Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: http://ees.elsevier.com

The first comprehensive micro use-wear analysis of an early Acheulean assemblage (Thiongo Korongo, Olduvai Gorge, Tanzania)

Patricia Bello-Alonso [a,b,*], Joseba Rios-Garaizar [a], Joaquin Panera [a,b], Susana Rubio-Jara [a,b], Alfredo Pérez-González [b,c], Raquel Rojas [b,c], Enrique Baquedano [b,d], Audax Mabulla [e], Manuel Domínguez-Rodrigo [b,f], Manuel Santonja [a,b,c]

[a] *Centro Nacional de Investigación sobre la Evolución Humana. Paseo Sierra de Atapuerca, nº3, 09002, Burgos, Spain*
[b] *Instituto de Evolución en África, Covarrubias 36, 28010, Madrid, Spain*
[c] *Asociación Nacional El Hombre y el Medio, Santo Tomás de Aquino, 21, 28980, Madrid, Spain*
[d] *Museo Arqueológico Regional, Plaza de las Bernardas s/n, 28801, Alcalá de Henares, Spain*
[e] *National Museums of Tanzania, Dar es Salaam, Tanzania*
[f] *Departamento de Historia y Filosofía, Universidad de Alcalá de Henares, 28040, Madrid, Spain*

ARTICLE INFO

Article history:
Received 26 December 2020
Received in revised form 19 April 2021
Accepted 24 April 2021
Available online xxx
Handling Editor: Giovanni Zanchetta

Keywords
Use-wear
Olduvai Gorge
Thiongo korongo
Naibor quartzite
Basalts
Archaeological results

ABSTRACT

Probably one of the most unanswered questions about the Acheulean is focused on the functional aspects of its lithic industry and, more specifically, its link to subsistence activities developed by hominins during the Early Stone Age. Historically, tecno-functional research on ESA techno-complex has focused on the role played by flakes and LCT in the processing of animal carcasses, but less attention has been payed to other possible activities related with subsistence and tool making. Previous traceological studies on African Lower Paleolithic lithic industries have shown the complexity of activities made with the earliest lithic tools, including not only the processing of animal carcasses, but also activities dedicated to processing wood, non-woody plants and underground storage organs (USOs). In this paper we present the use-wear results obtained from the analysis of the Early Acheulean lithic tools with potentially functional edges component of the lithic assemblage from the Thiongo Korongo archaeological site (TK) (Olduvai Gorge, Tanzania). The three main levels of the archaeological site, TKSF, TKLSC and TKLF, have been used as samples. From 466 lithic artefacts analyzed, 16 pieces present sufficient preservation of use related traces that are able to clearly identify the activities developed when compared with experimental reference collections. As a result, we have identified activities mainly related with the cutting and scraping of wood and non-woody plants, including USOs. In addition, some pieces have also presented traces indicating the processing of animal carcasses. These data provides important information about different activities developed in TK by early hominids, allowing us to make broader inferences about the different subsistence activities carried out during the Acheulean in Eastern Africa.

1. Introduction

The majority of studies dealing with the functionality of lithic industries during the African Acheulean have been centered on the morphological and experimental investigation concerning handaxes (Jones, 1980, 1994, 1994; Machin et al., 2005; Santonja et al., 2018), and pounding tools (de la Torre et al., 2013; Sánchez-Yustos et al., 2015; Arroyo and de la Torre, 2016, 2018; Arroyo et al., 2016; Benito-Calvo et al., 2018). Less attention has been payed to the flake lithic part of the assemblages, with some exceptions (Schick and Toth, 1993; Galán and Domínguez-Rodrigo, 2014), despite flakes being the main tool type identified in most African Acheulean assemblages (Semaw et al., 2020). In contrast, the use-wear studies developed in Oldowan contexts show a differential dynamism, have focused on the small and medium sized flakes.

Although the possibility of obtaining use-wear information from African Lower Palaeolithic lithic industries has been the subject of certain controversy, due to preservation issues (Sussman, 1987; Beyries, 1990) in recent year's use-wear analysis of these materials have proliferated. Also, the lack of appropriate and dedicated use-wear reference collections has hampered the correct analysis of the archaeological collections and the identification of wear traces (Bello-Alonso et al. 2019, 2020). Since the 1980's there have been several analyses of

* Corresponding author. Centro Nacional de Investigación sobre la Evolución Humana. Paseo Sierra de Atapuerca, nº3, 09002, Burgos, Spain.
E-mail address: patriciamariabelloalonso@gmail.com (P. Bello-Alonso)

https://doi.org/10.1016/j.quascirev.2021.106980
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Early Stone Age (ESA) assemblages, mostly focusing on the Oldowan. In 1981, Keeley and Toth (1981) published a traceological analysis applied to fifty-four Oldowan flakes from the site of Koobi Fora (Kenya). The results obtained in that work confirmed the processing of animal carcasses (slicing), but also of plants (grasses and/or canes) (slicing) and wood (scraping and sawing). In 1987, C. Sussman published the results after the total analysis of 105 artefacts of the Oldowan lithic industry from FLK (BED I), FLK North (Bed I) and HWK (Bed II) in the Olduvai Gorge, analyzing artefacts made on basalt, flint and quartz (Sussman, 1987). These studies were able to highlight activities dedicated to the processing of organic materials, such as wood. Nevertheless, Sussman importantly noted the bad preservation of these materials. In 1997, Keeley published new data on the functional analyses carried out on the Oldowan lithic industries from Koobi Fora. In this analysis he provided more information on post-depositional alterations documented on these lithic materials. Notwithstanding, Keeley was also able to provide more results that confirmed the processing of various materials such as plants, wood and animal carcasses (hide-flesh) through scraping, cutting and sawing activities, identified on nine flakes (Keeley, 1997).

More recently, data from Ain Hanech (Algeria) Oldowan site have also been published. In these studies use-wear has been documented on several flake tools, revealing bone and animal carcass processing activities (Vergés, 2003; Sahnouni et al. 2013, 2018). In 2014, the use-wear results from Kanjera South Oldowan assemblage (Kenia) were presented, revealing use-wear traces on quartz, quartzite, fenetized andesite and rhyolite flakes (Lemorini et al. 2014, 2019). In these studies macro and microscopic data presented indicates the existence of a wide range of actions and worked materials, and, for the first time, clear evidence of soft herbaceous plants and underground store organs (USOs) processing. At the same time, in this study some pieces with multiple use episodes were presented, also revealing activities linked with cutting, scraping and cutting-scraping actions for the processing of animal (hide, flesh and bone) and wood resources (Lemorini et al. 2014, 2019).

Moreover, in recent years several experimental and archaeological investigations on the functionality of pounding tools in the Early Paleolithic have been carried out (de la Torre et al., 2013; Sánchez-Yustos et al., 2015; Arroyo and de la Torre, 2016, 2018, 2020; Arroyo et al., 2016; Benito-Calvo et al., 2018). The results obtained from the analysis of such tools from various Acheulean sites in Olduvai Gorge Bed I and Bed II (BK, FC West, TK, SHK and FLK North level 6) have also revealed activities related with the processing of flesh, bone and nuts, similar to those observed in experimental samples (Arroyo and de la Torre, 2016; de la Torre et al., 2013). At the same time, the functionality of lithic tools has been approached from other analytical perspectives, such as the case of residue analyses from sites in Peninj, revealing the presence of wood residues (*Acacia* sp.) associated to a handaxe; suggesting that these tools could have been involved in wood working activities (Domínguez-Rodrigo et al., 2001).

All these use-wear analyses have based their functional interpretations of these traces on comparisons with experimental reference collections. These studies have additionally tried to overcome the rather simplistic idea that ESA tools were used exclusively for the processing of animal carcasses (Jones, 1980, 1981, 1994; Schick and Toth, 1993; Mitchell, 1996). Under this premise, in addition to the processing of animal and wood resources, a wide range of materials including herbaceous, under storage organs (USOs), nuts, and canes (Lemorini et al., 2014, 2019; Arroyo and de la Torre, 2016; Bello-Alonso et al., 2019, 2020; de Francisco, 2019). The development of other hypothetical activities in sites is based on previous traceological results (Keeley and Toth, 1981; Sussman, 1987; Keeley, 1997), as well as information obtained from other sources of information such as ethnography, diet reconstruction, ecology, paleo-environment, residue analysis and/or technology, all of them supporting that these early hominins have rather complex economic interactions with their landscapes and the array of resources found on them (Mercader et al. 2002, 2009, 2009; Marlowe and Berbesque, 2009; Jones, 1994; Lee-Thorp et al. 1994, 2012, 2012; Domínguez-Rodrigo et al., 2001; Herrygers, 2002; Cerling et al., 2011; Magill et al. 2013; Plummer and Bioshop, 2016).

In this paper, we present the first comprehensive micro use-wear analysis of an African Acheulean industry functionally characterized by the presence of one or more edges, using the case study of the lithic assemblages from the archaeological site of Thiongo Korongo (TK, Olduvai Gorge, Tanzania). The TK flake sample is composed of Naibor Soit Quartzite (NQ) and basalts which have been selected from each of the main archaeological levels of the site: TK *Lower* Floor (TKLF), TK Loamy Sand Channel level (TKLSC) and TK *Sivatherium* Floor (TKSF). In these archaeological levels we identified three main tool functional types: pounding tools, bifaces and tools with potentially functional edges (including retouched and non-retouched flakes, chunks and slab fragments). A total of sixteen pieces have preserved clearly identifiable use-wear traces. The previously published data on technological, taphonomic and spatial distribution data show TK to be an active occupation sites during different stages of the Acheulean. Technological studies show a marked diversity and intensity in the management and technological strategies developed at the different levels of TK, paying particular attention to the configuration and morphologies of the handaxes (Leakey, 1971; Santonja et al. 2014, 2018, 2018; Rubio-Jara et al., 2017), while, despite an important diversity of taxa, zooarchaeological results reveal low evidence of anthropogenic activities (Yravedra et al., 2016). From these data and results obtained through spatial studies (Panera et al., 2019), it is difficult to provide an accurate description of the subsistence activities developed by the hominins that occupied TK.

Use-wear results presented in this study are a fundamental tool for an initial interpretation of the subsistence activities performed through the different occupations represented in TK sequence. In this sense, the data obtained reveal an important diversity of used type tools and activities carried out at this site, specifically related with the processing of organic resources, such as wood, USOs and animal carcasses. This allows us to develop a better interpretation of the resource management carried out during Acheulean periods in East Africa.

2. TK archaeological site

TK is an Acheulean archaeological site located in Olduvai Gorge (Tanzania). This site is situated within the lateral hollow of a north-south running gully (known as a korongo in Swahili), located on the north slope of the Olduvai Main Gorge, approximately 2 km east of its junction with the Side Gorge (Leakey, 1971; Santonja et al., 2014) (Fig. 1). TK is located on the top of Bed II and associated with the Tuff IID (Leakey, 1971; Hay, 1976; Santonja et al., 2014), which has been dated by $^{40}Ar/^{39}Ar$ to 1.353 ± 0.35 Ma (Domínguez-Rodrigo et al., 2013).

TK was discovered by the team directed by Louis Leakey in 1931, thanks to an exposure on an outcrop of several bifaces (Leakey, 1979). Extensive excavations, however, were not carried out until 1963 under the direction of Mary Leakey (1971). From 2010 to present, The Olduvai Paleoanthropological and Paleoecological Project (TOPPP) resumed archaeological excavations in TK under the direction of Manuel Santonja, Alfredo Pérez-González since 2010, and Joaquín Panera, since 2018 (Santonja et al. 2014, 2018, 2018; Rubio-Jara et al., 2017; Panera et al., 2019; Bello-Alonso et al., 2019).

In this study, we have analyzed lithic materials recovered from three levels of TK: Thiongo Korongo Lower Floor (TKLF), Thiongo Korongo Loamy Sand Channel (TKLSC) and Thiongo Korongo Sivatherium Floor (TKSF). TKLF is a paleo-surface marked by a stratigraphic discon-

Fig. 1. Location of the Thiongo Korongo (TK) archaeological site. Figure from Hay (1976) and Santonja et al., (2014).

tinuity and a flat topography, partially covered by a tuff of sandy clays and a loamy sand channel- TKLSC, which displays a planar cross-stratification, has a NW–SE flow direction deposited by an ephemeral and seasonal channel with low transport capacity and a maximum thickness of 40 cm. This channel was probably active for a short period of time, only several dozen or perhaps a few hundred years. TKSF overlies TKLSC, creating a floor that is covered by a horizon of sandy clay. The bottom of this horizon marks a hiatus of slight erosion on the loamy sand channel (Santonja et al., 2014; Rubio-Jara et al., 2017; Panera et al., 2019).

2.1. Raw material

The lithic assemblages registered at Olduvai Gorge show a certain heterogeneity of raw materials related with the variety of lithological resources present in the area. Considering this wide range of raw materials available, studies about their location and, especially, their characterization (macroscopic, petrological and geochemical analysis) have been a topic of interest since the 1950′s (Pickering, 1958; Leakey, 1971; Hay, 1976; Mollel, 2007; Mollel et al., 2008, 2009; 2011; Mollel and Swisher, 2012; McHenry and de la Torre, 2018; Favreau et al., 2019; Soto et al., 2020). The particular case of Bed II presents a petrological characterization of the Acheulean lithic industry with the main raw materials used being Naibor Soit quartzites (NQ) (ca. normally represents around the 90% of the lithic material) as well as other volcanic rocks (VR) (Leakey, 1971; de la Torre, 2006; de la Torre and Mora, 2018; Santonja et al. 2014, 2018, 2018; Rubio-Jara et al., 2017).

Geological studies about the origin of these raw materials indicate that they came from two main sources: a) the belt of volcanoes that runs east and south of the area, being an important source of multiple VR which were available in secondary contexts near the site (volcanic lavas, phonolites, trachytes, rhyolites, and ignimbrites) (Pickering, 1958; Leakey, 1971; Hay, 1976; Mollel et al., 2007, 2008, 2009, 2011; Mollel and Swisher, 2012; McHenry and de la Torre, 2018; Favreau et al., 2019); and b) the Precambrian inselbergs of metamorphic rocks, with a great variety of quartzite and quartz rocks (Pickering, 1958; Leakey, 1971; Stiles et al., 1974; Hay, 1976; Favreau et al., 2019; Soto et al., 2020). According with geochemical analyses made on these raw materials, alongside technological studies (Leakey, 1971, 1994, 1994; de la Torre, 2006; de la Torre and Mora, 2018; Díez-Martín et al. 2010, 2015, 2015; Santonja et al. 2014, 2018, 2018; Rubio-Jara et al., 2017), it has been possible to determinate raw material provisioning strategies. In the Olduvai Gorge area, quartz and quartzite come from a primary source (the industry is configured from slabs located in the inselbergs), while VR likely come from a nearby secondary source (cobbles naturally transported from the primary source) (Leakey, 1971; Hay, 1976; Kyara, 1999; Mollel, 2007; McHenry and de la Torre, 2018). Therefore, the raw material procurement strategy is based primarily on local materials.

2.2. Lithic technology

5805 lithic pieces were recovered from TKLF in a 51.9 m^2 excavation (Santonja et al. 2014, 2018). A total of 92.4% are made from NQ, while 6.8% of items are VR, with the remaining 0.9% consisting of vesicular lava, non-Naibor quartzite, flint and gneiss (Table S1). All phases of the *chaînes opératoires* are recognized in NQ and VR. The knapping activities at TKLF are focused on producing flakes from cores that are occasionally retouched, as well as the shaping of LCTs through direct freehand percussion and bipolar percussion. About 65.7% of the assemblage (3812 items) are debris, fragments of NQ slabs and chunks. Almost half of all the volcanic rocks items consist of cobbles (181 pieces from 392), mainly used as hammerstones (69 from 181) and occasionally as cores. The majority of the exploitation schemes identified in cores (268 items in total) are simple, although peripheral unidirectional system was recognized in 43 pieces and the discoid in 32 pieces. A total of 1421 flakes (NQ: 91.8%; VR: 7.6%; and 0.6% in non-NQ, gneiss and flint) were identified. NQ flakes tend to be slightly larger and longer (L = 42.9xW = 38.3 mm), while VR flakes are often short and wide (L = 41.9xW = 46.4 mm). The size of flakes in both raw materials is similar, (ca. 80% of complete flakes) are 20–60 mm long, 11–14% are 60–100 mm long and 2% exceed 100 mm in length). The relationship between scar sizes on the cores and the size of flakes (in NQ 5.6 flakes per core and in VR 4.2), as well as the presence of cortical and full reduction flakes of all categories shows that NQ and VR were exploited in the site. Only 3.8% of the NQ flakes and 1.8% of VR flakes were modified by retouch (scrapers, denticulates, becs, awls and backed knives). The 5.7% of total flakes are *debitage* or natural backed knives, which points towards an intentional production of flakes with cutting edges. *Façonnage* is a characteristic feature in TKLF. It is observed in 85 bifaces (the 4.3% of lithic assemblage, excluded shatter): 77 handaxes, 3 thrihedral picks, 3 cleavers on flakes, and 2 large scrapers on flake. Most of them were processed at the site on NQ and only 11 were produced from VR.

The raw materials used at TKLSC are the same as in TKLF, with apparently more presence of NQ. Undifferentiated products are also very common, and flakes, cores and a large number of *façonnage,* some of them on flake, are represented.

TKSF is above TKLSC (Rubio-Jara et al., 2017). In this level a total of 1161 lithic pieces were recovered from surface area of 45.3 m^2. A total of 91% are made of NQ, 8% are VR, and the remaining 1% on other raw materials (Table S2). Knapping activities are focused on producing flakes, occasionally retouched and shaping of macro-tools. Nevertheless, differences in production between VR and NQ are identifiable among raw materials. VR was exploited outside the site while NQ would have been carried out and knapped on site. Knapping and probably percussion activities are relevant in TKSF, with 55,4% of VR cobbles were used as hammerstones. Simple operative schemes are dominated, the peripheral unidirectional system is represented in 16.3% of the cores, and the discoid in 22.4% of the cores. The freehand and bipolar knapping have been documented in cores and more than 40% of them were exploited by both techniques. A total of 341 flakes were identified (94.1% on NQ and 5.9% on VR). 10% of the NQ flakes are more than 100 mm of length and some of NQ are observed to measure 160 mm. 6.5% of all flakes show *debitage* or cortical backs, with a size and weight higher than that of the average total of flakes. These pieces tend to be elongated, therefore show a long active cutting edge, which is retouched in some cases. Only nine pieces were retouched between them four scrapers. *Façonnage* is composed of 53 items (the 9.6% excluded shatter): 37 handaxes, 8 trihedral picks, 4 cleavers and 4 large shaped flakes. Three of VR handaxes are made on flakes, while another three are on NQ, despite the difficulty of obtaining large flakes in this raw material. The bilateral shaping of these artefacts are generally bifacial and invasive, while the cutting edge covers all the perimeter of the tool including the tip, creating an active edge around the tool. The existence of preforms and points of handaxes on NQ suggests that tools were shaped and used in this level, and even re-sharpened by lateral and distal removals to lengthen the lifespan of the tool. More than half of the TKSF assemblage (52.6% = 611 pieces) are undifferentiated products.

3. Materials and method

3.1. Archaeological sample

In this study we have analyzed lithic materials recovered from TKLF, TKLSC and TKSF between 2010 and 2018. A total of 7750 lithic artefacts were surveyed for sampling. A final sample of 466 pieces were selected after discarding pieces without potentially functional edges (lengths over 10 mm and angles between 25 and 90° were selected) or those with bad preservation. All the edges of the lithic artefacts selected during the sampling for their subsequent analysis at CENIEH were collected by molds. This final sample consists of a single flint piece, 42 basalt and 423 NQ specimens. For TKLF, 162 pieces were analyzed, obtaining six pieces with results, representing 3.7% of the total. For TKLSC, 106 pieces were analyzed, obtaining one piece with use-wear evidence, representing 0.9% of the total. For TKSF, 198 pieces were analyzed, obtaining nine pieces with use-wear results, representing 4.5% of the total (Table 1).

All the levels considered present problems in preservation, as documented by previously published data, despite the estimated brief exposure time of each level (Yravedra et al., 2016; Panera et al., 2019). These alterations are caused by different processes, some of which are intimately linked with the fabrication and use of tools, especially in the case of NQ artefacts which tend to shatter and break (Leakey, 1971; Santonja et al., 2014; Rubio-Jara et al., 2018; Bello-Alonso et al., 2019). Other alterations are related to mechanical processes such as transport or trampling. The available evidence suggests that there is not much transport of the materials (Santonja et al., 2014), and, therefore, severe abrasion of surfaces or severe ridge and edge rounding has not been detected. Trampling is a common alteration in intensively occupied sites, and may cause breakage, most commonly on the weaker NQ artefacts (Fig. 2a). Diagenetic alterations are much more noticeable, usually obstructing the study of many traces, generally presented in the form of sedimentary adhesion (Fig. 2b and c), or calcium carbonate precipitation (Fig. 2d, e and 2f). Basalt artefacts are severely altered, suffering from the aforementioned alterations alongside abrasion, rounding and loss of material, usually observed on flake edges and ridges (Fig. 2c and e). These alterations have consequently conditioned the preservation and identification of use-wear traces. Much of the wear caused by these processes have been discriminated from use-wear by its chaotic distribution on the surfaces, which is different from those produced in experimentation (Knutsson and Lindé, 1990; Asryan et al., 2014; Bello-Alonso et al. 2019, 2020, 2020; Lemorini et al., 2014; Venditti et al., 2016). Additionally, all pieces with serious problems of conservation have been discarded from the study, using only those with coherent wear formation comparable to the experimental reference materials for analysis (Bello-Alonso et al. 2019, 2020).

3.2. Methods and analytical techniques

Selection and sampling process were made in the field laboratory at Emiliano Aguirre Station (Olduvai Gorge). The selection of the lithic industry was made considering the conservation of the artifact and the existence of one (or more) potentially functional areas. Sampling processes were subdivided into four phases: cleaning, photography, technical drawing and the making of molds. The cleaning process was carried out using water, alcohol (96%) and cotton swabs. After cleaning, artefacts were documented using photography and technical drawing. Considering how exportation of archaeological material outside of Tanzania is heavily restricted, and the lack of suitable microscopic equipment on site, negative molds of suitable edges were made using high precision silicone molds. This method has proved efficient and valid in previous studies (Banks and Kay, 2003; Lemorini et al. 2014, 2019, 2019; Pedergnana and Ollé, 2017). Molds were made

Table 1
Description of the total number of pieces analyzed according to each level, the pieces with use-wear traces and percentage of pieces with use-wear over the total number of artefacts analyzed.

Level	Analyzed pieces	Pieces with use-wear	%
TK-LF	162	6	3.7
TK-LSC	106	1	0.9
TK-SF	198	9	4.5

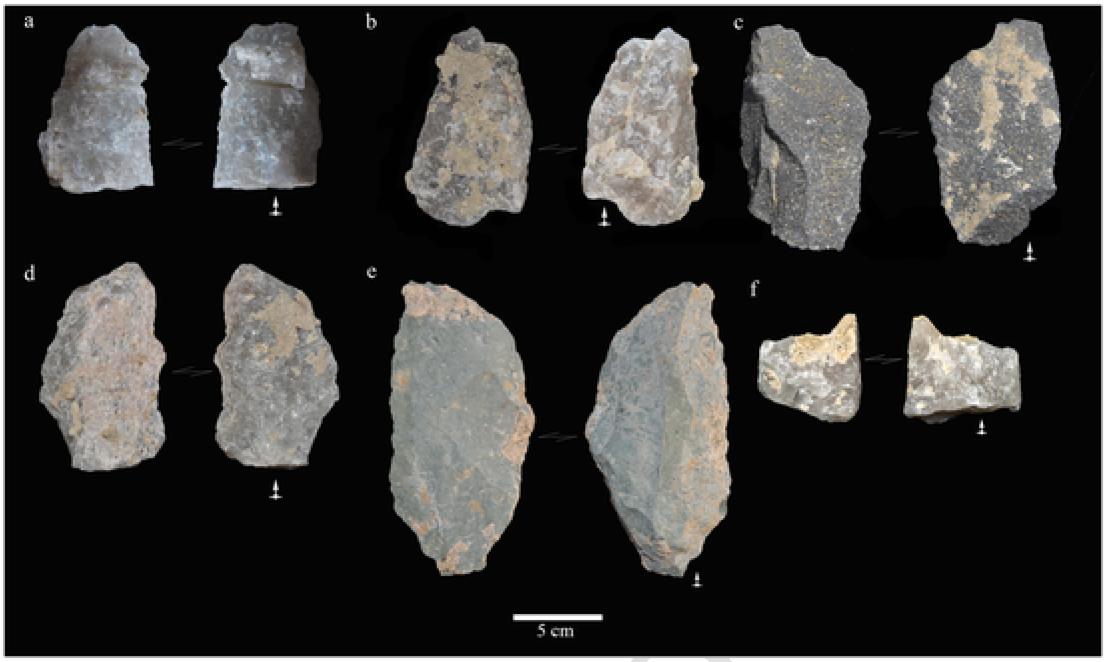

Fig. 2. Example of post-depositional alterations registered at the site of TK: a) NQ flake with fine-grained sediment adhesion on the dorsal face; b) fine-grained sediment adhesion on porous basalt flake; c) concretions on both sides of a NQ flake; d) concretions on basalt flake and recent fracture; e) concretions on the edge of a NQ flake; f) concretions on the surface of NQ.

using silicone molding (Coltene/President microsystem regular body 60019936) applied using a dispensing gun (59/75 ml). This method additionally benefits the archaeological materials themselves by minimizing direct manipulation of the pieces. Moreover, the use of molds facilitates the analysis of translucent materials such as NQ. Molds were then analyzed in the Technological and Archaeological Laboratories of the *Centro Nacional de Investigación sobre la Evolución Humana* (CENIEH, Burgos, Spain). This was carried out using optical light microscopy (Olympus BX51 with 5x, 10 × 20× and 40× objectives) coupled with Differential Interference Contrast (DIC) prisms. Photographs were taken using a Nikon camera (DS-8Fi2) and the NIS-Elements D 4.13.04 software. The series of images obtained at different focus lengths were reconstructed into multi-focus images using the Helicon Focus 6 software.

3.3. Reference collection

The Acheulean lithic industry of TK was compared with previous experimental reference collections using NQ and different types of basalt (Bello-Alonso et al. 2019, 2020). This reference collection is composed of flakes knapped with the same type of raw material identified in the lithic industries of TK. The collection was produced using experimental protocols that incorporated a broad range of tasks, including the processing of plants (USOs, wood, herbaceous plants and canes) and animal carcasses (butchery activities and bone manipulation). This experimental study was oriented towards the reconstruction of human behavior in the ESA (Bello-Alonso et al. 2019, 2020). At the same time, during the experimental protocol, special emphasis was placed on the incorporation of petrological and geochemical analyses that would allow us to structurally characterize each of the materials worked and thus preliminarily correlate their particularities with the formation and development of the use-wear traces. In this sense, for this objective it has been fundamental to locate two differential structural areas in the NQ (the large crystals and the recrystallized zones, also known as rough natural areas), while in the basalts we have been able to establish some significant differences based on the type of groundmass. Currently, this reference collection is deposited in the Laboratory of Prehistoric Technology of the CENIEH.

4. Results

Use-wear traces have been confidently identified on 16 lithic artefacts, 10 of which are found on NQ and 6 on basalt. In accordance with the data obtained, different movements (transversal and longitudinal), actions (sawing, cutting and scraping), material hardness (soft and hard) and materials worked (non-woddy plants, USOs, wood and butchering) have been identified (Table 2). This study includes those tools with clear use-wear traces and with the possibility of correlation (location of the use-wear, movements, action, hardness and/or material worked) with the experimental reference collection (Bello-Alonso et al. 2019, 2020). In this sense, 24 archaeological lithic tools have had to be discarded, for the moment, due to the lack of robustness for their identification as use-wear traces.

4.1. Level TKLF

The traceological study of this TKLF present a total of 6 pieces with enough use-wear traces to perform functional interpretations; two flakes (one of them cortical) made on NQ, one NQ chunk and three basalt flakes (Table 2).

4.2. Description

TK410 (Table 2): cortical basalt flake (Basalt type 4-BT4-according to Bello-Alonso et al., 2020). Identified traces are located on the distal edge, distributed bifacially (Fig. 3). Documented traces are rough to smooth, alongside rather bright polishes, distributed along both sides of edge (Fig. 3a, b, 3c and 3d) with traces on the dorsal surface appearing rather invasive (Fig. 3c). This polish is associated to a few longitudinal striations, oblique (Fig. 3b) and longitudinal lineal components (Fig. 3e and h), scattered patches of edge rounding (Fig. 3a and g) and the formation of continuous and overlapping micro scars (Fig. 3d and f). The distribution of polishes is more continuous along the ventral surface's edge (Table S3).

Table 2
Technical data and use-wear results obtained in the layers analyzed from TK including NQ and basalt lithic industries.

Reference	Level	Raw material	Technology	Lenght	Width	Thickness	Movement	Hardness	Action	Material worked
				(mm)						
5929	TKSF	NQ	scraper (retouched)	56	38	17	transversal/ longitudinal	soft	cutting/scraping	butchering (skin-flesh)
7008	TKSF	NQ	flake	43.5	39.7	15	longitudinal	soft	cutting	butchering (skin-flesh)
8338	TKSF	NQ	Biface	121	86	59	transversal	soft	undetermined	undetermined
10,372	TKSF	NQ	Flake	126.2	63.6	55.3	transversal	soft	scraping	USOs (vegetal)
10,577	TKSF	NQ	Flake	80.5	60.2	15	longitudinal	soft	cutting	USOs (vegetal)
11,079	TKSF	NQ	slab fragment	80.7	63.4	29.3	longitudinal	soft	cutting	USOs (vegetal)
11,159	TKSF	NQ	Flake	43	31	17	transversal	hard	scraping	wood (dry)
11,032	TKSF	Basalt (BT4)	Flake	86	37	23	longitudinal	hard	sawing	wood
12,473	TKSF	Basalt (BT4)	Flake	68.5	60.2	20	transversal	hard	scraping	wood
14,415	TKLSC	Basalt (BT1)	flake fragment	54.2	29	15.5	transversal	hard	scraping	wood (dry)
410	TKLF	Basalt (BT4)	cortical flake	78	64	22	longitudinal	hard	sawing	wood (dry)
598	TKLF	Basalt (BT1)	Flake	47.4	28	20.2	longitudinal	soft	cutting	USOs (vegetal)
6554	TKLF	Basalt (BT1)	flake	36	40	11	longitudinal	hard	sawing	wood (fresh)
6374	TKLF	NQ	chunk	54	45	12	longitudinal	soft	cutting	butchering (hide-flesh)
10,706	TKLF	NQ	flake	33.1	40	13.2	transversal	soft	scraping	USOs (vegetal)
13,427	TKLF	NQ	cortical flake (siret fracture)	37	31	11	longitudinal	hard	sawing	wood

TK598 (Table 2): basalt flake (BT4) with unifacial use-wear traces identified on the distal edge (Fig. 4). Documented traces are a very bright rough to smooth polish (Fig. 4a and b), continuous along the edge and rather invasive. This is associated with longitudinal lineal components (Fig. 4a) and patches of continuous and overlapping micro-scarring (Table S3).

TK6374 (Table 2): NQ chunk with bifacial use-wear traces identified on the distal edge (Fig. 5). The formation of well-developed and invasive smooth mate polish was documented on large crystal surfaces in association with patches of pits (Fig. 5a and a1). At the same time, on the extremities of these large crystals as well as inside of the micro-scars, an extensive rough to smooth polish with bright reflection was also noted (Fig. 5b, c, 5d, 5e and 5f). Longitudinal lineal components have been identified (Fig. 5d and f) in association with small areas of pits (Fig. 5b1, 5b2, 5c, 5e, and 5f). Finally, the development of micro-scarring patches with continuous and overlapping distributions were detected in association with scattered areas of rounding (Fig. 5b1, 5b2, 5c, 5d, 5e, and 5f) (Table S3).

TK6554 (Table 2): basalt flake (BT1) (Basalt Type 1 -BT1-according to Bello-Alonso et al., 2020) with bifacial use-wear traces developed on the distal edge (Fig. 6). A remarkable development of rough to smooth polish with a very bright reflection was located in association with longitudinal lineal components and striations (Fig. 6a and b) (Table S3).

TK10706 (Table 2): NQ cortical flake with bifacial use-wear traces developed on the distal edge (Fig. 7). Patches of invasive alterations in different phases of polish have been identified, observing rough, undulating and smooth (Fig. 7a), undulating to smooth (Fig. 7b) and rough to smooth (Fig. 7c, e, 7f, 7g and 7h) or only rough (Fig. 7d) polish with a very bright reflection. It has been possible to document few linear components with a transversal developments (Fig. 7b and f) alongside oblique striations (Fig. 7e) in association with patches of pits. Additionally, these attributes are accompanied by the formation of continuous and overlapping micro-scarring with scattered patches of rounding (Fig. 7g) (Table S3).

TK13427 (Table 2): NQ cortical flake with unifacial use-wear trace development on the distal edge (Fig. 8). Invasive rough to smooth very bright polishes have been identified along the extremities of the edge to the internal surface (Fig. 8a, b and 8c). These attributes appear in association with longitudinal lineal components and striations (Fig. 8a1, 8a2 and 8c). At the same time, the formation of scattered pits have been detected on large crystals (Fig. a1). The development of isolated micro-scars and some patches of continuous micro-scarring (Fig. 8a, a1, 8a2 and 8b) is also notable with scattered rounding areas (Fig. 8a, a1, 8a2 and 8b) (Table S3).

4.3. Interpretation

The tools that preserve use-wear traces from TKLF have been used for longitudinal and transversal motion activities. Three basalt flakes, one NQ flake and one NQ chunk have been documented for longitudinal motion activities, while one NQ flake has been associated with transversal motion activities. According with the characteristics of the traces, the longitudinal movements in two basalt flakes and one NQ flake have been interpreted in association with the sawing of hard plant materials, most probably wood (Figs. 3, 5 and 8). TK410 (Fig. 3) present similar trace formations and distributions to those observed when sawing wood (Bello-Alonso et al., 2020), while TK6554 (Fig. 5) has been identified to present patterns very similar to those documented when sawing wood (Bello-Alonso et al., 2019). Moreover, the use-wear traces documented in one basalt flake and one NQ flake were identified to be associated with the processing of soft vegetable material (USOs). TK598 (Fig. 4) presents longitudinal motions that have been interpreted as product of cutting movements, while in TK10706

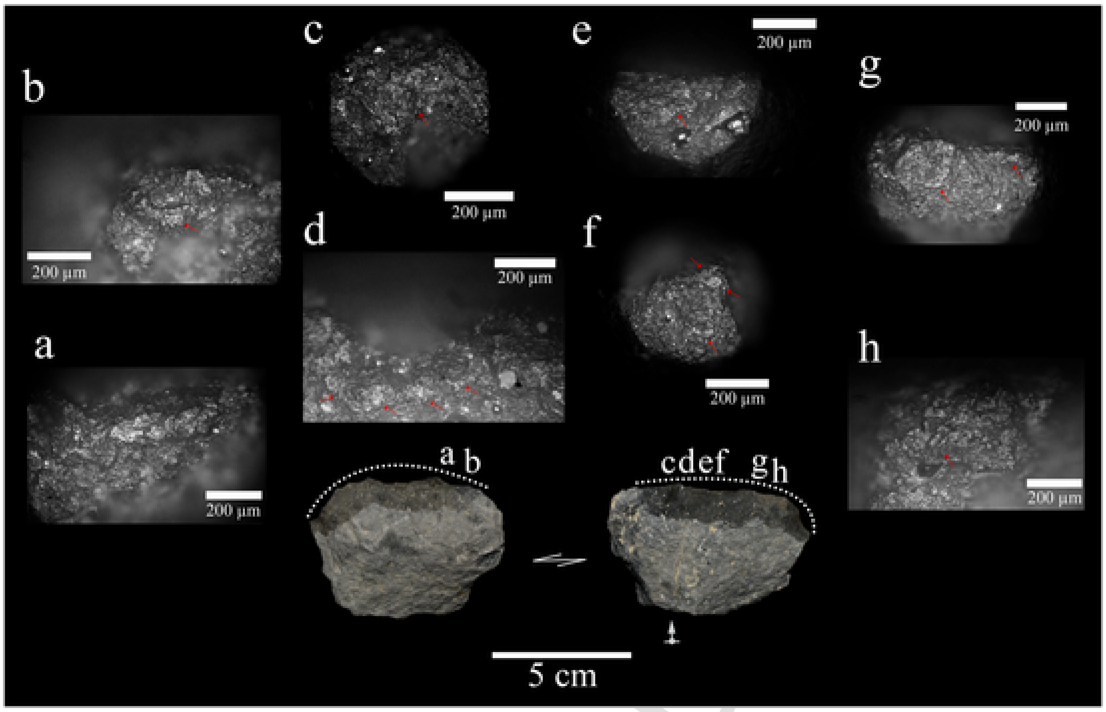

Fig. 3. TK410, cortical flake with use-wear traces located on the distal edge: a) very bright rough to smooth polish development within micro-scars (200x); b) very bright rough to smooth polish in association with continuous and no overlapping micro-scarring (200x); c) invasive rough to smooth polish with a very bright brittleness in association with scarce patches of rounding (200x); d) widespread invasive patches of very bright rough to smooth polishes (200x); e and f) development of rough polish in association with few longitudinal striations (200x); g) rough to smooth polish in association with scattered areas of rounding (200x); h) rough polish in association with longitudinal striations (200x); i) invasive rough to smooth polish with widespread distributions in association with patches of continuous and overlapping micro-scarring (200x); i1) detail from image i of the smooth areas under observation (200x); k) rough to smooth polish in association with oblique lineal components (200x); l) very bright rough polish developed on areas of intersecting continuous micro-scars; m) very bright rough to smooth polish (200x); n) bright rough to smooth polish in association with scattered patches of rounding (200x); o) invasive bright rough to smooth polishes with longitudinal lineal components (200x).

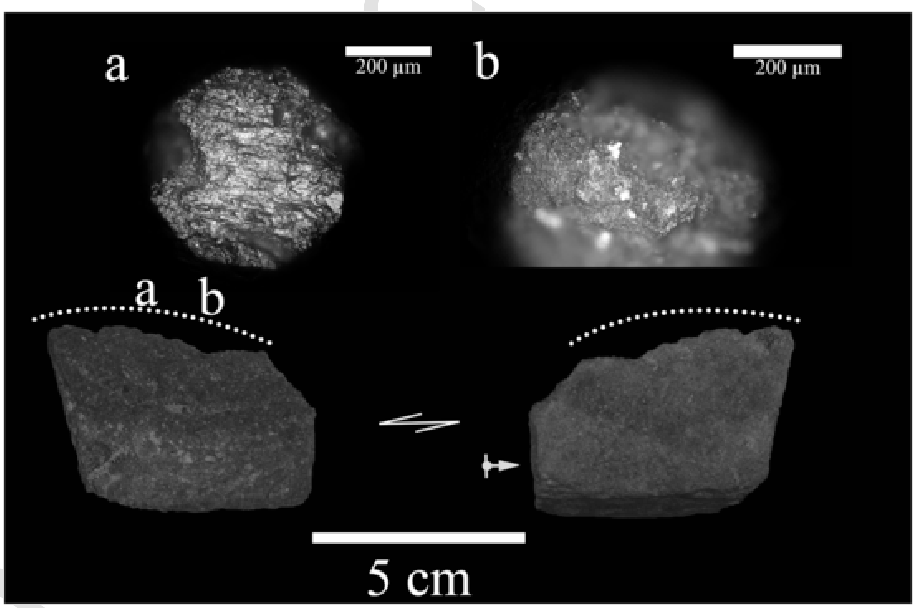

Fig. 4. TK598 basalt flake with use-wear traces located on the distal edge: a) very bright smooth polish in association with longitudinal lineal components (200x); b) widespread and invasive rough to smooth very bright polish in association with continuous and overlapping patches of micro-scarring (200x).

(Fig. 7) transversal motions have been identified and interpreted as scraping movements. Finally, for the NQ chunk TK6374 (Fig. 6), traces similar to those obtained when processing animal hide-flesh in butchery activities have been identified.

4.4. Level TKLSC

Only one basalt flake with preserved and clear use-wear traces has been identified in level TKLSC.

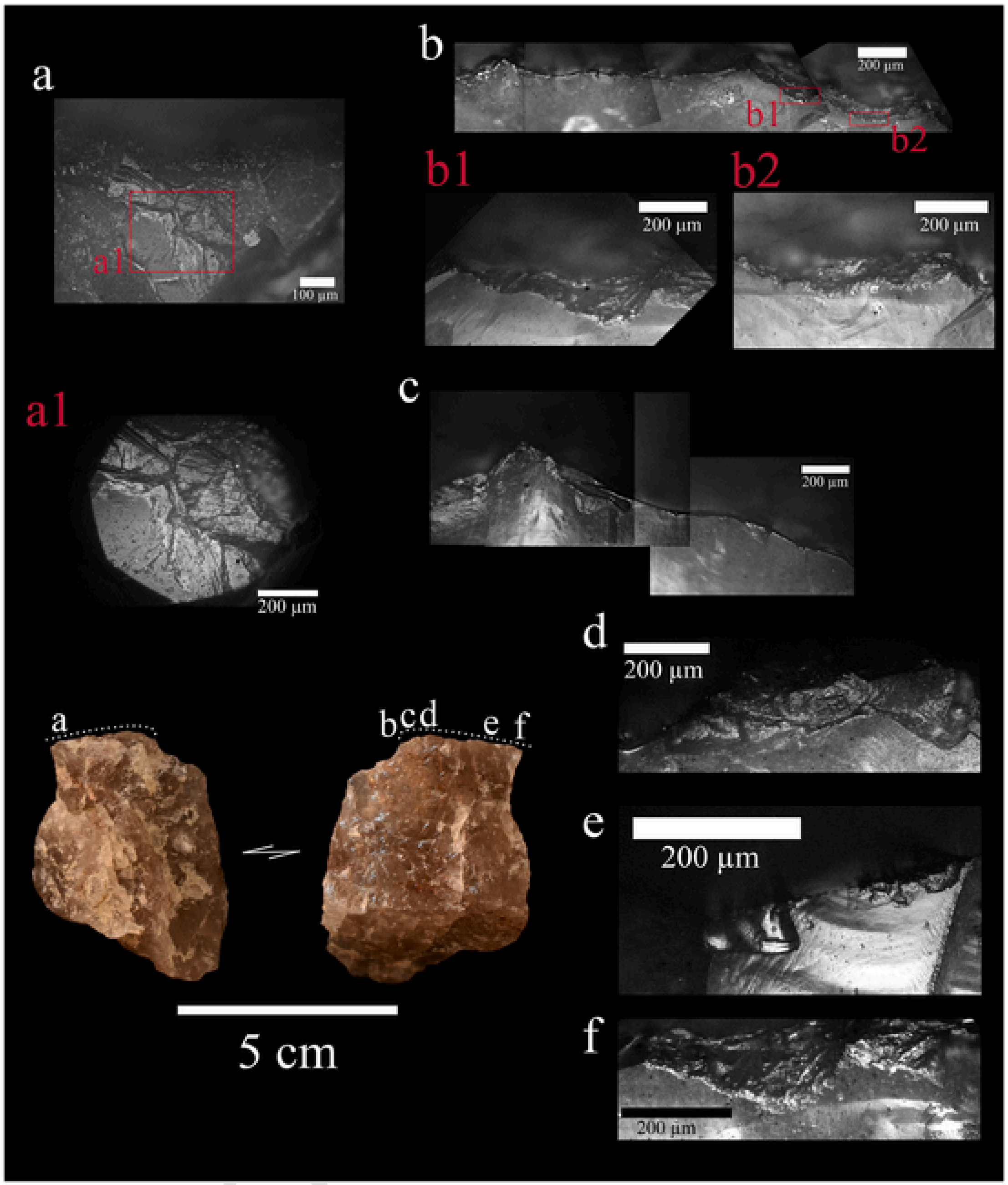

Fig. 5. TK6374 NQ chunk with use-wear traces on one edge: a) development of smooth mate polish on the extremities of large crystal surfaces and in association with transversal lineal components (100x); a1) detail of image a: longitudinal and transversal striations (200x); b) formation of very bright rough to smooth polishes in association with continuous and overlapping micro-scarring and scattered areas of rounding (200x); b1) detail of image b, bright rough to smooth polish with a few comet pits (200x); b2) bright rough to smooth polishes in association with a few pits formed on top of micro-scarring (200x); c) bright rough to smooth polishes in association with scarce number of pits, isolated and no overlapping distribution with scattered patches of rounding (200x); d) formation of rough to smooth polishes in association with continuous and overlapping micro-scarring and scattered patches of rounding (200x); e) bright rough polish formed on the areas with micro-scarring in association with scarce areas of rounding (200x); f) high development of bright rough to smooth polishes in association with few pits and continuous overlapping micro-scarring (200x).

4.5. Description

TK14415 (Table 2): in this basalt (BT1) flake we analyzed the right irregular edge, obtaining results on both faces (Fig. 9). The dorsal face present some points with bright rough (Fig. 9a) and rough to smooth polishes (Fig. 9b, c and 9d). Associated with the polishes transversal and oblique lineal components were also documented (Fig. 9c1). Similarly, the formation of rounding areas in protruding surfaces was also identified in association with smooth polishes (Fig. 9b and c), alongside isolated micro-scarring with a clear tendency towards half-moon and semicircular morphologies (Fig. 9a, b, 9c and 9d). In the ventral face patches of bright rough to smooth polishes (Fig. 9e, f, 9g and 9h) were detected in association with longitudinal lineal components (Fig. 9e and h), isolated micro-scarring and scattered points of rounding (Fig. 9e) (Table S3).

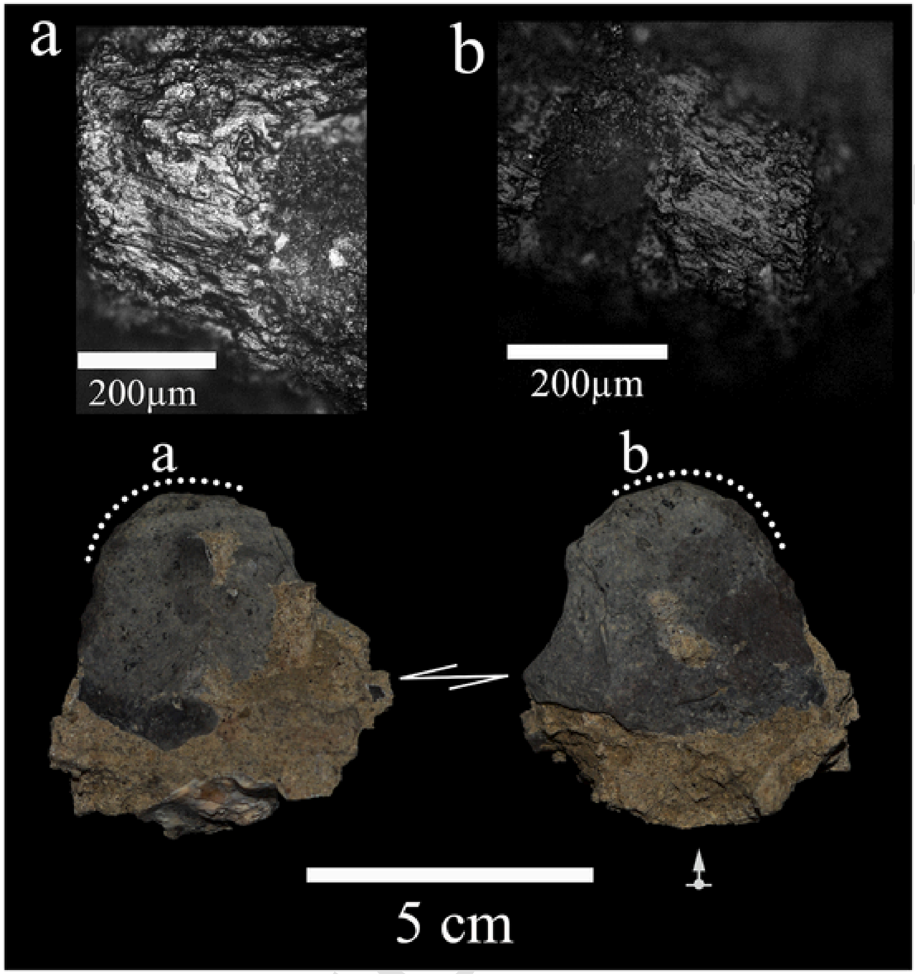

Fig. 6. TK6554 basalt flake with use-wear traces on the distal edge: a) remarkable development of rough to smooth polish with very bright brittleness in association with longitudinal lineal components and striations (200x); b) high very bright rough to smooth polish with longitudinal lineal components and striations (200x).

4.6. Interpretation

The data recovered from the singular basalt flake show transversal motions associated with scraping movements. In accordance with the data obtained in the reference collection (Bello-Alonso et al., 2020), use-wear traces formed on this piece have been interpreted in association with the processing of hard plant materials, most probably woodworking (Fig. 9). Moreover, further analogies have been made associating this piece with the processing of wood (Bello-Alonso et al., 2020).

4.7. Level TKSF

In this level a total of 9 artefacts were detected presenting suitable use-wear traces, 7 of which were made from NQ (retouched scraper, biface, flakes and slab fragment) and 2 were identified on flakes made from basalt (Table 2).

4.8. Description

TK5929 (Table 2): NQ endscraper with unifacial use-wear traces on the distal edge (Fig. 10). The ventral surface has suffered attrition resulting in the formation of bright rough polish (Fig. 10a) and discrete points of smooth polish formation (Fig. 10b). The development of oblique lineal components (Fig. 10a) and oblique striations (Fig. 10b) were found in association with the formation of these polishes. Focusing on the attributed of large crystals, the formation of patches of pits, mainly (Fig. 10a and b), on the top points of the crystal (Fig. 10b), were also identified. At the same time, the distribution of the pits are notably oblique (Fig. 10a) and transversal (Fig. 10b). Finally, in association with the formation of polish, continuous and poor overlapping micro-scarring was noted (Fig. 10a and b) (Table S3).

TK 7008 (Table 2): NQ flake with bifacial use-wear traces on the left edge (Fig. 11). On the limit of the edge a very bright rough to smooth polish is observable (Fig. 11a, b, 11c and 11d). In association with the polishes a few oblique striations were also detected (Fig. 11b) alongside patches of pits, mostly located on the uppermost areas of large crystals (Fig. 11c and d). Moreover, these pits seem to follow a longitudinal orientation, while there is also some edge rounding on the extremities of large crystals (Fig. 11a and c) accompanied with a well-developed, continuous and sometimes overlapping micro-scarring (Fig. 11c and d) (Table S3).

TK8338 (Table 2): NQ biface with unifacial use-wear traces on the distal edge (Fig. 12). Bright and very bright rough to smooth polishes were detected (Fig. 12a, b, 12c and 12d) with two types of distribution: a) polishes restricted to the border of the edge (Fig. 12a and d) and b) more invasive polishes (Fig. 12b and c). In association with the formation of invasive and smooth polish transversal (Fig. 12b) and oblique lineal components were also noted (Fig. 12c). At the same time, the development of scarce patches of pits on the large crystal sur-

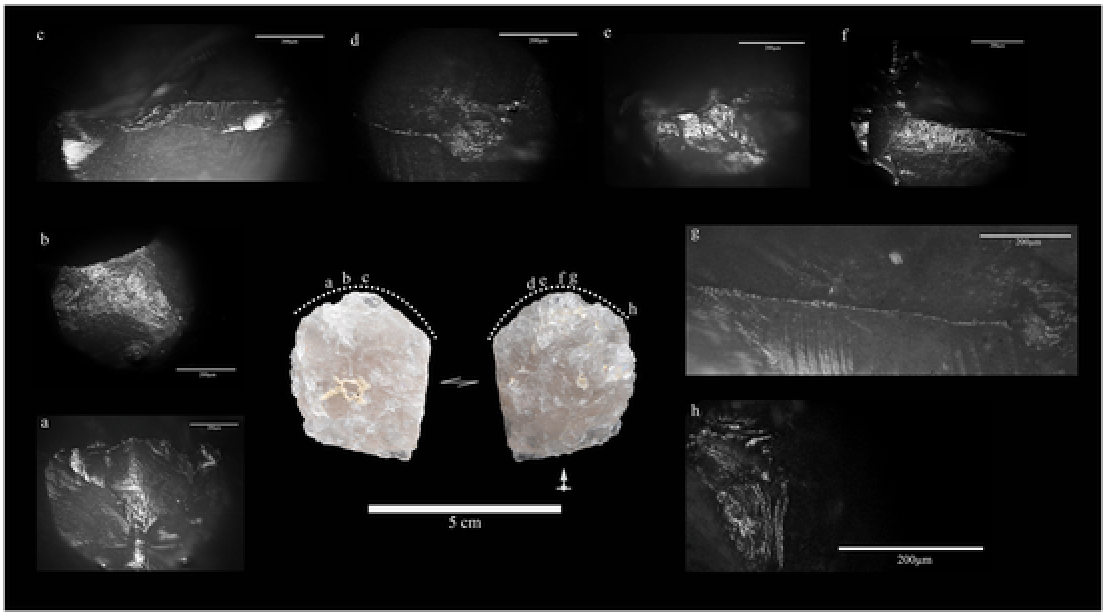

Fig. 7. TK10706 NQ cortical flake with use-wear traces on the distal edge: a) bright to very bright invasive and progressive formation of rough, undulating and smooth polishes (200x); b) very bright invasive undulating to smooth polish in association with few numbers of pits (200x); c) very bright rough to smooth polishes in association with continuous and no overlapping micro-scarring (200x); d) very bright rough polishes developed on the extremities of the used edge (200x); e) development of very bright rough to smooth polishes in association with few pits and oblique lineal components (200x); f) very bright rough to smooth formation of polish in association with longitudinal lineal components (200x); g) very bright extensive development of rough to smooth polish on the limits of large crystals in association with patches of continuous and overlapping micro-scarring as well as scattered rounding (200x); h) formation of very bright patches of rough to smooth polish (200x).

faces were also observed (Fig. 12d). Finally, observations also noted some patches of edge rounding (Fig. 12d) (Table S3).

TK10372 (Table 2): NQ flake with unifacial use-wear traces formed on the left edge (Fig. 13). The formation of a patch of mate (rough) to bright (smooth) polish was detected and seen to develop into some edge rounding (Fig. 13a). This is associated with transversal lineal components and scarce oblique striations (Fig. 13a) (Table S3).

TK10577 (Table 2): NQ flake with bifacial use-wear traces formed on the distal edge (Fig. 14). Albeit the traces are poorly developed, there are patches of very bright rough to smooth polish (Fig. 14a) and bright rough polish (Fig. 14b and c). These polishes appear alongside longitudinal linear components (Fig. 14b and c) (Table S3).

TK11032 (Table 2): basalt flake (BT4) with bifacial use-wear traces formed on the left edge (Fig. 15). Analyses show the formation of rough (mate) to smooth (bright) polishes (Fig, 15a, 15b, 15c, 15d, 15e and 15f). Some of these polishes are rather invasive (Fig. 15b). Further longitudinal lineal components were observed in association with these polishes (Fig. 15a and c), alongside few patches of edge rounding (Fig. 15b, c, 15d, 15e and 15f), and continuous and overlapping patches of micro-scarring (Fig. 15f) (Table S3).

TK11079 (Table 2): NQ flake with unifacial use-wear traces formed on the distal edge (Fig. 16). An extensive and invasive very bright rough to smooth polish was noted on the rough natural area of the NQ (Bello-Alonso et al., 2019), located within the micro-scarring (Fig. 16a). In association with this polish, longitudinal lineal components were detected as well as a few patches of large sized pits (Fig. 16a). At the same time, the smooth polish formation was seen to generate some edge rounding. Finally, continuous and overlapping micro-scarring was observed (Fig. 16a) (Table S3).

TK11159 (Table 2): NQ flake with unifacial use-wear traces formed on the distal irregular edge (Fig. 17). The formation of a very bright, extensive and invasive rough to smooth polish was also noted (Fig. 17a). The smooth polish appears on the top areas of the large crystals and also creates some edge rounding, while the rough polish appears on the rough natural areas of the NQ (Fig. 17a1) (Bello-Alonso et al., 2019). In relation with the polish, we observed the development of transversal lineal components (Fig. 17a and a1). In terms of micro-scarring, we observed a predominance of patches with continuous distributions (Fig. 17a) (Table S3).

TK12473 (Table 2): basalt flake (BT4) with bifacial use-wear traces formed on the right regular edge (Fig. 18). Observations noted bright patches of rough to smooth polish (Fig. 18a, b, 18c and 18f) and a few areas with rough to undulating polish (Fig. 18d and e). Transversal linear components and striations were observed in association with polish (Fig. 18a, d and 18f). Also, there is a moderate rounding of the edges (Fig. 18a, c, 18d, 18e and 18f), alongside patches of overlapping micro-scarring (Fig. 18a, e and 18f) (Table S3).

4.9. Interpretation

Tools that preserve use-wear traces from TKSF have been used for longitudinal and transversal motion activities while two flakes in NQ, one NQ slab fragment, and one basalt flake, have been used in longitudinal motion activities. Finally four pieces have been used in transversal motion activities including one NQ biface, two NQ flakes, and one basalt flake. One retouched scraper on NQ presents longitudinal and transversal movements. In accordance with these characteristics and their corresponding traces, the movements and use-wear of two NQ flakes and one basalt flake have been attributed to scraping; one of the NQ flake is considered to be used for scraping soft plan material (USO) (Fig. 13), while the other two have likely been used for the scraping a harder plant materials, most probably wood (Figs. 16 and 18). For the piece TK11079 (NQ) (Fig. 16) traces similar to those obtained during the processing of wood have been detected (Bello-Alonso et al., 2019). The traces identified on the NQ small biface (TK8338) could be related to transversal movements of the used edge, but have a bifacial distribution and are rather invasive. The identified polish does not correspond clearly with any of the experimental activities made with NQ (Bello-Alonso et al., 2019), but given its characteristics, we can propose that the worked material was not very resistant but abrasive, while the movement detected suggests some kind of launched percussion and thus been used as a pounding tool.

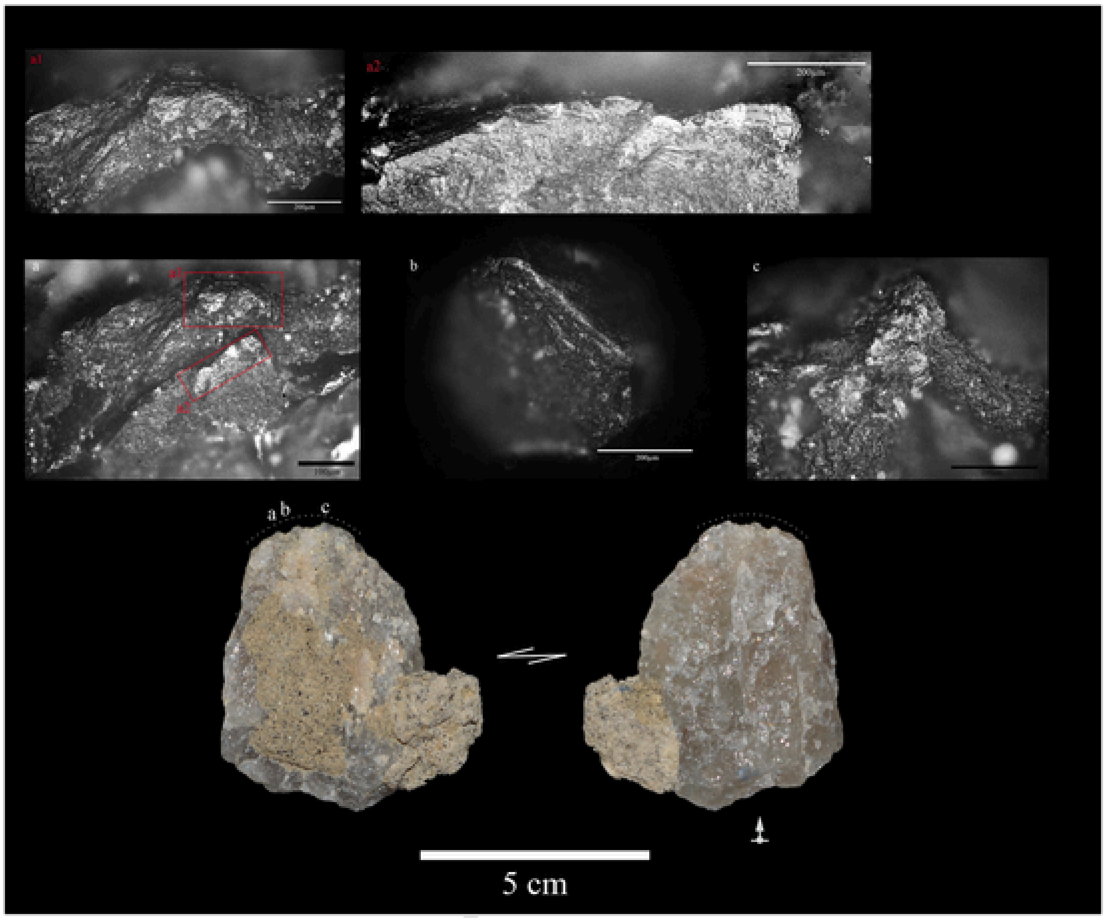

Fig. 8. TK13427 cortical flake with use-wear traces on the distal edge: a) widespread distribution of very bright rough to smooth polish (100x); a1) formation of rough to smooth polish in association with longitudinal lineal components with few pits and in relation with isolated micro-scarring and scattered rounding points (200x); a2) high development of very bright rough to smooth polish in association with patches of continuous micro-scarring and scattered rounding areas (200x); b) very bright rough to smooth polish in association with moderate rounding development (200x); c) very bright rough to smooth polish between two scars in association with longitudinal lineal components and few striations with the same orientation (200x).

Longitudinal motion activities have been interpreted for two NQ flakes, one NQ slab fragment, and one basalt flake. According with the use-wear traces three pieces were used for cutting. One of them presents use-wear traces close to those obtained experimentally in the processing of animal carcasses (hide-flesh) (Fig. 11), while the other NQ flake and NQ slab fragment present use-wear traces similar to those obtained when cutting USOs (Figs. 14 and 15). The basalt flake presents use-wear patterns similar to those obtained experimentally when sawing wood (Fig. 17).

Finally, one endscraper elaborated on NQ presents a mixed of transversal and longitudinal movements. This double pattern was interpreted as a result of a change in orientation during the processing of soft organic material. The activities performed with this piece would be scraping and cutting for the processing of animal carcass (hide-flesh) (Fig. 10).

5. Discussion

The technological studies carried out in TK since excavations resumed in 2010 (Santonja et al. 2014, 2018, 2018; Rubio-Jara et al., 2017) have identified three main tool classes in the assemblage; pounding tools (percussion tools and slabs), bifaces, and flakes with potentially functional edges. These classes hypothetically correspond with different functional classes intervening in different types of activities or in different phases of complex productive processes. The present study has concentrated on the analysis of flakes with potentially functional edges while discerning the different subsistence activities developed at TK using this tool category. Although there are some studies dealing with the possible functional role of flakes during the Acheulean (Galán and Domínguez-Rodrigo, 2014), and others that highlight its relevance in the Acheulean technological repertoire (Semaw et al., 2020), most research carried out on the function of African Acheulean industries have been dedicated to the morphological and potential analyses of handaxes (Jones, 1980, 1994, 1994; Keeley, 1980; Machin et al., 2005; Yustos et al., 2015; Santonja et al., 2018).

Nevertheless, for the first time microscopic use-wear traces have been identified in an African Acheulean flake assemblage after a systematic study. The obtained results show how traceological studies on Acheulean lithic industries are feasible, as is the case of TK. In spite of the existence of post-depositional alterations, which have indeed limited trace preservation rates, a total of 16 pieces with clearly identifiable use-wear traces have been identified from a sample of 466 pieces (1 flint, 42 basalts and 423 NQ). This sample roughly corresponds to the composition of the archaeological assemblage from TK, where NQ is the most abundant and the best preserved raw material (Leakey, 1971; Santonja et al. 2014, 2018, 2018; Rubio-Jara et al., 2017). The preservation issues are tricky. We are speaking about very old collections with great possibilities of being altered beyond the possibilities of use-wear analysis. These problems are even greater with collections collected on the surface, because they suffer a lot of atmospheric alteration. In TK, there is certainly alteration, which, in our opinion, has been honestly and thoughtfully described in the manuscript. These alterations have, of course, affected the material and probably this is the

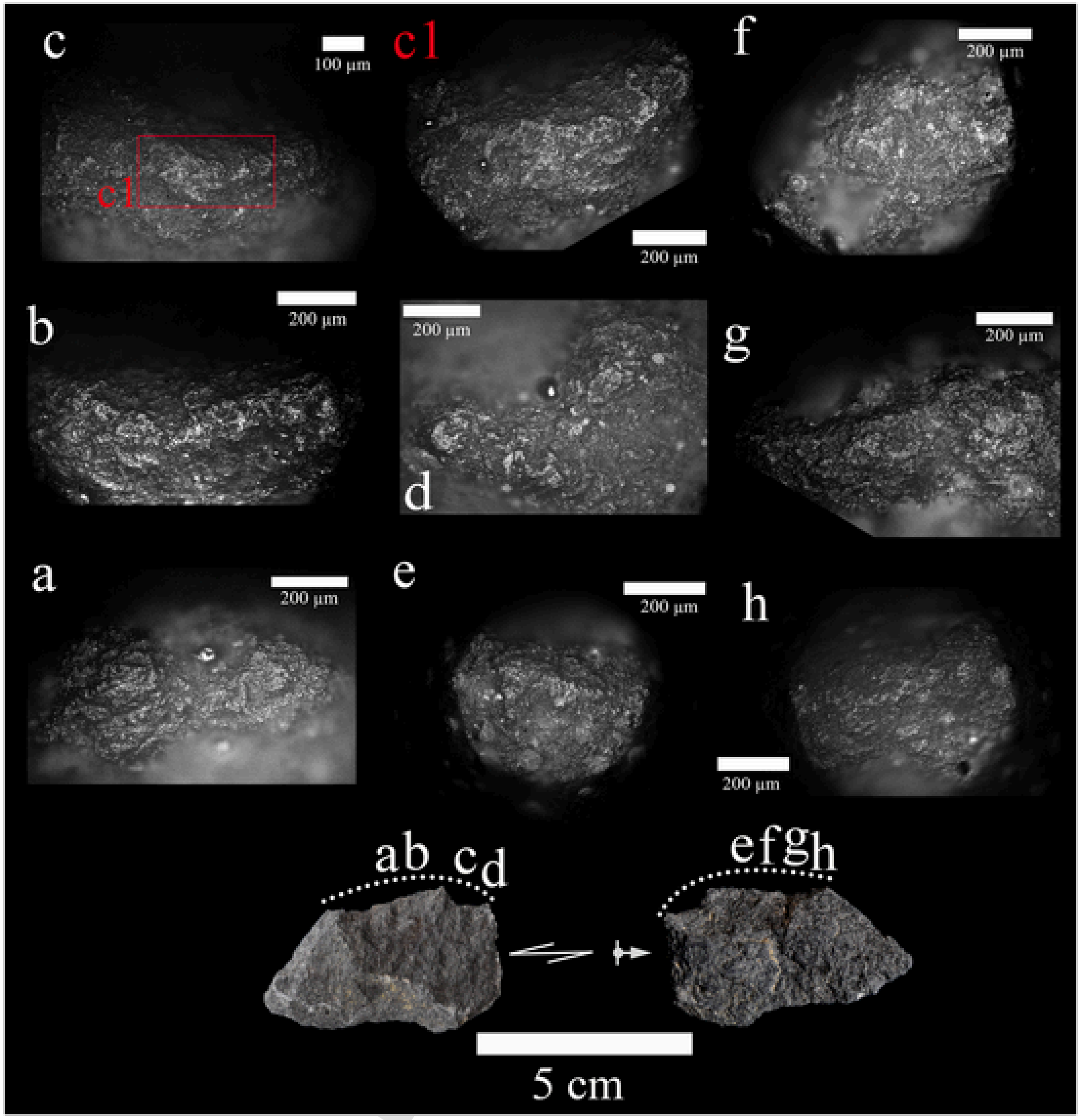

Fig. 9. TK14415 basalt flake with use-wear traces on the right edge: a) rough bright polish with longitudinal movements (200x); b) development of bright rough to smooth polish on the top of micro-scars in association with scattered areas of rounding (200x); c) patch of rough to smooth polish in association with micro-scarring (100x); c1) detail of image c: polish in association with longitudinal lineal components and a few transversal striations (200x); d) invasive development of rough to smooth polishes along the edge area (200x); e) bright rough to smooth polish formation (200x); f) widespread bright rough to smooth polishes in association with scattered rounding points (200x); g) patches of rough to smooth polish in association with continuously distributed micro-scars (200x); h) scattered bright rough to smooth polish formation (200x).

major bias (along with the short use times) for use-wear preservation. However, this alteration has not affected equally all the material (freshly recovered from excavation), and it has been possible to identify clear traces in a limited set of pieces. In addition to these pieces with clear use-wear traces, others (ca. 3% of the sample) also show traces likely related with their use, nevertheless the low development of these traces and their poor state of preservation have obstructed their identification, consequently resulting in their excluding from this study.

The identification and interpretation of each of these use-wear traces has been made through analogies established with experimental collections; all of which were created using the same raw materials that appear in the archaeological record (Bello-Alonso et al. 2019, 2020). In order to determine how the internal structure and composition of these lithologies influence the development of use-wear traces, a petrological and geochemical approach was used for each raw material (Bello-Alonso et al. 2019, 2020).

In NQ, observations noted that the size of the crystals determine the fracture of the used edge. In accordance with this, the larger the crystal, the more likely the used edge will shatter during use. This consequently hinders the development of traces (Bello-Alonso et al., 2019). Information of this type is especially relevant for the study of archaeological materials. Although post-depositional alterations have also hindered their conservation, this fracturing of NQ during use has probably played a relevant role in the conservation and recording of use-wear information. Likewise, the peculiar petrographic nature of NQ offers two different types of surfaces on the same piece; large crystals and rough natural areas. According to each of these surfaces, traces such as polish and striations develop differently, with polish intensities being more evident in the latter (Bello-Alonso et al., 2019). Through the results shown in this article, it can be seen how large crystals condition the development of striations as they appear associated with surface erosion. As observed in experimental studies (Bello-Alonso et al., 2019), after longer periods of usage, these pitted surfaces eventually develop striations by the connecting of separate pits. Nevertheless, the formation of grooves in large crystals may not always be related with polish, considering how polishes rarely develop on the surface of large

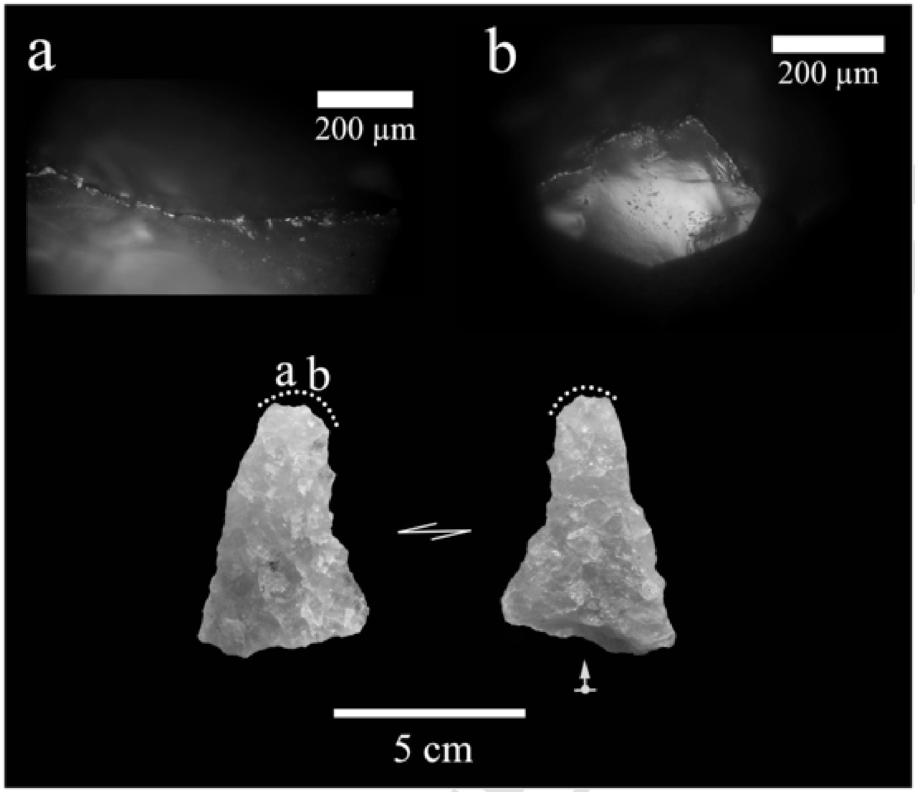

Fig. 10. TK5929 retouched scraper with use-wear traces on the distal edge: a) patches of very bright rough polish and attrition formed on the limits of the used edge in association with oblique lineal components and patches of continuous and scattered overlapping micro-scarring (200x); b) very bright rough polish and few areas with smooth polish on the limits of the used edge, associated with transversal and longitudinal striations, and scarce pits formed on the large crystals with a transversal orientation: all of which are linked with continuous and scattered overlap micro-scarring (200x).

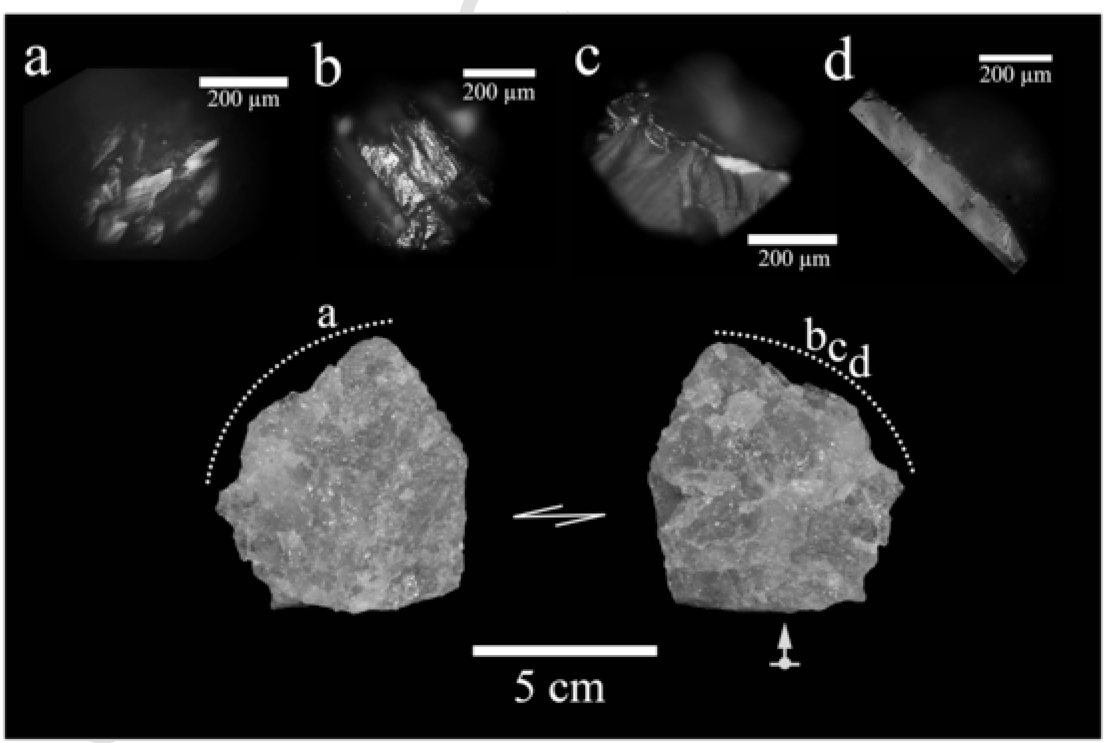

Fig. 11. TK7008 NQ flake with use-wear traces on the left edge: a) very bright rough polish associated with longitudinal lineal components formed on the extremities of large crystals and linked with moderate rounding (200x); b) bright rough polish in association with oblique striations (200x); c) bright rough to smooth polish on the limits of the edge in association with an abundance of pits distributed in patches and, in relation with the micro-scarring, additional areas of rounding (200x); d) well developed continuous and scattered overlapping of micro-scarring presenting a semi-circular morphology as well as step and hinge terminations (200x).

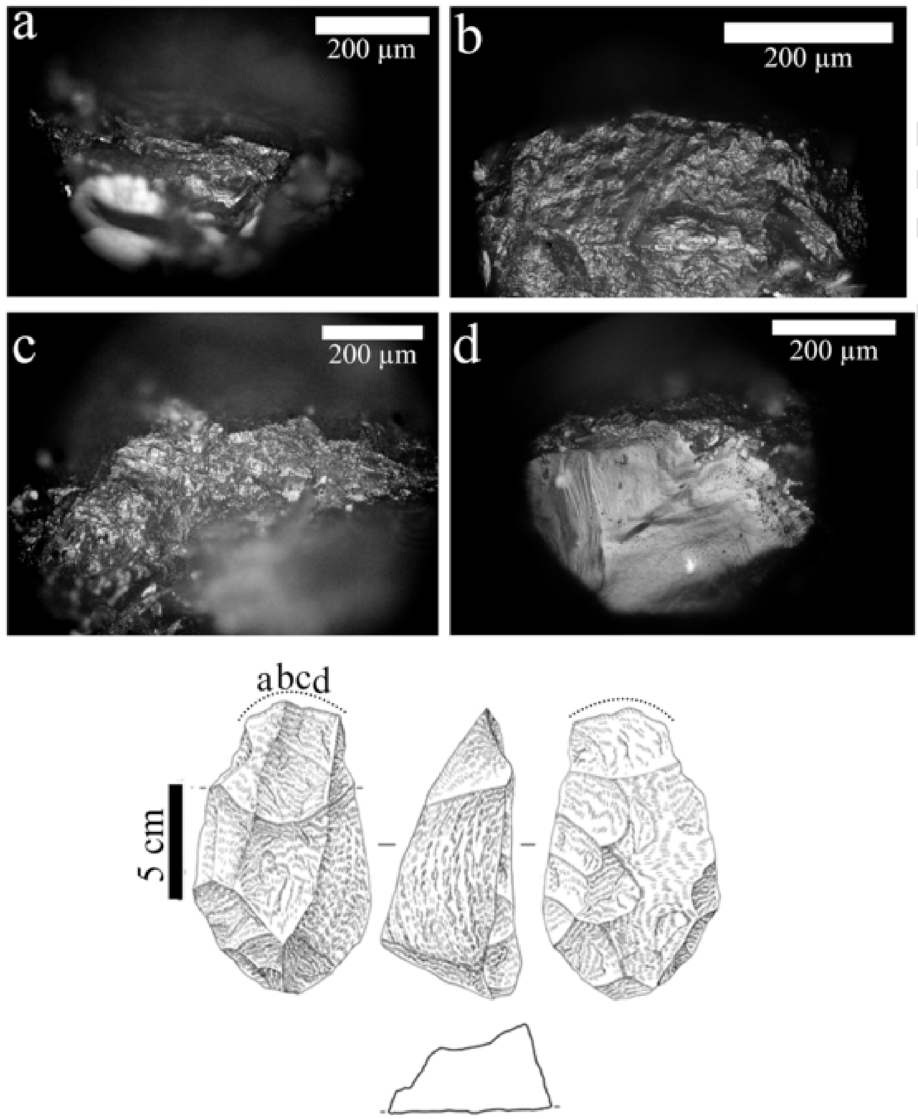

Fig. 12. TK8338 NQ biface with use-wear traces on the distal edge: a) patch of bright rough polish and scarce areas with smooth polish on the edge's limit (200x); b) invasive very bright rough to smooth polish with associated transversal lineal components (200x); c) invasive very bright rough to smooth polish associated with oblique lineal components (200x); d) very bright rough to smooth polish in association with pits and the formation of moderate rounding on the limits of large crystal (200x).

crystals. In contrast, in naturally rough surface areas the development of the striations is always linked with the development of polish (rough, undulating and smooth), following a pattern widely described in literature in association with materials such as flint (Keeley, 1980; Sussman, 1988; Ibáñez-Estévez and González-Urquijo, 1996).

In the case of basalts, experimental observations show the formation of use-wear traces in BT1 to be lower than in the case of BT4 (Bello-Alonso et al., 2020). Unlike our previous experimental data, BT4 in the archaeological record has preserved a fairly record of use-wear traces. These traces do not appear in isolated patches with low development, but are extensive and invasive in multiple areas along the edge. This has allowed a more accurate identification of the movement, the action, and the resistance of the worked material when using this material. In some cases, even the nature of the worked material can be inferred.

Additionally, the wide range of materials processed in experimental studies (USOs, wood, carcasses, grasses, canes, etc.) has facilitated the recognition and description of use-wear traces, as observed in the archaeological record. The incorporation of different materials in these experiments has been driven by the information obtained from other sources, such as; topics related with the diet of living non-human primates; ethnographical documentation of hunter-gatherer populations; ecological studies; as well as other use-wear analyses (Keeley and Toth, 1981; Vincent, 1984; Sussman, 1987; Peters and O'Brien, 1994; Keeley, 1997; Cordain et al., 2000; Mercader et al., 2002; Rodman, 2002; Tactikos, 2005; Ungar et al., 2006; Van der Merwe et al., 2008; Marlowe and Berbesque, 2009; Antonio and Lee, 2010; Pontzer et al., 2012; Henry et al., 2012; Cerling et al., 2013; Lemorini et al., 2014, 2019; Arroyo and de la Torre, 2016; Arráiz et al., 2017; Motes-Rodrigo et al., 2019). This actualistic approach has allowed for a broader perspective regarding the identification and description of activities, creating analogies between experimental and archaeological materials. The results obtained through this facilitate a direct interpretation of the subsistence activities developed using flakes with potentially functional edges by Acheulean populations.

It is generally assumed that early lithic technologies were mostly involved in the processing of animal carcasses (Jones, 1980, 1981, 1994; Schick and Toth, 1993; Mitchel, 1996; Machin et al. 2005, 2007). Nevertheless, direct evidence of processing wood and other

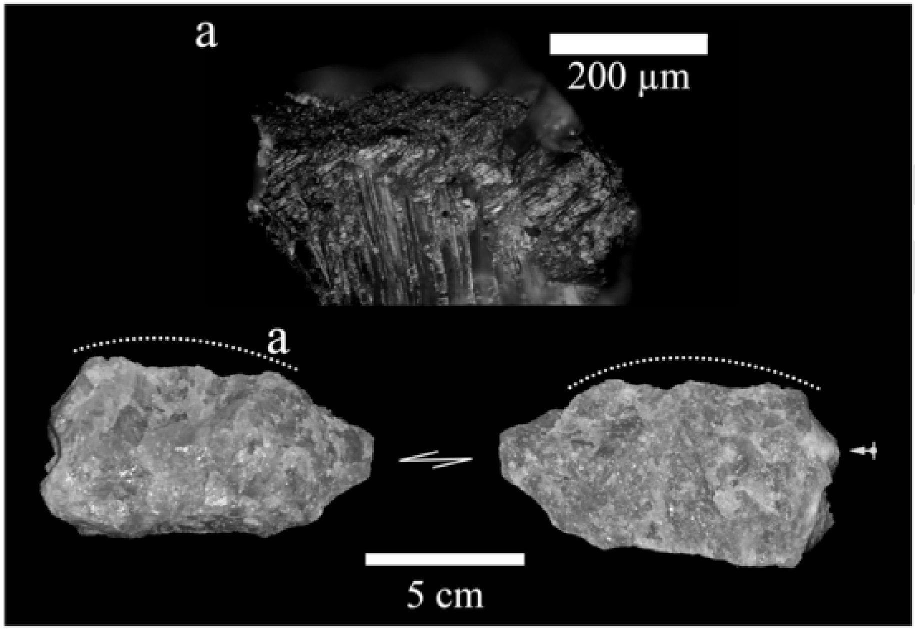

Fig. 13. TK10372 NQ flake with use-wear traces on the right edge: a) bright rough to smooth polish formation in association with transversal lineal components and scarce oblique striations (200x).

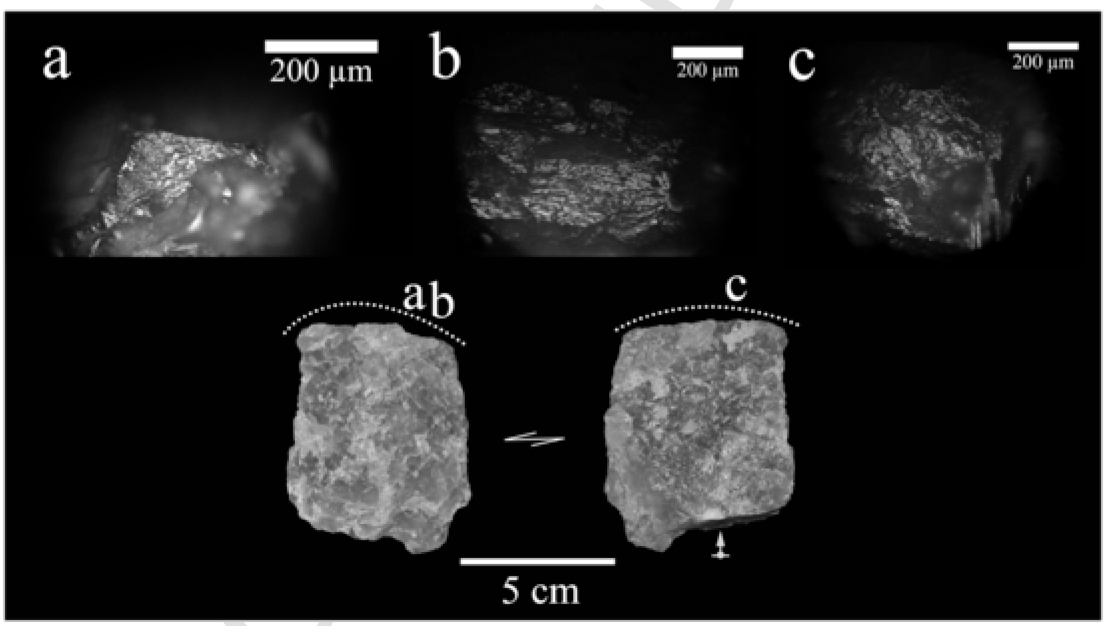

Fig. 14. TK10577 NQ flake with use-wear traces on the distal edge: a) very bright rough to smooth polish (200x); b) bright rough polish associated with longitudinal lineal components (200x); c) patch of rough polish linked with longitudinal lineal components (200x).

plant resources, such as USOs, has been directly demonstrated through use-wear and residue analyses (Keeley and Toth, 1981; Keeley, 1997; Domínguez-Rodrigo et al., 2001; Herrygers, 2002; Lemorini et al. 2014, 2019). In TK, different proxies suggest the development of different activities. The archaeozoological analysis performed at TKLF has shown that most of the faunal resources recovered were accumulated by natural agents, therefore supporting that carcass processing activities were of little importance in this site (Yravedra et al., 2016). Likewise, technological analyses of lithic industries suggest that different activities could have been made with handaxes, slabs, hammers and flakes recovered here (Santonja et al., 2014). The data available from TKSF indicates a similar variability within the lithic assemblage, yet with a greater importance in animal processing activities as seen in archaeozoological analysis (Panera et al., 2019). Interestingly, the spatial analysis of TKSF's paleo-surface suggest that activity areas were not directly linked with carcass processing, presenting new possibilities for the tasks that were performed at this site (Panera et al., 2019).

The results obtained in this study show that, in general, the intensity of flake usage is relatively low. This impression may be biased by other conditioning factors such as the low development of traces in shorter use periods, mostly for the case of NQ (Bello-Alonso et al., 2019). Moreover, problems in preservation effect certain traces more, such as those generated during the cutting of flesh, for example. The proportion of pieces with use-wear is extremely low in TKLSC, but in TKSF reaches 4.5%. The activities identified are similar in TKLF and

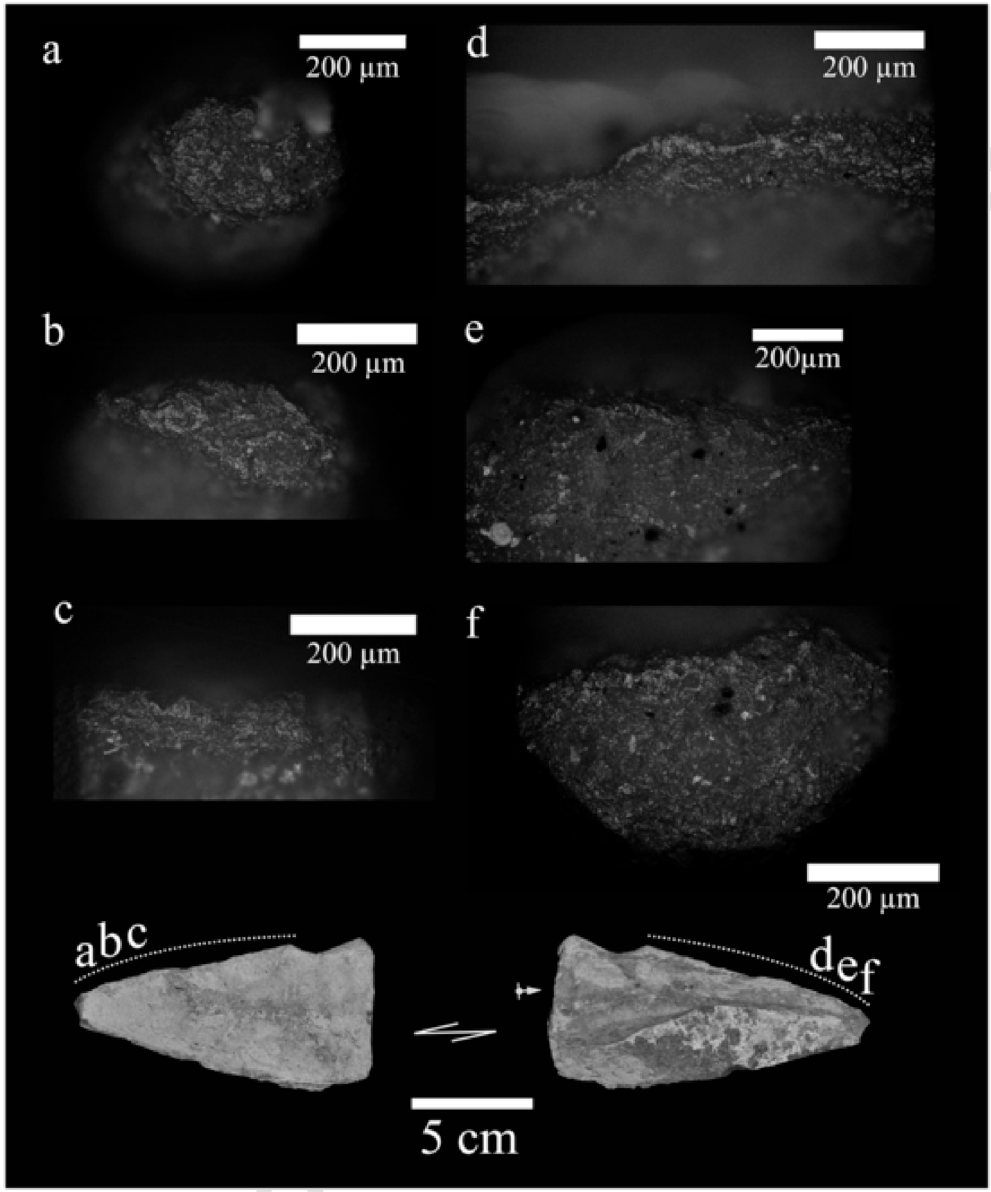

Fig. 15. TK11032 basalt flake with use-wear traces on the right edge: a) mate rough to smooth polish associated with longitudinal lineal components (200x); b) invasive bright rough to smooth polish associated with moderate rounding and scarce isolated micro-scarring (200x); c) mate and bright rough to smooth polish formed on the borders of micro-scarring, all associated with longitudinal lineal components and moderate rounding (200x); d) bright rough to smooth polish in association with areas of moderate rounding (200x); e) rough to smooth polish on the border of the used edge in association with the formation of rounding (200x); f) widespread rough to smooth polish on the edge's limits associated with the formation of continuous and overlapping micro-scarring and areas of moderate rounding (200x).

TKSF, basically involving wood-working, USOs processing and some carcass processing (hide-flesh).

Carcass processing has been identified in TKLF and TKSF, these traces indicate that transversal and longitudinal movements have been applied. Combinations of these type of actions can be related to the removal of flesh and fat from animal hide, once separated from the muscle (Wiederhold, 2004). This result is of particular interest when contextualised with the taphonomic studies from this site. Taphonomic interpretations have been noted to present significant difficulties when evaluating the access, processing and consumption of animal carcasses by hominins in TK, especially when considering poor cortical preservation rates (Yravedra et al., 2016; Panera et al., 2019). The appearance of lithic pieces with butchery use-wear traces indicate that TKLF and TKSF are places where animal carcasses were consumed. Both levels, however, suggest that butchery activities were less important than the processing of wood or USOs, especially in the case of TKSF. Nevertheless, as previously mentioned, there are several factors (preservation issues, edge fracture of NQ during use, short use times, etc.) that may be generating bias in the underestimation of these types of activity (see the experimental observations in Bello-Alonso et al., 2019, 2020).

In addition to the processing of animal carcasses we have also located traces that correspond to the processing of USOs. In TKSF one flake and one slab fragment made on NQ register use-wear traces corresponding with longitudinal movements on soft and abrasive materials that have been interpreted as products of cutting USOs. In TKLF one basalt flake and one NQ flake register use-wear traces corresponding to longitudinal movements and scraping of USOs. The identification of USO scraping activities is especially interesting and could indicate pre-cutting actions, perhaps even peeling. In the ethnographic record, it has been observed that the peeling of vegetables is a common process when the external part is not suitable or appropriate for consumption (Dominy, 2012; Lemorini et al. 2014, 2019; Schnorr, 2016;

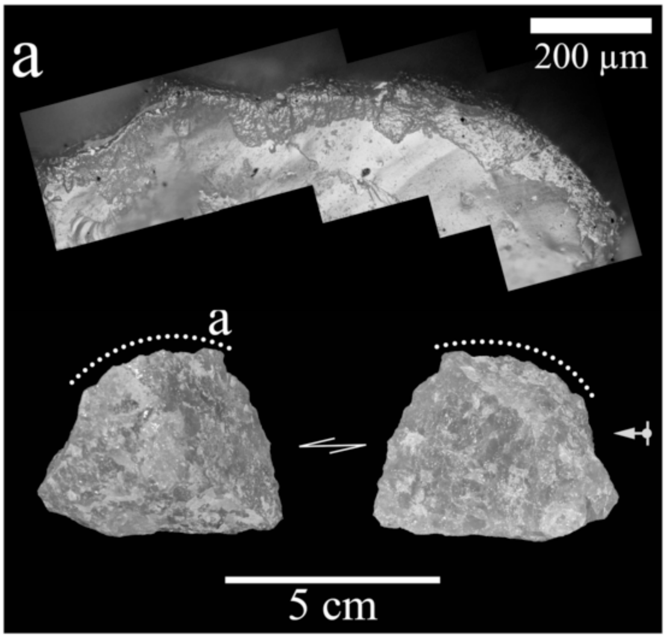

Fig. 16. TK11079 NQ slab fragment with use-wear traces on the distal edge: a) invasive and extensive very bright rough to smooth polish formed inside the micro-scarring and in association with the formation of high and intensive rounding. A few patches of large pits are observed in association with the polish as well as longitudinal lineal components (200x).

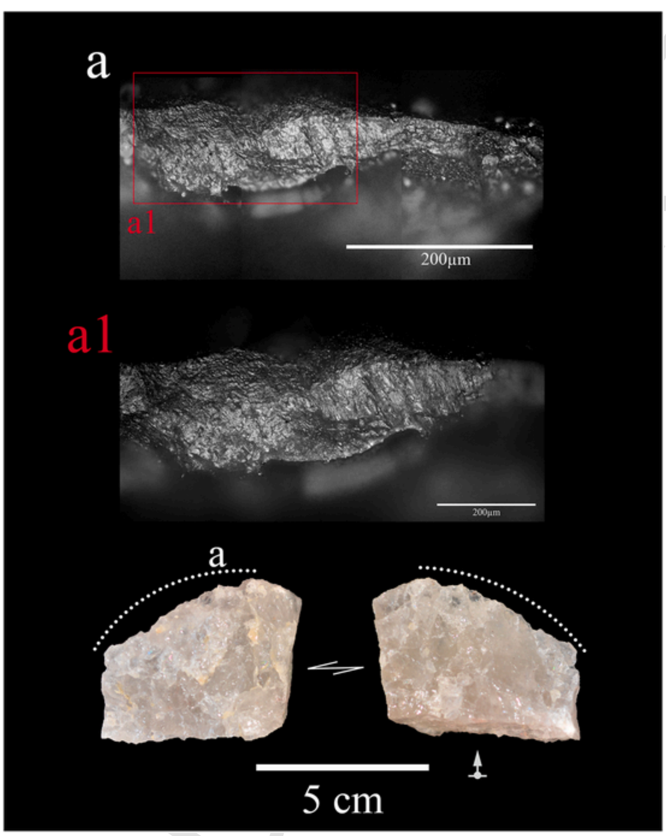

Fig. 17. TK11159 NQ flake with use-wear traces on the distal edge: a) invasive very bright rough to smooth polish linked with transversal lineal components and a high level of rounding formation. The polish is more developed on the uppermost areas such that additional fracturing is less likely to occur which would have lost this information (200x); a1) Detail of image a presenting very bright rough to smooth polish linked with transversal lineal components (200x).

Schnorr et al., 2016; Bello-Alonso et al. 2019, 2020). Nevertheless, we would need precise information about the type of USOs available in the landscape or those that were consumed at this site in order to provide more specific reflections on this issue.

The acquisition and consumption of wild plants, roots and USOs was very likely to be an important element of ESA hominin diets. According to ethnographic studies, these are an indispensable part of hunter-gatherer diets in combination with meat and other elements (Cordain et al., 2000; Crittenden and Schnorr, 2017), as in the case of the Hadza hunter-gatherers (Oliver, 1993; Murray et al., 2001; Dominy et al., 2008; Marlowe and Berbesque, 2009). Likewise, studies about the behaviour of primates point out how the acquisition and consumption of plant elements played an important role in their diet, including diverse catchment areas and a wide range of organic matter consumed depending on the geographical area that they occupy (Gaulin, 1979; Peters and O'Brien, 1981, 1994; Mercader et al., 2002; Wrangham et al., 2009). At the same time, early hominid diet analyses through isotopes analysis, dental morphology and dental microwear analysis, reveal a high consumption of C3 and C4 organic matter during the Early Pleistocene (Stahl et al. 1984; Lee-Thorp et al. 1994, 2012, 2012; Laden and Wrangham, 2005; Van der Merwe et al., 2008; Wrangham et al., 2009; Cerling et al., 2011; Henry et al., 2012; Magill et al., 2016; Melamed et al., 2016). This data regarding the hominid diet are also supported by studies on ecology and palaeoenvironment which, in broader terms, point to diverse environments with different resource catchment areas (Sept 1986; Peters and O'Brien, 1994; Tactikos, 2005; Magill et al. 2013 Plummer and Bishop, 2016). Finally, traceological analyses are progressively adding to this data. From this approach, it has been possible to record the processing and possible consumption of wild plants and USOs in Kanjera South (Kenya) (Lemorini et al. 2014, 2019). Therefore wild plants and/or USOs played a relevant role in the diet of hominins during the early Pleistocene. In the case of TK, subsistence strategies included the consumption of flesh and USOs.

Finally, the greatest number of results have been obtained regarding woodworking. Within the three levels analyzed, the development of activities associated with wood processing have been recorded. For TKSF, four flakes have been recorded, two on NQ and two on basalt. Three show transversal movements on hard materials have been identified as product of wood scraping. Only one piece shows longitudinal movements on hard materials that have been interpreted as the sawing of wood. For level TKLSC one flake on NQ has been documented with the presence of transversal movements on hard material that are likely product of wood scraping. For TKLF three pieces have been detected with similar traces including; a simple flake, a cortical flake on basalt and a cortical flake on NQ. Two have longitudinal and one transverse movements, all identified to the processing of hard materials. The longitudinal movements have been linked to sawing activities and the transversal movements to scraping. As with wild plants, roots and vegetables, the use of wood for Early Pleistocene hominins is yet to be resolved given the lack of conservation of these elements in the archaeological record. Once again, ethnography, ecology and residue analyses together with traceological results help configure plausible hypotheses (Yamagiwa et al., 1988; Keeley and Toth, 1981; Keeley, 1997; Sussman, 1987; Whiten et al., 1999; Dominguez-Rodrigo et al., 2001; Schoeninger at al. 2001; Herrygers, 2002; Carvalho et al., 2009; Plummer et al., 2009; Bunn and Gurtov, 2014; Lemorini et al. 2014, 2019; Schoch et al., 2015). According to the results obtained and the interpretations made prior to this study, use-wear traces detected in these pieces could be related to the manufacture of wooden tools for diverse task such digging implements to extract tubers, roots or insects. Perhaps, the sawing marks correspond to the obtaining and manipulation of branches and/or trunks, while the scraping marks may indicate the shaping of these branches to obtain suitable tools.

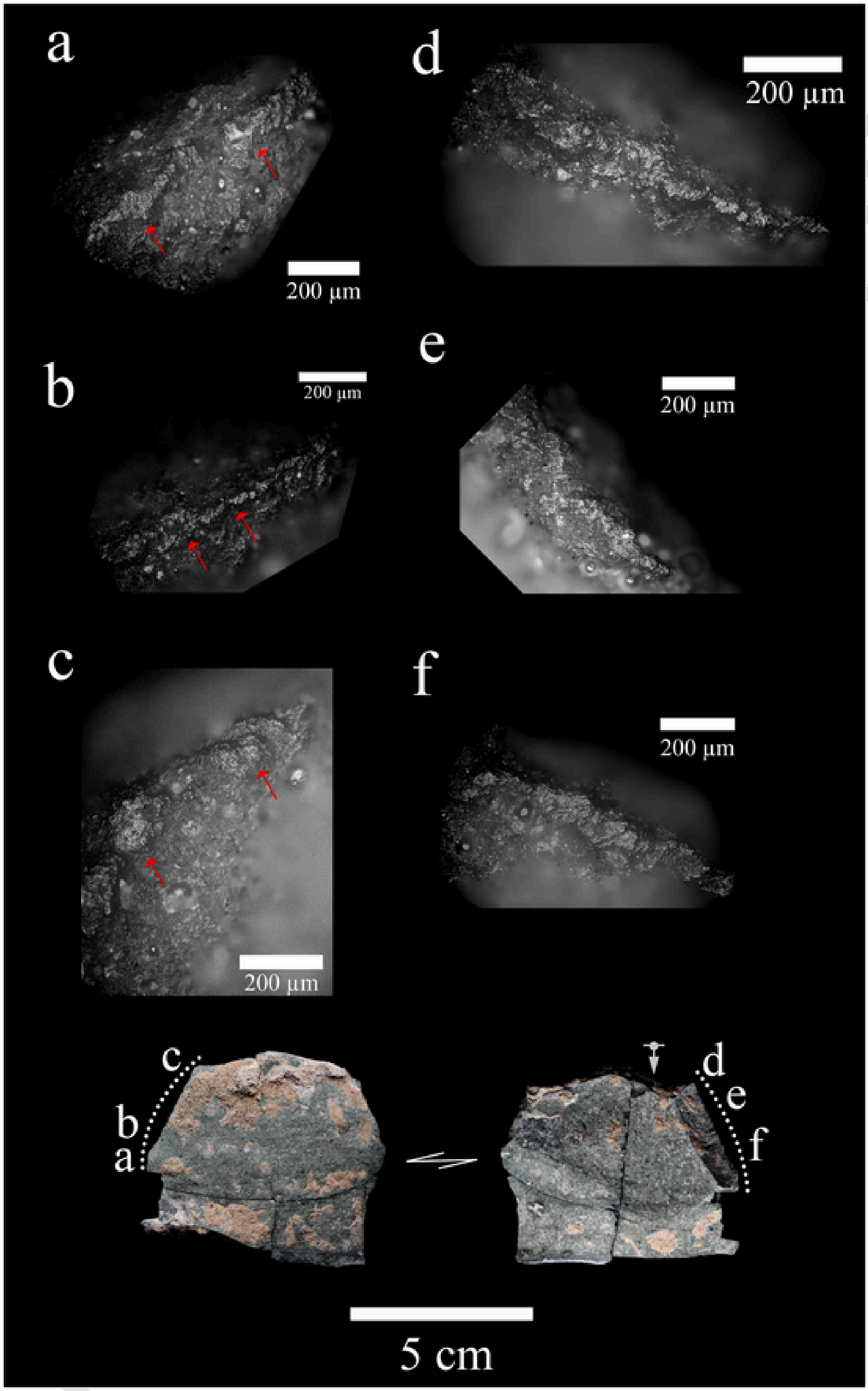

Fig. 18. TK12473 basalt flake with use-wear traces on the right edge: a) bright rough to smooth polish formed on the uppermost areas of the micro-scarring, linked with transversal lineal components and a few striations (200x); b) extensive bright rough polish (200x); c) bright rough to smooth polish associated with pronounced areas of rounding (200x); d) extensive bright rough to undulating polish with transversal lineal components and few striations (200x); e) extensive bright rough to smooth polish linked with transversal striations (200x); f) extensive and scattered invasive bright rough to smooth polish (200x); g) bright rough to smooth polish (200x).

Use-wear results obtained after the analysis of a large sample of flakes from three levels of TK show that functional analyses of ESA lithic artefacts through high power analyses is very difficult due to problems of preservation, and the fact that tool-kits have been made on raw materials not frequently experimented with in use-wear studies (NQ or basalts). This can be easily observed in the low numbers of ESA pieces with positive use-wear results (Keeley and Toth, 1981; Sussman, 1987; Keeley, 1997; Lemorini et al., 2014, 2019; Arroyo and de la Torre, 2016, 2018). This means that, even with low numbers, every chunk of information relative to the use of these early lithic tools is of great value. We have tried to overcome all these difficulties, first by carrying out extensive experimental research on use-wear formation on NQ and basalt (Bello-Alonso et al. 2019, 2020), then by analysing a large archaeological sample (466 pieces). This has resulted in data obtained from 16 pieces. These results are relevant to understanding the role flake tools played in the Acheulean of TK and the activities carried out at these levels (e.g. TKSF and TKLF). Thanks to these analyses we have documented activities related with tool making (sawing and shaping of wood), alongside the production of lithic tools. Each of which can be considered the most important activities carried out on both levels (Santonja et al., 2014; Panera et al., 2019). Additionally, this data confirms that some butchery activities took place here (Yravedra et al., 2016; Panera et al., 2019), while other subsistence activities, such as USO processing, are equally if not more important.

6. Conclusion

TK is a site that shows, once again, great potential as a narrator for the Acheulean period. Prior to this study, technological, paleontological and spatial data have been able to provide approximations that highlight the complexity of human behavior in the initial phases of the Acheulean technocomplex. Traceological results presented here, contribute positively to a deeper understanding regarding the variety of subsistence activities developed during the Acheulean. These use-wear results additionally elaborate a better dialogue about the nature of these occupations, as well as the functional role played by the associated flakes.

Here results show that different activities were carried out at TKSF and TKLF, including lithic tool production, woodworking, butchery and USOs processing. This is in agreement with the current hypotheses presented by these levels as the result of recurrent occupations (Santonja et al., 2014; Panera et al., 2019). This information, as obtained from the analysis of one of the tool classes identified at TK, must also be complemented in future by information obtained from handaxes, slabs and hammers. Through this, a more complete view of the subsistence activities made during the Acheulean occupations of TK can be obtained. The results described from TKSF handaxes, which have been identified as pounding tools for soft material, suggest that the variability of activities, and the complexity of the productive processes will grow considerably after including these type of tools in the analysis.

Uncited reference

Mitchell, 1996, Sahnouni et al., 2018.

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.

Acknowledgements

First, we would like to express our sincere gratitude to all our field workmates who have made the excavation, registration and conservation of TK's archaeological materials possible, from 2010 to the present: Julius Sulley, Yona Thomas, Caroli Maole, Francis Fabiano, Shabany Bakary, Lovico, Enguiriya, Thomas Madangi, Lisandro and Daniel Chilonzi. At the same time, we want to express our gratitude to Aixa San Emeterio, lab technician at the CENIEH Prehistoric Technology and Archaeology Laboratory, for their help in the photographic recording and image processing. We also want to thank Lloyd Courtenay for his help providing editing services in the English version of this article. Finally, we are grateful to the Spanish Ministry of Science and Technology for funding this research (Projects HAR2013-45246-C3-2-P and HAR2017-82463-C4-2-P), and the Tanzanian Commission for Science and Technology (COSTECH), the Department of Antiquities and Ngorongoro Conservation Area Authority in the Ministry of Natural Resources and Tourism for permission to conduct research at Olduvai Gorge. Our work was carried out in the framework of The Olduvai Paleoanthropological and Paleoecological Project (TOPPP).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quascirev.2021.106980.

Author contributions

Joseba Rios-Garaizar, traceologist supervisor. Joaquin Panera, technology supervisor and TK co-director. Susana Rubio-Jara, technology supervisor. Alfredo Pérez-González, geologist supervisor. Raquel Rojas, restorative supervisor. Enrique Baquedano, co-director of The Olduvai Paleoanthropological and Paleoecological Project (TOPPP) and financially responsable of the project. Provides financial resources for the field laboratory and camp facilities. Audax Mabulla, co-director of the TOPPP and responsible for the Tanzanian administration. Provides the necessary legal permits to carry out the studies and excavations. Manuel Domínguez-Rodrigo, director of the TOPPP and archaeozoologist supervisor. Manuel Santonja, technology supervisor and TK director.

All authors interpreted the data. All authors wrote and provided comments on the manuscript.

Uncited references

; Favreau et al., 2019; Magill et al., 2013; Schoeninger et al., 2001; Stahl et al., 1984.

References

Antonio, C.D.A., Lee, P.C., 2010. Wild capuchins show male-biased feeding tool use. Int. J. Primatol. 31 (3), 457–470. doi:10.1007/s10764-010-9406-6.

Arráiz, H., Barboni, D., Ashley, G.M., Mabulla, A., Baquedano, E., Dominguez-Rodrigo, M., 2017. The FLK Zinj paleolandscape: reconstruction of a 1.84 Ma wooded habitat in the FLK Zinj-AMK-PTK-DS archaeological complex, middle bed I (Olduvai Gorge, Tanzania). Palaeogeogr. Palaeoclimatol. Palaeoecol. 488, 9–20. doi:10.1016/j.palaeo.2017.04.025.

Arroyo, A., De la Torre, I., 2016. Assessing the function of pounding tools in the Early Stone Age: a microscopic approach to the analysis of percussive artefacts from Beds I and II, Olduvai Gorge (Tanzania). J. Archaeol. Sci. 74, 23–34. doi:10.1016/j.jas.2016.08.003.

Arroyo, A., De la Torre, I., 2018. Pounding tools in HWK EE and EF-HR (Olduvai Gorge, Tanzania): percussive activities in the Oldowan-Acheulean transition. J. Hum. Evol. 120, 402–421. doi:10.1016/j.jhevol.2017.10.005.

Arroyo, A., Hirata, S., Matsuzawa, T., De La Torre, I., 2016. Nut cracking tools used by captive chimpanzees (Pan troglodytes) and their comparison with Early Stone Age percussive artefacts from Olduvai Gorge. PloS One 11 (11), e0166788.

Asryan, L., Ollé, A., Moloney, N., 2014. Reality and confusion in the recognition of post-depositional alterations and use-wear: an experimental approach on basalt tools. Journal of Lithic Studies 1 (1), 9–32.

Banks, W.E., Kay, M., 2003. High-resolution casts for lithic use-wear analysis. Lithic Technol. 28.

Bello Alonso, P., Rios-Garaizar, J., Panera, J., Pérez-González, A., Rubio-Jara, S., Rojas-Mendoza, R., Domínguez-Rodrigo, M., Baquedano, E., Santonja, M., 2019. A use-wear interpretation of the most common raw materials from the Olduvai Gorge: Naibor Soit quartzite. Quat. Int. 526, 169–192. doi:10.1016/j.quaint.2019.09.025.

Bello Alonso, P., Rios-Garaizar, J., Panera, J., Martín-Perea, D.M., Pérez-González, A., Rubio-Jara, S., Rojas-Mendoza, R., Domínguez-Rodrigo, M., Baquedano, E., Santonja, M., 2020. Experimental approaches to the development of use-wear traces on volcanic rocks: basalts. Archaeological and Anthropological Sciences 12 (7), 1–26.

Benito-Calvo, A., Arroyo, A., Sánchez-Romero, L., Pante, M., de la Torre, I., 2018. Quantifying 3D micro-surface changes on experimental stones used to break bones and their implications for the analysis of early stone age pounding tools. Archaeometry 60 (3), 419–436. doi:10.1111/arcm.12325.

Beyries, S., 1990. Problems of Interpreting the Functional Results for Ancient Periods. The Interpretative Possibilities of Microwear Studies, Uppsala, pp. 71–76 Aun 14).

Bunn, H.T., Gurtov, A.N., 2014. Prey mortality profiles indicate that Early Pleistocene Homo at Olduvai was an ambush predator. Quat. Int. 322, 44–53.

Carvalho, S., Biro, D., McGrew, W.C., Matsuzawa, T., 2009. Tool-composite reuse in wild chimpanzees (Pan troglodytes): archaeologically invisible steps in the technological evolution of early hominins? Anim. Cognit. 12 (1), 103–114.

Cerling, T.E., Mbua, E., Kirera, F.M., Manthi, F.K., Grine, F.E., Leakey, M.G., Sponheimer, M., Uno, K.T., 2011. Diet of paranthropus boisei in the early Pleistocene of East Africa. Proc. Natl. Acad. Sci. Unit. States Am. 108 (23), 9337–9341.

Cerling, T.E., Manthi, F.K., Mbua, E.N., Leakey, L.N., Leakey, M.G., Leakey, R.E., Brown, F.H., Grine, F.E., Hart, J.A., Kaleme, P., Roche, H., Uno, K.T., Wood, B.A., 2013. Stable isotope-based diet reconstructions of Turkana Basin hominins. Proc. Natl. Acad. Sci. Unit. States Am. 110 (26), 10501–10506.

Cordain, L., Miller, J.B., Eaton, S.B., Mann, N., Holt, S.H., Speth, J.D., 2000. Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets. Am. J. Clin. Nutr. 71 (3), 682–692. doi:10.1093/ajcn/71.3.682.

Crittenden, A.N., Schnorr, S.L., 2017. Current views on hunter-gatherer nutrition and the evolution of the human diet. Am. J. Phys. Anthropol. 162, 84–109. doi:10.1002/ajpa.23148.

de Francisco, S., 2019. El estudio funcional lítico en la Early Stone Age (ESA) africana. Aplicación analítica, metodológica y experimental en los yacimientos arqueológicos del Lecho II de la Garganta de Olduvai, Tanzania.. Universidad de Valladolid. Facultad de Filosofía y Letras, Universidad de Valladolid. http://uvadoc.uva.es/handle/10324/40264. In press.

de la Torre, I., 2006. Estrategias tecnológicas en el Pleistoceno inferior de África oriental (Olduvai y Peninj, norte de Tanzania). Universidad Complutense de Madrid, Servicio de Publicaciones.

de la Torre, I., Mora, R., 2018. Technological behaviour in the early acheulean of EF-HR (Olduvai Gorge, Tanzania). J. Hum. Evol. 120, 329–377. doi:10.1016/j.jhevol.2018.01.003.

de la Torre, I., Benito-Calvo, A., Arroyo, A., Zupancich, A., Proffitt, T., 2013. Experimental protocols for the study of battered stone anvils from Olduvai Gorge (Tanzania). J. Archaeol. Sci. 40 (1), 313–332. doi:10.1016/j.jas.2012.08.007.

Díez-Martín, F., Sánchez Yustos, P., Domínguez-Rodrigo, M., Mabulla, A.Z.P., Bunn, H.T., Ashley, G.M., Barba, R., Baquedano, E., 2010. Newinsights into hominin lithic activities at FLK north bed I, Olduvai Gorge, Tanzania. Quat. Res. 74, 376–387. doi:10.1016/j.yqres.2010.07.019.

Díez-Martín, F., Yustos, P.S., Uribelarrea, D., Baquedano, E., Mark, D.F., Mabulla, A., Fraile, C., Duque, J., Pérez-González, A., Yravedra, J., Egeland, C.P., Organista, E., Domínguez-Rodrigo, M., 2015. The origin of the acheulean: the 1.7 million-year-old site of FLK west, Olduvai Gorge (Tanzania). Sci. Rep. 5 (1), 1–9. doi:10.1038/srep17839.

Dominy, N.J., Vogel, E.R., Yeakel, J.D., Constantino, P., Lucas, P.W., 2008. Mechanical properties of plant underground storage organs and implications for dietary models of early hominins. Evol. Biol. 35 (3), 159–175. doi:10.1007/s11692-008-9026-7.

Dominy, N.J., 2012. Hominins living on the sedge. Proc. Natl. Acad. Sci. Unit. States Am. 109, 20171–20172.

Domínguez-Rodrigo, M., Serrallonga, J., Juan-Trasserras, J., Alcala, L., 2001. Woodworking activities by early humans: a plant residue analysis on Acheulian stone tools from Peninj (Tanzania). J. Hum. Evol. 40, 289–299. doi:10.1006/jhev.2000.0466.

Domínguez-Rodrigo, M., Pickering, T.R., Baquedano, E., Mabulla, A., Mark, D.F., Musiba, C., Pérez-González, A., 2013. First partial skeleton of a 1.34-million-year-old paranthropus boisei from bed II, Olduvai Gorge, Tanzania. PloS One 8 (12), e80347. doi:10.1371/journal.pone.0080347.

Favreau, J., Soto, M., Nair, R., Bushozi, P.M., Clarke, S., DeBuhr, C.L., Durkin, P.R., Hubbard, S.M., Inwood, J., Itambu, M., Larter, F., Lee, P., Marr, R.A., Mwambwiga, A., Patalano, R., Tucker, L., Mercader, J., 2019. Petrographic characterization of raw material sources at oldupai Gorge, Tanzania. Front. Earth Sci. 8, 158. doi:10.3389/feart.2020.00158.

Galán, A.B., Domínguez-Rodrigo, M., 2014. Testing the efficiency of simple flakes, retouched flakes and small handaxes during butchery. Archaeometry 56 (6), 1054–1074. doi:10.1111/arcm.12064.

Gaulin, S., 1979. A Jarman/Bell model of primate feeding niches. Hum. Ecol. 7, 1–19.

Hay, R.L., 1976. Geology of the Olduvai Gorge. University of California Press, Berkeley.

Henry, A.G., Ungar, P.S., Passey, B.H., Sponheimer, M., Rossouw, L., Bamford, M., Sandberg, P., de Ruiter, D.J., Berger, L., 2012. The diet of Australopithecus sediba. Nature 487 (7405), 90–93.

Herrygers, C., 2002. A comparative analysis of wood residues on experimental stone tools and Early Stone Age artifacts: a Koobi Fora case study. McNair Scholars Journal 6 (1), 10.

Ibáñez Estévez, J.J., Urquijo, J.E.G., 1996. In: From Tool Use to Site Function: Use-Wear Analysis in Some Final Upper Palaeolithic Sites in the Basque Country. BAR International Series, 658. Archaeopress, Oxford.

Jones, P.R., 1980. Experimental butchery with modern stone tools and its relevance for Palaeolithic archaeology. World Archaeol. 12 (2), 153–165.

Jones, P.R., 1981. Experimental implement manufacture and use; a case study from Olduvai Gorge, Tanzania. Philosophical Transactions of the Royal Society of London. Biological Sciences 292 (1057), 189–195.

Jones, P.R., 1994. Results of experimental work in relation to the stone industries of Olduvai Gorge. In: Leakey, M. (Ed.), Olduvai Gorge. 5. Excavations in Beds III, IV and the Masek Beds, 1968-1979. Cambridge University Press, pp. 254–298.

Keeley, L.H., 1980. Experimental Determination of Stone Tool Uses: A Microwear Analysis. The University of Chicago Press, Chicago.

Keeley, L.H., 1997. Microwear Traces on a Selected Sample of Stone Artefacts from Koobi Fora. Appendix 7F. En *Koobi Fora Research Project*. Clarendon Press, Oxford, pp. 396–401.

Keeley, L.H., Toth, 1981. Microwear polishes on early stone tools from Koobi Fora, Kenya. Nature 293, 464–495. doi:10.1038/293464a0.

Knutsson, K., Lindé, K., 1990. Post depositional alterations of wear marks on quartz tools. Preliminary observations on an experiment with aeolian abrasion. Cah. Du. Quat. 17, 607–618.

Kyara, O.A., 1999. Lithic Raw Materials and Their Implications on Assemblage Variation and Hominid Behavior during Bed II, Olduvai Gorge, Tanzania. Ph.D. Dissertation. Rutgers University.

Laden, G., Wrangham, R., 2005. The rise of the hominids as an adaptive shift in fallback foods: plant underground storage organs (USOs) and australopith origins. J. Hum. Evol. 49 (4), 482–498. doi:10.1016/j.jhevol.2005.05.007.

Leakey, M.D., 1971. In: Olduvai Gorge. Excavations in Beds I and II, 1960–1963, 3. Cambridge University Press.

Leakey, M.D., 1979. Olduvai Gorge: My Search for Early Man. HarperCollins.

Leakey, M.D., 1994. Olduvai Gorge. In: Excavations in Beds III, IV and the Masek Beds, 1968-1971, ume 5. Cambridge University Press, Cambridge.

Lee-Thorp, J.A., van der Merwe, N.J., Brain, C.K., 1994. Diet of Australopithecus robustus at Swartkrans from stable carbon isotopic analysis. J. Hum. Evol. 27 (4), 361–372. doi:10.1006/jhev.1994.1050.

Lee-Thorp, J., Likius, A., Mackaye, H.T., Vignaud, P., Sponheimer, M., Brunet, M., 2012. Isotopic evidence for an early shift to C4 resources by Pliocene hominins in Chad. Proc. Natl. Acad. Sci. Unit. States Am. 109, 20369–20372. doi:10.1073/pnas.1204209109.

Lemorini, C., Plummer, T.W., Braun, D.R., Crittenden, A.N., Ditchfield, P.W., Bishop, L.C., Hertel, F., Oliver, J.S., Marlowe, F.W., Schoeninger, M.J., Potts, R., 2014. Old stones' song: use-wear experiments and analysis of the Oldowan quartz and quartzite assemblage from Kanjera South (Kenia). J. Hum. Evol. 72, 10–25. doi:10.1016/j.jhevol.2014.03.002.

Lemorini, C., Bishop, L.C., Plummer, T.W., Braun, D.R., Ditchfield, P.W., Oliver, J.S., 2019. Old stones' song-second verse: use-wear analysis of rhyolite and fenetized andesite artifacts from the Oldowan lithic industry of Kanjera South, Kenya. Archaeological and Anthropological Sciences 11 (9), 4729–4754 https://doi.org/10. 1007/s12520-019-00800-z.

Machin, A.J., Hosfield, R., Mithen, S.J., 2005. Testing the functional utility of handaxe symmetry: fallow deerbutchery with replica handaxes, *Lithics*. The Journal of the Lithic Studies Society 26, 23–37.

Machin, A.J., Hosfield, R., Mithen, S.J., 2007. Why are some handaxes symmetrical? Testing the influence of handaxe morphology on butchery effectiveness. J. Archaeol. Sci. 34, 883–893.

Magill, C.R., Ashley, G.M., Freeman, K.H., 2013. Ecosystem variability and early human habitats in eastern Africa. Proc. Natl. Acad. Sci. Unit. States Am. 110 (4), 1167–1174.

Magill, C.R., Ashley, G.M., Domínguez-Rodrigo, M., Freeman, K.H., 2016. Dietary options and behavior suggested by plant biomarker evidence in an early human habitat. Proc. Natl. Acad. Sci. Unit. States Am. 113 (11), 2874–2879.

Marlowe, F.W., Berbesque, J.C., 2009. Tubers as fallback foods and their impact on Hadza hunter-gatherers. Am. J. Phys. Anthropol. 140, 751–758. doi:10.1002/ajpa.21040.

McHenry, L.J., De la Torre, I., 2018. Hominin raw material procurement in the Oldowan-Acheulean transition at Olduvai Gorge. J. Hum. Evol. 120, 378–401. doi:10.1016/j.jhevol.2017.11.010.

Melamed, Y., Kislev, M.E., Geffen, E., Lev-Yadun, S., Goren-Inbar, N., 2016. The plant component of an Acheulian diet at Gesher Benot Ya 'aqov, Israel. Proc. Natl. Acad. Sci. Unit. States Am. 113 (51), 14674–14679.

Mercader, J., Panger, M., Boesch, C., 2002. Excavation of a chimpanzee stone tool site inthe African rainforest. Science 296 (5572), 1452–1455. doi:10.1126/science.1070268.

Mercader, J., 2009. Mozambican grass seed consumption during the Middle Stone Age. Science 326 (5960), 1680–1683. doi:10.1126/science.1173966.

Mitchell, J., 1996. Studying biface utilisation at Boxgrove: roe deer butchery with replica handaxes. Lithics 16, 64–69.

Mollel, G.F., 2007. Petrochemistry and Geochronology of Ngorongoro Volcanic Highland Complex (NVHC) and its Relationship to Laetoli and Olduvai Gorge, Tanzania. Ph.D. Dissertation, Rutgers University https://doi.org/doi:10.7282/T32N52NH.

Mollel, G.F., Swisher, C.C., III, Feigenson, M.D., Carr, M.J., 2008. Geochemical evolution of Ngorongoro Caldera, Tanzania: implications for crust-magma interaction. Earth Planet Sci. Lett. 271, 337–347. doi:10.1016/j.epsl.2008.04.014.

Mollel, G.F., Swisher, C.C., III, McHenry, L.J., Feigenson, M.D., Carr, M.J., 2009. Petrogenesis of basalt-trachyte lavas from Olmoti crater, Tanzania. J. Afr. Earth Sci. 54, 127–347. doi:10.1016/j.jafrearsci.2009.03.008.

Mollel, G.F., Swisher, C.C., III, Feigenson, M.D., Carr, M.J., 2011. Petrology, geochemistry, and age of Satiman, Lemagurut and Oldeani: sources of the volcanic deposits of the Laetoli area. In: Harrison, T. (Ed.), Paleontology and Geology of Laetoli: Human Evolution in Context 1. Springer, Dordrecht, pp. 99–119. doi:10.1007/978-90-481-9956-3_5.

Mollel, G.F., Swisher, C.C., III, 2012. The Ngorongoro volcanic highland and its relationships to volcanic deposits at Olduvai Gorge and east african rift volcanism. J. Hum. Evol. 63, 274e283. doi:10.1016/j.jhevol.2011.09.001.

Motes-Rodrigo, A., Majlesi, P., Pickering, T.R., Laska, M., Axelsen, H., Minchin, T.C., Tennie, C., Hernandez-Aguilar, R.A., 2019. Chimpanzee extractive foraging with excavating tools: experimental modeling of the origins of human technology. PloS One 14 (5). doi:10.1371/journal.pone.0215644.

Murray, S.S., Schoeninger, M.J., Bunn, H.T., Pickering, T.R., Marlett, J.A., 2001. Nutritional composition of some wild plant foods and honey used by Hadza foragers of Tanzania. J. Food Compos. Anal. 14 (1), 3–13. doi:10.1006/jfca.2000.0960.

Oliver, J.S., 1993. Carcass processing by the Hadza: bone breakage from butchery to consumption. From bones to behavior: ethnoarchaeological and experimental contributions to the interpretation of faunal remains 21, 200–227.

Panera, J., Rubio-Jara, S., Domínguez-Rodrigo, M., Yravedra, J., Méndez-Quintas, E., Pérez-González, A., Bello-Alonso, P., Moclán, A., Baquedano, E., Santonja, M., 2019. Assessing functionality during the early acheulean in level TKSF at Thiongo korongo

site (Olduvai Gorge, Tanzania). Quat. Int. 526, 77–98. doi:10.1016/j.quaint.2019.09.013.
Pedergnana, A., Ollé, A., 2017. Monitoring and interpreting the use-wear formation process on quartzite flakes through sequential experiments. Quat. Int. 427, 35–65. doi:10.1016/j.quaint.2016.01.053.
Pickering, R., 1958. Oldoinyo Ogol. Quarter Degree Sheet 12 S.W. First Edition Geologicl Survey, Department of Dodoma (Tanzania).
Peters, C.R., O'Brien, E.M., 1994. Potential Hominid Plant Foods from Woody Species in Semiarid versus Sub-humid Subtropical Africa. The Digestive System in Mammals: Food, Form and Function. Cambridge University Press, Cambridge, pp. 166–192.
Plummer, T.W., Ditchfield, P.W., Bishop, L.C., Kingston, J.D., Ferraro, J.V., Braun, D.R., Hertel, F., Potts, R., 2009. Oldest evidence of toolmaking hominins in a grassland-dominated ecosystem. PloS One 4 (9).
Plummer, T.W., Bishop, L.C., 2016. Oldowan Hominin Behavior and Ecology at Kanjera South, Kenya.
Pontzer, H., Raichlen, D.A., Wood, B.M., Mabulla, A.Z., Racette, S.B., Marlowe, F.W., 2012. Hunter-gatherer energetics and human obesity. PloS One 7 (7), e40503. doi:10.1371/journal.pone.0040503.
Rodman, P.S., 2002. Plants of the apes: is there a hominoid model for the origins of the hominid diet? In: Ungar, P., Teaford, M.F. (Eds.), Human Diet. Bergin and Garvey, Westport, pp. 76–109.
Rubio-Jara, S., Panera, J., Santonja, M., Pérez-González, A., Yravedra, J., Domínguez-Rodrigo, M., Bello, P., Rojas, R., Mabulla, A., Baquedano, E., 2017. Site function and lithic technology in the Acheulean technocomplex: a case study from Thiongo Korongo (TK), bed II, Olduvai Gorge, Tanzania. Boreas 46 (4), 894–917. doi:10.1111/bor.12275.
Sahnouni, M., Rosell, J., van der Made, J., Vergès, J.M., Ollé, A., Kandi, N., Harichane, Z., Derradji, A., Medig, M., 2013. The first evidence of cut marks and usewear traces from the Plio-Pleistocene locality of El-Kherba (Ain Hanech), Algeria: implications for early hominin subsistence activities circa 1.8 Ma. J. Hum. Evol. 64 (2), 137–150.
Sahnouni, M., Parés, J.M., Duval, M., Cáceres, I., Harichane, Z., van der Made, J., Pérez-González, A., Abdessadock, S., Kandi, N., Derradji, A., Medig, M., Boulaghraif, K., Semaw, S., 2018. 1.9-million-and 2.4-million-year-old artifacts and stone tool–cut marked bones from Ain Boucherit, Algeria. Science 362 (6420), 1297–1301. doi:10.1126/science.aau0008.
Sánchez-Yustos, P., Diez-Martin, F., Díaz, I.M., Duque, J., Fraile, C., Domínguez, M., 2015. Production and use of percussive stone tools in the Early Stone Age: experimental approach to the lithic record of Olduvai Gorge, Tanzania. J. Archaeol. Sci.: Report 2, 367–383.
Santonja, M., Panera, J., Rubio-Jara, S., Pérez-González, A., Uribelarrea, D., Domínguez-Rodrigo, M., Mabulla, A.Z.P., Bunn, H.T., Baquedano, E., 2014. Technological strategies and the economy of raw materials in the TK (Thiongo Korongo) lower occupation, Bed II, Olduvai Gorge, Tanzania. Quat. Int. 322, 181–208. doi:10.1016/j.quaint.2013.10.069.
Santonja, M., Rubio-Jara, S., Panera, J., Pérez-González, A., Rojas-Mendoza, R., Domínguez-Rodrigo, M., Mabulla, A.Z.P., Baquedano, E., 2018. Bifacial shaping at the TK acheulean site (bed II, Olduvai Gorge, Tanzania): new excavations 50 Years after mary Leakey. In: The Emergence of the Acheulean in East Africa and beyond. Springer, Cham, pp. 153–181. doi:10.1007/978-3-319-75985-2_8.
Schnorr, S.L., 2016. *Nutritional Contribution of Plant Foods to Human Diet in Evolution* (Doctoral Dissertation). doi:10.1080/19442890.2016.1150629.
Schnorr, S.L., Crittenden, A.N., Henry, A.G., 2016. Impact of brief roasting on starch gelatinization in whole foods and implications for plant food nutritional ecology in human evolution. Ethnoarchaeology 8 (1), 30–56.
Schoeninger, M.J., Bunn, H.T., Murray, S.S., Marlett, J.A., 2001. Composition of tubers used by Hadza foragers of Tanzania. J. Food Compos. Anal. 14 (1), 15–25. doi:10.1006/jfca.2000.0961.
Schick, K., Toth, N., 1993. Making Silent Stones Speak. Simon & Schuster, New York.
Semaw, S., Rogers, M.J., Simpson, S.W., Levin, N.E., Quade, J., Dunbar, N.W., McIntosh, W.C., Cáceres, I., Stinchcomb, G.E., Holloway, R.L., Brown, F.H., Butler, R.F., Stout, D., Everett, M., 2020. Co-occurrence of Acheulian and Oldowan artifacts with Homo erectus cranial fossils from Gona, Afar State, Ethiopia. American Association for the Advancement of Science.
Sept, J.M., 1986. Plant foods and early hominids at site FxJj 50, Koobi Fora, Kenya. J. Hum. Evol. 15, 751–770. doi:10.1016/S0047-2484(86)80008-2.
Soto, M., Favreau, J., Campeau, K., Carter, T., Abtosway, M., Bushozi, P.M., Clarke, S., Durkinf, P.R., Hubbardg, S.M., Inwood, J., Itambu, M., Koromoh, S., Lartera, F., Lee, P., Mwambwigaa, A., Nairg, R., Olesilauh, L., Patalano, R., Tuckera, L., Mercader, J., 2020. Fingerprinting of quartzitic outcrops at oldupai Gorge, Tanzania. J. Archaeol. Sci.: Report 29, 102010. doi:10.1016/j.jasrep.2019.102010.
Stahl, A.B., Dunbar, R.I.M., Homewood, K., Ikawa-Smith, F., Kortlandt, A., McGrew, W.C., Milton, K., Peterson, J.D., Poirier, F.E., Sugardjito, J., Tanner, N.M., Wrangham, R.W., 1984. Hominid dietary selection before fire [and Comments and Reply]. Curr. Anthropol. 25 (2), 151–168.
Stiles, D.N., Hay, R.L., O'Neil, J.R., 1974. The MNK chert factory site, Olduvai Gorge, Tanzania. World Archaeol. 5, 285–308.
Sussman, C., 1987. Résultats d'une étude des microtraces d'usure sur un échantillon d'artefacts d'Olduvai (Tanzanie). L'Anthropologie 91 (2), 375–380.
Sussman, C., 1988. In: A Microscopic Analysis of Use-Wear Polish Formation on Experimental Quartz Tools. British Archaeological Reports International Series, 395. Archaeopress, Oxford.
Tactikos, J.C., 2005. A Landscape Perspective on the Oldowan from Olduvai Gorge, Tanzania. Rutgers The State University of New Jersey-New Brunswick.
Ungar, P.S., Grine, F.E., Teaford, M.F., 2006. Diet in early Homo: a review of the evidence and a new model of adaptive versatility. Annu. Rev. Anthropol. 35, 209–228. doi:10.1146/annurev.anthro.35.081705.123153.
Van der Merwe, N.J., Masao, F.T., Bamford, M.K., 2008. Isotopic evidence for contrasting diets of early hominins Homo habilis and Australopithecus boisei of Tanzania. South Afr. J. Sci. 104 (3–4), 153–155.
Vincent, A., 1984. Plant foods in savanna environments: a preliminary report of tubers eaten by the Hadza of northern Tanzania. World Archaeol. 17, 132–142.
Venditti, F., Tirillò, J., Garcea, E.A., 2016. Identification and evaluation of post-depositional mechanical traces on quartz assemblages: an experimental investigation. Quat. Int. 424, 143–153. doi:10.1016/j.quaint.2015.07.046.
Vergés, J.M., 2003. Caracteritzaci_o dels Models d'Instrumental Lític del Mode 1 a Partir de les Dades de l'an_alisi Funcional dels Conjunts Litot_ecnics d'Aïn Hanech i El-Kherba (Alg_eria), Monte Poggiolo i Isernia La Pineta (It_alia). Departament d'hist_oria i Geografia (Ph.D. thesis). Universitat Rovira i Virgili, Tarragona (Spain).
Whiten, A., Goodall, J., McGrew, W.C., Nishida, T., Reynolds, V., Sugiyama, Y., Tutin, C.E.G., Wrangham, R.W., Boesch, C., 1999. Cultures in chimpanzees. Nature 399 (6737), 682–685.
Wrangham, R., Cheney, D., Seyfarth, R., Sarmiento, E., 2009. Shallow-water habitats as sources of fallback foods for hominins. Am. J. Phys. Anthropol.: The Official Publication of the American Association of Physical Anthropologists 140 (4), 630–642.
Wiederhold, J.E., 2004. Toward the Standardization of Use-Wear Studies: Constructing an Analogue to Prehistoric Hide Work. Graduate Thesis. Texas A&M University.
Yamagiwa, J., Yumoto, T., Ndunda, M., Maruhashi, T., 1988. Evidence of tool-use by chimpanzees (Pan troglodytes schweinfurthii) for digging out a bee-nest in the Kahuzi-Biega National Park, Zaire. Primates 29 (3), 405–411.
Yravedra, J., Domínguez-Rodrigo, M., Santonja, M., Rubio-Jara, S., Panera, J., Pérez-González, A., Uribelarrea, D., Egeland, C., Mabulla, A., Baquedano, E., 2016. The larger mammal palimpsest from TK (Thiongo korongo), bed II, Olduvai Gorge, Tanzania. Quat. Int. 417, 3–15. doi:10.1016/j.quaint.2015.04.013.