorf and Schild, 1975; McBrearty and Tryon, 2005; Sahle, 2013; Tryon and Faith, 2016; Maíllo-Fernández et al., 2019a, 2019b), primarily due to the better preservation of the deposits of the former (Straus, 1990).

MSA sites from East Africa offer well-preserved stratigraphic sequences, which are essential to understanding technological and behavioral variability. The Aduma open-air site, in the Middle Awash region of Ethiopia (~90 ka), preserves a series of stratified open-air deposits with well-dated lithic assemblages that provide insights into technological organization during the late MSA (Yellen et al., 2005). Porc Epic Cave, in southeastern Ethiopia, is dated to ~70–60 ka and is notable for its large lithic assemblage and one of the richest MSA ochre collections in Africa (Pleurdeau, 2004, 2005; Leplongeon, 2014). Panga ya Saidi, a large rockshelter on the coastal margin of Kenya dated to ~78 ka, contains a long cultural sequence spanning the MSA–LSA transition, with evidence of symbolic behavior and diverse lithic technologies (Shipton et al., 2018). Goda Buticha, a cave site in southeastern Ethiopia dated to ~63–25 ka, has yielded rich faunal and lithic records illustrating shifts in subsistence and technological practices through time (Leplongeon et al., 2017).

Although research on eastern African MSA sites has expanded considerably, the archaeological record shows substantial technological variability rather than a single "typical" MSA pattern. Assemblages often differ significantly even within small regions, reflecting local adaptations and raw material constraints. This diversity has led some researchers to identify "generic" MSA assemblages in certain contexts, while recognizing a spectrum of period-specific technological traits across the region (Will and Scerri, 2024; Basell and Spinapolice, 2024; Shea, 2024).

In Tanzania, MSA occupations are recorded at numerous sites distributed across varied ecological settings, from rockshelters to open-air sites. These include Nasera rockshelter (Mehlman, 1989; Martín-Perea et al., 2020; Solano-Megías et al., 2020), Mumba rockshelter (Mehlman, 1989; Prendergast et al., 2007, 2014; Díez-Martín et al., 2009; Bushozi et al., 2020), Magubike rockshelter (Werner and Willoughby, 2017), Kisese II rockshelter (Tryon et al., 2018), Gordfani 2 rockshelter (Mehlman, 1989), and Sonjo Buri (Mehlman, 1989; Mabulla, 1996; Seitsonen, 2007), as well as open-air localities such as Isimila (Clark, 1988), the Ndutu area in the Serengeti (Mturi, 1976), some sites within the Lake Eyasi Basin (Mehlman, 1977; Mabulla, 1996; Domínguez-Rodrigo et al., 2007) or the Kilwa sites on the coast (Beyin and Ryano, 2020; Beyin et al., 2025). Collectively, these sites span much of the later Middle Pleistocene and Late Pleistocene and reflect the technological variability, raw material diversity, and adaptive strategies of human groups in the region.

Within the LMSA, several sites in Tanzania stand out for their well-defined chronologies and rich archaeological deposits. Mumba rockshelter, located in northern Tanzania about 50 km from Nasera, preserves a long stratigraphic sequence spanning from the MSA (~130–50 ka) into the Pastoral Neolithic, with evidence of lithic variability, human and faunal remains (Mehlman, 1989; Prendergast et al., 2007, 2014; Díez-Martín et al., 2009; Bushozi et al., 2020). Kisese II rockshelter in central Tanzania, dated to ~65 ka, has yielded stratified MSA and LSA deposits, including use of red ochre and ostrich eggshell beads among the earliest personal ornaments in the region (Tryon et al., 2018). Magubike rockshelter, in southern Tanzania, spans ~64–40 ka and contains well-preserved faunal remains, lithic assemblages, and ochre fragments, offering insights into late MSA subsistence strategies (Werner and Willoughby, 2017). Finally, Nasera rockshelter, in the Angata Kiti Basin of northern Tanzania, is dated to >60–50 ka and has produced MSA lithic assemblages alongside faunal remains that document environmental and behavioral changes during the later Pleistocene (Mehlman, 1989; Tryon and Faith, 2016; Ranhorn and Tryon, 2018; Martín-Perea et al., 2020; Solano-Megías et al., 2020).

In this context, Mumba and Nasera rockshelters play a key role in the description of the MSA for the northern Tanzania region. These sites are well-dated and contain extensive archaeological sequences with evidence of multiple industries that are critical for understanding the region (Bräuer and Mehlman, 1988; Mehlman, 1977, 1979, 1989; Prendergast et al., 2007; Marks and Conard, 2008; Díez-Martín et al., 2009; Tryon and Faith, 2016; Bushozi et al., 2020; Solano-Megías et al., 2020; Martín-Perea et al., 2020).

Does the so-called Kisele industry truly represent a coherent technological entity at least in part, a construct resulting from its characterization through a single analytical approach? To answer this question, we apply an alternative methodological framework that enables us to evaluate the validity and coherence of this definition, while providing a more precise characterization of the assemblage's technological variability. For this reason, this study presents a techno-typological reassessment of Level 22 at Nasera, originally excavated by Mehlman.This analysis is situated within the broader framework of the regional MSA, allowing direct comparison with other assemblages studied under comparable methodological parameters.

2. Nasera rockshelter

The Nasera rockshelter (Fig. 1) is one of the most representative Stone Age sites in northern Tanzania. Its stratigraphy contains levels ranging from the MSA to the Pastoral Neolithic. The MSA horizons at Nasera date to >60,900 ± 3,500 – 50,000 ± 3,900 years, the LSA to 50,000 ± 3,900 – 5,400 ± 150 years, and the Pastoral Neolithic to 2,060 ± 100 years. This stratigraphic sequence also provides valuable information on the transitions between these periods at the site (Mehlman, 1989; Martín-Perea et al., 2020).

The Nasera rockshelter is located on a large quartz-feldspar gneiss inselberg north of the Ngorongoro Conservation Area Authority (NCAA) referred to as Nasera Soit ('white stone' in the Masai language), and 27 km north of Olduvai Gorge. This large gneiss stands out in a striking way with respect to the Angata Kiti plains. Due to its predominance within the landscape, it was a magnificent location to settle on seasonally, as attested by its stratigraphy (Mehlman, 1989; Martín-Perea et al., 2020; Fig. 2a–c). Louis Leakey excavated the site in 1932, which he named Apis Rock (Leakey, 1936) (Fig. 2a). Here, Leakey noted the rich stratigraphy of the rockshelter, defining a sequence from the Upper Pleistocene to the Holocene. Based on the 100 m^2 he excavated over a month and a half, Leakey noticed a small problem: the shelter did not have matching stratigraphies in its eastern and western areas (Mehlman, 1977; Fig. 2a). Around 2500 artefacts were recovered during the 1930 s excavations, which today can be found in the Dar es Salaam National Museum (Tanzania) and the Nairobi National Museum (Kenya) (Mehlman, 1977, 1989).

Between 1975 and 1976, Michael Mehlman worked at the shelter over six months. In total, around 75 m^2 were excavated, in some trenches, reaching a depth of 9 m (Fig. 2). Mehlman identified a stratigraphic and cultural sequence slightly different from Leakey's (Mehlman, 1989). He also documented a total of 25 levels at the site: levels 25–18 (Kisele industry, MSA); levels 17–12 (also Kisele industry, MSA); levels 11–8/9 (Mumba industry, MSA-LSA); levels 6/7 (Nasera industry, MSA/LSA); levels 4/5 (Lemuta industry, LSA); level 3b (Silale industry, LSA); level 3B (Olmoti industry, LSA); and level 3A (Angata Kiti industry, Pastoral Neolithic).

The materials from these excavations were later revisited and re-

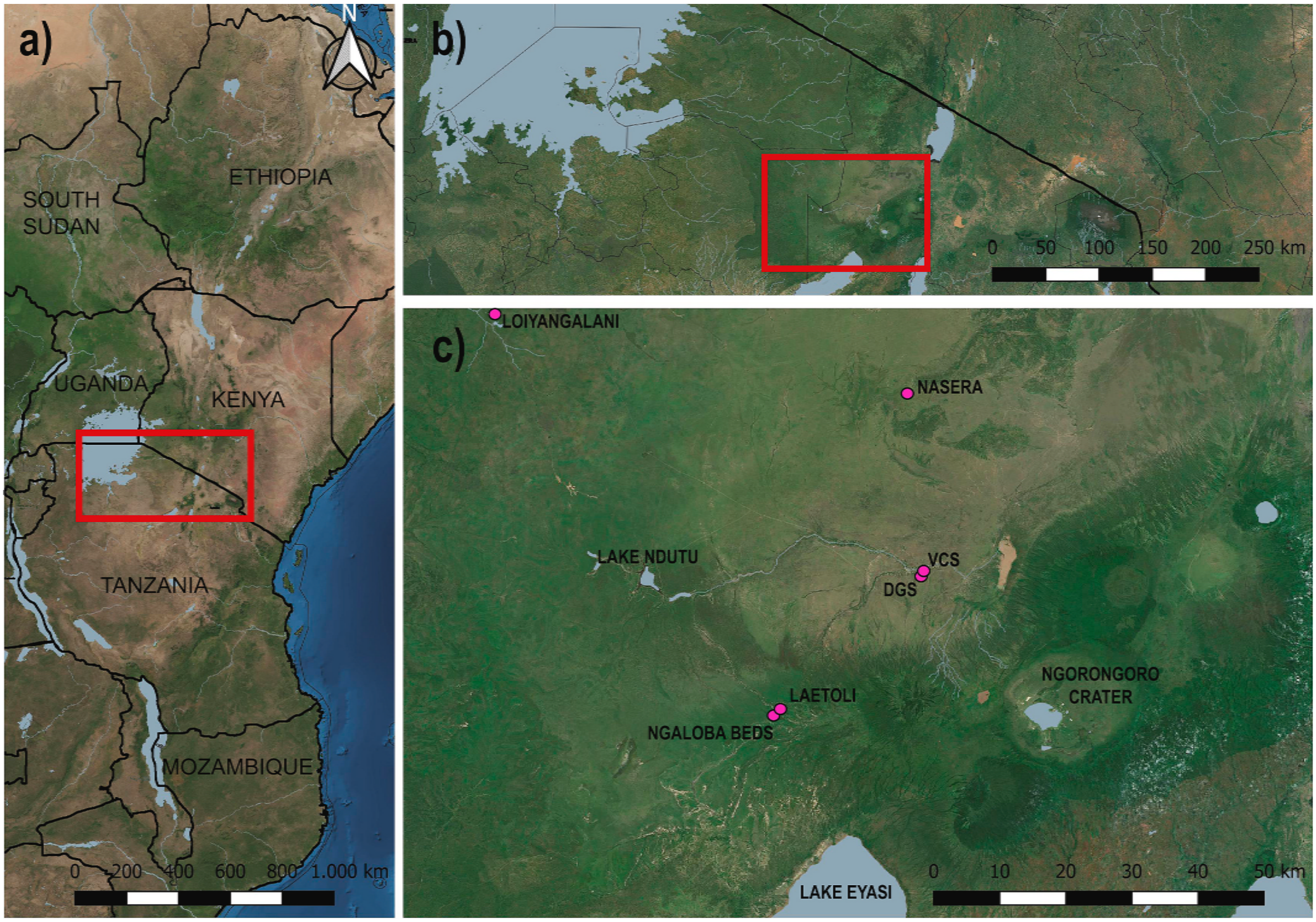

Fig. 1. Map of Northern Tanzania showing the geographical location of Nasera rockshelter.

examined, including the fauna (Tryon and Faith, 2016), the chronology (Ranhorn and Tryon, 2018), and the lithic industry (Bushozi, 2011; Solano-Megías et al., 2020). However, no further works were carried out until 2018 when our team began excavating at the site again and re-studying previously excavated materials (Martín-Perea et al., 2020, Solano-Megías et al., 2020).

The lower levels in the shelter (12–22) were classified as a Kisele-type MSA (Mehlman, 1989). The assemblages from levels 18–25 and 12–17 were combined to have a greater number of elements available when undertaking the techno-typological definition (Mehlman, 1989).

2.1. The Kisele industry

The Kisele industry is an MSA industry that chronologically dates between 108,200 ± 7,700–63,400 ± 5,700 / 55,960 ± 2,600 years ago (Mehlman, 1989; Gliganic et al., 2012; Bushozi et al., 2020). This industry has been documented at the sites of Mumba (Unit VIA), Nasera (levels 12–25), the Gordfani 2 rockshelter, and possibly at Sonjo Buri (Mehlman, 1989; Mabulla, 1996; Seitsonen, 2007).

It was techno-typologically characterized based on the Nasera and Mumba sites (Mehlman, 1989). It is defined by discoidal and peripheral knapping methods, with less frequent use of Levallois methods. The retouched pieces include unifacial and bifacial points, scrapers, and backed pieces, with quartz being the predominant raw material. Additionally, it has been noted that this industry is smaller in size compared to the preceding Sanzako and Njarasa industries (Mehlman 1989: 200). Mabulla (1996) corroborates Mehlman's definition but highlights the use of other local raw materials in addition to quartz. Similarly, Bushozi (2011) supports the same definition but emphasizes the role of retouched points, which account for 15 % at Mumba and 18 % at Nasera.

3. Materials and methods

The study of level 22 at Nasera presents several challenges. The primary issue stems from the fact that during Michael Mehlman's excavations in 1976–77, the level divisions were unclear, and so materials from various levels were merged at certain points. As a result, at the Olduvai Museum, some bags contained lithic pieces from different levels, making it impossible to determine their exact provenance. To ensure analytical accuracy, only the bags that clearly belonged to level 22 have been analyzed, and any materials with uncertain stratigraphic attribution were excluded from this study. In addition, some of the most significant artefacts, such as points, were taken to the USA and are currently not housed in the Olduvai Gorge Museum. However, drawings of some of these pieces are included in Mehlman's PhD dissertation (1989).

For this study we have only used material clearly attributed to level 22, supplemented by the pieces drawn by Mehlman that were physically inaccessible to us, to provide the clearest possible view of the level.

As a result, the assemblage we have analyzed comes from Mehlman's excavations in level 22 consists of 390 pieces housed at the Olduvai Museum, plus the 43 drawings included by Mehlman in his PhD thesis (Table 1). While we acknowledge the limitations of this study due to the physical absence of some of the pieces, as well as the potential biases introduced by past excavation and curation practices, we believe that it still allows for a meaningful techno-typological study. This approach is

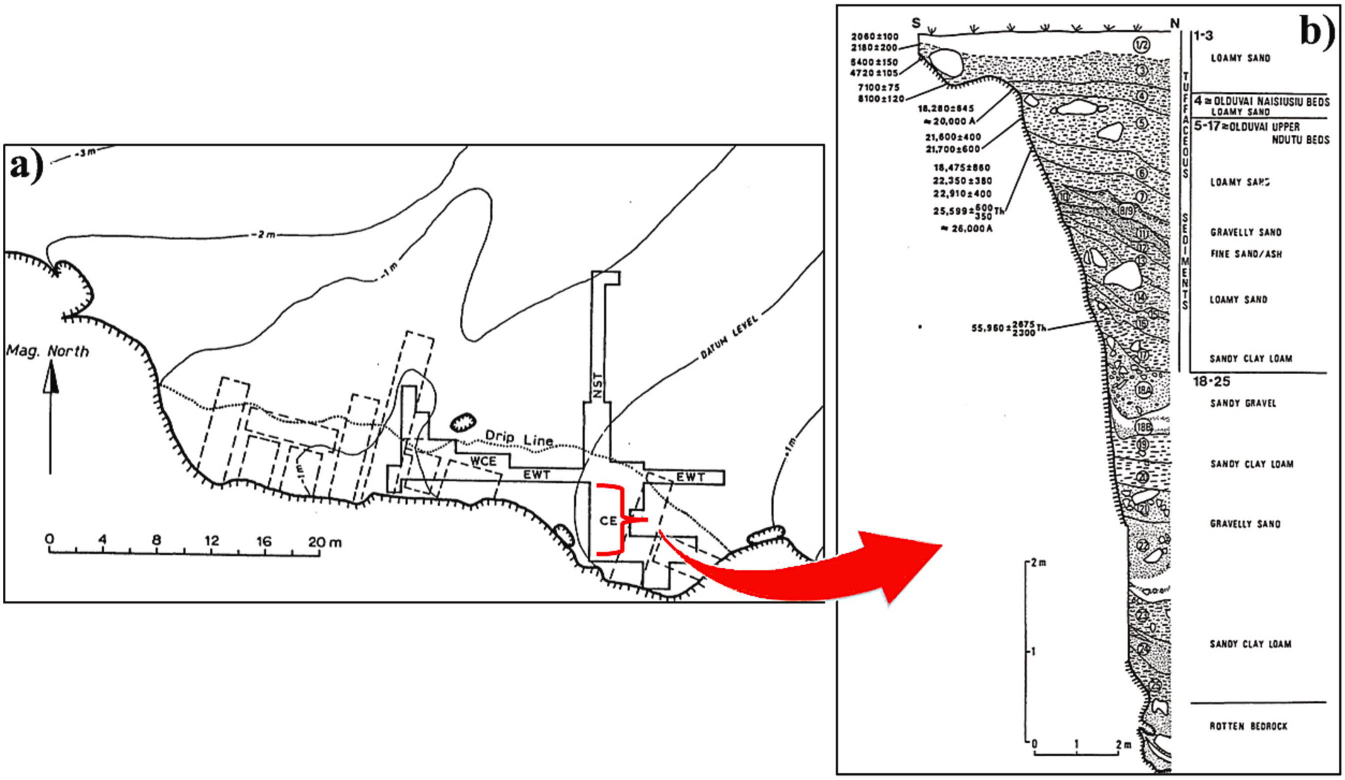

Fig. 2. Stratigraphic section from the CE trench. A) Plan of the Nasera Rockshelter excavations. Dotted lines represent Louis Leakey's excavation, whereas bold lines represent Michael Mehlman's excavation. B) Stratigraphic section at Nasera rockshelter profile CE trench made by Mehlman in 1976. A) and B) Taken and modified from Mehlman (1989).

Table 1
Total pieces from level 22 by raw material.

	Chert	Hyaline quartz	Limonite	Quartz	Quartzite	Obsidian	Sandstone	Total
Olduvai Museum	76	43	1	260	5	5	1	390 (90.07 %)
Mehlman drawings	9			33		1		43 (9.93 %)
Total	85 (19.63 %)	43 (9.93 %)	1 (0.23 %)	293 (67.44 %)	5 (1.15 %)	6 (1.39 %)	1 (0.23 %)	433 (100 %)

essential to understanding the characteristics of the Kisele industry from the Nasera rockshelter, ensuring that the analysis is based on material from a single level rather than a mixture of several.

The analysis of the lithic assemblage from level 22 at Nasera rockshelter was conducted using taphonomic, technological, and typological analysis criteria also applied to other sites in the region (Maíllo-Fernández et al., 2019a, 2019b, see Supplementary Information 1, 2, 3, 4 and 5). This methodology offers a unified framework that facilitates comparisons between different assemblages. While there is a wide variety of approaches to studying the diversity of approaches to studying the MSA lithic industry (Clark and Kleindienst, 1974; Merrick, 1975; Mehlman, 1989; Conard et al., 2004; Yellen et al., 2005; Shea, 2008), we believe that our technological, taphonomic and typological approach is well-suited to addressing our research questions, despite the challenges posed by the site formation processes and the history of excavation at Nasera.Unlike previous methodologies, which often combine technological and typological terms and tend to focus on retouched materials such as points, our approach maintains a clear distinction between these aspects, allowing for a more precise and comprehensive interpretation. By analyzing the material from a technological perspective, we aim to understand how and why the pieces were made, which enables us to explore questions related to manufacturing techniques, site use, and the human groups that inhabited the region. This methodology is adaptable to different lithic assemblages and encompasses both retouched and unretouched pieces, offering a broader and less biased perspective that facilitates meaningful comparisons between sites.

3.1. *Taphonomic analysis*

To properly interpret archaeological assemblages, it is essential to study the taphonomic modifications observed on the pieces, as these provide information on the formation processes of the assemblage. The analysis was conducted followed previous studies carried out as part of Solano-Megías' PhD project (Solano-Megías et al., 2020; Solano-Megías et al., 2024; Solano-Megías et al., in press) In this study, which is focused particularly on pseudo-retouch (Stapert, 1976; Thiébaut et al., 2010; Berlirán, 2014; Levi-Sala, 1986; McBrearty et al., 1998; Weitzel and Sánchez, 2021), porcelainization/abrasion (Shackley, 1978; Pedraza, 1996; Bernaldo de Quirós et al., 1981), rounding (Shackley, 1978; Bernaldo de Quirós et al., 1981), thermal extractions (Ahler, 1983; Luedtke, 1992; Fiers et al., 2021) and white patina (Schmalz, 1960; Röttlander, 1975; Stapert, 1976; Texier, 1981; Luedtke, 1992; Caux et al., 2018), among others [see Supplementary Information 1].

Each alteration provides specific data about the interactions of materials with their environment and its burial and deposit formation processes. Pseudo-retouch, linked to mechanical processes such as trampling or fluvial, wind, lacustrine, or marine movements, offers insights into material displacement and the possible formation of pseudotools (Stapert, 1976; Levi-Sala, 1986). On the other hand, porcelainization or abrasion can indicate surface wear resulting from sediment contact or heat exposure (Shackley, 1978; Pedraza, 1996). Rounding, often associated with mechanical movements or chemical processes of diagenetic dissolution, reveals the loss of edge sharpness (Shackley, 1978; Bernaldo de Quirós et al., 1981).

Finally, thermal extractions and white patina reflect more specific environmental factors. Thermal extractions, caused by heat exposure or freeze–thaw cycles, leave characteristic marks on artifacts (Ahler, 1983; Luedtke, 1992). Meanwhile, white patina, exclusive to chert, results from chemical alterations in high pH soils, producing a whitening effect on the material (Schmalz, 1960; Röttlander, 1975; Texier, 1981; Caux et al., 2018). Detailed analysis of these modifications enhances the understanding of taphonomic processes and their impact on archaeological assemblages.

3.2. Technological analysis

The analysis of the assemblage was conducted using previously published technological criteria (Maíllo-Fernández et al., 2019a, 2019b).

The technological analysis is carried out based on the chaîne opératoire concept, which provides a comprehensive understanding of the lithic economic system tailored to each lithic assemblage (Inizan et al., 1995; Karlin, 1992; Karlin et al., 1992; Audouze and Karlin, 2017; Bar-Yosef and Van Peer, 2009). This approach allows us to infer human behavior by studying the operational schemes, defining technological strategies, examining the raw material economy, and understanding the purpose and management of the lithic artifacts (Pelegrin et al., 1988; Geneste, 1991; Perlès, 1992).

The study of the lithic assemblage from level 22 at Nasera has been conducted by combining qualitative and quantitative analyses of individual piece characteristics such as: raw material; measurements; presence/absence of platform and cortex; knapping accidents; number of scars, etc. [see Supplementary Information 2]. For pieces showing retouch, the analysis included the type, technique, depth and location of the retouch. Additionally, cores have been examined based on their morphology, knapping method, flake type (flake/blade or bladelet), dimensions (length and width), and the measurements of the last extraction (Geneste, 1985; Maíllo-Fernández, 2003) [see Supplementary Information 2 and 3].

The results are presented based on the different débitage concepts identified, and which are commonly found in MSA assemblages: discoid (Boëda, 1993, 1995; Terradas, 2003; Mourre, 2003), Levallois (Boëda et al., 1990; Boëda, 1994, 1995; Tryon et al., 2005), single platform (Fuertes-Prieto, 2004; Delagnes and Roche, 2005), centripetal (Kuhn, 1995; Mourre, 2003), bipolar (Díez-Martín et al., 2011; de la Peña and Wadley, 2014; de la Peña, 2015a, 2025b; Yeşilova et al., 2024) and kombewa (Owen, 1938; Balout et al., 1967; Tixier et al., 1980; Boëda, 2013) [see Supplementary Information 5].

3.3. Typological analysis

The typological approaches to MSA lithic assemblages in East Africa and across the continent vary widely (Mehlman, 1989; Clark and Kleindienst, 2001; Douze, 2012; Shea, 2008, 2020; Will and Scerri, 2024), making direct comparisons challenging at times. Therefore, we chosen to categorize the retouched pieces into broad typological groups: sidescrapers, denticulates, notches, endscarpers, burins, points, retouched points, etc. [see Supplementary Information 4]. Generally, these types of groups can be identified across different sites, regardless of the specific typological framework used.

3.4. Statistical analysis

To delve deeper into the techno-typological characteristics of the lithic assemblage studied here, we considered it important to perform statistical analyses to assess its degree of similarity with other sites in the area. Thus, we used the different technological categories of the knapping methods and the typology of the retouched tools from the assemblage studied here to compare it with the sites of Mumba (levels VI-A Lower, VI-A Upper, VI-B Middle and Upper) and Nasera (levels 12–17, 18–25) (Mehlman, 1989; Solano-Megías et al., 2024).

For the comparison, we employed the percentage values [see Supplementary Information 9] of the various techno-typological categories in their assemblages to avoid sites with significantly more remains having greater weight in the analyses. Percentages were calculated separately for the technological and typological categories.

First, we conducted a principal component analysis (PCA), including the contribution of each variable to better understand the data distribution. Then, we generated a dendrogram to evaluate how the assemblages group together. Dendrograms were assessed using the Manhattan, Euclidean, and Maximum methods, and for each of these three types, we evaluated the single, complete, average, centroid, ward.d, and maximum methods. The selected dendrogram was the one that produced the highest cophenetic correlation [see Supplementary Information 10], i.e., the one closest to the value of 1. The number of clusters in the dendrogram was determined using an average silhouette method.

Both the PCA and the dendrogram were created using the ‘factoextra’ library (Kassambara and Mundt, 2020) in R, version 4.1.3 (R Core Team, 2022).

4. Results

The assemblage analyzed from Level 22, combined with the illustrations presented in Mehlman’s PhD dissertation, forms the basis of our study (Table 1).

The technological assemblage presents a wide variety of raw materials, predominantly fine-grained, including quartz, chert, and hyaline quartz. Quartz is the most frequently used raw material at the site (67.44 %), followed by chert (19.63 %), hyaline quartz (9.93 %), obsidian (1.39 %), and quartzite (1.15 %), among others (Table 1).

The remaining raw materials are coarser-grained and less abundant, each accounting for less than 1 %. These include limonite (0.23 %) and sandstone (0.23 %), which are the only materials with significantly coarser grain compared to the others (Table 1).

The primary sources of the most commonly used raw materials, such as quartz, chert, and hyaline quartz, are found in the hills surrounding the rockshelter. Quartz veins have even been found on the Nasera Soit itself. Chert primarily originates from Olduvai Gorge, though other types of chert with unknown origins have also been identified. Researchers like Mehlman have suggested that some of the chert used at Nasera rockshleter could have come from the Lake Natron region (Mehlman, 1989). Obsidian, though rare, is also present and originates from Lake Naivasha in Kenya (Mehlman, 1989). Additionally, the type of cortex observed on the material indicates that the blanks used for knapping were predominantly pebbles.

The raw material percentages from level 22 at Nasera rockshelter align with those observed in levels 8/9, 10 and 11 at this same site, which date to the early stages of the LSA (Solano-Megías et al., 2020).

Of the 433 pieces in the collection, 59.35 % (n = 257) are fractured (Table 2; Fig. 3; see Supplementary Information 6). Quartz is the most commonly fractured raw material, followed by chert and hyaline quartz. Bending is the most common cause (42.96 %), likely related to the knapping processes or, to a lesser extent, to the inherent properties of the raw materials, such as quartz, which contains numerous internal fractures. Percussion-induced fractures are rare (4.85 %), whereas natural (1.39 %) and thermal fractures (0.92 %) are infrequent and incidental (see Supplementary Information 6).

The presence of cortex in the assemblage suggests that core reduction from the initial stages of decortication did not occur at the site, as only 5.13 % of the pieces have fully cortical surfaces, and 18.2 % are only

Table 2
Fracture pieces by raw material. In parentheses the pieces drawn in Mehlman's PhD (1989).

	Chert	Hyaline quartz	Limonite	Quartz	Quartzite	Obsidian	Sandstone	Total
Fractured pieces	49 (+4)	26		163 (+9)	1	4	1	257
No fractured pieces	27 (+5)	17	1	97 (+24)	3	2		176
Total	85	43	1	293	4	6	1	433

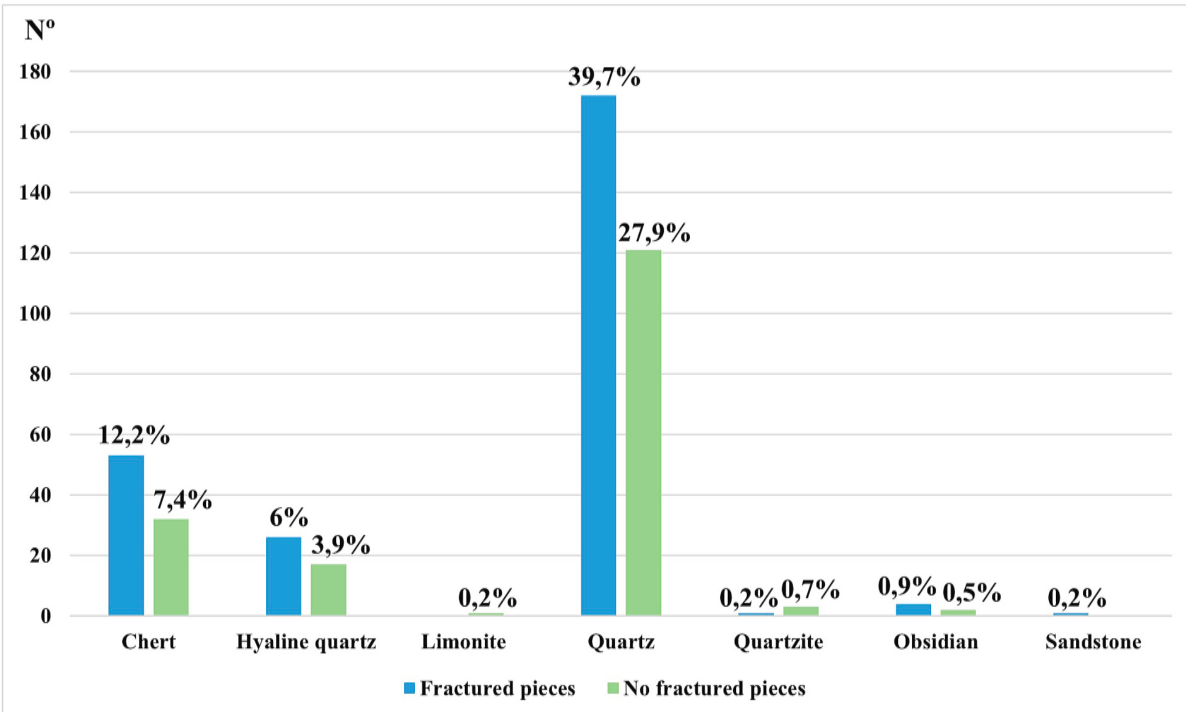

Fig. 3. Bar chart with fractured and non-fractured pieces grouped according to raw material.

partially (Table 3). Chert and quartz are the raw materials with the most cortex remnants, although most pieces across all raw materials lack cortex entirely. This indicates that most of the cores at the site were partially decorticated elsewhere, away from the site.

4.1. Taphonomic results

The lithic assemblage shows that 53.08 % of the pieces exhibit taphonomic alterations (Table 4). Pseudo-retouch is the most common alteration, occurring in 37.95 % of the pieces, with varying degrees: marginal pseudoretouch (31.03 %), and deep pseudoretouch (6.92 %) (Table 4). This mechanical modification can result from trampling due to natural processes or triggered by human activity. Given the limited extent of alteration and pseudo-retouch, we can conclude that the material has not experienced significant post-depositional displacement. Additionally, the fact that much of the pseudo-retouch is located on the edges suggests it may even be linked to macro use wear.

The remaining alternations account for less than 5 % of the total of the assemblage. Rounding is the second most frequent alteration, present in 4.36 % of the pieces, with varying degrees: marginal rounding (3.85 %), deep rounding (0.26 %), and very deep rounding (0.26 %) (Table 4). This alteration is also of mechanical origin, caused by the movement and rubbing of the pieces against the sediment. While some displacement of the pieces cannot be ruled out, it does not appear to have been significant.

Porcelainization is the third most common alteration, found in only 2.56 % of the assemblage, followed by thermal extractions (2.05 %) and cracking (1.54 %) (Table 4). These alterations are all closely associated with the use of fire, either through direct or indirect exposure affecting the pieces or the raw material blanks from which they were made. Since these alterations do not appear to be related to the knapping process and show no evidence of polish (which would suggest intentional heating), we can conclude that the alterations observed on these pieces are likely the result of unintentional exposure to fire, possibly due to proximity to hearths.

White patina is found exclusively on chert pieces. This alteration is

Table 3
Presence of cortex in the pieces.

	Chert	Hyaline quartz	Limonite	Quartz	Quartzite	Obsidian	Sandstone	Total
I	12			6	2			20 (5.13 %)
IIa	3	1		4				8 (2.05 %)
IIb	4			9	1			14 (3.59 %)
IIc	16	4		29				49 (12.56 %)
III	41	38	1	212	1	5	1	299 (76.67 %)
Total	76 (19.49 %)	43 (11.03 %)	1 (0.26 %)	260 (66.67 %)	4 (1.03 %)	5 (1.28 %)	1 (0.26 %)	390 (100 %)

Table 4
Taphonomic alterations.

Taphonomic alteration	N	% each alteration	% total collection
Marginal white patina (DS1)	0	0.0	0.0
Deep white patina (DS2)	0	0.0	0.0
Very deep white patina (DS3)	7	100	1.79
Total piece white patina (DS4)	0	0.0	0.0
Total white patina	*7*	*100*	*1.79*
Porcelained	10	100	–
Total porcelained	*10*	*100*	*2.56*
Marginal pseudoretouch (PY)	121	81.76	31.03
Deep pseudoretouch (PM)	27	18.24	6.92
Very deep pseudoretouch (PR)	0	0.0	0.0
Total pseudoretouch	*148*	*100*	*37.95*
Cracked	6	100	–
Total cracked	*6*	*100*	*1.54*
Marginal rounding (RD1)	15	88.24	3.85
Deep rounding (RD2)	1	5.88	0.26
Very Deep rounding (RD3)	1	5.88	0.26
Total rounding	*17*	*100*	*4.36*
Thermal extractions	8	100	–
Total thermal extractions	*8*	*100*	*2.05*
Calcine	3	100	–
Total calcine	*3*	*100*	*0.77*
Dehydrated	4	100	–
Total dehydrated	*4*	*100*	*1.03*
Patina	3	100	–
Patina	*3*	*100*	*0.77*
Total pieces with alterations	207	100	*53.08*

present to a highly developed degree ('very deep'). It is only minimally represented within the assemblage (1.79 %), which suggests that the material was altered because of its contact with the alkaline soils and water (Table 4).

Other alterations, such as dehydration, calcination, and patina, have been documented within the assemblage, but they are rare and barely representative (Table 4).

Chips are very scarce in the assemblage (n = 21; Table 5), which could be explained by several factors: 1. During the 1976 and 1977 excavations, chips may not have been collected or only those that were identifiable were gathered; 2. knapping may not have taken place at the site, as knapping typically produces a larger number of chips than what has been found in level 22 at Nasera (Maíllo-Fernández, 1998); and 3. chips may have been displaced by taphonomic phenomena, such as wind or light runoff. Since we lack sufficient data to support the first hypothesis, and the second is unlikely given that most of the assemblage reflects instances of complete exploitation of the core, the third explanation seems the most plausible.

4.2. Technological analysis

For the analysis of level 22 at Nasera rockshelter, several challenges must be considered, including questions about the collection's integrity, as some pieces were taken to the USA (Mehlman, 1989) and are therefore not currently housed at the Olduvai Gorge Museum, where the rest of the collection is stored (see Solano-Megías et al., 2020).

As previously noted, M. Mehlman studied levels 18–25 at Nasera collectively, and some of the bags contained material from two separate levels. While this did not impact Mehlman's combined analysis (1989), it affects our study, as we have only analyzed materials that can be definitely attributed to level 22 (Table 5).

Therefore, the assemblage from level 22 excavated by M. Mehlman and which we have studied consists of a total of 390 pieces, along with six additional pieces with this information published by Mehlman (1989) (Total = 396; Table 5). The assemblage includes products representing different stages of the chaîne opératoire (Table 5), documenting knapping methods typical of the MSA such as the discoid, Levallois, single platform, bipolar, and, though very scarcely, the laminar.

4.2.1. Discoid knapping methods

The pieces associated with discoid methods are the most abundant in the assemblage, totaling 69 pieces (15.94 % of the total, Supplementary Information 7) (Fig. 4). Of the 69 pieces, five are cores and 64 are flakes (Table 6). The most commonly used raw material in the discoid pieces is quartz (85.50 %), followed by hyaline quartz (7.25 %), with chert being more marginal (5.80 %) (Table 6). Notably, all the raw materials used are fine-grained.

Among the cores, four are discoid bifacial and one is a unifacial discoid fragment, all knapped on quartz except for one specimen, whose raw material is unknown as Mehlman does not specify it in his drawing (Mehlman 1989:238–239). Three of these cores are drawings published by Mehlman, while the other two we were able to analyze in person, and these are described below.

The average dimensions of the cores are 36x31x23 mm. Of the two cores we examined (one bifacial and one unifacial core fragment), we were only able to identify the knapping blank of the bifacial discoid core, which was a plaquette. The bifacial discoid core, knapped on quartz, shows residual cortex and preparation of the striking surface. Six removals, all centripetal in direction, were observed, with the last removal being a flake measuring 24x22 mm (length x width).

On the other hand, the unifacial discoid fragment, knapped on quartz, shows no cortical, and there is evidence of preparation prior to knapping. Only two centripetal removals were observed, the last being a 12x15 mm (length x width) flake. The core was abandoned due to a fracture, which made further knapping impossible.

The knapping products (n = 69) account for 14.78 % of the total assemblage. The identified discoid flakes include 43 centripetal flakes (62.32 %; Fig. 4a and b, g, i), 17 chordal flakes (24.64 %; Fig. 4c, f), 3 pseudo-Levallois points (4.35 %; Fig. 4d and e,h); and 1 tangential centripetal flake (1.45 %) (Table 6; Supplementary Information 8). Most of these flakes were knapped from quartz (n = 59), hyaline quartz (n = 5), and chert (n = 4) (Table 6). The absence of cortex on the discoid flakes is notable, with 89.39 % of the pieces lacking cortical, while only 10.60 % exhibit it marginally (Table 7). The platforms show a range of types: plain (45.31 %), dihedral (23.44 %), rectilinear facetted (7.81 %), convex facetted (3.13 %); cortical (3.13 %), filiform (1.56 %) and punctiform (1.56 %). Additionally, 7.81 % platforms were broken and 6.25 % lacked a platform altogether (Table 8). The number of previous scars on the dorsal surface of the discoid flakes ranges between one and six, whereas the direction of these scars is primarily proximal (37.50 %), centripetal (34.38 %), and proximo-lateral (17.19 %) (Table 9; Table 10), all in line with the typical dynamics observed for this method (Boëda, 1993; Mourre, 2003; Terradas, 2003).

4.2.2. Levallois knapping methods

Levallois methods represent the second most common operational scheme in the assemblage, comprising 28 pieces (6.47 % of the total collection) Supplementary Information 7) (Fig. 5). Of these, 4 are cores and 24 are flakes (Tabla 6). The most commonly used raw materials are quartz (46.34 %), chert (42.86 %), and hyaline quartz (10.71 %) (Tabla 6). This suggests a preference for certain fine-grained raw materials for Levallois débitage, especially chert and hyaline quartz.

The four Levallois cores are represented by two Levallois recurrent

Table 5
Level 22 pieces by identified raw material. In parentheses the pieces drawn in Mehlman's PhD (1989).

Technological clasification/Raw material	Chert	Hyaline quartz	Limonite	Quartz	Quartzite	Obsidian	Sandstone	Total
Unknapped cobble/block				2			1	3 (0.76 %)
Entame flake	3			2	1			6 (1.52 %)
Cortical flake with no cortical platform	6							6 (1.52 %)
Cortical blade with no cortical platform				1				1 (0.25 %)
Naturally backed knife	2			4				6 (1.52 %)
Debordant flake	1	1		2				4 (1.01 %)
Débitage preparation flake	12	2		5				19 (4.8 %)
Pseudolevallois point	1			2				3 (0.76 %)
Cordal flake	2	1		14				17 (4.29 %)
Ordinary flake	18	17		104	1	4	1	145 (36.62 %)
Single platform flake	1	2		13				16 (4.04 %)
Bipolar platform flake		6		1				7 (1.77 %)
Bipolar method flake				1				1 (0.25 %)
Centripetal flake		4		39				43 (10.86 %)
Centripetal tangential flake	1							1 (0.25 %)
Preferential Levallois flake		1		1				2 (0.51 %)
Unipolar recurrent Levallois flake	2			5				7 (1.77 %)
Centripetal recurrent Levallois	2			1				3 (0.76 %)
Levallois indet.	5			3				8 (2.02 %)
Ordinary blade				1				1 (0.25 %)
Ordinary bladelet	2			1				3 (0.76 %)
Indet. Fragment			1					1 (0.25 %)
Core	3 (+2)	1		10 (+4)				20 (5.05 %)
Retouched chip	6	4		2				12 (%)
Knapped chip	1					1		2 (0.51 %)
Termal chip	7							7 (1.77 %)
Chunk	1	3		41				45 (11.36 %)
Hammerstone				4				4 (1.01 %)
Anvil					2			2 (0.51 %)
Unknapped piece				1				1 (0.25 %)
Total	78 (19.70 %)	42 (10.61 %)	1 (0.25 %)	264 (66.67 %)	4 (1.01 %)	5 (1.26 %)	2 (0.51 %)	396 (100 %)

centripetal specimens (Fig. 5c, e), one Levallois unipolar (Fig. 5d) and one Levallois indeterminate. Two have been produced on Olduvai chert, one on quartz, and one on hyaline quartz. The average dimensions of these cores is 30x24x10mm. The blanks for three of the four cores are pebbles, whereas one of them could not be identified. Cortex is only found marginally on two of the cores, whereas one presents a fully cortical striking surface. This is linked to the fact that only one core (recurrent centripetal Levallois) shows preparation of the striking surface, whereas on the others, if there ever was, it has not been preserved. The exploitation of the recurrent centripetal cores is intense, with 11 and 6 scars in two of the cases (Fig. 5c, e), whereas on the other two cores the exploitation is less intense, with only two removals in each, some linked to the unipolar exploitation system (Fig. 5). The direction of these removals are centripetal and proximal. In three of the four cores, the final removals are flakes averaging 17x17 mm each, whereas it was not possible to identify the last removal on the indeterminate Levallois core.

Of the Levallois pieces, 24 are flakes, representing 5.54 % of the total collection. The identified flakes include 8 indeterminate Levallois flakes (28.57 %); 7 recurrent unipolar flakes (25 %); 4 débordant flakes (14.29 %, Fig. 5f and h); 2 Preferential Levallois flakes (7.14 %, Fig. 5g); and 3 Centripetal Recurrent flakes (10.71 %, Fig. 5i) (Table 6, Supplementary Information 8). The Levallois flakes were primarily knapped from quartz (n = 12), chert (n = 10), and hyaline quartz (n = 2) (Table 6). None of the Levallois flakes exhibit cortex (n = 24) (Table 7). The platforms of these flakes are consistent with this method: convex facetted (41.67 %); rectilinear facetted (25 %); and dihedral (8.33 %). Plain platforms were also documented (12.5 %), while 12.5 % showed no striking platform due to breakage (Table 8). Most Levallois flakes display two, three, and four previous scars (Table 9), with proximal (45.83 %), centripetal (29.17 %), proximo-lateral (20.83 %), and convergent (4.17 %) directions (Table 10).

4.2.3. Single platform knapping methods

The single platform method is the third most abundant in the assemblage, with a total of 26 pieces, representing 6 % of the collection (Supplementary Information 7). Of the 26 pieces, 4 are cores and 22 flakes (Table 6). A total of 24 pieces were analyzed in person, with two additional pieces illustrated in Mehlman's PhD dissertation (Mehlman 1989:234–235; 239–238). All documented raw materials are fine-grained, and well-suited for knapping, with quartz being the most commonly used raw material (76.92 %), followed by chert (15.38 %), and hyaline quartz (7.69 %) (Table 6).

Of the four cores, two are illustrated in Mehlman's PhD thesis, whereas the other two were analyzed in detailed by us. Three of the cores were knapped from quartz, and one from chert. The two cores we analyzed were both knapped on quartz. In one core, the knapping blank (a pebble) was identifiable, while it could not be determined in the other. Cortex is present only marginally on one of the cores. Notably, only one of the cores showed preparation. Two removals were documented on one core and four on the other, all unipolar in direction, with the final removals producing flakes averaging 14x9 mm.

Of the 22 flakes documented (representing 5.08 % of the total assemblage; see Supplementary Information 8), most were produced from quartz (n = 17), with the remainder knapped from chert (n = 3) and hyaline quartz (n = 2) (Table 6; Supplementary Information 8). Half of the flakes show no cortical (n = 11), whereas the rest (n = 11) present it in a residual way (Table 7). The flake platforms from the single platform methods are predominantly plain (68.18 %), with a smaller proportion being dihedral (9.09 %) (Table 8). The flakes show between one and four previous scars (Table 9), with most having proximal direction (90.91 %) (Table 10).

4.2.4. Bipolar knapping methods

Although rare, bipolar methods are still present in the assemblage. A total of 11 bipolar pieces have been identified: two cores and nine flakes, accounting for 2.54 % of the total assemblage (see Supplementary Information 7). The two cores are drawings by M. Mehlman (1989: 234–235). The most frequently used raw material for these methods is hyaline quartz (63.64 %), followed by quartz (27.27 %), and chert (9.09 %) (Table 6).

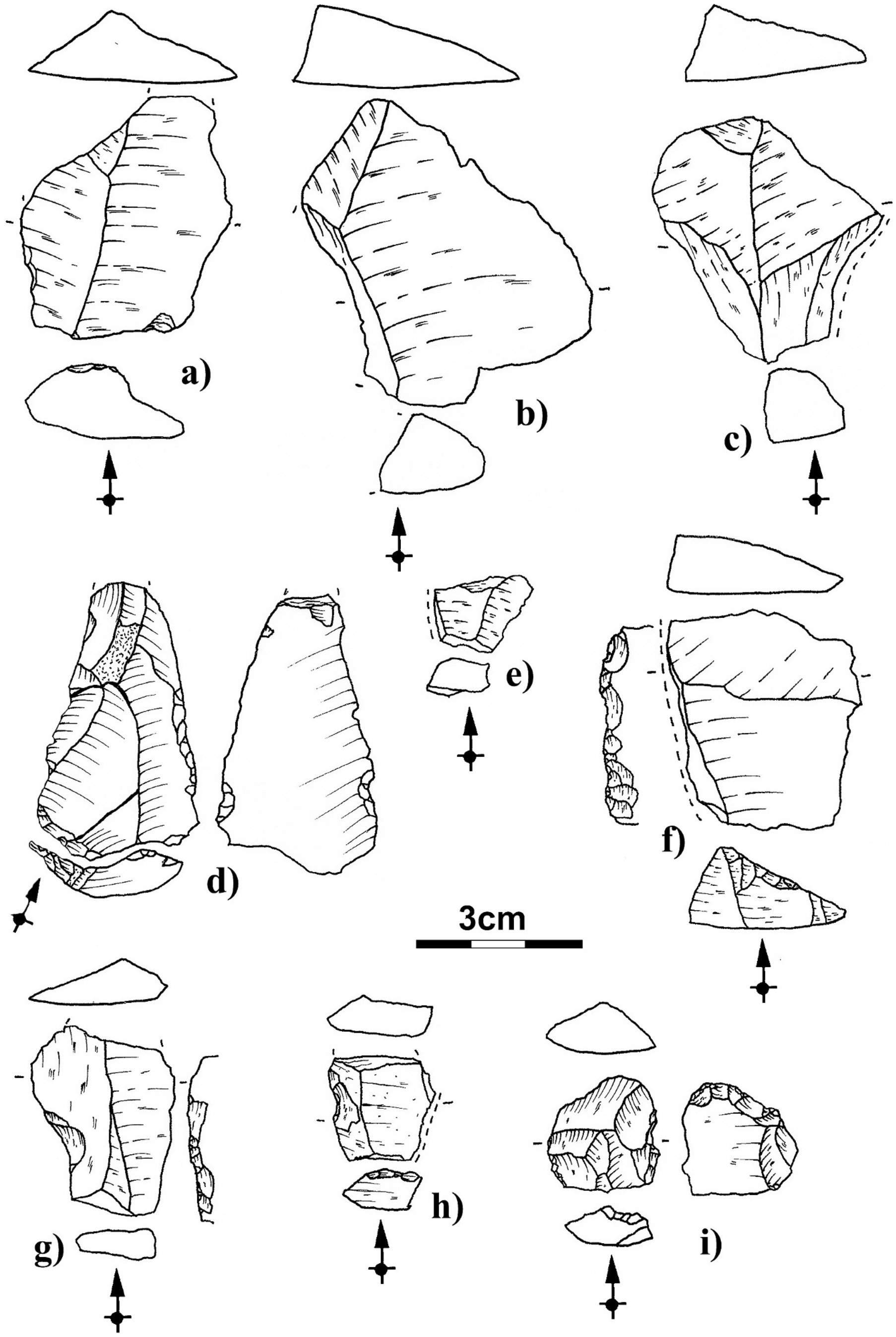

Fig. 4. Discoid-method pieces. a-b, g, i: Centripetal flake; c, f: Chordal flake; d-e,h,: Pseudolevallois point. Raw materials: Quartz: a-c, e-g; Chert: d; Hyaline quartz: h-i. Retouched tools: Point: d; Retouched blank: f,i; Notch: g.

Of the 9 flakes, 7 were knapped from hyaline quartz and 2 from quartz (see Supplementary Information 8). Most of the flakes (n = 7; 77.78 %) show no cortical, whereas two (22.22 %) have it only marginally (Table 7). The platforms are classified as edges (44.44 %), cortical (22.22 %), plain (11.11 %), and 2 flakes (22.22 %) presented a proximal fracture, making it impossible to determine its platform type (Table 8). The previous scars on the dorsal surfaces of these flakes range between one and four (Table 9), presenting proximal (44.45 %), bipolar (22.22 %) and proximo-lateral (11.11 %) directions (Table 10).

4.2.5. Other knapping methods

Other methods have also been observed, although only marginally, but which are still worth noting (Tables 6, 7, 8, 9 and 10; see Supplementary Information 7 and 8).

Laminar methods (prismatic core type) have been identified from one blade and three bladelets. Two of these (50 %) were knapped from Olduvai chert, and the other two (50 %) from quartz (Table 6). None of these pieces presented cortex (Table 7). The blade and bladelet lacked platforms due to proximal fractures, whereas the remaining bladelets featured a dihedral platform on one and a plain platform on the other (Table 8). On the dorsal surface, the blade had two previous scars, while the bladelets showed between two and three (Table 9), all unidirectional (Table 10). Notably, prismatic cores used for laminar exploitation are completely absent from the assemblage, raising questions about whether these pieces should be classified within the single-platform type schemes.

Table 6
Raw material by knapping methods. In parentheses the pieces drawn in Mehlman's PhD (1989).

Débitage/Raw material	Chert	Hyaline quartz	Quartz	Indet	Total
Discoid method					
Cordal flake	2	1	14		17 (24.64 %)
Pseudolevallois point	1		2		3 (4.35 %)
Centripetal flake		4	39		43 (62.32 %)
Centripetal tangential flake	1				1 (1.45 %)
Discoid core			2 (+2)	(+1)	5 (7.25 %)
Total	4 (5.80 %)	5 (7.25 %)	59 (85.50 %)	1 (1.45 %)	69 (100 %)
Centripetal method					
Centripetal core	0		2		2 (100 %)
Total	0 (0 %)		2 (100 %)		2 (100 %)
Levallois method					
Debordant flake	1	1	2		4 (14.29 %)
Preferential Levallois flake	0	1	1		2 (7.14 %)
Unipolar recurrent Levallois flake	2		5		7 (25 %)
Centripetal recurrent Levallois	2		1		3 (10.71 %)
Levallois indet.	5		3		8 (28.57 %)
Levallois core	2	1	1		4 (14.29 %)
Total	12 (42.86 %)	3 (10.71 %)	13 (46.43 %)	0 (0 %)	28 (100 %)
Bipolar method					
Bipolar platform flake		7	2		9 (81.82 %)
Bipolar core	(+1)		(+1)		2 (18.18 %)
Total	1 (9.09 %)	7 (63.64 %)	3 (27.27 %)	0 (0 %)	11 (100 %)
Kombewa method					
Kombewa core	1				1 (100 %)
Total	1 (100 %)	0 (0 %)	0 (0 %)	0 (0 %)	1 (100 %)
Single platform method					
Backed knife	2		4		6 (23.08 %)
Single platform flake	1	2	13		16 (61.54 %)
Single platform core	(+1)		2 (+1)		4 (15.38 %)
Total	4 (15.38 %)	2 (7.69 %)	20 (76.92 %)	0 (0 %)	26 (100 %)
Blade method					
Blade	0		1		1 (25 %)
Bladelet	2		1		3 (75 %)
Total	2 (50 %)	0 (0 %)	2 (50 %)	0 (0 %)	4 (100 %)
Total	24 (17.02 %)	17 (12.06 %)	99 (70.21 %)	1 (0.71 %)	141 (100 %)

Centripetal cores are rare in the assemblage, represented by only two examples knapped from quartz (Table 6). Identifying pieces associated with these cores has been challenging, as they tend to resemble discoid products or ordinary flakes, making their distinction difficult.

The two centripetal cores we have identified exhibit a circular morphology, with centripetal extractions and a completely exhausted final flake removal surface, resulting in a flat shape. This last configuration and the angles of the surfaces lead us to classify them as centripetal cores in the later stages of reduction (Kuhn, 1995; Mourre, 2003; Fuertes Prieto 2004, 2006). Lastly, there is one Kombewa core made of Olduvai chert (Table 6). The core features one entirely cortical face and only two unipolar flake removals on the flake surface. No Kombewa flakes have been identified.

From a typometric perspective (Fig. 6), we confirmed that the greater length and width correspond to ordinary flakes. Regarding the flakes associated with the identified operational schemes, the Levallois flakes tend to follow a pattern of greater length and width with minimal thickness, as expected for this type of piece. Pieces from the single platform schemes show a high length and shorter width, undoubtedly linked to the morphology of this débitage, which favors the production of elongated blanks, including blades and bladelets. The discoid pieces display a similar length-to-width ratio with greater width, consistent with the square and thick characteristics typical of this type of piece (Mourre, 2003; Terradas, 2003).

In terms of raw materials, typometric observations were only feasible for chert, quartz, and hyaline quartz due to their greater number of pieces. We observe that the pieces with the greatest length, width, and thickness are made from chert, which is, on average, considerably larger than the rest of the raw materials (Fig. 7.). Quartz, being the most abundant raw material, also shows large dimensions, with widths and thicknesses comparable to those of chert. Lastly, hyaline quartz exhibits the smallest dimensions, which may be linked to the size of the original nodules.

From this perspective, we can conclude that there appears to be a raw material economy (*sensu* Perlès, 1992) with chert, with bigger-sized pieces. Furthermore, the metric characteristics of the different débitage methods align with the size of the pieces: Levallois pieces are elongated, wide and thin; single platform pieces are relatively long and narrow; and discoid pieces are square and thick.

4.3. Typological analysis

A total of 62 retouched pieces have been identified in the assemblage (Table 11 and Table 12). It is important to note that only 29 of these retouched pieces were physically analyzed, as they were found in the collection housed at the Olduvai Gorge Museum. The remaining pieces were documented based on M. Mehlman's PhD drawings (1989).

The retouched pieces represent 14.31 % of the total collection. The predominant raw material is quartz (69.35 %), followed by chert (17.74 %), and hyaline quartz (11.29 %); a very small number of obsidian

Table 7
Presence of cortex by knapping methods.

Débitage/Raw material	I	IIa	IIb	IIc	III	Total
Discoid method						
Cordal flake				3	14	17 (25.76 %)
Pseudolevallois point					3	3 (4.55 %)
Centripetal flake				2	41	43 (65.15 %)
Centripetal tangential flake				1		1 (1.52 %)
Discoid core				1	1	2 (3.03 %)
Total	0 (0 %)	0 (0 %)	0 (0 %)	7 (10.60 %)	59 (89.39 %)	66 (100 %)
Centripetal method						
Centripetal core				2		2 (100 %)
Total	0 (0 %)	0 (0 %)	0 (0 %)	2 (100 %)	0 (0 %)	2 (100 %)
Levallois method						
Debordant flake					4	4 (14.29 %)
Preferential Levallois flake					2	2 (7.14 %)
Unipolar recurrent Levallois flake					7	7 (25 %)
Centripetal recurrent Levallois					3	3 (10.71 %)
Levallois indet.					8	8 (28.57 %)
Levallois core	1			2	1	4 (14.29 %)
Total	1 (3.57 %)	0 (0 %)	0 (0 %)	2 (7.14 %)	25 (89.29 %)	28 (100 %)
Bipolar method						
Bipolar platform flake				2	7	9 (100 %)
Total	0 (0 %)	0 (0 %)	0 (0 %)	2 (22.22 %)	7 (77.78 %)	9 (100 %)
Kombewa method						
Kombewa core	1					1 (100 %)
Total	1 (100 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	1 (100 %)
Single platform method						
Backed knife			1	5		6 (25 %)
Single platform flake			3	2	11	16 (66.67 %)
Single platform core			1		1	2 (8.33 %)
Total	0 (0 %)	0 (0 %)	5 (20.83 %)	7 (29.17 %)	12 (50 %)	24 (100 %)
Blade method						
Blade					1	1 (25 %)
Bladelet					3	3 (75 %)
Total	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	4 (100 %)	4 (100)
Total	2 (1.49 %)	0 (0 %)	5 (3.73 %)	20 (14.93 %)	107 (79.85 %)	134 (100 %)

pieces were also retouched (1.61 %) (Table 11).

Sidescrapers dominate the assemblage, accounting for 32.26 % (Fig. 8d, Fig. 5h). Points are present, but less common, including bifacial (16.13 %, Fig. 9d–m) and unifacial points (4.84 %, Fig. 9a–c). Denticulates (Fig. 8b, d–e) and retouched flakes each make up 11.29 %, (Fig. 4f, i; Fig. 5e and i; Fig. 8c), while notches represent 9.68 % (Fig. 4g, Fig. 8: 7). Additionally, there are other MSA pieces in smaller quantities, such as bifacial pieces (6.45 %, Fig. 8a), becs, endscrapers, and pointed pieces, the latter being quite rare (1.61 % each, Fig. 4d) (Table 11).

The majority of the retouched pieces are found on ordinary flakes (27.42 %). Blanks from specific methods are less common: discoid (8.06 %), Levallois (6.45 %), bipolar (3.23 %), and single platform (1.61 %, Table 12).

Overall, there is a selection of retouched blanks, these being bigger pieces in all three dimensions than the non-retouched (Fig. 10.).

Fig. 11 shows that quartz is the most commonly retouched raw material, accounting for 9.9 %, followed by chert at 2.5 %, and hyaline quartz at 1.6 %. Obsidian, while present, is very marginal at 0.2 % (Fig. 11). Notably, chert is proportionately more retouched compared to the other raw materials, reinforcing the earlier observation of a differentiated raw material economy for chert (Fig. 11).

4.4. Statistical analysis

Principal Component Analysis (PCA) helped us identify key patterns in the techno-typological variability of the lithic assemblages. The first two dimensions explained 65.6 % of the total variation, indicating a good representation of the data in two-dimensional space. Dim1 (39.4 %) separates the assemblages based on the prevalence of Levallois cores, discoid/centripetal/peripheral cores, denticulates, and notches, which are associated with the Kisele industry. Meanwhile, Dim2 (26.2 %) highlights opportunistic cores, heavy-duty tools, flakes with hafting notches, and points.

In the plot, Kisele industry assemblages (Mumba VI-A Lower and Upper, Nasera levels 12–17 and 18–25) tend to cluster closely, reflecting technological similarities. In contrast, Sanzako industry assemblages (Mumba VI-B Middle and Upper) are differentiated by a greater emphasis on more robust and/or bigger technologies.

In the PCA, This study is positioned far from levels traditionally associated with the Kisele industry, such as Mumba VI-A Lower and Upper and Nasera levels 12–17 and 18–25. This is mainly because the assemblage is proportionally smaller, as previously indicated, due to the mixing of levels in Nasera. Although This study belongs to the Kisele industry, its separation could be explained by several key factors. Firstly, the presence of Kombewa cores, notches, and denticulates, which were not analyzed or categorized by Mehlman, significantly influences its position in dimensional space. Additionally, Mehlman observed tools such as backed pieces, composite tools, and heavy-duty implements in

Table 8
Platform type by knapping methods.

Flake type/Platform type	Cortical	Dihedral	Edge	Filiform	Rectilinear facetted	Convex facetted	Plain	Punctiform	Broken	No platform	Total
Discoid method											
Cordal flake		2		1	3	1	9	1			17 (26.56 %)
Pseudolevallois point		1					2				3 (4.69 %)
Centripetal flake	2	12			2	1	18		5	3	43 (67.19 %)
Centripetal tangential flake										1	1 (1.56 %)
Total	2 (3.13 %)	15 (23.44 %)	0 (0 %)	1 (1.56 %)	5 (7.81 %)	2 (3.13 %)	29 (45.31 %)	1 (1.56 %)	5 (7.81 %)	4 (6.25 %)	64 (100 %)
Levallois method											
Debordant flake						1	1			2	4 (16.67 %)
Preferential Levallois flake					1	1					2 (8.33 %)
Unipolar recurrent Levallois flake					2	4	1				7 (29.17 %)
Centripetal recurrent Levallois		1				1				1	3 (12.5 %)
Levallois indet.		1			3	3	1				8 (33.33 %)
Total	0 (0 %)	2 (8.33 %)	0 (0 %)	0 (0 %)	6 (25 %)	10 (41.67 %)	3 (12.5 %)	0 (0 %)	0 (0 %)	3 (12.5 %)	24 (100 %)
Bipolar method											
Bipolar platform flake	2		4				1			2	9 (100 %)
Total	2 (22.22 %)	0 (0 %)	4 (44.44 %)	0 (0 %)	0 (0 %)	0 (0 %)	1 (11.11 %)	0 (0 %)	0 (0 %)	2 (22.22 %)	9 (100 %)
Single platform method											
Backed knife							3		1	2	6 (27.27 %)
Single platform flake		2	1				12			1	16 (72.73 %)
Total	0 (0 %)	2 (9.09 %)	1 (4.55 %)	0 (0 %)	0 (0 %)	0 (0 %)	15 (68.18 %)	0 (0 %)	1 (4.55 %)	3 (13.64 %)	22 (100 %)
Blade method											
Blade										1	1 (25 %)
Bladelet		1					1			1	3 (75 %)
Total	0 (0 %)	1 (25 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	1 (25 %)	0 (0 %)	0 (0 %)	2 (50 %)	4 (100 %)
Total	4 (3.25 %)	20 (16.26 %)	5 (4.07 %)	1 (0.81 %)	11 (8.94 %)	12 (9.76 %)	49 (39.84 %)	1 (0.81 %)	6 (4.88 %)	14 (11.38 %)	123 (100 %)

Mumba VI-A Lower and Upper and Nasera levels 12–17 and 18–25, which we did not find in Nasera level 22.

We also observe that methodological differences and classification criteria for tools may have contributed to this separation, as our studied assemblages are located on the left side of the graph, while those studied by Mehlman are on the right. Overall, the divergent position of this study in the PCA does not invalidate its association with the Kisele industry but instead highlights the need to review methodological differences when studying various assemblages to account for variations within the same lithic industry.

The hierarchical clustering analysis, represented by the dendrogram, complemented the PCA by organizing the assemblages according to their techno-typological similarity. Using Euclidean distances and the average linkage method, three main groups ($k = 3$) were identified, confirmed by a high cophenetic correlation coefficient (0.9644), indicating that the model faithfully reflects the relationships between the data. The dendrogram shows a clear division between the assemblages associated with the Kisele (blue) and Sanzako (green and yellow) industries, emphasizing the internal consistency within each group as well as the marked differences between them.

Assemblages from the Kisele industry, including This study, Mumba VI-A Lower and Upper, and Nasera levels 12–17 and 18–25, form a well-defined group. These assemblages are characterized by a high proportion of discoid cores, Levallois cores, single-platform cores, and points. On the other hand, Mumba VI-B Middle and Upper levels, representing the Sanzako industry, cluster separately. This industry shows an

Table 9
Scar number in pieces by knapping methods.

Flake type/Scar number	1	2	3	4	5	6	8	Indet	Total
Discoid method									
Cordal flake	1	9	3	1	1	1		1	17 (26.56 %)
Pseudolevallois point		1	1					1	3 (4.69 %)
Centripetal flake	1	12	14	11	3			2	43 (67.19 %)
Centripetal tangential flake					1				1 (1.56 %)
Total	2 (3.13 %)	22 (34.38 %)	18 (28.13 %)	12 (18.75 %)	5 (7.81 %)	1 (1.56 %)	0 (0 %)	4 (6.25 %)	64 (100 %)
Levallois method									
Debordant flake			1	2			1		4 (16.67 %)
Preferential Levallois flake				1			1		2 (8.33 %)
Unipolar recurrent Levallois flake		4	3						7 (29.17 %)
Centripetal recurrent Levallois			1	2					3 (12.5 %)
Levallois indet.		2	5	1					8 (33.33 %)
Total	0 (0 %)	6 (25 %)	10 (41.67 %)	6 (25 %)	0 (0 %)	0 (0 %)	2 (8.33 %)	0 (0 %)	24 (100 %)
Bipolar method									
Bipolar platform flake	1	5	1	2					9 (100 %)
Total	1 (11.11 %)	5 (55.56 %)	1 (11.11 %)	2 (22.22 %)					9 (100 %)
Single platform method									
Backed knife	5	1							6 (27.27 %)
Single platform flake	1	8	6	1					16 (72.73 %)
Total	6 (27.27 %)	8 (40.91 %)	6 (27.27 %)	1 (4.55 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	22 (100 %)
Blade method									
Blade		1							1 (25 %)
Bladelet		1	2						3 (75 %
Total	0 (0 %)	2 (50 %)	2 (50 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	4 (100 %)
Total	9 (7.32 %	44 (35.77 %)	37 (30.08 %)	21 (17.07 %)	5 (4.07 %)	1 (0.81 %)	2 (1.63 %)	4 (3.25 %)	125 (100 %)

Table 10
Scar direction by pieces and knapping methods.

Flake type/Scar direction	Bipolar	Centripetal	Proximal	Convergent	Lateral	Proximo-lateral	Indet	Total
Discoid method								
Cordal flake		4	8		2	2	1	17 (26.56 %)
Pseudolevallois point				1	1	1		3 (4.69 %)
Centripetal flake		17	16	1		8	1	43 (67.19 %)
Centripetal tangential flake		1						1 (1.56 %)
Total	0 (0 %)	22 (34.38 %)	24 (37.50 %)	2 (3.13 %)	3 (4.69 %)	11 (17.19 %)	2 (3.13 %)	64 (100 %)
Levallois method								
Debordant flake		1				3		4 (16.67 %)
Preferential Levallois flake		2						2 (8.33 %)
Unipolar recurrent Levallois flake			6			1		7 (29.17 %)
Centripetal recurrent Levallois		2		1				3 (12.5 %)
Levallois indet.		2	5			1		8 (33.33 %)
Total	0 (0 %)	7 (29.17 %)	11 (45.83 %)	1 (4.17 %)	0 (0 %)	5 (20.83 %)	0 (0 %)	24 (100 %)
Bipolar method								
Bipolar platform flake	2		4			1	2	9 (100 %)
Total	2 (22.22 %)	0 (0 %)	4 (44.45 %)	0 (0 %)	0 (0 %)	1 (11.11 %)	2 (22.22 %)	9 (100 %)
Single platform method								
Backed knife			6					6 (27.27)
Single platform flake	1		14			1		16 (72.73 %)
Total	1 (4.55 %)	0 (0 %)	20 (90.91 %)	0 (0 %)	0 (0 %)	1 (4.55 %)	0 (0 %)	22(100 %)
Blade method								
Blade			1					1 (25 %)
Bladelet			3					3 (75 %
Total	0 (0 %)	0 (0 %)	4 (100 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	4 (100 %)
Total	3 (2.44 %)	29 (23.58 %)	63 (51.22 %)	3 (2.44 %)	3 (2.44 %)	18 (14.63 %)	4 (3.25 %)	123 (100 %)

emphasis on discoid, opportunistic, and Levallois core reduction methods, as well as denticulates, notches, and scrapers.

5. Discussion

Level 22 at Nasera reflects a human occupation from which several techno-typological observations can be drawn. Firstly, the industry is

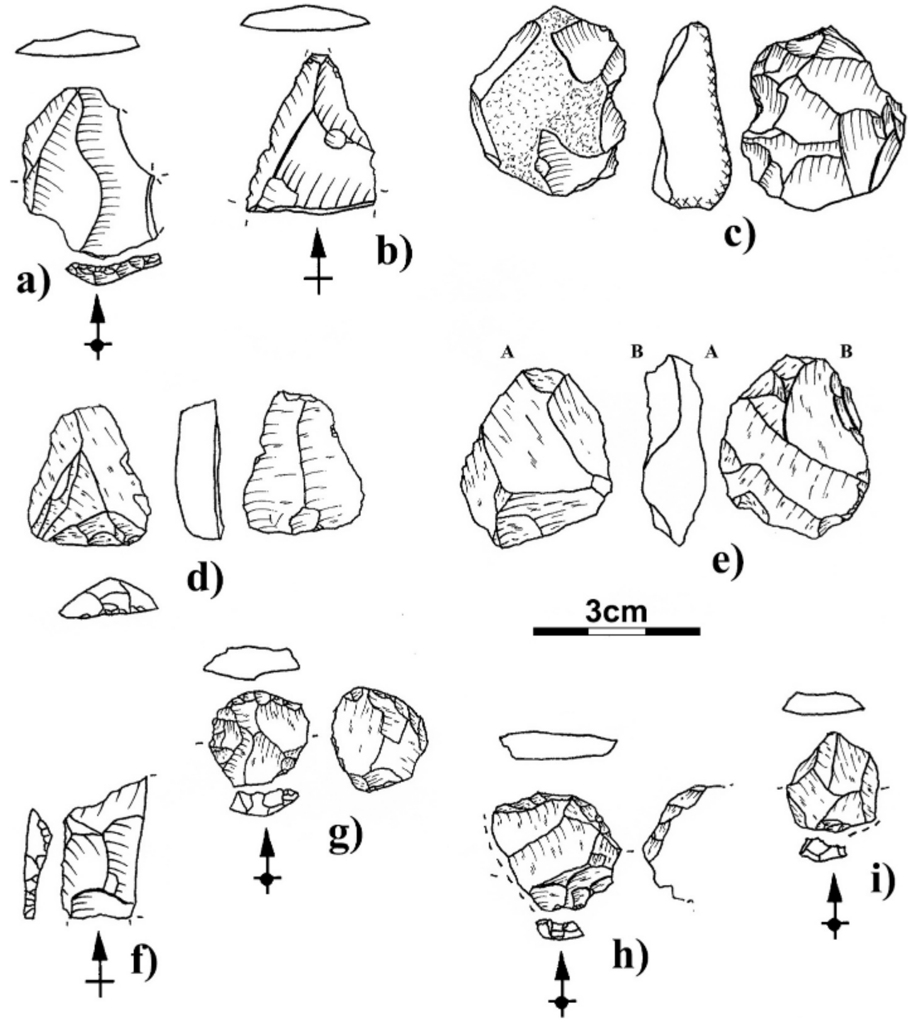

Fig. 5. Levallois-method pieces. a-b,i: Centripetal Recurrent Levallois flakes; c, e: Centripetal recurrent Levallois cores; d: Unipolar Levallois core; f: Debordant flake; g-h: Preferential Levallois flake. Raw materials. Chert: a-c, f; Hyaline quartz: d, g, h; Quartz: e, i. Retouched tools: Sidescraper: h.

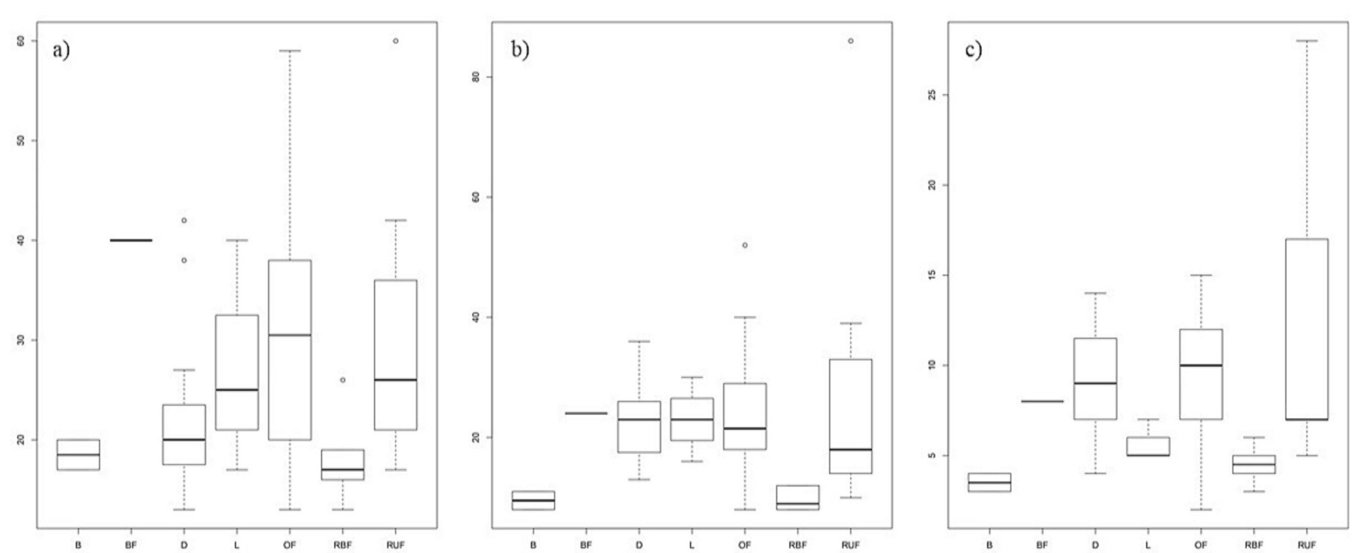

Fig. 6. Typometries. a) Length vs. knapping method; b) Width vs. knapping method; c) Thickness vs. knapping method. CODES: B = Bladelet; BF = Bipolar flake; D = Discoid flake; L = Levallois flake; OF= Ordinary flake; RBF = Recurrent bidirectional flake; RUF = Recurrent unidirectional flake.

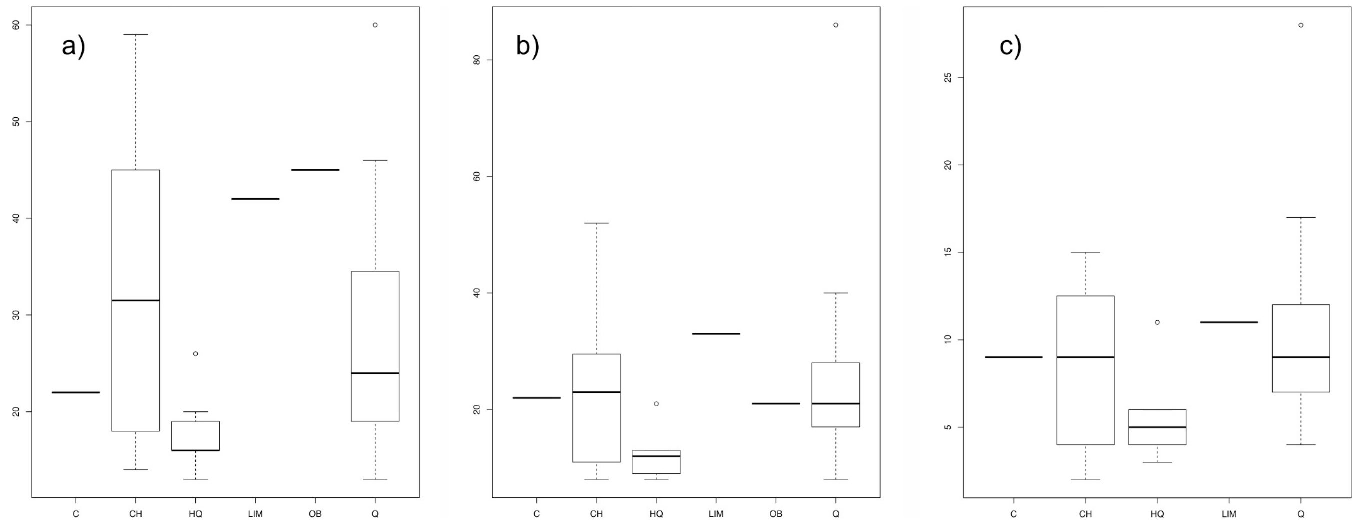

Fig. 7. Tipometries. a) Length vs. raw material; b) Width vs. raw material; c) Thickness vs. raw material. CODES: BC = Beige chert; CQ = Quartzite-Quartz; HQ= Hyaline quartz; IC = Indet chert; Lim = Limonite; OB= Obsidian; OC= Olduvai Chert; Q = Quartz; QC = Quartz.quartzite.

Table 11
Retouched pieces and raw material. In parentheses the pieces drawn in Mehlman's PhD (1989).

Type	Chert	Hyaline quartz	Quartz	Obsidian	Total
Bec		1			1 (1.61 %)
Bifacial piece			1 (+3)		4 (6.45 %)
Denticulate	3	1	3		7 (11.29 %)
Notch		2	4		6 (9.68 %)
Flake with hafting notches			1		1 (1.61 %)
Sidescraper	1 (+2)	2	1 (+13)	(+1)	20 (32.26 %)
Endscraper			(+1)		1 (1.61 %)
Retouched flake	2	1	4		7 (11.29 %)
Point	1				1 (1.61 %)
Unifacial point			(+3)		3 (4.84 %)
Bifacial point	(+1)		(+9)		10 (16.13 %)
Pointed piece	1				1 (1.61 %)
Total	11 (17.74 %)	7 (11.29 %)	43 (69.35 %)	1 (1.61 %)	62 (100 %)

clearly MSA, characterized by discoid production and dominated by sidescrapers and points, both bifacial and unifacial.

The raw materials are locally sourced, with quartz (65.4 %) being the most abundant, and readily available in the surrounding area and even within the rockshelter itself. This raw material is used across all the operational schemes described. On the other hand, the only non-local raw material (*sensu* Geneste, 1985) found within a radius of less than 30 km is the chert from Olduvai. The remaining raw materials are present in very small numbers, but the presence of obsidian (1.39 %) is noteworthy. Its origin has been tracked to Lake Naivasha in Kenya, approximately 240 km from the site (Merrick and Brown, 1984; Merrick et al., 1994; Mehlman, 1989). Some researchers propose obsidian sources at Monduli, 140 km east of Nasera (Bushozi et al., 2020), although this has yet to be confirmed.

This distribution of obsidian from the Lake Naivasha basin can also be observed at the site of Mumba, which has occupations contemporary to Nasera's level 22, suggestions a potential north–south axis of contact between human groups during the MSA. Furthermore, these same routes can be traced in late MSA or early LSA levels at Lake Nyanza (Lake Victoria) and Lake Baringo basin (Faith et al., 2015; Mant-Melville et al., 2022; Hoare et al., 2020; Blegen, 2017; Blegen et al., 2021). The presence of obsidian from the Lake Naivasha basin at both Nasera and Mumba suggests its integration within a regional exchange network, consistent with the concept of "exchange networks" proposed by Knappett (2013). These networks facilitated the movement of materials like obsidian over significant distances, with a north–south axis potentially connecting diverse human groups during the MSA. Such networks were likely dynamic, serving not only practical needs but also fostering cultural and symbolic exchanges (Sauvet, 2019). Following Binford's (1982) model, the Naivasha region could represent a peripheral or visiting zone for groups at Nasera and Mumba or vice versa, linked through sporadic but significant intergroup interactions. Furthermore, the presence of obsidian at later MSA and early LSA levels at Lake Nyanza and Lake Baringo reinforces the idea of a broader, stable social territory, where interactions transcended subsistence requirements. This aligns with Whallon's (2006) concept of "non-utilitarian mobility" and Wiessner's (2002) observations on social bonds formed through resource sharing and dispersal. Consequently, the distribution of obsidian highlights the intricate interplay between material exchanges, social networks, and shared cultural practices in the Middle and Late Stone Age. The reasons behind this phenomenon may be multifactorial, including climatic changes, famines, migrations of herbivores, or social relationships, between others. One significant factor is the necessity for intergroup connections, especially if low population levels resulted from the Toba supereruption, as suggested by Ambrose (1998).

Techno-typologically, as noted, the discoid methods, both the unifacial and bifacial, and the presence of points, were the key reasons why M. Mehlman (1989) classified this level as Kisele industry (specifically, levels 18–25 at the site, combined). These levels, along with levels 12–17 at Nasera and Mumba VIA (Upper and Lower), dated between 108 ka BP and 50 ka BP (Bushozi et al., 2020; Martín-Perea et al., 2020), represent this industry in northern Tanzania (Mehlman, 1989). Additional, smaller collections, such as Gordfani 2 or Sonjo Buri (Mabulla, 1996; Seitsonen, 2007), have been included alongside these original

Table 12
Retouched pieces.

Type	Discoid	Levallois	Bipolar	Single platform flake	Ordinary flakes	Mehlman drawings	*Total*
Bec					1		1 (1.61 %)
Bifacial piece					1	3	4 (6.45 %)
Denticulate					7		7 (11.29 %)
Notch	3		1		2		6 (9.68 %)
Flake with hafting notches					1		1 (1.61 %)
Sidescraper		2	1		1	16	20 (32.26 %)
Endscraper						1	1 (1.61 %)
Retouched flake	1	2			4		7 (11.29 %)
Point	1						1 (1.61 %)
Unifacial point						3	3 (4.84 %)
Bifacial point						10	10 (16.13 %)
Pointed piece				1			1 (1.61 %)
Total	5 (8.06 %)	4 (6.45 %)	2 (3.23 %)	1 (1.61 %)	17 (27.42 %)	33 (53.23 %)	62 (100 %)

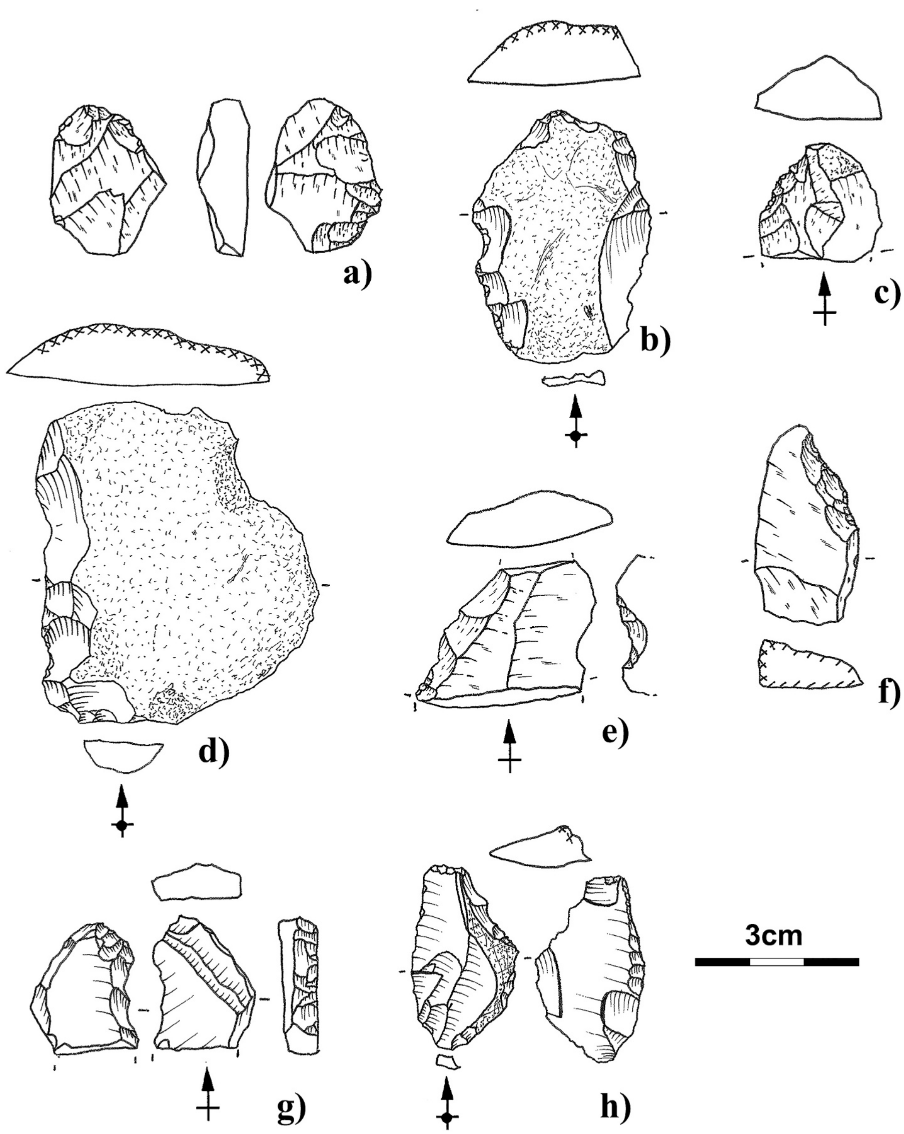

Fig. 8. Retouched pieces. Bifacial piece: a; Denticulate: b, d, e; Sidescraper: c; Abrupt retouched piece: f; Composite tool: g (notch + backed); Pointed piece: h. All on ordinary flakes. Raw materials: Quartz: a, c, e-f; Chert: b, d, g-h.

levels. Kisele is characterized by the presence of non-standardised "scrapers", a significant proportion of retouched points (around 13 %), and a low occurrence of heavy duty pieces. Technologically speaking, the operational schemes involved prepared cores *sensu lato*, with "radial" (discoid and Levallois) methods being the most common, and bipolar methods rare (Mehlman, 1989).

The retouched blanks represent approximately 14 % (n = 62) of the total assemblage at Nasera 22. Comparable percentages have been

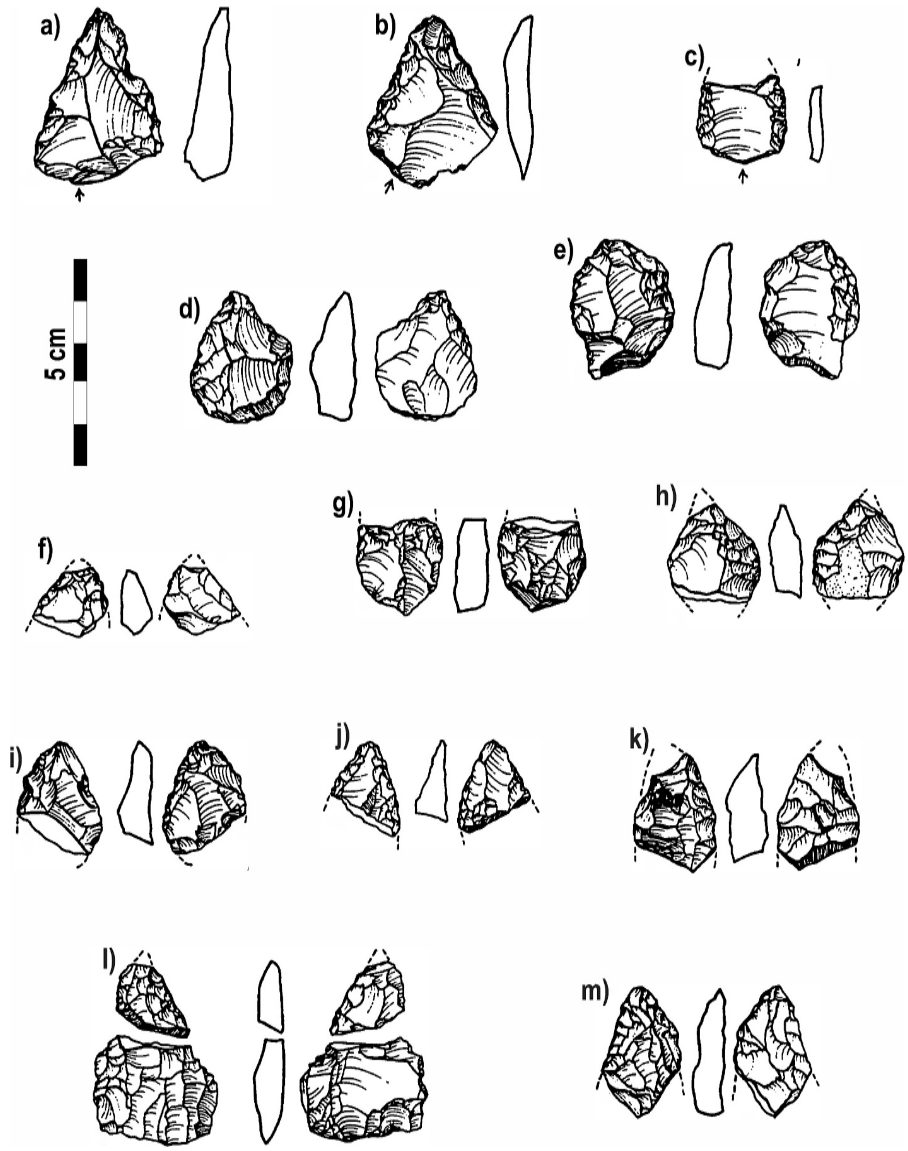

Fig. 9. Points drawn in M. Mehlman's PhD (1989). a) – c) unifacial points on chert; d)-h); j)-m) bifacial points on quartz; i) bifacial tip on chert. (Modified from Mehlman, 1989: 212–215).

reported for the Kisele and Sanzako industries at Mumba (Tryon and Faith, 2013), although in our study the Sanzako assemblage shows no more than 9 % (Solano-Megías et al., 2024). Recent excavations at Loiyangalani also yielded similar values, with 13.7 % (Maíllo-Fernández et al., 2019a). By contrast, older excavations often report higher proportions. At Kisese II, for example, pit XX yielded 34 %, pit XXII 31 %, and pit XV 42.5 % of retouched pieces (Tryon et al., 2018). Likewise, at Mlambalasi in Iringa, recent excavations revealed 56 % in pit 90–100 and 59 % in pit 110–120 (Willoughby, 2012). The proportion of retouched artifacts in a lithic assemblage may result from several factors, including recovery bias, site function, spatial distribution, and raw material use. Nevertheless, it seems clear that earlier excavations tend to report higher percentages of retouched pieces, most likely because of selective collection practices.

Broadly speaking, from a qualitative perspective, the assemblage of Nasera 22 aligns well with the characteristics described for the Kisele industry, although our study allows us to refine and update the information for this level. Firstly, it provides evidence of an intense occupation at the site, based on the number of remains and the 60 ka. sedimentary package, located at a depth of more than two meters. Furthermore, we examine the role played by the discoid operational schemes (methods and flakes) and dissect the concept of "Peripherically worked cores" (Mehlman, 1989: 142). We identify these types of cores and flakes using the terminology currently employed in the debate on the regional MSA. For example, we separate Mehlman's "disc core" type into recurrent centripetal Levallois and unifacial discoid.

Technologically, we can conclude that discoid methods are much more common than the Levallois, with the latter being applied more frequently to raw materials with fewer internal fractures, such as chert. Additionally, it is important to highlight that single platform methods are nearly as common as the Levallois, as we were able to identify not only the cores, but also part of their flake production.

These data allow us to compare earlier studies on the Kisele industry, observe the structural dynamics of the Kisele industry in relation to earlier industries like the Sanzako (Solano-Megías et al., 2024), and evaluate how more recently excavated sequences can be incorporated into the broader framework of the regional MSA. Despite falling within Kisele's chronological range, and even closer to Nasera 22, these newer sequences show significant differences. This is evident at sites like Loiyangalani in the Serengeti (Bower and Mabulla, 2012; Maíllo-

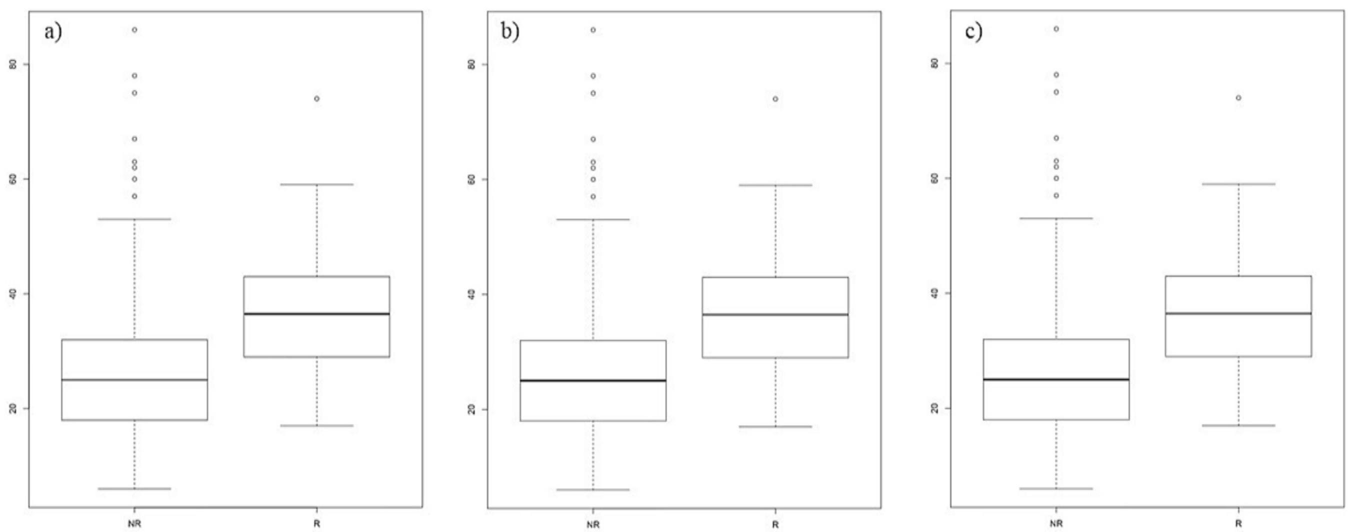

Fig. 10. Typometries. a) Retouched and non-retouched pieces vs. length; b) Retouched and non-retouched pieces vs. width; c) Retouched and non-retouched pieces vs. thickness. CODES: R = Retouched; NR= Non-retouched.

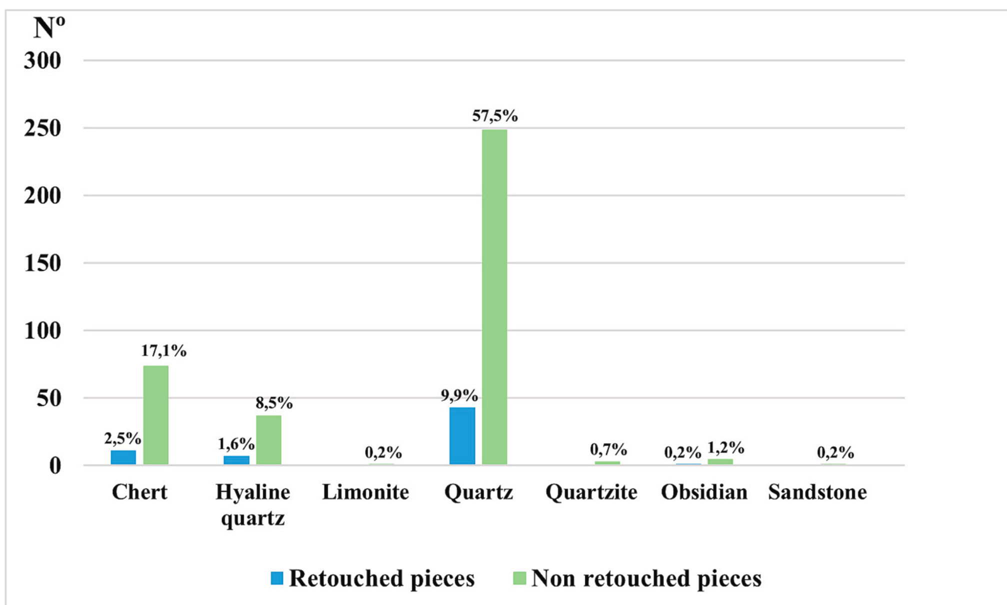

Fig. 11. Bar chart with retouched and non-retouched pieces by raw material.

Fernández et al., 2019a) and DGS and VCS at Olduvai Gorge (Maíllo-Fernández et al., 2019b, 2022).

The comparison between the different assemblages of the Kisele industry, along with the addition of the Sanzako industry, was conducted using a simple statistical analysis, which has yielded some very interesting observations. The PCA (Fig. 12a) revealed key patterns in the techno-typological variability of the lithic assemblages, with the first two dimensions accounting for 65.6 % of the total variance. Dim1 (39.4 %) highlights the prevalence of Levallois cores, denticulates, and notches linked to the Kisele industry, while Dim2 (26.2 %) emphasizes opportunistic cores, heavy-duty tools, and points. Kisele industry assemblages (e.g., Mumba VI-A and Nasera levels 12–25) cluster closely, reflecting shared technological traits, whereas Sanzako industry assemblages (e.g., Mumba VI-B) are distinct, showcasing more rudimentary technologies.

This study aligns with the Kisele industry but is positioned separately in the PCA due to factors such as methodological differences, the presence of Kombewa cores, and the absence of certain tools previously reported in Mumba and Nasera assemblages. These differences highlight the importance of reviewing classification criteria across studies.

Hierarchical clustering (Fig. 12b) further supports the division between Kisele and Sanzako industries, grouping assemblages based on their techno-typological similarities. The dendrogram, with a high cophenetic correlation coefficient (0.9644), confirms the consistency of these groups: Kisele industry assemblages cluster together, characterized by discoid cores, Levallois cores, and points, while Sanzako industry assemblages emphasize opportunistic cores, denticulates, and scrapers.

The Sanzako industry, identified only in level VI-B at Mumba rockshelter and dated between 131–109 ka BP (Mehlman, 1989), is characterized by the use of local raw materials, particularly quartz and, as in Nasera 22, the marginal use of obsidian (3 %) sourced from the Naivasha Basin in Kenya (Mehlman, 1989, Merrick and Brown, 1984). Based on the study of Mehlman's excavated raw materials, which remained unpublished (Solano-Megías, et al., 2024), and similar to what we observe

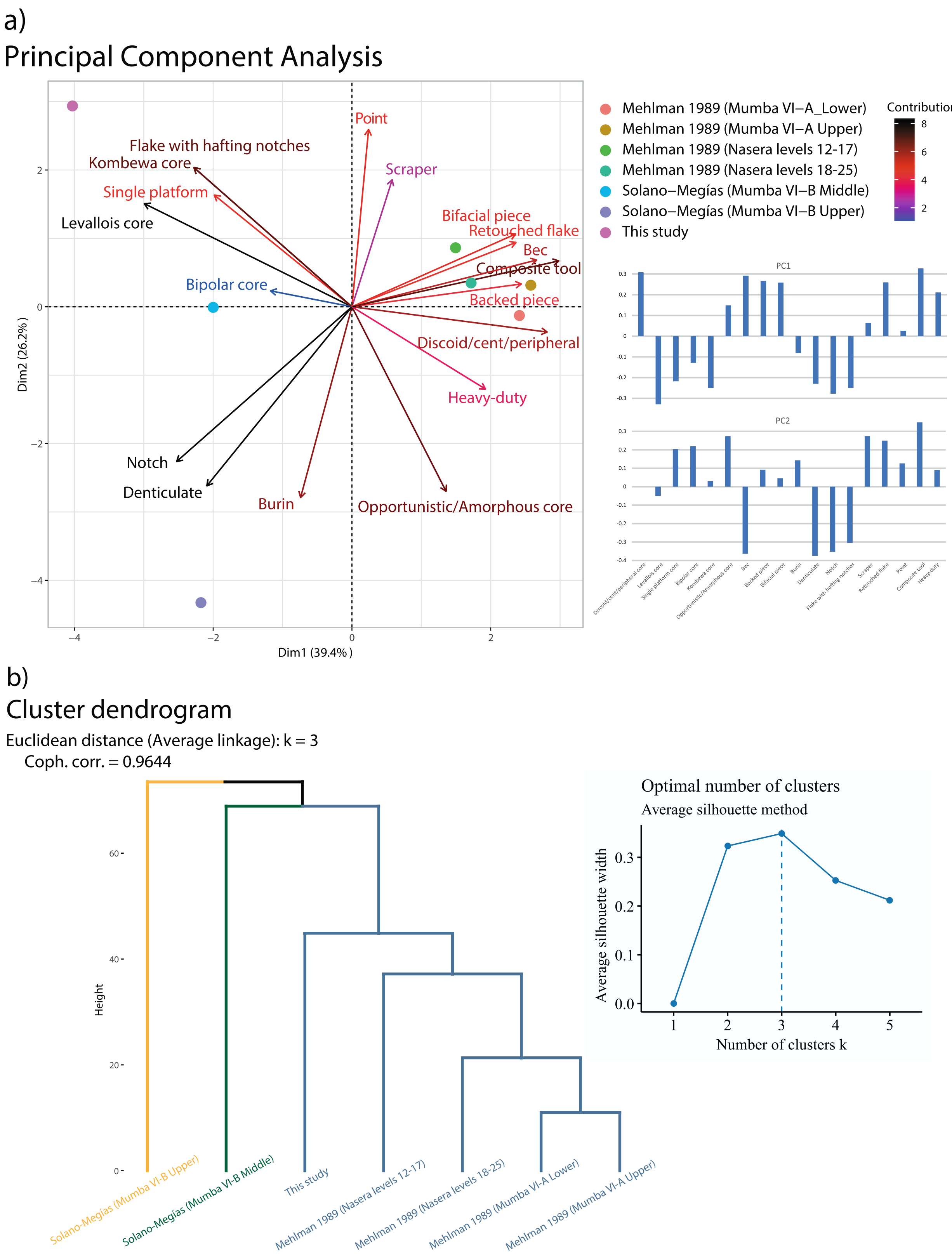

Fig. 12. Principal component Analysis and cluster dendogram.

at Nasera 22, the main operational schemes are discoid. In terms of the retouched pieces, they range between 7 % and 4.6 % in level VIB at Mumba, but like Nasera 22, sidescrapers, denticulates, and bifacial pieces are the most common tools. Unlike Nasera 22, however, there is a modest presence of heavy-duty tools and an almost complete absence of points. Therefore, while the differences between Mumba VIB (Sanzako) and Nasera 22 (Kisele) are not numerous, they are nonetheless significant: the absence of points and the presence of heavy-duty tools are two key indicators that help distinguish between different technological traditions and possibly territorial use. These conclusions are also supported by the Correspondence Analysis (Fig. 12).

As noted earlier, the identification of the Kisele industry cannot be considered unique of the MSA between MIS 5 and MIS 3. Several collections from recent excavations must be added to the classic sites of Nasera and Mumba to build a more complete chrono-cultural framework for the MSA in northern Tanzania.

The first of these is Loiyangalani in the Serengeti, an open-air site that produced an abundant MSA assemblage associated with faunal remains showing clear signs of human activity (Bower et al., 1985; Bower and Mabulla, 2012). The industry at Loiyangalani is characterized by discoid débitage as its primary operational scheme, followed by bipolar débitage and Levallois. The raw materials used are of local origin, with quartzite being the most commonly used (± 60 %). Retouched pieces are dominated by sidescrapers, denticulates, and notches. Two key points are worth noting: there are no points, and bipolar débitage is significant (12.6 % of the collection), despite quartz –the most used raw material for this débitage–, making up only a third of the assemblage (Maíllo-Fernández et al., 2019a). The site has been interpreted as a place to butcher and process the carcasses of hunted animals took place (Bower and Mabulla, 2012; Masele, 2020).

The other two sites, located at Olduvai Gorge, are VCS and DGS (Maíllo-Fernández et al., 2019b, 2022).

VCS is a multi-level, open-air site within a fluvial environment with a small, yet clearly MSA assemblage associated with faunal remains; a direct link between the fauna and human activity could not be confirmed. The significance of this site lies in the fact that it is the first with stratified MSA findings, and which include radiometric dates placing it in MIS5, between 75 and 86 ka BP. The industry is dominated by discoid débitage, with the few retouched pieces found consisting of sidescrapers, denticulates, and a few possible heavy-duty pieces. No points have been found (Maíllo-Fernández et al., 2019b).

DGS is located 400 m north of VCS. It is an open-air site of eolian origin with a single archaeological level, which has yielded a large lithic assemblage along with associated fauna. In this case, the fauna shows clear evidence of human activity. Again, the main débitage found is the discoid, with smaller representations of Levallois and single platform methods. The presence of bipolar débitage is minimal. Retouched pieces are also scarce, with the assemblage dominated by denticulates and notches. As with VCS and Loiyangalani, no points have been found (Maíllo-Fernández et al., 2022).

In sum, the differences between the Kisele industry and the collections from Loiyangalani, VCS and DGS are clear. These differences raise intriguing questions, for which we currently lack definitive answers, though it can be hypothesized that these techno-typological differences were due to differential responses linked site use. However, what can be concluded is that the monolithic view of the MSA between MIS5 and MIS3 is far more complex than what can be inferred solely from rock-shelter sites.

6. Conclusion

The techno-typological study of level 22 at Nasera reveals a distinctly MSA lithic assemblage, characterized by the production of discoid methods and dominated by tools such as sidescrapers and points (both bifacial and unifacial). The raw materials used are primarily of local origin, including quartz and chert from Olduvai. The small, but notable presence of obsidian from the distant Lake Naivasha basin suggests that long-distance contact between MSA groups may have taken place.

From a technological perspective, discoid methods are more prevalent than the Levallois, which are used more often on raw materials with better fracture properties, such as chert. Additionally, single platform methods are almost as common as the Levallois, highlighting a diversity of production techniques. This variability aligns with patterns observed at other regional MSA sites, such as DGS or Loiyangalani, where there is significant variability, although not necessarily identical to that of Nasera.

In comparison, other regional industries, such as the Sanzako, and contemporaneous sites like Loiyangalani, VCS and DGS, exhibit significant differences. These techno-typological differences reflect variations in technology, as well as potential differences in how these groups used their tools and their subsistence strategies within the region.

In conclusion, the study of level 22 at Nasera offers a detailed and nuanced perspective on the Kisele industry within the regional MSA, showcasing the complexity and diversity of technologies and human interactions during this period. This study not only enhances our understanding of the MSA in northern Tanzania, but also challenges the traditional monolithic view of the MSA between MIS 5 and MIS 3, revealing a far more intricate network of interactions and technological adaptations than previously thought. Therefore, our results indicate that the so-called Kisele industry cannot be regarded as a single, coherent technological entity. Instead, its definition partly reflects the limitations of earlier analytical frameworks, and a reassessment such as that presented here reveals a more complex and variable technological reality within the regional MSA.

Funding information

This study has been funded by the Project PID2020-113547 GB-I00/AEI/https://doi.org/10.13039/501100011033 from the Spanish Ministry of Science and Innovation, Fundación PALARQ, and UNED. Irene Solano-Megías has been supported by an FPI Predoctoral grant PRE2019-091409 from the Spanish Ministry of Science and Innovation.

CRediT authorship contribution statement

Irene Solano-Megías: Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization. **José Manuel Maíllo-Fernández:** Writing – review & editing, Validation, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization. **Juan Marín:** Writing – review & editing, Investigation. **David M. Martín-Perea:** Writing – review & editing, Investigation. **Agness Gidna:** Writing – review & editing, Project administration. **Audax Z.P. Mabulla:** Writing – review & editing, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors wish to thank COSTECH (Tanzania Commission for Science and Technology) for the permission to carry out the work and the Department of Antiquities of Tanzania for its support. Also, we want to thank the Ngorongoro Conservation Area Authority for allowing us to conduct our study and especially, Eng. Joshua Mwankunda, Manager for Cultural Heritage and Geopark. We want to thank to Museum of Olduvai, especially to its director Paul Aloyce Njelo. We want to thank Abel Moclán and Julia Aramendi enormously for their great help. Moreover, we would like to thank TOPPP's team members for their help and support, specially Manuel Domínguez Rodrigo, Enrique Baquedano and Fernando Díez.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2025.105423.

Data availability

All data are in the research paper

References

Ahler, S.A., 1983. Heat Treatment of Knife River Flint. Lithic Technol. 12 (1), 1–8. https://doi.org/10.1080/01977261.1983.11760607.

Ambrose, S.H., 1998. Late Pleistocene human population bottlenecks, volcanic winter, and differentiation of modern humans. J. Hum. Evol. 34, 623–651.

Audouze, F., Karlin, C., 2017. La chaîne opératoire a 70 ans: Qu'en ont fait les préhistoriens français. Journal of Lithic Studies 4 (2), 1–69.

Balout, L., Biberson, P., Tixier, J., 1967. L'Acheuléen de Ternifine (Algérie), gisement de l'Atlanthrope. L'Anthropologie 71 (3–4), 217–237.

Bar-Yosef, O., Van Peer, P., 2009. The chaîne operatoire approach in Middle Paleolithic archaeology. Curr. Anthropol. 50 (1), 103–131.

Basell, L.S., 2008. Middle Stone Age (MSA) site distributions in eastern Africa and their relationship to Quaternary environmental change, refugia and the evolution of Homo sapiens. Quat. Sci. Rev. 27 (27–28), 2484–2498.

Basell, L.S., Spinapolice, E.E., 2024. Time, the Middle Stone Age and lithic analyses following theThird Science Revolution. Azania: Archaeol. Res. Afr. 59 (1), 140–159. https://doi.org/10.1080/0067270X.2023.2285167.

Berlirán, C., 2014. Trampling, taphonomy, and experiments with lithic artifacts in the southeastern Baguales Range (Santa Cruz, Argentina). Intersecciones En Antropología, Special Issue 1, 85–95.

Bernaldo de Quirós, F., Cabrera, V., Cacho, C., Vega, L.G., 1981. Proyecto de análisis técnico para las industrias líticas. Trab. Prehist. 38, 9–37.

Beyin, A., Ryano, K.P., 2020. Filling the void: a study of sites characterized by Levallois and blade technologies in the Kilwa Basin, coastal Tanzania. Journal of Paleolithic Archaeology 3 (4), 1048–1094.

Beyin, A., Ryano, K.P., Buylaert, J.P., Wright, D.K., 2025. Late Quaternary human occupation of the Kilwa coast (Tanzania): OSL ages and paleoenvironmental proxies from isotope geochemistry. J. Archaeol. Sci. Rep. 61, 104874.

Binford, L.R., 1982. The archaeology of place. J. Anthropol. Archaeol. 1 (1), 5–31.

Blegen, N., 2017. The earliest long-distance obsidian transport: evidence from the ~200 ka middle stone age sibilo school road site, Baringo. Kenya. J. Hum. Evol. 103, 1–19.

Blegen, N., Faith, J.T., Peppe, D.J., 2021. Tephrostratigraphy of the eastern Lake Victoria Basin including the Nyanza Rift, Kenya: building a stratigraphic and chronological framework for modern human evolution. Quat. Sci. Rev. 256, 106823.

Blinkhorn, J., Grove, M., 2018. The structure of the Middle Stone Age of eastern Africa. Quat. Sci. Rev. 195, 1–20.

Blinkhorn, J., Grove, M., 2021. Explanations of variability in Middle Stone Age stone tool assemblage composition and raw material use in Eastern Africa. Archaeol. Anthropol. Sci. 13 (14). https://doi.org/10.1007/s12520-020-01250-8.

Boëda, E., Geneste, J.M., Meignen, L., 1990. Identification de chaînes opératoires 117 lithiques du Paléolithique ancien et moyen. Paléo 2, 43–80.

Boëda, E., 1993. Le débitage discoïde et le débitage Levallois recurrent centripède. Bulletin De La Société Préhistorique Française 90 (6), 392–404.

Boëda, E., 1994. Le Concept Levallois: Variabilité des Méthodes. Monographie du C.R.A, Paris.

Boëda, E., 1995. Caractéristiques techniques des chaînes opératoires lithiques des niveaux micoquiens de Külna (Tchécoslovaquie). Actes du colloque Les industries à pointes foliacées d'Europe Centrale, Miscolk 1991. Paléo, Supplément 1, 57–72.

Boëda, E., 2013. Techno-logique & Technologie. Une paléo-histoire des objets lithiques tranchants. Prigonrieux: Archeo-editions.

Bower, J.R.F., Gifford, D., Livingstone, D., 1985. Excavations at the Loiyangalani site, Serengeti National Park, Tanzania. National Geographic Society Research Reports, (1979 projects) 20, 41–56.

Bower, J.R.F., Mabulla, A., 2012. Settling In: Evidence of territorial exclusion in the Late Middle Stone Age of Northern Tanzania. Studies in the African Past 11, 7–24.

Boisard, S., Ben Arous, E., 2024. A critical inventory and associated chronology of the Middle Stone Age and Later Stone Age in Northwest Africa. J. Open Archaeol. Data 12 (1), 5.

Bräuer, G., Mehlman, M.J., 1988. Hominid molars from a middle stone age level at the Mumba rock shelter, Tanzania. Am. J. Phys. Anthropol. 75 (1), 69–76.

Brooks, A.S., Yellen, J.E., Potts, R., Behrensmeyer, A.K., et al., 2018. Long distance stone transport and pigment use in the earliest Middle Stone Age. Science 360, 90–94.

Brown, F.H., McDougall, I., Fleagle, J.G., 2012. Correlation of the KHS Tuff of the Kibish Formation to volcanic ash layers at other sites, and the age of early Homo sapiens (Omo I and Omo II). J. Hum. Evol. 63, 577–585.

Bushozi, P., Skinner, A., de Luque, L., 2020. The Middle atone Age (MSA) Technological patterns, Innovations, and Behavioral changes at Bed VIA of Mumba Rockshelter, Northern Tanzania. Afr. Archaeol. Rev. 37, 293–310.

Bushozi, P., 2011. Lithic technology and hunting behavior during the Middle Stone Age in Tanzania. University of Alberta. PhD Dissertation.

Caux, S., Galland, A., Queffelec, A., Bordes, J.-G., 2018. Aspects and characterization of chert alteration in an archaeological context: A qualitative to quantitative pilot study. J. Archeol. Sci.: Rep. 20, 210–219.

Chazan, M., Berna, F., Brink, J., Ecker, M., Holt, S., Porat, N., Horwitz, L.K., 2020. Archeology, environment, and chronology of the Early Middle Stone Age component of Wonderwerk Cave. J. Paleolith. Archaeol. 3 (3), 302–335.

Clark, J.D., Kleindienst, M.R., 1974. The Stone Age cultural sequence: terminology, tipology and raw material. In: Clark, J.D. (Ed.), Kalambo Falls Prehistoric Site, Volume II: the Later Prehistoric Cultures. Cambridge University Press, Cambridge, pp. 71–106.

Clark, J.D., 1988. The Middle Stone Age of East Africa and the beginnings of regional identity. J. World Prehist. 2, 235–305.

Clark, J.D., Kleindienst, M.R., 2001. The Stone Age cultural sequence: Terminology, typology and raw material. In: Clark, J.D. (Ed.), Kalambo Falls Prehistoric Site, Vol. III. Cambridge University Press, pp. 34–65.

Clark, J.D., Beyene, Y., WoldeGabriel, G., Hart, W.K., et al., 2003. Stratigraphic, chronological and behavioural contexts of Pleistocene Homo sapiens from Middle Awash, Ethiopia. Nature 423, 747–752.

Conard, N.J., Soressi, M., Parkington, J.E., Wurz, S., Yates, R., 2004. A unified lithic taxonomy based on patterns of core reduction. South African Archaeological Bulletin 59 (179), 13–17.

Day, M.H., 1969. Early Homo sapiens remains from the Omo River region of South-west Ethiopia: Omo human skeletal remains. Nature 222, 1135–1138.

Delagnes, A., Roche, H., 2005. Late Pliocene hominid knapping skills: the case of Lokalalei 2C, West Turkana. Kenya. Journal of Human Evolution 48 (5), 435–472.

De la Peña, P., Wadley, L., 2014. Quartz knapping strategies in the Howiesons Poort at Sibudu (KwaZulu-Natal, South Africa). PLoS One 9 (7), e101534.

De la Peña, P., 2015a. The interpretation of bipolar knapping in African Stone Age studies. Curr. Anthropol. 56 (6), 911–923.

De la Peña, P., 2015b. A qualitative guide to recognize bipolar knapping for chert and quartz. Lithic Technol. 40 (4), 1–16.

Díez-Martín, F., Domínguez-Rodrigo, M., Sánchez, P., Mabulla, A.Z., Tarriño, A., Barba, R., de Luque, L., 2009. The Middle to Later Stone Age technological transition in East Africa. New data from Mumba Rockshelter Bed V (Tanzania) and their implications for the origin of modern human behavior. J. Afr. Archaeol. 7 (2), 147–173.

Díez-Martín, F., Sánchez-Yustos, P., Domínguez-Rodrigo, M., Prendergast, M., 2011. An experimental study of bipolar and freehand knapping of Naibor Soit quartz from Olduvai Gorge (Tanzania). Am. Antiq. 76 (4), 690–708.

Domínguez-Rodrigo, M., Díez-Martín, F., Mabulla, A., Luque, L., Alcalá, L., Tarriño, A., Bushozi, P., 2007. The archaeology of the middle Pleistocene deposits of Lake Eyasi, Tanzania. J. Afr. Archaeol. 5 (1), 47–78.

Douze, K., 2012. Le Early Middle Stone Age d'Éthiopie et les changements techno-économiques à la période de l'émergence des premiers Homo sapiens. University of Bordeaux. Ph.D. Dissertation.

Faith, J.T., Tryon, C.A., Peppe, D.J., Beverly, E.J., Blegen, N., Blumenthal, S., Chritz, K.L., Driese, S.G., Patterson, D., 2015. Paleoenvironmental context of the Middle Stone Age record from Karungu, Lake Victoria Basin, Kenya, and its implications for human and faunal dispersals in East Africa. J. Hum. Evol. 83, 28–45.

Fiers, G., Halbrucker, E., Kock, de, T., Vandendriessche, H., Crombé, P., Cnudde, V., 2021. Thermal Alteration of Flint: an Experimental Approach to Investigate the effect on Material Properties. Lithic Technol. 46 (1), 27–44.

Fleagle, J.G., Assefa, Z., Brown, F.H., Shea, J.J., 2008. Paleoanthropology of the Kibish Formation, southern Ethiopia: introduction. J. Hum. Evol. 55, 360–365.

Fuertes Prieto, N., 2004. Estudio tecnológico de las industrias líticas del Paleolítico Superior y del Epipaleolítico en la Cuenca del Duero. Tesis Doctoral. Universidad de León.

Geneste, J.-M., 1985. Analyse lithique d'industries mousteriennes du Périgord: une approche tecnologique du comportement des groups humains au Paléolithique Moyen. PhD Dissertation. Université De Bordeaux 1, 2 tomes.

Geneste, J.-M., 1991. Systèmes techniques de production lithique: variations techno-économiques dans les processus de réalisation des outillages paléolithiques. Techniques et Culture 17–18, 1–35.

Gliganic, L.A., Jacobs, Z., Roberts, R.G., Dominguez-Rodrigo, M., Mabulla, A.Z., 2012. New ages for Middle and later Stone Age deposits at Mumba rockshelter, Tanzania: Optically stimulated luminescence dating of quartz and feldspar grains. J. Hum. Evol. 62 (4), 533–547.

Goodwin, A.J.H., van Riet Lowe, C., 1929. The Stone Age cultures of South Africa. Ann. South Afr. Museum 27 (1–289), 119–129.

Henshilwood, C.S., Marean, C.W., 2003. The origin of modern human behaviour: a review and critique of models and test implications. Curr. Anthropol. 44 (5), 627–651.

Hoare, S., Rucina, S.M., Gowlett, J.A.J., 2020. Initial source evaluation of archaeological obsidian from Middle Stone Age site Kilombe GqJh3 West 200, Kenya, East Africa. In: Cole, J., McNabb, J., Grove, M., Hosfield, R. (Eds.), Landscapes of Human Evolution: Contributions in Honour of John Gowlett. Archaeopress, pp. 141–148.

Hublin, J.J., Ben-Ncer, A., Bailey, S.E., Freidline, S.E., et al., 2017. New fossils from Jebel Irhoud, Morocco and the pan-african origin of Homo sapiens. Nature 546, 289–292.

Inizan, M.-L., Reduron, M., Roche, H., Tixier, J., 1995. Technologie de la Pierre taillée. E. P, Paris, C.R.

Karlin, C., 1992. Connaissance et savoir-faire: comment analyser un processus technique en Prehistoire. Introduction. In: Mora, R., Terradas, X., ParpaL, A., Plana, C. (Eds.) Tecnología y cadenas operativas líticas. Treballs d'Arqueologia, Universitat Autónoma Barcelona, 1, 99–122.

Karlin, C., Bodu, P., Pelegrin, J.P., 1992. Processus techniques et chaînes opératoires: comment les préhistoriens s'approprient un concept élaboré par les ethnologues. In: Balfet, P. (Ed.), Observer l'action technique: des chaînes opératoires, pour quoi faire?, 101-117.

Kassambara, A., Mundt, F., 2020. factoextra: Extract and Visualize the Results of Multivariate Data Analyses.

Knappett, C., 2013. (Ed.), Network Analysis in Archaeology. New Approaches to Regional Interaction. Oxford University Press.

Kuhn, S.L., 1995. Mousterian lithic technology: an ecological perspective. Princeton University Press.

Leakey, L.S.B., 1936. Stone Age Africa: an outline of Prehistory in Africa. Oxford University Press.
Leplongeon, A., 2014. Microliths in the Middle and Later Stone Age of eastern Africa: new data from Porc-Epic and Goda Buticha cave sites, Ethiopia. Quat. Int. 343, 100–116.
Leplongeon, A., Pleurdeau, D., Hovers, E., 2017. Late Pleistocene and Holocene lithic variability at Goda Buticha (southeastern Ethiopia): Implications for the understanding of the Middle and Late stone age of the horn of Africa. J. Afr. Archaeol. 15 (2), 202–233.
Levi-Sala, I., 1986. Use wear and post-depositional surface modifications: a word of caution. Journal of Archaeological Sciences 13, 229–244.
Luedtke, B.E., 1992. An archaeologist's guide to chert and flint. Archaeological Research Tools, 7. Institute of Archaeology, University of California, Los Angeles.
Mabulla, A., 1996. Middle and later Stone Age land-use and lithic technology in the Eyasi Basin, Tanzania. The University of Florida, Gainesville. Ph.D. dissertation.
Maíllo-Fernández, J.M., 1998. Proporciones de debris en réplicas de talla experimental. Espacio, Tiempo y Forma, Serie i, Prehistoria y Arqueología 11, 45–55.
Maíllo-Fernández, J.M., 2003. La Transición Paleolítico Medio-Superior en Cantabria: análisis tecnológico de la industria lítica de Cueva Morín. Tesis Doctoral, UNED, p. 547.
Maíllo-Fernández, J.M., Solano-Megías, I., Mabulla, A.Z.P., Arriaza, M.C., Bower, J.F.R., 2019a. Lithic technology at Loiyangalani, a late Middle Stone Age Site in the Serengeti, Tanzania. Afr. Archaeol. Rev. 36, 291–315.
Maíllo-Fernández, J.M., Marín, J., Solano-Megías, I., Uribelarrea, D., Martín-Perea, D., Aramendi, J., Medialdea, A., Arteaga, C., Pernas-Hernández, M., Gidna, A., Neogi, S., Baudot, E., Narváez, E., Mabulla, A., 2019b. Victoria cabrera site: a middle stone age site at Olduvai Gorge, Tanzania. Quat. Int. 526 (129), 154.
Maíllo-Fernández, J.M., Marín, J., Martín-Perea, D.M., Uribelarrea, D., Solano-Megías, I., Asiaín, R., Baquedano, E., Domínguez-Rodrigo, M., Gidna, A., Medialdea, A., Mwamakimbula, S.H., Haruni Chilonzi, D., Arteaga, C., Mabulla, A.Z.P., 2022. The Dorothy Garrod Site: a new Middle Stone Age locality in Olduvai Gorge. Tanzania. Archaeological and Anthropological Sciences 14, 177. https://doi.org/10.1007/s12520-022-01644-w.
Mant-Melville, A., Blegen, N., Faith, J.T., 2022. Technological diversity in the Late Pleistocene of the Nyanza Rift, Kenya: Archaeological excavations at Kapsarok 1 and Anderea's Farm 1. J. Archaeol. Sci. Rep. 41, 103257.
Marks, A.E., Conard, N., 2008. Technology vs. typology: The case for and against a transition from the MSA to the LSA at Mumba Cave, Tanzania. In: Aubry, T., Almeida, F., Araújo, A.C., Tiffagom, M. (Eds.), Space and Time: Which Diachronies, Which Synchronies, Which Scales? BAR International Series, Oxford, pp. 123–131.
Martín-Perea, D., Maíllo-Fernández, J.M., Medialdea, A., Marín, J., Solano-Megías, I., Gidna, A., Mabulla, A., 2020. Revisiting an old profile: an updated geoarchaeological study at Nasera Rockshelter (Tanzania). J. Quat. Sci. 35 (7), 951–960.
Masele, F., 2020. Testing meat-eating by Middle Stone Age hominins at Loiyangalani open-air site in Serengeti National Park. Tanzania. Archaeological and Anthropological Sciences 12, 55.
McBrearty, S., Bishop, L., Plummer, T., Dewar, R., Conard, N., 1998. Tools underfoot: Human trampling as an agent of lithic artifacts Edge damage. Am. Antiq. 63 (1), 108–129.
McBrearty, S., Brooks, A.S., 2000. The revolution that wasn't: a new interpretation of the origin of modern human behaviour. J. Hum. Evol. 39, 453–563.
McBrearty, S., Tryon, C.A., 2005. From Acheulian to Middle Stone Age in the Kapthurin formation, Kenya. In: Hovers, E., Kuhn, S.L. (Eds.), Transitions before the transition: Evolution and stability in the middle Paleolithic and Middle Stone Age. Kluwer Press, pp. 257–278.
McDougall, I., Brown, F.H., Fleagle, J.G., 2005. Stratigraphic placement and age of modern humans from Kibish, Ethiopia. Nature 433, 733–736.
Mehlman, M., 1977. Excavations at Nasera rock, Tanzania. Azania: Archaeol. Res. Afr. 12 (1), 111–118.
Mehlman, M.J., 1979. Mumba-Höhle revisited. the relevance of a forgotten excavation to some current issues in East Africa prehistory. World Arcaheology 11 (1), 80–94.
Mehlman, M.J., 1989. Late Quaternary Archaeological Sequences in Northern Tanzania (Tesis doctoral). University of Illinois.
Merrick, V.H., Brown, F.H., 1984. Obsidian sources and patterns of resource utilization in Kenya and northern Tanzania: some initial findings. Afr. Archaeol. Rev. 2, 129–152.
Merrick, H.V., Brown, F.H., Nash, W.P., 1994. Use and movement of obsidian in the Early and Middle Stone Ages of Kenya and northern Tanzania. In: Childs, S.T. (Ed.), Society, Culture, and Technology in Africa. MASCA, pp. 29–44.
Merrick, H.V., 1975. Change in later Pleistocene Lithic Industries in Eastern Africa. Ph.D. Dissertation, Department of Anthropology. University of California at Berkeley.
Mitchell, P., Loftus, E., Babatunde Babalola, A., 2024. Archaeological science in Africa: twenty-one papers for the twenty-first century. J. Archaeol. Sci. 163, 105933.
Mourre, V., 2003. Discoïde ou pas discoïde? Réflexions sur la pertinence des critères techniques définissant le débitage discoïde. In: Peresani, M. (Ed.) Discoid lithic technology. Advances and implications, 19–32. BAR International Series 1120. Oxford.
Mturi, A., 1976. New hominid from Lake Ndutu, Tanzania. Nature 262, 484–485.
Ossendorf, G., Groos, A.R., Bromm, T., Tekelemariam, M.G., Glaser, B., Miehe, G., 2019. Middle Stone Age foragers resided in high elevations of the glaciated Bale Mountains. Ethiopia. Science 365 (6453), 583–587.
Owen, W.E., 1938. The Kombewa culture. Kenya Colony. Man 38 (218), 203–205.
Pedraza, J., 1996. Geomorfología. Principios, Métodos y Aplicaciones. Editorial Rueda, Madrid.
Pelegrin, J., Karlin, C., Bodu, P., 1988. Chaînes opératoire: un outil pour le préhistorien. Technologie Préhistorique 25, 55–62.
Perlès, C., 1992. In Search of Lithic strategies, a Cognitive Approach to Prehistoric Chipped stone Assemblages. In: Gardin, J.C., Peebles, C.S. (Eds.), 1992. Indiana University Press, Representations in Archaeology, pp. 223–247.
Pleurdeau, D., 2003. Le Middle Stone Age de la grotte du Porc-épic (Dire Dawa, Éthiopie): gestion des matières premières et comportements techniques. L'anthropologie 107, 15–48.
Pleurdeau, D., 2004. Gestion des matières premières et comportements techniques dans le Middle Stone Age africain: les assemblages lithiques de la grotte du Porc-Épic (Dire Dawa, Éthiopie). British Archaeological Reports International Series, 1317.
Pleurdeau, D., 2005. Human technical behaviour in the African Middle Stone Age: the lithic assemblage of Porc-Epic Cave (Dire Dawa, Ethiopia). Afr. Archaeol. Rev. 22 (4), 177–197.
Prendergast, M.E., Luque, L., Domínguez-Rodrigo, M., Diez- Martín, F., Mabulla, A.Z.P., Barba, R., 2007. New excavations at Mumba rockshelter, Tanzania. Journal of african. Archaeology 5 (2), 217–243.
Ranhorn, K., Tryon, C.A., 2018. New Radiocarbon Dates from Nasera Rockshelter (Tanzania): Implications for Studying Spatial patterns in Late Pleistocene Technology. Journal of African Archaeology 16, 211–222.
Richter, D., Grün, R., Joannes-Boyau, R., et al., 2017. The age of the hominin fossils from Jebel Irhoud, Morocco, and the origins of the Middle Stone Age. Nature 546, 293–296.
Rosas, A., García-Tabernero, A., Fidalgo, D., Fero Meñe, M., Rodríguez-Berriguete, A., Ebana Ebana, C., Mateo Ornia, J., Fernández-Martínez, J., Morales, J.I., 2025. Widespread evidence of Middle Stone Age (MSA) presence in Equatorial Guinea (West-Central Atlantic Africa). Quat. Int. 736–737, 109849.
Röttlander, R., 1975. The formation of patina on chert. Archaeometry 17, 106–110.
R Core Team, 2022. R: A language and environment for statistical computing.
Sahle, Y., 2013. Hominin technological behavior during the later middle Pleistocene in the Gademotta formation, main Ethiopian rift. University of Cape Town, PhD.
Sauvet, G., 2019. The lifeworld of hunter-gatherers and the concepts of territory. Quat. Int. 503 (B), 191–199.
Scerri, E.M.L., Niang, K., Candy, I., Blinkhorn, J., et al., 2021. Continuity of the Middle Stone Age into the Holocene. Sci. Rep. 11, 70. https://doi.org/10.1038/s41598-020-79418-4.
Schmalz, R.F., 1960. Chert and the patination of chert artifacts. Proc. Prehist. Soc 26, 44–49.
Seitsonen, O., 2007. Middle Stone Age component at the abandoned Sonjo Buri Village site, Tanzania. Nyame Akuma 67, 75–82.
Shackley, M.L., 1978. The behavior of artefacts as sedimentary particles. Archaeometry 20 (1), 55–61.
Shea, J.J., 2008. The Middle Stone Age archaeology of the lower Omo Valley Kibish Formation: Excavations, lithic assemblages, and inferred patterns of early Homo sapiens behavior. J. Hum. Evol. 55 (3), 448–485.
Shea, J.J., 2011. Homo sapiens is as Homo sapiens was: Behavioral variability versus "behavioral modernity" in Paleolithic archaeology. Curr. Anthropol. 52 (1), 1–35.
Shea, J.J., 2020. Prehistoric stone tools of Eastern Africa: a Guide. Cambridge University Press.
Shea, J.J., 2024. A generic MSA: what problems will it solve and what problems will it créate? Azania: Archaeol. Res. Afr. 59 (1), 160–172. https://doi.org/10.1080/0067270X.2024.2306078.
Solano-Megías, I., Maíllo-Fernández, J.M., Marín, J., Martín-Perea, D., Mabulla, A.Z.P., 2020. Lithic technology in the Earliest later Stone age at Nasera Rockshelter (Tanzania). Lithic Technol. 46 (1), 60–79.
Shipton, C., Roberts, P., Archer, W., Armitage, S.J., Bita, C., Blinkhorn, J., Boivin, N., 2018. 78,000-year-old record of Middle and Later Stone Age innovation in an East African tropical forest. Nat. Commun. 9 (1), 1832.
Solano-Megías, I., Maíllo-Fernández, J.M., Mabulla, A.Z.P., 2024. Deciphering Middle Stone Age Technological Behaviors: an Analysis of the Lithic Technology from Level VI-B at Mumba. African Archaeological Review, In press, Tanzania.
Stapert, D., 1976. Some natural surface modifications on chert in the Netherlands. Palaeohistoria, XVIII, pp. 7–41.
Straus, L.G., 1990. Underground Archaeology: Perspectives on Caves and Rockshelters. Archaeol. Method Theory 2, 255–304.
Terradas, X., 2003. Discoid flaking method: Conception and technological variability. In: Peresani, M. (Ed.). Discoid lithic technology. Advances and implications, 19–20. B.A. R. International Series 1120. Oxford, Archaeopress.
Tixier, J., Inizan, M.L., Roche, H., 1980. Préhistoire de la pierre taillée I. Terminologie et technologie, CREP, p. 55.
Texier, P.J., 1981. Désilification des silex taillés. Quaternaria, XXIII, pp. 159–169.
Thiébaut, C., Costamagno, S., Coumont, M.-P., Mourre, V., Provenzano, N., Théry-Parisot, I., 2010. Approche expérimentale des conséquences du piétinement des grands hervibores sur les vestiges lithiques et osseux. In: Coumont, M.-P., Thiebaut, C., et Averbouh, A. (Eds.), Actes du workshop 16, Mise en commun des approches en Taphonomie, XVème Congrès de l'UISPP, 4-9 septembre 2006, Lisbonne. Paleo, supplément 3, pp. 109–129.
Tryon, C.A., McBrearty, S., Texier, P.J., 2005. Levallois lithic technology from the Kapthurin Formation, Kenya: Acheulian origin and Middle Stone Age diversity. Afr. Archaeol. Rev. 22 (4), 199–229.
Tryon, C.A., Faith, T., 2013. Variability in the Middle Stone Age of Eastern Africa. Curr. Anthropol. 54 (8), S234–S254.
Tryon, C.A., Faith, J.T., 2016. A demographic perspective on the Middle to later Stone Age transition from Nasera rockshelter, Tanzania. Philosoph. Trans., Roy. Soc. B 371, 20150238.
Tryon, C.A., Lewis, J.E., Ranhorn, K.L., Kwekason, A., Alex, B., Laird, M.F., Mabulla, A. Z., 2018. Middle and later stone age chronology of Kisese II rockshelter (UNESCO World Heritage Kondoa Rock-Art Sites), Tanzania. PLOS ONE 13 (2), e0192029.

Vidal, C., Lane, C.S., Asrat, A., Barfot, D.N., et al., 2022. Age of the oldest known Homo sapiens from eastern Africa. Nature 601, 579–583.
Werner, J., Willoughby, P.R., 2017. Middle Stone Age Technology and Cultural Evolution at Magubike Rockshelter, Southern Tanzania. Afr. Archaeol. Rev. 34, 249–273.
Whallon, R., 2006. Social networks and information: Non-"utilitarian" mobility among hunter-gatherers. J. Anthropol. Archaeol. 25 (2), 259–270.
Wiessner, P.R., 2002. Hunting, healing, and hxaro exchange: a long-term perspective on ! Kung (Ju/'hoansi) large game hunting. Evol. Hum. Behav. 23, 407–436.
Weitzel, C., Sánchez, A., 2021. A Trampling Experiment to Assess Fractures and Edge damage in Quarry's Lithic Assemblages. Lithic Technol. 46 (4), 286–301.
Wendorf, F., Schild, R., 1975. A Middle Stone Age Sequence from the Central Rift Valley, Ethiopia. Ossolineum, Warsaw.
White, T.D., Asfaw, B., DeGusta, D., Gilbert, H., et al., 2003. Pleistocene Homo sapiens from Middle Awash, Ethiopia. Nature 423, 742–747.
Will, M., Conard, N.J., Tryon, C.A., 2019. Timing and trajectory of cultural evolution on the African continent 200,000–30,00 years ago. In: Sahle, Y., Reyes-Centeno, H., Bentz, C. (Eds.), Modern Human Origins and Dispersal, pp. 25–72.
Will, M., Scerri, E., 2024. The generic Middle Stone Age: fact or fiction. Azania: Archaeol. Res. Afr. 59 (1), 4–21. https://doi.org/10.1080/0067270X.2024.2323374.
Willoughby, P.R., 2012. The Middle and later Stone Age in the Iringa Region of southern Tanzania. Quat. Int. 270, 103–118.
Wurz, S., 2013. Technological trends in the Middle Stone Age of South Africa between MIS 7 and MIS 3. Curr. Anthropol. 54 (S8), S305–S319.
Yellen, J., Brooks, A., Helgren, D., Tappen, M., Ambrose, S., Bonnefille, R., Feathers, J., Goodfriend, G., Ludwig, K., Renne, P., Stewart, K., 2005. The Archaeology of Aduma Middle Stone age sites in the Awash Valley Ethiopia. PaleoAnthropology 10, 25.
Yeşilova, G.C., Arroyo, A., Vergès, J.M., Ollé, A., 2024. New Approaches to the Bipolar Flaking Technique: Qualitative, Quantitative, and Kinematic Perspectives. J. Archaeol. Method Theory 1–50. https://doi.org/10.1007/s10816-024-09639-8.

Further reading

Solano-Megías, I., Maíllo-Fernández, J.M., Marín, J., Martín-Perea, D.M., Gidna, A., Mabulla, A.Z., 2025. Exploring the Middle Stone Age lithic technology at DGS, Olduvai Gorge, Tanzania. Archaeol. Anthropol. Sci. 17 (2), 1–27.