
Lithic variability and raw material exploitation at the Middle Stone Age (MSA) site of Gotera, southern Ethiopia: A combined technological and quantitative approach

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Abstract:

Technological variability within East African Middle Stone Age (MSA) lithic assemblages is considered a reflection of regional or local identities. These identities are a possible outcome of different social dynamics in human populations or interaction with the environment. Here we analysed the lithic assemblage from GOT 1-S site, in the Gotera area (Southern Ethiopia) in order to integrate fresh data from the region into the broader discussion on the technological variability of the MSA of Eastern Africa. To reach this goal, we considered lithic data from a surface dispersion, through the combination of different methods. Technological and statistical analyses performed on lithic assemblage suggest the existence of two distinct reduction sequences related to different raw materials: quartz and basalt. The technological analysis shows a more opportunistic reduction strategy on basalt artefacts, while the quartz lithic assemblage exhibits a more accurate preparation of core striking platforms and more predetermined products. The results of technological analyses on flakes, tools and cores were elaborated using Principal Component Analysis and Cluster Analysis. The two analyses allowed to confirm the hypothesis of two reduction strategies according to different raw material selection and managing. Furthermore, the categorical attributes from cores and flakes were processed by means of Correspondence Analysis, highlighting the technological differences linked to the different raw materials exploited. Moreover, the combined results from the technological and statistical analyses proved the validity of this integrated methodology to analyse a lithic collection from a surface context.

Keywords: Ethiopia; Middle Stone Age; lithic technology; multivariate analyses; Principal Component Analysis; Cluster Analysis; Correspondence Analysis



1. Introduction

East Africa has generally been considered as an area of great importance for the evolution of the genus *Homo* (Blome *et al.* 2012; Mirazón Lahr & Foley 2016; Mounier & Lahr 2019; Stringer 2016), although older specimens of *Homo sapiens* have been recently discovered in Morocco (Hublin *et al.* 2017; Richter *et al.* 2017; Stringer & Galway-Witham 2017), and a model of genetically structured population of *Homo sapiens* across the whole African continent has been recently proposed (Bergström *et al.* 2021; Scerri 2018; 2019; Scerri *et al.* 2018). Notwithstanding recent re-evaluation of modern human origin and expansion (Bergström *et al.* 2021), according to paleoanthropological, archaeological, and genetic data East Africa still remains an important area to investigate for the worldwide expansion of *Homo sapiens* (Blinkhorn & Grove 2021; Grove & Blinkhorn 2020), and the region is still central in the debate (Blinkhorn & Grove 2018; 2021; Brooks *et al.* 2018; Grove & Blinkhorn 2020; Mirazón Lahr & Foley 2016; Neubauer *et al.* 2018; Potts *et al.* 2018) as a potential source for ancient population as well as a gateway for the Out of Africa (Groucutt *et al.* 2015; Lamb *et al.* 2018; Petraglia *et al.* 2010). In fact, East Africa with its archaeological record provides the richest source of information about the evolution of modern humans (Stringer 2016).

The Middle Stone Age (hereafter, MSA) constitutes the archaeological frame for the early representatives of our species. Spanning from ~300 to ~40 ka, it is deeply related to the predominance of the Mode 3 technologies (Clark 1988; Foley & Mirazón Lahr 1997; Tryon & Faith 2013) differentiated from the Early Stone Age (ESA) for the scarcity of large cutting tools such as cleavers and handaxes (Clark 1988). MSA is characterised, by definition, by the predominance of prepared core technologies, the emergence of blades, points, hafted tools, and the frequent use of the Levallois method (Ambrose 2001; Blinkhorn & Grove 2018; 2021; Grove & Blinkhorn 2020; Tryon & Faith 2013). However, the association of several reduction systems, *i.e.*, non-Levallois flake production systems, discoidal technology, laminar Levallois, platform cores, and irregular or multidirectional core removal pattern, highlights a significant technological variability. The presence of different techno-complexes chronologically related and possibly spatially structured within the African MSA has been widely suggested (*e.g.*, the Aterian, the Sangoan-Lupemban, the Fauresmith, *etc.*) (Herries 2011; Scerri 2013; 2017; Scerri *et al.* 2014; Scerri & Spinapolice 2019; Tryon and Ranhorn, 2020; Van Peer *et al.* 2004). The study of MSA structure can play a central role in the understanding of the behavioural characteristics of hominins in a key moment of our evolutionary history (Spinapolice 2020), highlighting the presence of regional identity, different patterns of mobility, or adaptations to local environments. It has been shown already that it is possible to understand the population structures of past hominins through the analysis of their behavioural signature (Blinkhorn & Grove 2018; 2021; Scerri *et al.* 2014).

To reach this goal, it is of primary importance to understand the lithic variability and the causes and modes of such variations. Unfortunately, the MSA analyses have suffered from divergent research traditions, and it has become clear in recent years that a joint effort is needed in order to unify the processing of the technological data (Leplongeon 2017; Will *et al.* 2019) in a broader “Middle Range Theory” (Tostevin 2012: 29-31). Quantitative and attribute-based analyses on lithic industries are currently used to analyse a single assemblage and to favour extensive inter-assemblage comparisons (*e.g.*, Andrefsky 2005: 61-84 Clarke 1968: 328-354; Hovers 2009; Nigst 2012: 3-15; Scerri *et al.* 2016; Shott 1994; Tostevin 2012: 90; Tryon and Ranhorn 2020). One of the reasons for the success of this approach is the possibility to untangle and differentiate the sources of the observed lithic variation. The idea at the basis of such an approach is to give measurable and comparable technological attributes to a single lithic item, with the purpose of going beyond the differences between different

techno-typological methods (Will *et al.* 2019). The technological analysis needs to be at the foundation of the attribute analysis, not in opposition, as a fundamental starting point for the computational analysis.

In this paper, we apply attribute analysis to an assemblage collected in surface from a single area, Gotera, in Southern Ethiopia. Therefore, we methodologically assess a perspective to study this lithic assemblage from an almost unknown part of East Africa, in order to highlight the presence of characteristic features that can contribute to elucidate the technological adaptation of the MSA to local conditions, and, in a further step, connect them with the general variability of the African MSA. We tested a combination of technological and quantitative analyses in order to set a starting point for the next part of the investigation on this context. In fact, the application of the combined method of analyses to a surface dispersion studied at high resolution can constitute the basis for a future comparative model of data integration.

The association of quantitative methods with technological analysis is here proposed as a useful solution in managing the data coming from a surface collection to investigate specific research objectives: i) how were raw materials used at Gotera? ii) Were there different reduction strategies linked to the raw materials available within the area; iii) to highlight the importance of using a combined integrated approach to analyse a lithic collection from a surface context.

2. Site and context

The lithic artefacts here considered were collected in year 2017 (Figure 1). Since 2016 the Gotera area has been newly surveyed in the frame of the (H)ORIGIN Project (Spinapolice *et al.* 2017). The area is located in the Borana zone (Oromia Region), not far from the Kenyan border, and 500 km south of Addis Ababa. The Gotera area is part of a large and deep sedimentary basin on the Teltele plateau, at the margin of the southern area of the main Ethiopian Rift. The region is part of the north-eastern area of the Sagan River catchment; the latter river crosses the Rift Valley from East to West and then flows southward into the Chew Bahir. The depression is limited by the escarpment of the Teltele-Konso range, exposing basalts and trachytic formations, covering Precambrian basement units (Davidson 1983; Foerster *et al.* 2012). Quartzite outcrops are occasionally present.

The Gotera archaeological area was discovered by Guillemot in 1974, and surveyed and excavated by Chavaillon in 1978 and 1979 (Chavaillon & Chavaillon 1985). The open-air complex included nine archaeological localities. Several distinct stratigraphic layers were described by Chavaillon & Chavaillon (1985): four of them preserve archaeological remains, while other archaeological evidences were collected on topographic erosional surfaces, marking the top of those layers. The archaeological materials were described in Chavaillon & Chavaillon (1985), who attributed them to a final phase of the Acheulean (ESA) or initial phase of the MSA, based on the presence of choppers and chopping tools associated with more typical MSA features (*e.g.*, Levallois unipolar flakes).

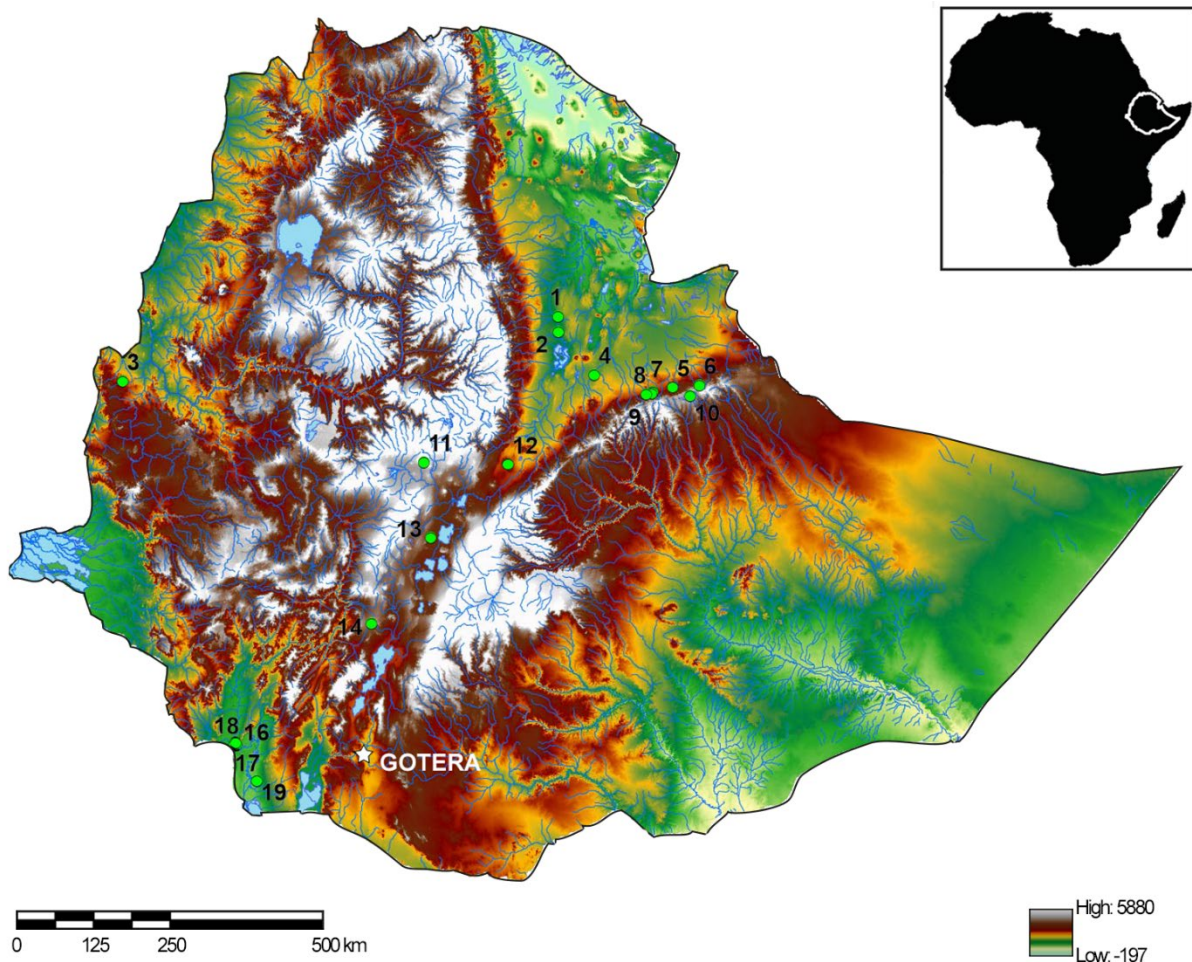


Figure 1. Map of Ethiopia with main MSA sites and location of Gotera area: 1 Bodo; 2 Ardu; 3 Bel ash-Saharifu; 4 Aladi Springs; 5 Porc-Epic; 6 Goda Dubetta; 7 Goda Buticha; 8 Goda Dessa; 9 Gilbo Tate; 10 Goda Wonji; 11 Melka Kunture; 12 Kone; 13 Gademotta; 14 Mochena Borago; 15-19 Omo Kibish.

During the 2017 survey activities, we identified one of the Chavaillon contexts located in the silty playa sediments of a palaeo-fluvial lacustrine system, with dense scatters of lithic artefacts and fauna, and two different palaeosols, all possibly associated with human frequentation. This locality has been named GOT 1-S Main Site (Figure 2).

From the palaeoenvironmental point of view, the archaeological site of Gotera is included into a sedimentary sequence constituted by alluvial and marsh deposits, alternated by lenses of coarser sediments (channel facies). The general sedimentary setting of the area is one of a low-energy fluvial environment – likely an endorheic delta environment – that alternates occasional (or seasonal) phases of higher energy. The sequence consists of massive silty to clayey strata, locally very rich in organic matter, mostly related to decantation processes. Low energy layers are occasionally interlayered by lenses of sandy sediments, interpreted as canal facies and testifying sporadic changes in the load and intensity of streams or palaeochannels (Figure 2). At least two palaeosoil horizons were described along the main sedimentary sequence; they are related to two buried topographic surfaces. Recently, strong erosion dissected the sedimentary sequence into a badlands landscape and promoted the dispersion of archaeological material (Figure 3).

The archaeological material collected is the result of a secondary deposition and it was located on the surface, both along the mound slopes and in the plain. The state of artefacts dispersion is strongly related to erosional events that occurred at different times and caused the scattering of the materials as we found them. Therefore, the attribution of the assemblage

to the MSA is currently based on the nature of the archaeological finds, where any form of Later Stone Age (LSA) material (both lithic such as backed pieces and/or microliths, and pottery) is absent. Moreover, the preliminary results on absolute chronology seem to confirm the attribution to the Late Pleistocene (Talamo pers. comm).

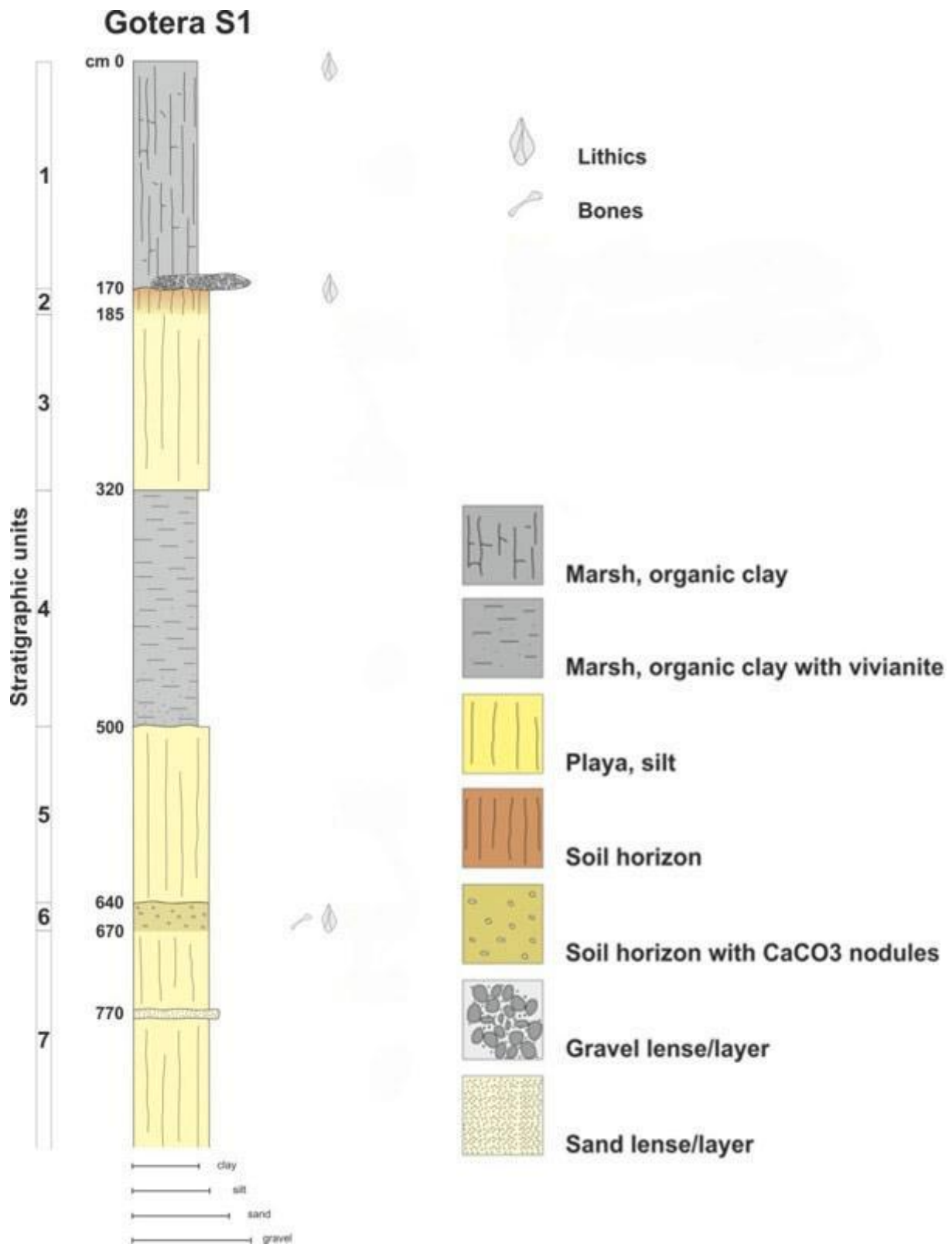


Figure 2. Schematic log representing the stratigraphic sequence of the Gotera area.

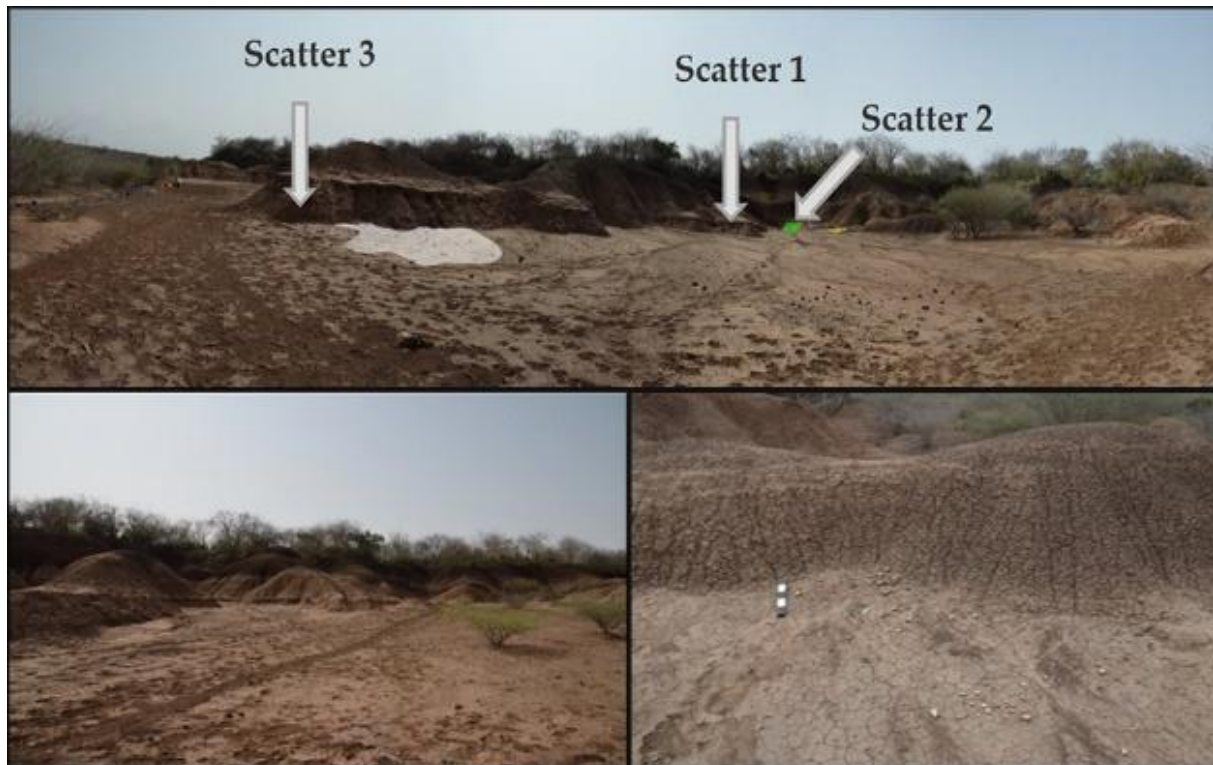


Figure 3. GOT 1-S Main Site and location of the scatters on the top; Gotera sporadic finds on the bottom.

3. Materials and methods

The lithic assemblage consists of 332 pieces including cores, flakes, and tools (Table 1). This study considers only lithics in quartz and basalt since they are the main raw materials exploited in the area, while evidence for the presence of other raw materials such as chert or obsidian is too scanty (only 7 pieces) (Table 1).

The sample analysed includes 325 pieces, 25 cores (19 on basalt and 6 on quartz), and 300 flakes (175 on basalt and 125 on quartz).

During the fieldwork, a systematic survey was carried out in an area of about two kilometres (Figure 4) with selected collections in particularly significant scatters, with a specific focus on the GOT 1-S Main Site. Here the most dense scatters in basalt were recorded and collected.

Around the GOT 1-S Main Site the survey allowed the identification and collection of several archaeological artefact concentrations. Lithic materials are associated with well-preserved faunal remains, mostly small herbivores, currently under study. The continuity between sites is significant and shows a substantial overall occupation of the area. We are thus considering the whole system of GOT 1 as a single occupation area since the technological coherence in the archaeological materials reveals a certain uniformity. The analysis of the stratigraphy reveals several occupational events (Figure 2), thus the archaeological material found on surface and collected may have eroded from different stratigraphic units. This argument will be clarified, and further research and excavation activities in the area are necessary to establish a correlation between the stratigraphy and the archaeological record.

Concerning the chronological span of the human frequentation, radiometric dating of the main sequence (Figure 2) (OSL and AMS ^{14}C) is ongoing.

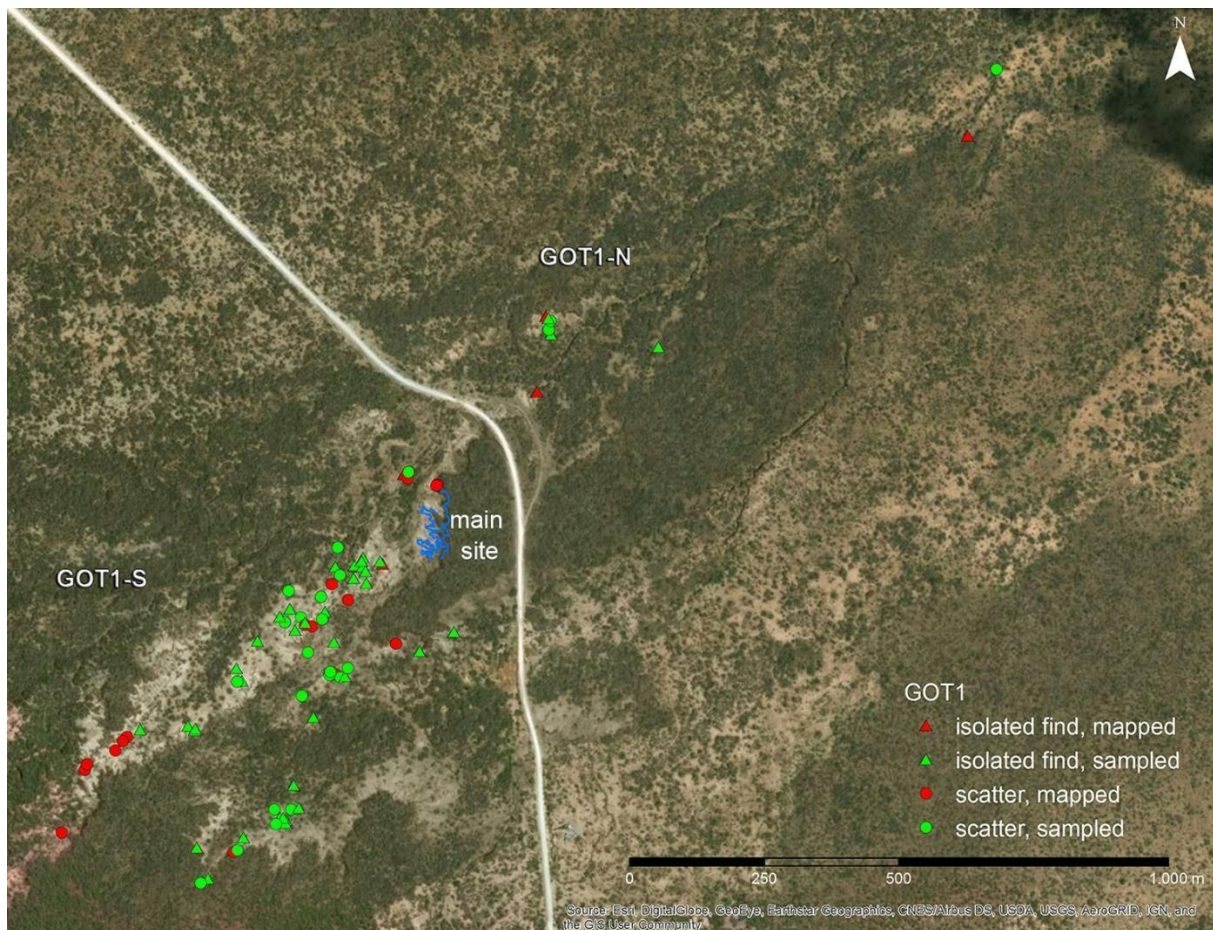


Figure 4. Detail of Gotera area with main sites and surveyed area (2017). Map data: Google Earth.

In the main site, we defined three different high-density scatters of archaeological materials (Scatter 1, 2 and 3), and mapped and collected every evidence from Scatter 1 (Sc 1) and Scatter 2 (Sc 2). Sc 1 and Sc 2 are likely to be identified as the result of the secondary accumulation of lithic implements after the erosion of palaeosurfaces bearing lithics currently visible along the stratigraphic sections; they are a few meters apart. However, an excavation of the *in-situ* layers is ongoing to confirm this hypothesis. Other scatters were recorded within the Gotera area (EC22, EC14, MG32) as well as a huge number of isolated finds (Figure 4).

For this analysis we considered all the lithics collected: the two major artefacts concentrations of the main site (Sc 1 and Sc 2), as well as isolated finds and other lithic scatters recorded within the surveyed area, both from slopes and plains (Figure 4; Table 1). Both the isolated finds and the other scatters are coherent in technology with the artefacts from the Main Site. In the area there is no evidence for LSA or younger occupation, so we decided to consider the assemblage as unitarian. In the statistical analyses single scatters and isolated finds were considered to allow the correlations within the data.

For the technological analysis, lithics were analysed according to metric and descriptive characteristics. Each variable has been recorded within a database set up with the E4 software (see the OSA - OldStoneAge web site - McPherron & Dibble 2020). Therefore, all the artefacts that preserve sufficient technological information (incomplete and complete flakes, blades and blade fragments, cores and core fragments and retouched pieces) were considered for the technological analysis.

Table 1. Lithic assemblage in basalt and quartz from GOT 1-S.

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

Hence, we delineated and tested an attribute-based statistical approach, which can be applied to further investigation of the Gotera archaeological area. This approach combines three quantitative, attribute-based multivariate analyses: Principal Component Analysis (PCA), Cluster analysis and Correspondence Analysis (CA). Numerical variables were analysed with the PCA and the Cluster analysis.

The analysis of categorical variables of Gotera lithic assemblages was performed by means of Correspondence Analysis (CA). Categorical variables chosen were based on the traditional parameters used in lithics attribute analysis, and the results of experimental studies (Scerri 2016).

We ran the analyses on the selected sample (Table 1) using the open-source softwares RStudio and Past. The Principal Component Analysis (PCA) is a multivariate technique that helps to explore specific patterns within the data, reducing a complex set of data to a smaller number of variables for analysis. We started with the PCA on flakes, considering the number of flakes as cases and comprising values for six attributes (Table 2). Since “Raw Material” is not a quantitative attribute, we used the function *as.factor()* to consider it a categorical variable, in order to avoid affecting the result.

We extracted components with the R function *PRCOMP()* using a singular value decomposition of the rectangular data matrix. Before running the function, we standardized the values. This is equivalent to extracting vectors using a correlation matrix. The correlation matrix is the best option when the variables are measured in different units, and are considered to be equally important. If we used the covariance matrix, it would retain the units of measurement and the differences in the variance among the variables. In addition, when using the covariance matrix the variables should have comparable variances; if they do not, the largest ones will dominate the results.

Table 2. Attributes for flake analysis

Variables used in the PCA for Flakes	
XFL	Maximum flake length
XFLB	Maximum flake breadth
XFT	Maximum flake thickness
XEI	Elongation Index
XPW	Maximum platform width
XPT	Maximum platform thickness

To perform the PCA on cores, we considered the number of cores as cases and comprising values for nine attributes: five technological and four morphological. We did not consider “raw material” as an active quantitative variable, as it would disturb the results, and again we considered it a categorical variable using the function *as.factor()* (Table 3). We considered length, width, elongation index and thickness in order to describe differences in size and to investigate the procurement and economic strategies of the local raw materials within the site. The number of technological and morphological striking platforms and the

number of major flakes detached from the core are two useful variables to investigate the process of reduction.

PCA was performed using RStudio v. 4.0.4 (R Core Team) while FactoMineR package was used to perform the multivariate analyses on flakes and cores, with the function *prcomp* ().

Table 3. Attributes for core analysis

Variables used in the PCA for Cores	
XL	Maximum length
XB	Maximum breadth
XT	Maximum thickness
XEI	Elongation Index
NSP	Number of morphological striking platforms
NTSP	Number of technological striking platforms
NFR	Number of flakes removed

The outcome has been compared with the results obtained with the Hierarchical clustering, a multivariate method of exploring data. We obtained size and shape data from the technological analysis, and created a dataset to include all the morphological and technological information on the artefacts.

For the Cluster analysis we computed a hierarchical clustering. The Hierarchical Cluster analysis is a form of clustering that iteratively merges cases into groups using a measure of closeness. To weight the variables equally, we replaced them with principal component scores and finally, we computed a Euclidean distance. We performed the analysis with Past 4.01 software.

Categorical variables for flakes and cores were explored through Correspondence Analysis (CA). This multivariate analysis is a useful tool to summarize categorical data in a reduced number of dimensions.

For CA performed on flakes, three active categorical variables and two supplementary categorical variables were considered (Table 4), and four active categorical variables and two supplementary variables were taken into account for cores analysis (Table 5).

CA was performed using RStudio v. 1.4.1103 (R Core Team 2021) while FactoMineR and Factoshiny packages were used to perform the analyses on flakes and cores, with the function *factoshiny* ().

The datasets and R code used to perform the analyses are available as supplementary electronic material on a Zenodo repository (see the link in the Supplementary information section below).

Table 4. List of categorical variables used to perform the Correspondence analysis on flakes.

Active qualitative variables		
Cortex	Percentage of cortex	0 - 100%
Platform type	Abraded	PL_AB
	Cortical	PL_CTX
	Dihedral	PL_DH
	Facetted	PL_FC
	Linear	PL_LIN
	Plain	PL_PLA
	Punctiform	PL_PUN
	Missing	PL_MIS
Direction of scars pattern	Cortical	DSP_CTX
	Unipolar	DSP_UNI
	Unipolar convergent	DSP_UNIC
	Bipolar	DSP_BIP
	Centripetal	DSP_CEN
	Not visibile	N/A
Supplementary variables		
Site	Scatters	EC22
		SCATTER1
		SCATTER IS
		EC14
		MG32_ND
		MG32
	Isolated finds grouped by raw material	IS_FIND_B
Raw Material	Basalt and quartz	IS_FIND_Q
		BAS/QUA

Table 5. List of categorical variables used to perform the Correspondence analysis on cores.

Active qualitative variables		
Cortex	Percentage of cortex	0 - 100%
Core Type	Levallois preferential	L_PREF_CL
	Levallois preferential bipolar	L_PREF_BIP
	Levallois recurrent bipolar	L_REC_BIP
	Levallois recurrent unipolar	L_REC_UNI
	Levallois recurrent centripetal	L_REC_CEN
	Polyhedral	POLY
	Triangular	TRIANG
	Core on flake	CORE_FL
	Disc	DISC
Flake Scar Direction	Bidirectional	BID
	Bidirectional irregular	BID_IRR
	Centripetal	CENT
	Convergent	CONV
	Multidirectional	MULT
	Unidirectional	UNID
Degree of Core reduction	Primary	PRIM
	Secondary	SEC
	Tertiary	TER
	Exhausted	EXHA
Supplementary variables		
Site	Scatters	EC22
		SCATTER1
		MG32
	Isolated finds grouped by raw material	IS_FIND_B
		IS_FIND_Q
Raw materials	Basalt and quartz	BAS/QUA

4. Results

4.1. Technological analysis

The analysis of raw materials demonstrated that quartz and basalt were exploited in the whole Gotera. Both are of local origin, and were frequently found during the 2017 survey in pebbles or cobbles (basalt and quartz) and in outcrops (quartz). In fact, basalt cobbles and pebbles are currently found in the alluvial deposits around the Gotera depression. Furthermore, quartz outcrops were identified during the survey a few kilometres away from the main Gotera 1 site.

Results from the analysis on lithic assemblage from GOT 1-S show the artefacts are generally fresh and not patinated (Table 6): when present, the patina is usually whitish or reddish. The general degree of alteration is very low; this means that the degree of conservation is high, and the assemblage has been exposed to low activities of post-depositional processes. In addition, despite dealing with a surface collection, the assemblage integrity is supported by the presence of one refit from the Sc1.

The entire lithic assemblage is composed of many *débitage* flakes from the early stages of production (Table 7) with the occurrence of a huge number of cortical flakes, the presence of convexity preparation flakes -such as *débordant* flakes- and core preparation flakes.

The flake analysis shows a higher percentage of cortex for basalt artefacts, conversely quartz flakes are characterized by a general lack of cortex (Table 8).

Table 6. GOT 1-S lithic assemblage state of preservation.

		Basalt		Quartz		Total
		N	%	N	%	N
Fresh	0-50 %	188	57%	132	40%	327
	50-75 %	6	100%			6
Worn	0-50 %	167	55%	131	43%	305
	50-75 %	27	96%	1	4%	28
Patina	0-50 %	170	57%	122	41%	297
	50-75 %	24	67%	10	28%	36
Burn	0-50 %	191	58%	132	40%	330
	50-75 %	3	100%			3

Table 7. GOT 1-S flake operational stages.

	Preparation		Use		Abandon		Total	
	N	%	N	%	N	%	N	%
Basalt	60	75%	101	49%	28	78%	189	58%
Quartz	20	25%	104	51%	8	22%	132	42%
Total	80	25%	205	64%	36	11%	321	100%

Table 8. Percentage of cortex among flakes from GOT 1-S.

Raw material	Percentage of cortex									
	0%		0-25%		25-50%		50-75%		Total	
	N	%	N	%	N	%	N	%	N	%
Basalt	111	49%	38	86%	17	80%	9	90%	175	58%
Quartz	114	51%	6	14%	4	20%	1	10%	125	42%
Total	225	75%	44	14%	21	7%	10	4%	300	100%

The flake production is then characterised by the frequent use of the Levallois method in both basalt and quartz. Specifically, flake production on basalt involved Levallois preferential, unipolar convergent and centripetal removal pattern as it is shown by the dorsal scar direction on flakes. Levallois flake scar patterns are mainly unipolar convergent, centripetal with a low occurrence of preferential products. This argument is based on the different dorsal scar patterns of Levallois flakes, and scar patterns on the upper surface of Levallois cores. Technological analysis of flake production on quartz shows a frequent use of the Levallois centripetal method.

In addition to the Levallois method, volumetric exploitation of convexities to produce elongated flakes with a wide platform angle is observed, while the presence of blades, crest blades, and bladelets -the latter especially on quartz- confirms the presence of the laminar reduction system (Figures 5, 6 and 7).

Cortical platforms occur only in basalt débitage flakes, while plain and non-prepared platforms in basalt are highly attested (65%). On the other hand, lithics on quartz show a higher percentage of prepared platform (faceted and dihedral) (Table 9).

The analysis of bulbs indicates a higher variability among basalt artefacts, conversely a reduced diversity of quartz bulb morphologies (Figure 7). According to bulb and platform analysis, the technique used to produce flakes and tools is direct percussion with a hard hammer.

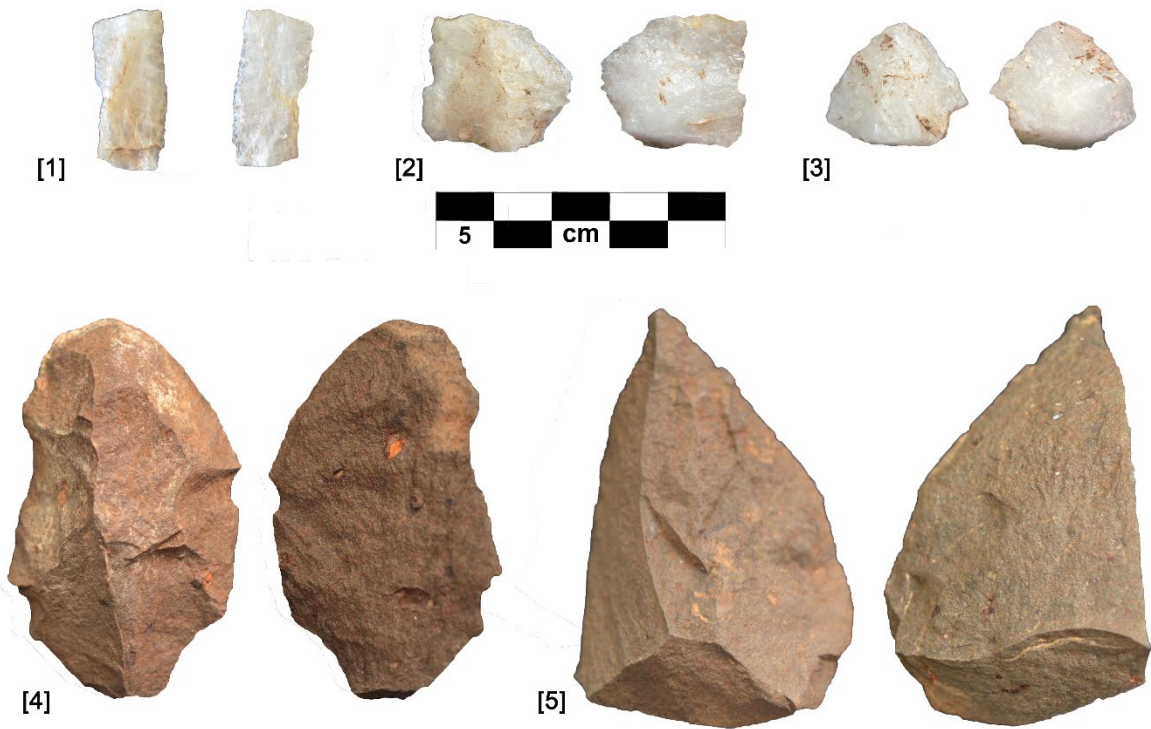


Figure 5. *Débitage* flakes in quartz (top) and basalt (base): [1] quartz bladelet; [2,3] quartz Levallois flakes; [4] basalt cortical flake; [5] basalt point.

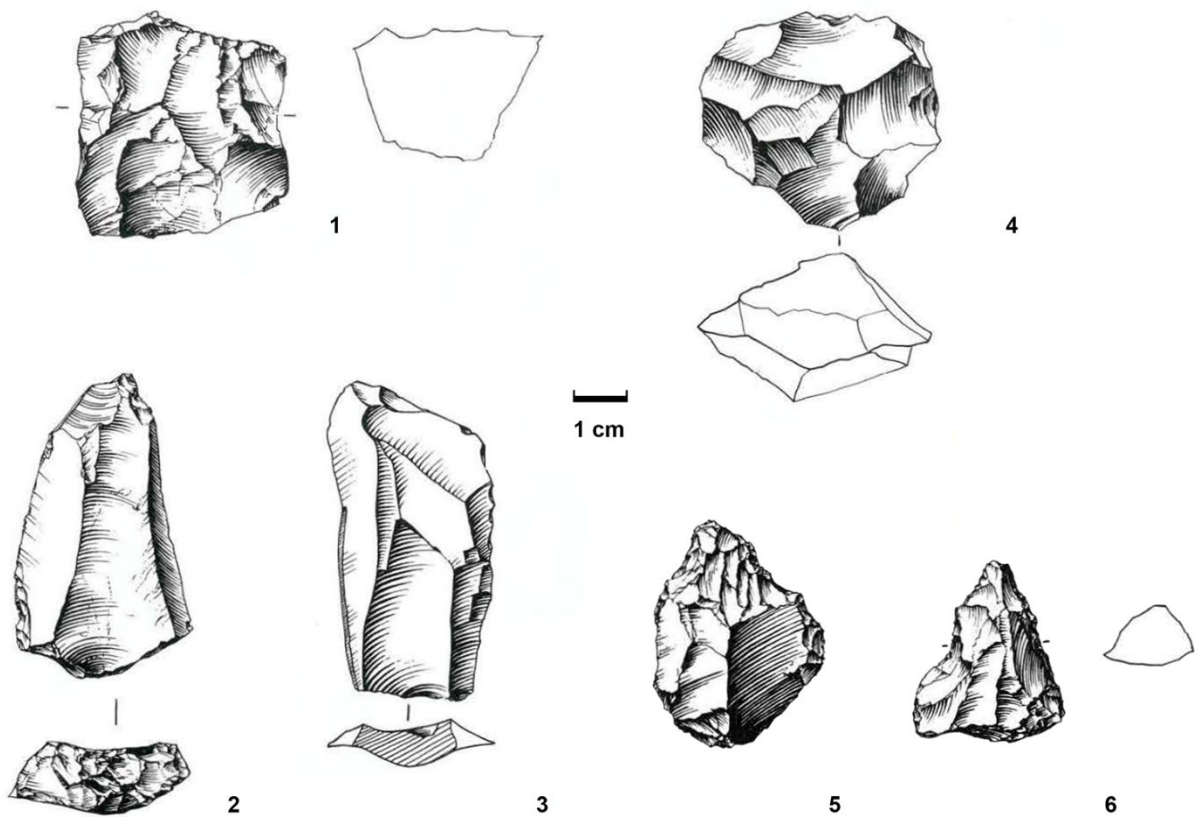


Figure 6. Reduction sequences on basalt (1, 2, 3) and quartz (4, 5, 6). Modified after Chavaillon and Chavaillon 1985.

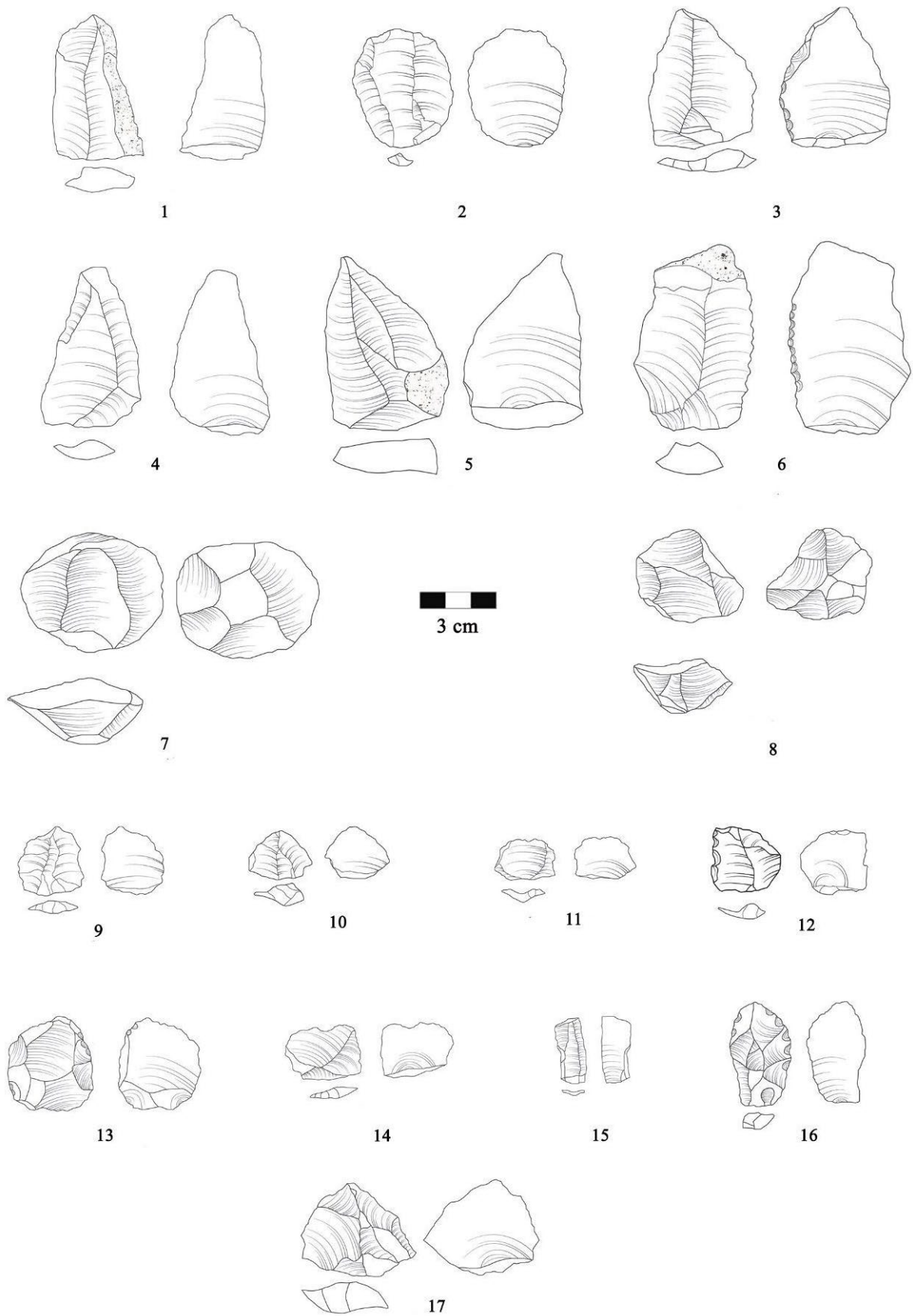


Figure 7: Lithics from GOT 1-S: basalt [1-7] volumetric points [1, 4], Levallois flake [2] and Levallois retouched point [3], point [5], retouched flake [6], Levallois core [7]; quartz [8-17], Levallois flakes [9-14, 17], bladelet [15], Levallois core [15].

Table 9. Platform types from GOT 1-S lithic assemblages.

	Abraded		Cortex		Plain		Dihedral		Facetted		Linear		Punctiform		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Basalt	3	60%	9	100%	97	65%	10	58%	12	36%	1	50%	-	-	132	60%
Quartz	2	40%	-	-	52	35%	7	42%	21	64%	1	50%	2	100%	85	40%
Total	5	2%	9	4%	149	69%	17	7%	33	16%	2	1%	2	1%	217	100%

The presence of retouched flakes is scanty, however the assemblage presents the occurrence of denticulates, flakes with irregular retouch on the interior, and flakes with abrupt or alternate retouch, mostly on basalt.

The technological analysis of flakes clearly suggests differences in the production sequence according to different raw material choices (Figures 5, 6 and 7). Basalt products appear to be more elongated, and platforms are usually plain, thick, and large with a wide platform angle. On the other hand, quartz production seems to have different knapping goals: in fact, quartz flakes are generally smaller with a high percentage of prepared platforms and a minor incidence of plain ones (Figure 7).

Core analysis shows a general lack of cortex, with a higher percentage of cortex among basalt cores (Table 10). The presence of Levallois method is registered as well. Levallois cores occur within the assemblage and are mostly on basalt (80%) and exhibit mostly a recurrent-bipolar removal pattern (39%) (Table 11). However, centripetal, unidirectional convergent, and less often bidirectional removals occur as well, outlining a variety of exploitation strategies (Table 8).

Table 10. Percentage of cortex among cores from GOT 1-S.

Raw material	Percentage of cortex									
	0%		0-25%		25-50%		50-75%		Total	
	N	%	N	%	N	%	N	%	N	%
Basalt	9	47%	8	43%	1	5%	1	5%	19	76%
Quartz	6	100%							6	34%
Total	15	60%	8	32%	1	4%	1	4%	25	100%

Table 11. Levallois core types from GOT 1-S.

Levallois core	Basalt		Quartz		Total	
	N	%	N	%	N	%
Preferential-classical	1	12%	-	-	1	10%
Preferential-bipolar	1	12%	-	-	1	10%
Recurrent-bipolar	3	39%	-	-	3	30%
Recurrent-unipolar	1	12%	-	-	1	10%
Recurrent-centripetal	2	25%	2	100%	4	40%
Total	8	80%	2	20%	10	100%

Other cores on basalt show an opportunistic exploitation of their natural convexities, also testified by the presence of natural surfaces on some of them.

Irregular reduction strategies are represented by cores on flakes, polyhedral and triangular cores with opportunistic exploitation of convexities, mostly on basalt (Table 12). The majority of discarded cores at GOT1-S were used for flake removals and were not organized by the Levallois concept. There are a variety of core types in this category, including cores with multiple platforms, minimal cores with just a few removals, and centripetally exploited.

Table 12. Complete cores from GOT 1-S.

	Basalt		Quartz		Total	
	N	%	N	%	N	%
Regular core	8	80%	2	20%	10	40%
Levallois	8	80%	2	20%	10	40%
Irregular core	11	73%	4	27%	15	60%
Polyhedral	5	63%	3	37%	8	32%
Core on flake	1	-	-	-	1	4%
Triangular	2	83%	1	17%	3	12%
Disc	3	100%	-	-	3	12%
Total	19	76%	6	24%	25	100%

The combination of Levallois methods (preferential or recurrent) and other flake removal patterns (irregular cores associated with laminar reduction sequences) contributes to generating a substantial variability within the exploitation strategies for the production.

4.2. Statistical analyses

The PCA on flakes produces a solution with two principal components with Eigenvalues greater than 1. The first two components together explain more than the 50% of the variance within the data. The results of the PCA are displayed in a biplot that shows the observations and the variables on a single plot (Figures 8 and 9). Here, we can identify at least two groups: quartz flakes and tools, in black, are displayed on the right side, in contrast with basalt production, characterised by a wider distribution (Figure 9). Since the loadings have positive scores, the more we move up along the first two components, the larger the artefact size, their platform angle, and their curvature from the platform. This means that we can identify interpretable differences between the two lithic productions in Gotera on different raw materials. First, we can assess that, on the one hand, quartz implements are smaller. On the other hand, basalt flakes increase in size, especially in flake elongation. In fact, the technological analysis shows that basalt curve and elongated flakes with a plain platform and a wide platform angle are widespread in the Gotera site and they are linked to a volumetric method aiming to produce elongated flakes (Figure 7: 1 and 4) and blades or through opportunistic knapping.

We thus argue that these different inter-assemblage morphometric features reflect different methods of production. To complete the understanding of the production dynamics in Gotera, we then analysed cores (Table 7) and the results of the PCA for the cores are displayed in Figure 10. The first principal component explains 47.5% of the variance and the second component explains 39.8%. We can describe over 70% of the variation in the data with just two of the nine components. The first component is clearly describing technological aspects of variability, while the second one seems to emphasize size. The third component concerns morphological variation and the technological traits weakly load against it. Since the loadings are positive, bigger and less prepared cores have positive scores on the first two components and smaller and more prepared cores have negative scores. It is important to notice that prepared and regular cores are here not synonymous - cores can count several preparation flakes without being “regular”, while “regular” has been attributed exclusively to a specific knapping method (*e.g.*, Levallois). The plot displays quartz and basalt artefacts distribution in two dimensions: quartz cores are clustered together in the lower right part of the graph, suggesting that they are characterised by strong technological and morphological similarities. Quartz cores are smaller and show the presence of several preparation flakes. The flake removal surface is shaped by the removal of preparatory flakes with the aim to adjust

core lateral convexities to continue the flake production. These new convexities are necessary to control the fracture pattern. On the contrary, basalt cores are generally not prepared, and the fine grain of the raw material allows the exploitation of its natural convexities, without the requirement of a preparation phase. It also allows a wider technological variability of cores, usually exploited using mixed methods of flake removal on the same implement (Figure 11).

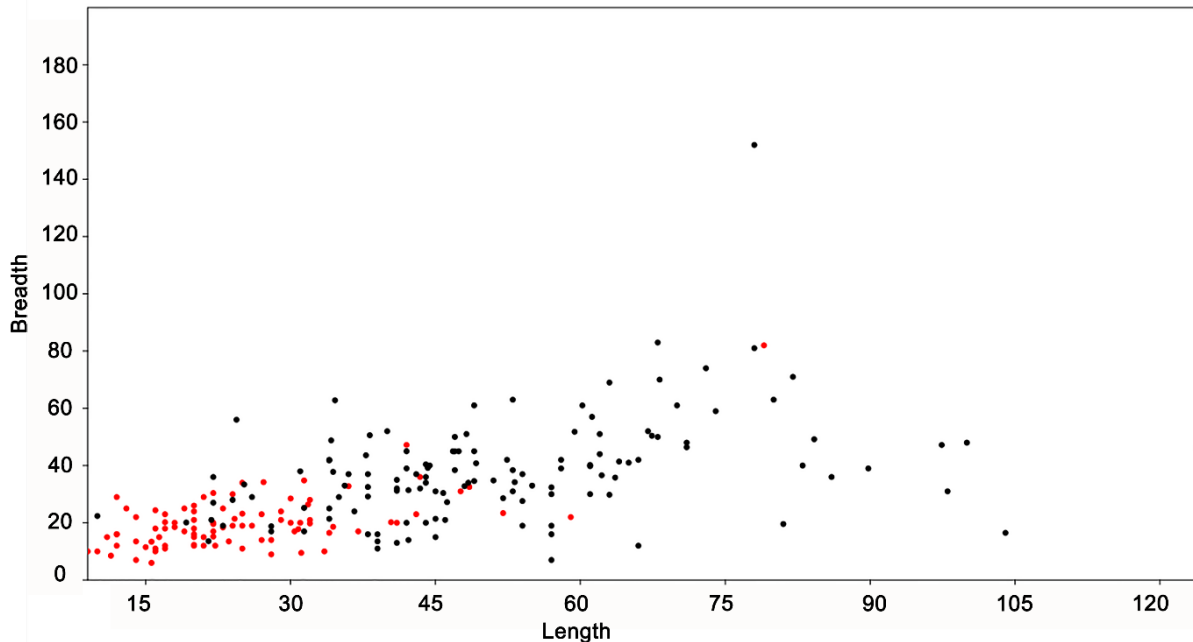


Figure 8. Scatter plot showing quartz (red) and basalt flakes (black) distribution according to their dimensions. Quartz artefacts are clearly smaller in size than basalt implements.

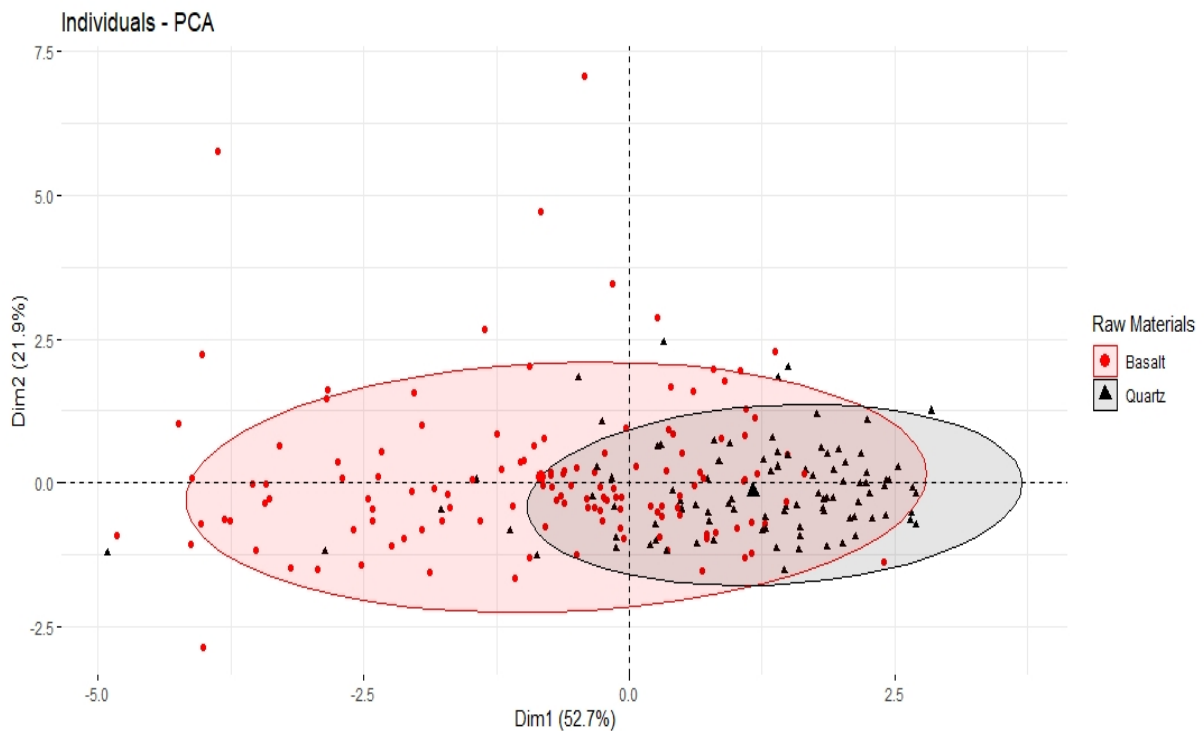


Figure 9. PCA of *débitage* flakes illustrating the relationship between artefacts of different raw materials and using 95% data capture ellipses.

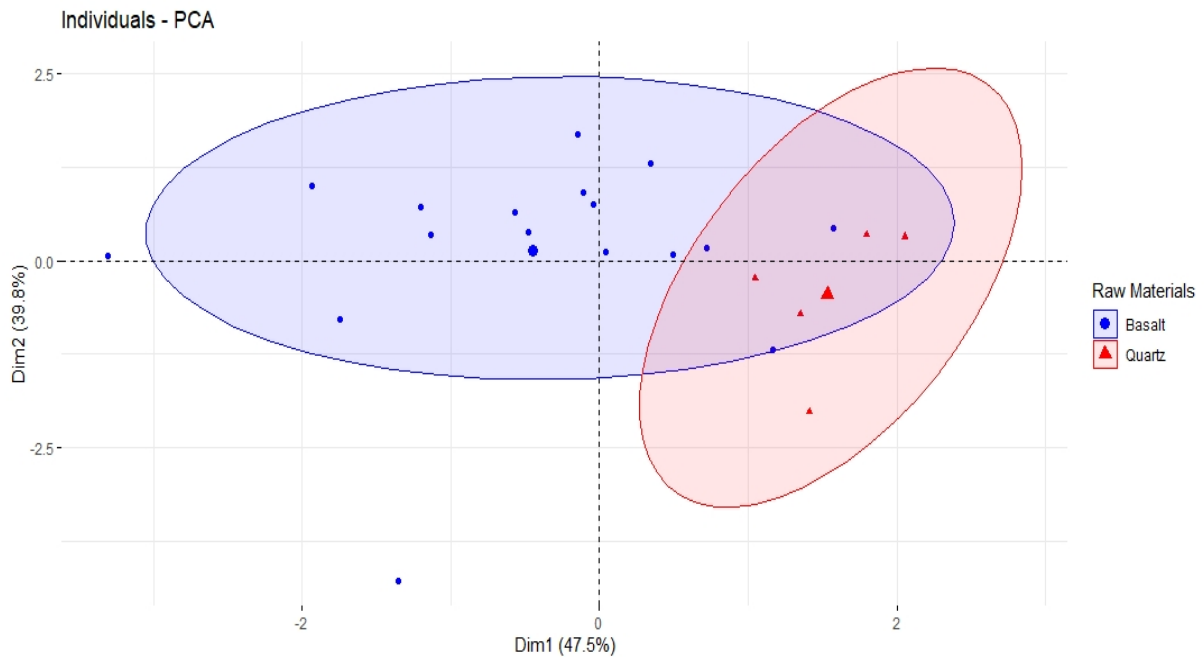


Figure 10. Principal Components Analysis results for cores exploitation dynamics, using 95% data capture ellipses and coloured by raw material.



Figure 11. Quartz (base) and basalt cores (top) from the Gotera lithic collection: [1] irregular core with cortex; [2] Levallois centripetal core.

The dendrogram from the Cluster Analysis shows how specimens are combined to form groups (Figure 12). Visually drawing a horizontal line at the height of 45.0, the dendrogram allows us to identify two basal clusters of artefacts: the largest cluster includes 14 of the 16 basalt core types and is structured into two sub-clusters, while quartz artefacts, characterised again by strong similarities, are clustered together on the left side of the dendrogram.

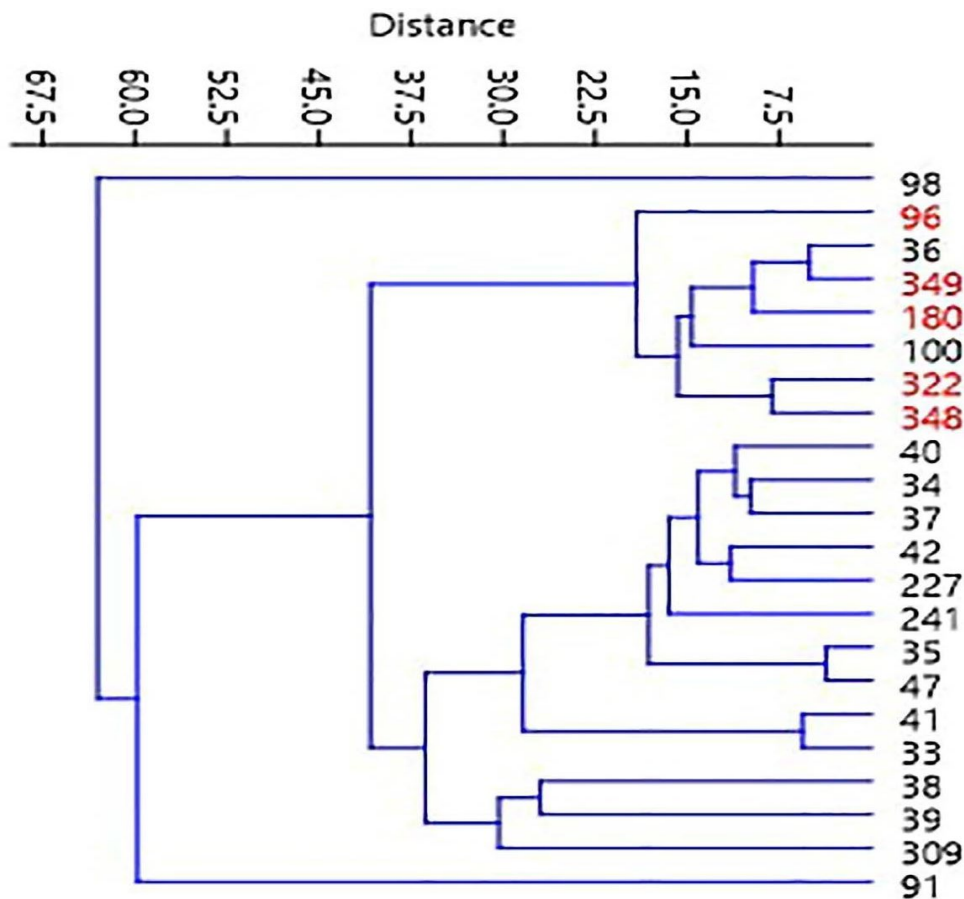


Figure 12. Hierarchical Clustering of basalt (black) and quartz (red) cores using principal components scores and computing a Euclidean distance.

Results for CA are represented for flakes (Figures 13 and 14) and cores (Figures 15 and 16). The flake analysis (Figures 13 and 14) presents two dimensions which represent the 67.02% of the overall variability within the assemblage. The first dimension (45.93%) shows a correlation between a high percentage of cortex for flakes on basalt with cortical platforms, together with plain platform and bipolar scar pattern; on the other hand, it shows a correlation between quartz flakes with no cortex and faceted platforms. The second dimension (21.09%) is characterised by the correlation between more prepared platforms on quartz flakes, despite less prepared and cortical platforms on basalt flakes. Basalt and quartz represent here the 80% of contributions between variables.

For core analysis (Figures 15 and 16) the first two dimensions represent the 78.85% of the overall variability. The first dimension (49.35%) is characterised by the correlation between cores from scatters in basalt, mostly belonging to a primary stage of knapping process, Levallois preferential and recurrent bipolar reduction strategies and more cortex, while on the other hand polyhedral and Levallois recurrent centripetal reduction strategies are more associated with quartz assemblages with no percentage of cortex and mostly belonging to a tertiary stage of the knapping process. The second dimension (29.48%) is characterised by a correlation between a high percentage of cortex in basalt and the absence of cortex on quartz exploitation.

The Principal Component Analysis together with the Cluster analysis and the Correspondence analysis illustrate the association of dimensional and technological traits with each component of the sample, and reveal the high degree of patterning of the lithic assemblage. In fact, the outcomes appear to be very similar in content. Furthermore, the presence of outliers provides an interesting point of view, because the analyses have identified

two basalt cores distant from any other observation points. The first is a prismatic unidirectional core with two striking platforms, and it is an interesting example of irregular core exploited for the detachment of blades and laminar flakes, which at the same time cannot be strictly attributed to the laminar method type. The second one is an irregular unidirectional core characterised by the detachment of a single flake and has a very high percentage of cortex (around 80%). It is interesting to notice that, despite the abundance of local cobbles of basalt, this is the only core pertaining to the very first stage of preparation for the knapping.

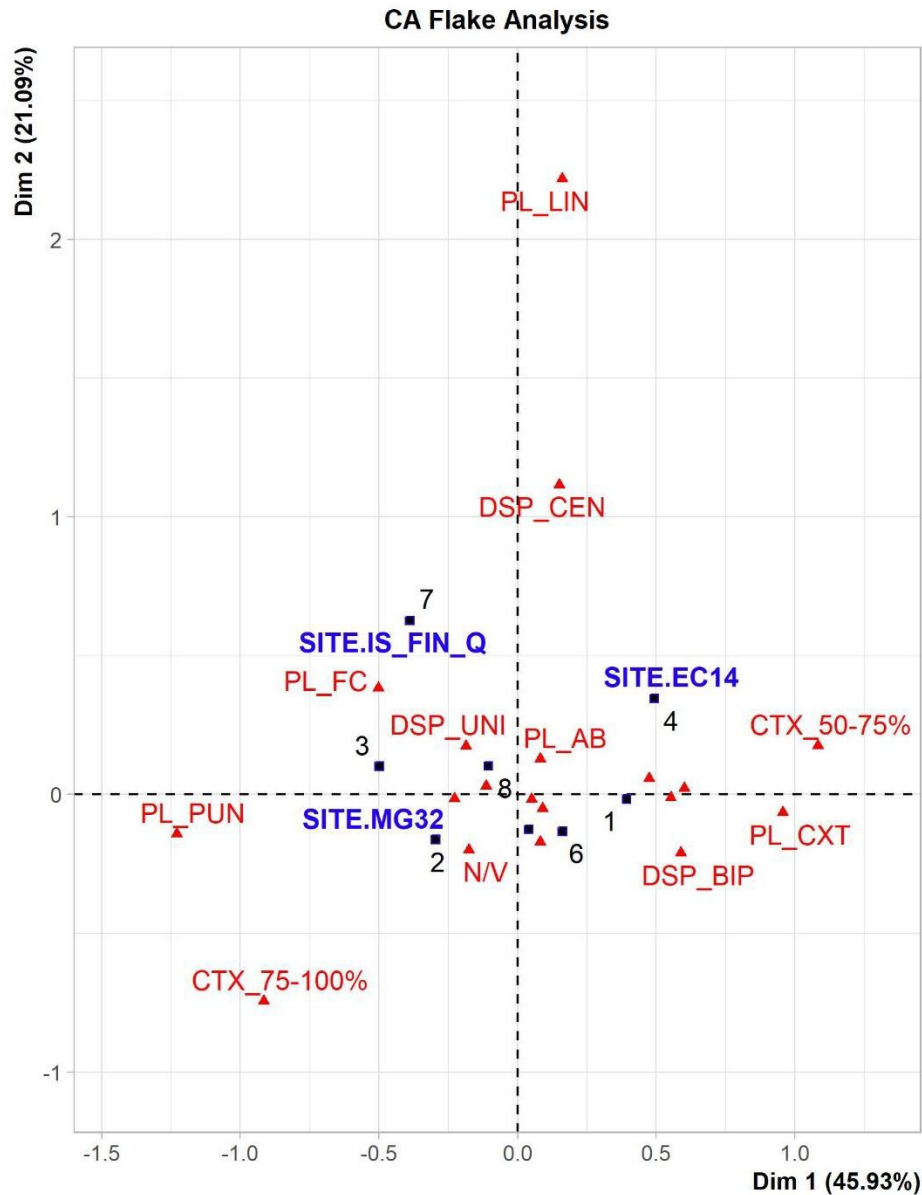


Figure 13. Correspondence analysis of flakes. Supplementary variables are marked in blue while active variables are marked in red.

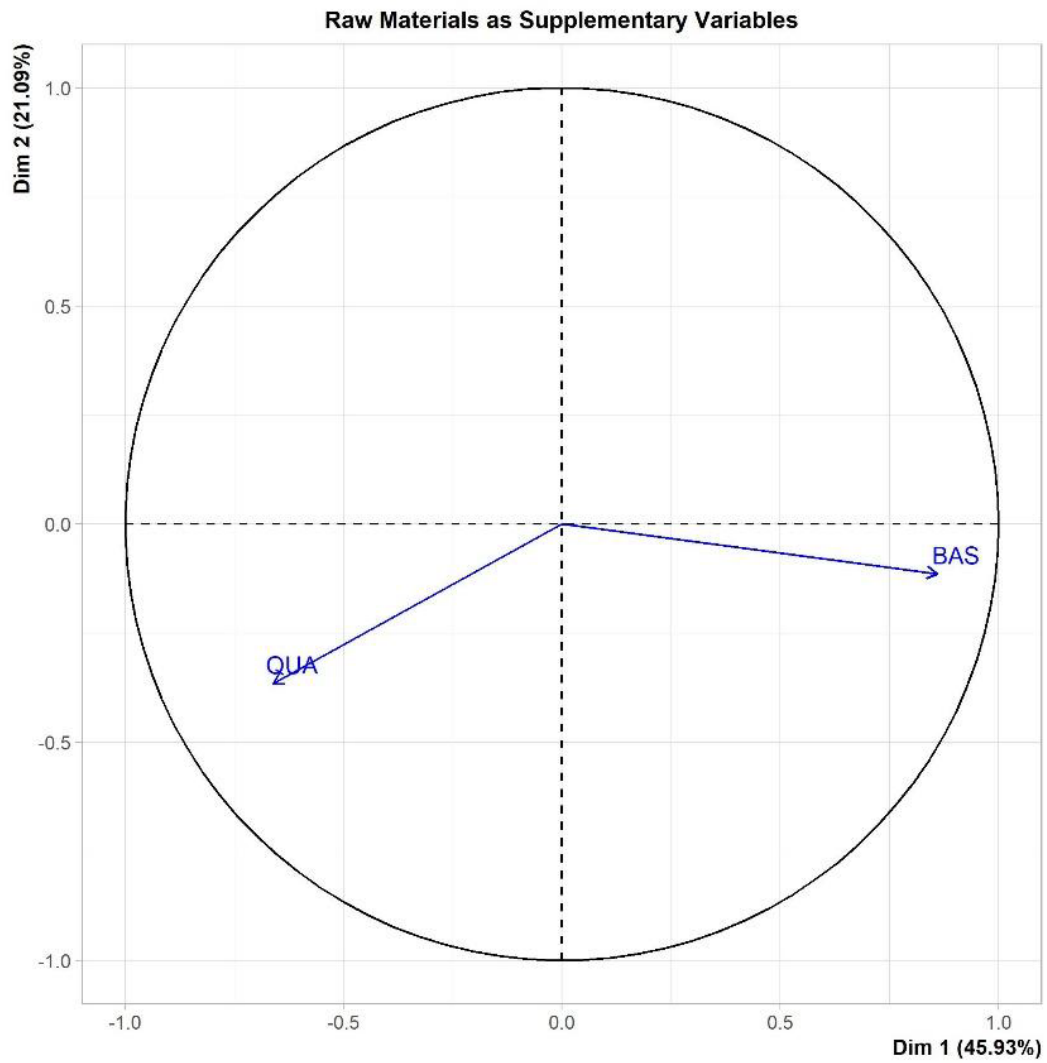


Figure 14: graph showing the disposition of raw material as supplementary variable for flake analysis

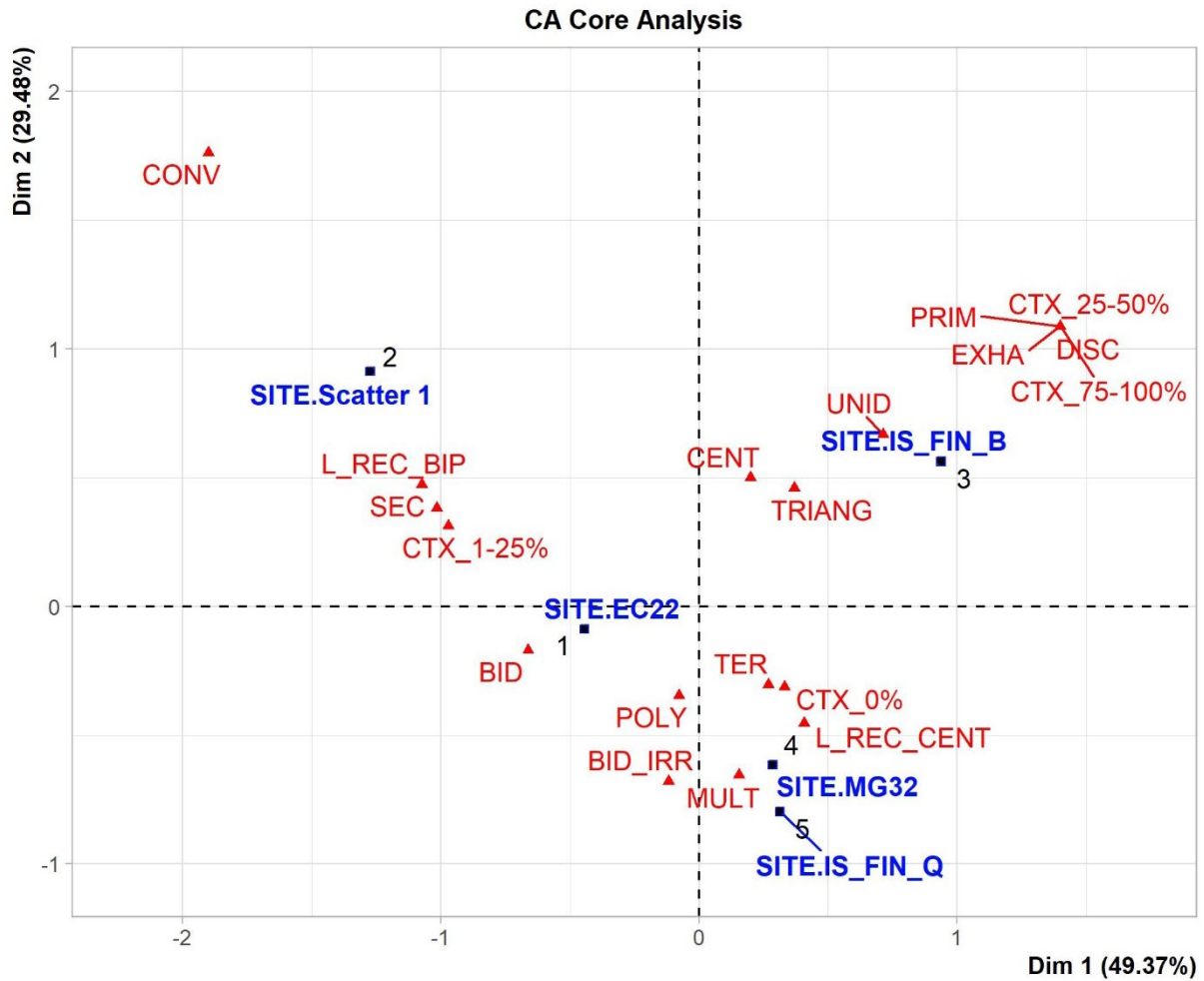


Figure 15: Correspondence analysis of cores. Supplementary variables are marked in blue while active variables are marked in red.

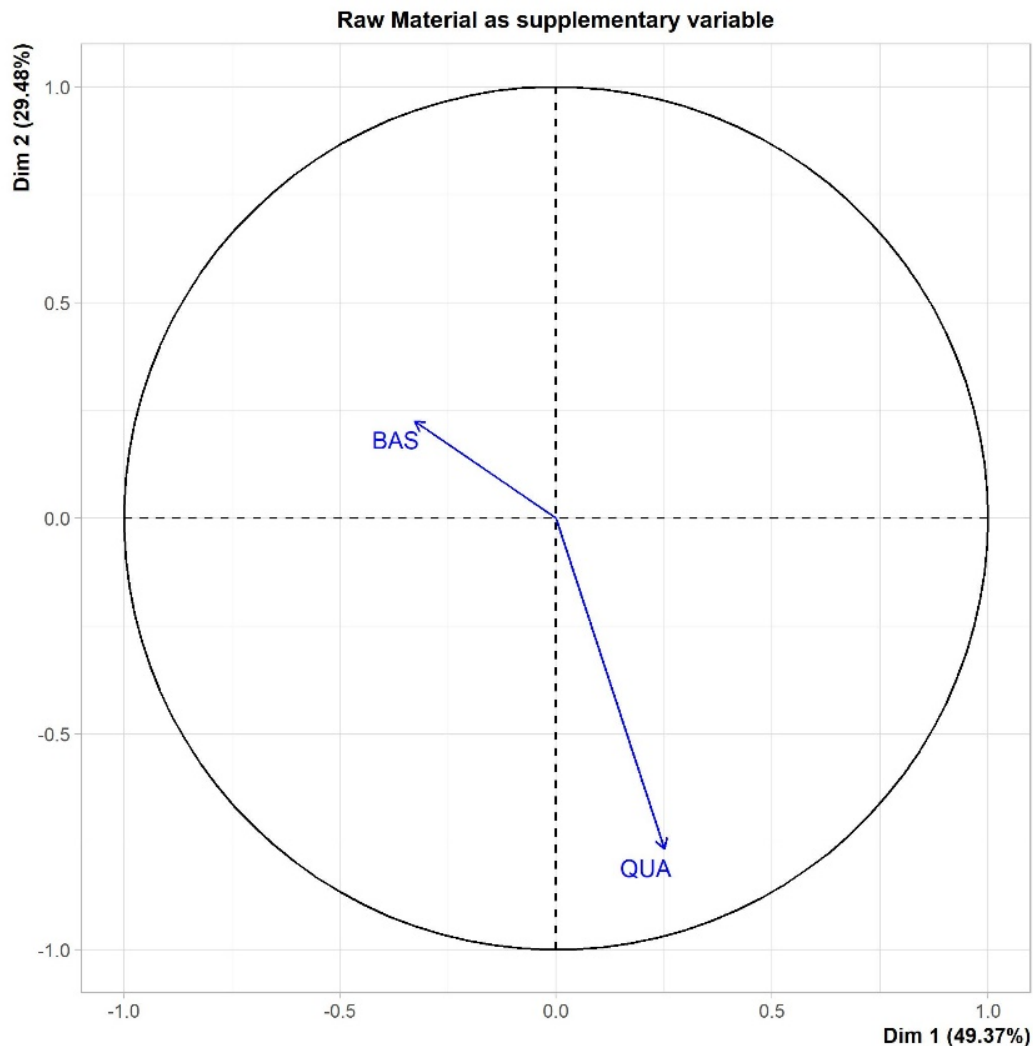


Figure 16. Graph showing the disposition of raw material as supplementary variable for core analysis.

5. Discussion

Despite dealing with a relatively small sample, the results highlight the potential of combining different methods to explore lithic data. The use of technological and statistical analyses combined to explore lithic assemblages is already widely accepted as a good method to quantify inter assemblage variability (Blinkorn & Grove 2018; 2020; Scerri *et al.* 2016). Our results provide an effective contribution to the argument, highlighting the importance of quantifying the data for exploring the variability even within a small sample. The use of quantitative methods helped us to distinguish two different ways of raw material exploitation and quantify the data collected in surface.

The results obtained through the PCA, the Cluster analysis, and the CA are meaningful, revealing the presence of two different behaviours linked to different raw material choices. We argue that these distinct technological differences are clearly affected by raw material dimensions, quality, and abundance: raw materials are selected and then exploited using specific approaches. Quartz artefacts show strong technological affinities - careful core and platform preparation, size reduction, recurrence of Levallois and laminar methods, and other flake removal patterns (Figure 7). Two different varieties of quartz have been exploited: one more vitreous and one coarser. Conversely, the basalt production shows a more opportunistic exploitation of cores and their natural convexities, also for Levallois production. In fact basalt cores present a large percentage of cortex, suggesting an initial phase in the reduction process

or a more opportunistic strategy of reduction. Besides, this reveals the abundance and availability of this raw material, since the cores were not heavily exploited. The recurrence of regular, irregular, and multidirectional flake removal patterns is concomitant, producing substantial variability within the strategies to basalt flake production. In Gotera, the Levallois method often occurs together with a volumetric exploitation of the natural convexities of the basalt cobbles. This combined method contributes to produce a high proportion of curved and elongated flakes with plain, rarely dihedral platforms with a wide angle, widespread at the Gotera site. Overall, the lithic assemblage is highly patterned according to size, shape, and technology. Multivariate analyses here applied indicate that lithic implements of the same raw material share similar features and show an internal coherence within the two sub-ensembles of different raw material, which is notable, given the fact that they come from a surface collection. This correlation suggests that raw material plays a central and dominant role in driving the assemblage structure. We assume that the interassemblage variability characteristic of the Gotera lithic complex is affected by raw material selection and exploitation strategies. Technological differences between quartz and basalt artefacts may reflect a difference in raw material procurement strategies and managing, or a selection of the raw material in function of the desired products. Moreover, according to the preliminary results obtained during the 2018 excavation activities, it seems more likely that the technology of basalt and quartz was integrated in the same subsistence strategy. Thus, the difference in *chaînes opératoires* is the result of an excellent management of the available sources because they belong to the same occupational event as they have been found buried in the same levels.

Furthermore, results from technological analysis allow to highlight the difference with the lithic assemblages analysed by Chavaillon & Chavaillon (1985), as they referred to the assemblage as an Early MSA (EMSA) occupation of the area for the presence of LCT in association with the Levallois prepared technology. The absence of EMSA features within the GOT 1-S assemblage may be due to a research *bias* since we have not been able to reach deeper levels during the last field campaign. Current research in the area involving stratigraphic excavations will help clarify the chronological and behavioural meaning of this result, as well as the evidence of an earlier occupation of the area. In particular, further hypotheses will be tested such as: i) that hominins used different raw materials for different purposes in the frame of the same technological system, or ii) if the exploitation of the area did include the use of only raw materials of local origin, and iii) what is the relationship between Gotera lithic assemblages and other lithic technologies of the region?

The differential utilisation of quartz and basalt in Gotera is peculiar and sheds light on the managing of environmental resources in the area during the Late Pleistocene. The exploitation of local raw materials reflects a strong adaptation to that specific landscape which is also characterised by the lack of obsidian as well, generally present in other Ethiopian MSA sites - such as Melka Kunture, Mochena Borago or Gademotta-Kulkuletti formation (Brandt *et al.* 2012; Douze & Delagnes 2016; Mussi *et al.* 2014). The exploitation of chert is also indicated by the presence of only six artefacts, but there is not a clear evidence of a local origin. The presence of chert sources in Kibish Member I (Shea *et al.* 2007), located about 130 km away (as the crow flies), is attested, however a possible exotic provisioning will represent a further goal to be deeply investigated in the next seasons of research. The Gotera assemblage confirms the regional character of the MSA, where human groups built lithic tradition upon conditions that are strictly local.

6. Conclusion

Associated attributes and technological analyses have confirmed the differential exploitation patterns of the main raw materials attested in the investigated area. This preliminary study aims to be a first methodological step in order to tackle the lithic variability of a surface site. The aim is a wider exploration and definition of lithic production trends within the MSA lithic complex from Gotera, in order to understand the specific archaeological signatures of this understudied region. The Gotera site shows that the MSA is not exclusively linked to the exploitation of good quality and/or easy workable raw materials, and that other conditions (*e.g.*, the availability of water and game) may have influenced the choice of *Homo sapiens* to exploit an area. Our combined applications confirm the importance of associating the classical technological analysis with a statistical approach to better analyse specific regional contexts and to obtain data comparable at a larger scale with other MSA sites of East Africa.

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Supplementary Information

The datasets and R code used to perform the analyses are available as supplementary electronic material on a Zenodo repository (<https://doi.org/10.5281/zenodo.5141337>).

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