Afr Archaeol Rev (2019) 36:505–534
https://doi.org/10.1007/s10437-019-09352-y

ORIGINAL ARTICLE

Check for updates

Gouges: Iconic Artifacts of the Early Neolithic Period in Central Sudan

Katarína Kapustka · Lenka Lisá · Aleš Bajer · David Buriánek · Ladislav Varadzin · Lenka Varadzinová

Published online: 19 November 2019

Abstract Neolithic stone tool production in Sudan was quite diverse but exhibited high standards of production, as exemplified by the adze-like artifacts called "gouges". Drawing on data from several sites in Jebel Sabaloka, and comparative data from Shaheinab and Sheikh el-Amin, our paper examines the economy of gouge production from a technological point of view. More specifically, we discuss the process of gouge production and distribution through the study of raw material sourcing and methods of manufacture. We determine that the Neolithic people of central Sudan preferred rhyolites for the manufacture of gouges and that the production was highly standardized. We also examine the implications of gouge production for understanding Neolithic social networks in the region.

Archaeological period: Early Neolithic, ca. 4900–3800 cal. BC
Country and region discussed: Central Sudan, Nile Valley, Jebel Sabaloka

K. Kapustka (✉) · L. Varadzin
Institute of Archaeology of the Czech Academy of Sciences, Prague, v. v. i., Letenská 4, 118 01 Prague 1, Czech Republic
e-mail: culakova@arup.cas.cz

L. Lisá
Institute of Geology of the Czech Academy of Sciences, v. v. i., Rozvojová 269, 165 00 Prague 6, Czech Republic

A. Bajer
Department of Geology and Pedology, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic

D. Buriánek
Czech Geology Survey, Leitnerova 22, 658 69 Brno, Czech Republic

L. Varadzin · L. Varadzinová
Czech Institute of Egyptology, Faculty of Arts, Charles University, Celetná 20, 110 00 Prague 1, Czech Republic

Résumé La production néolithique d'outils en pierre au Soudan était très variée mais respectait des normes technologiques élevées, comme en témoignent des artefacts en forme dherminette appelés «gouges». En utilisant des données de plusieurs sites à Jebel Sabaloka, et des données comparatives des sites de Shaheinab et de Sheikh el-Amin, notre article examine l'économie de la production de gouges d'un point de vue technologique. Plus spécifiquement, nous discutons du processus de production et de distribution des gouges, y compris l'approvisionnement en matière première et les méthodes de fabrication. Nous déterminons que le peuple néolithique du Soudan central a préféré les rhyolites pour la fabrication des gouges, et que la production était hautement standardisée. Nous examinons également les implications pour la compréhension des réseaux sociaux néolithiques dans la région.

Keywords Neolithic · Gouges · Lithic economy · Lithic technology · Middle Nile · Sudan

Introduction

Since Anthony J. Arkell's identification of the Early Neolithic culture in Sudan in 1949, gouges—adze-like lithic artifacts produced from high-quality materials—

have been recognized as the iconic artifact of the late prehistory of central Sudan. Fascinated by their precise craftsmanship and treating them as a type-artifact, Arkell initially named the central Sudan Neolithic as the Gouge Culture, but renamed it later as Khartoum or Shaheinab Neolithic (Arkell 1949, 1953). Characteristic of the Early Neolithic period, dated between ca. 4900 and 3800 cal. BC (Krzyzaniak 1995), gouges were produced nearly exclusively from rhyolite. The only known sources of this rock are in the volcanic Sabaloka Mountains (Jebel Sabaloka) at the Sixth Cataract of the Nile (Arkell 1949). The gouges occurred predominantly at sites along the Nile between the Sixth Cataract and Jebel Aulia on the White Nile (ca. 25 km south of Khartoum) and were believed by Arkell to have been used as adzes for the working of wood, especially in the production of boats (Arkell 1953).

Since Arkell's pioneering work, archaeologists have identified gouges from various sites in the region, but the mention has rarely surpassed the basic recording of formal attributes based on Arkell's schemes for typology, technology, function, consumption, and distribution of gouges (e.g., Caneva 1988; Haaland 1982). However, subsequent research has shown that the geographical spread of gouges was more extensive than previously thought, reaching as far as the Blue Nile region (Fernández et al. 2003) and perhaps the areas farther from the Nile, such as Khashm el-Girba in eastern Sudan (Magid 1989).

Describing this type of artifact, Arkell relied on the definition offered by Gertrude Caton-Thomson for the material of the Faiyum Neolithic B culture. Caton-Thomson and Gardner (1934) described gouges as:

> "… conical in outline… The dorsal face is either wholly polished… or polished and flaked. The ventral face is flaked only. The cross-section is a thin-pointed oval. The working hollow edge is obtained by oblique flaking from the polished side" (Arkell 1953, p. 31).

By accepting this definition, Arkell (1953, p. 32) set a division line between gouges and celts "that were flaked only" and of which only some pieces "subsequently … underwent some degree of polishing." The presence and degree of polishing later became the main criterion that Anwar Magid (1989, p. 159) used for classifying these artifacts into five types: Type I—gouges flaked on both faces; Type II—gouges polished on both sides; Type III—gouges flaked on the upper face and polished on the lower one; Type IV—gouges flaked on the upper face and partly flaked and partly polished on the lower one; Type V—gouges partly flaked and partly polished on both faces.

Many other authors maintained the division between gouges and celts (e.g., Caneva 1988), while others have treated gouges and celts as the same (e.g., Fernández et al. 2003) or used the term "gouge" exclusively for both polished and unpolished adze-like tools (e.g., Kobusiewicz 2011). We present in this paper the result of the comparative regional study of gouges—understood as flaked and often polished artifacts that were presumably used as adzes—from technological, production, consumption, and distribution perspectives. The research originated from our fieldwork in the western part of Jebel Sabaloka. Our main aim is to contribute to the understanding of the cultural significance, definition, and typology of this iconic artifact.

Study Area and Collections

A total of 1,012 gouges from three regions in central Sudan are included in this study (Fig. 1): Jebel Sabaloka (80 km to the north of Khartoum), Shaheinab (on the west bank of the Nile, 50 km to the north of Khartoum), and Wadi Soba (on the east bank of the Blue Nile, 20 km to the east of Khartoum). The core samples in our analysis came from the western part of Sabaloka. We use these to identify and describe the main characteristics of gouge production and its economy. The collections from Shaheinab, located in the Sudan National Museum, and Wadi Soba were used as comparative collections to verify the observations from Sabaloka.

Jebel Sabaloka, one of the younger granite igneous complexes of Sudan, emerges like a rocky island out of the dusty plain of central Sudan. The basic character of this hilly region is the selectively eroded hard core of the ring structure encircled by amphibole gneisses of Neoproterozoic Basement Complex and partly, on Mt. Rauwiyan, by silicified "Nubian" sandstone. The Nile River has eroded the relatively soft Upper Cretaceous sandstone, deep into the hard rock of Sabaloka, to create a spectacular 100-m deep valley (Almond and Ahmed 1993). This area is dominated by volcanic and subvolcanic facies of a massive intrusion of early Phanerozoic rocks composed mainly of grey porphyric rhyolites, red microgranites, and numerous dykes of

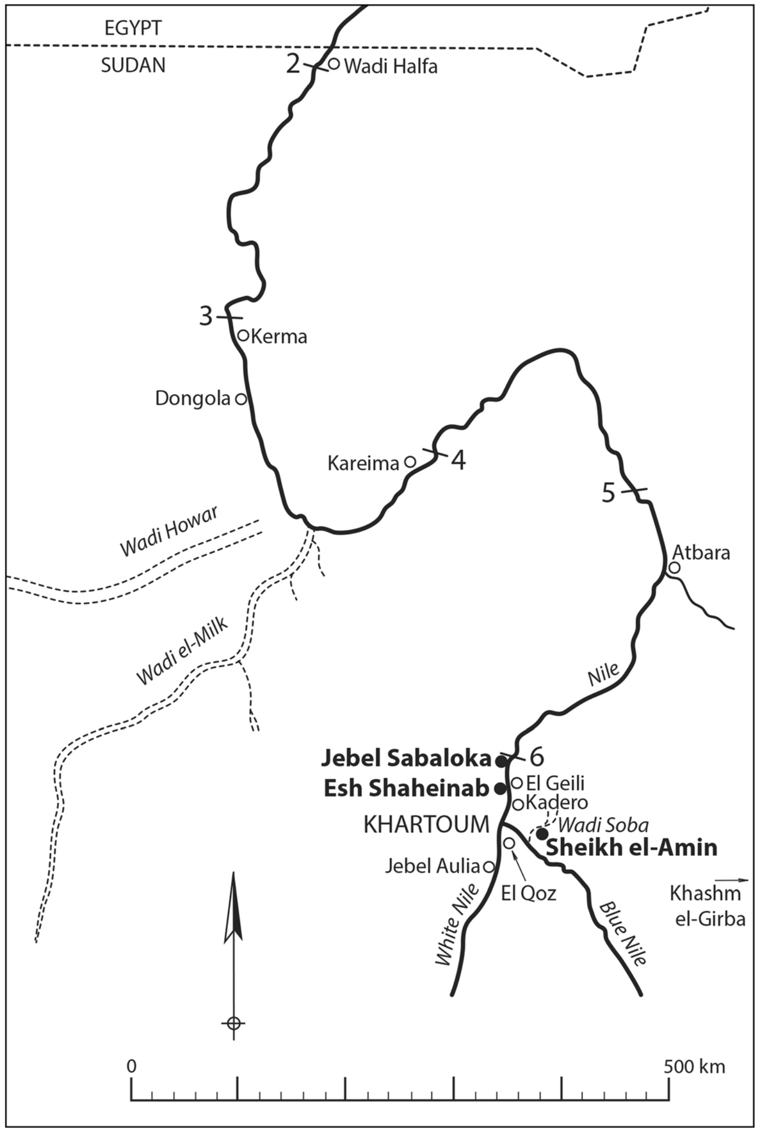


Fig. 1 Study area. Map of the Nile between the 6th and 2nd cataracts showing the location of the study area and sites compared in this paper. Drawn by L. Vařeková and L. Varadzinová

rhyolitic, microgranitic, and trachybasaltic composition, including fine-grained and glassy materials suitable for local production of stone artifacts.

The gouges from Sabaloka presented in this paper come from an 18 × 6 km research area, corresponding to the western part of the volcanic mountains and their surroundings on the west bank of the Nile. Between 2011 and 2018, the mission of Charles University in Prague identified 16 Early Neolithic sites in this area and recorded gouges on six locations (Suková and Varadzin 2012; Varadzinová et al. 2018; Fig. 2). The two most significant of the sites are Fox Hill (SBK.W-20), with its abundant prehistoric remains, and the Rhyolite Site (SBK.W-58) located at the most prominent outcrops of red rhyolite in the western part of the mountains. Two other locations, the Donkey (SBK.W-24/25) and Grove (SBK.W-56) Sites, represent smaller and less significant settlements located on granite outcrops in the vicinity of Fox Hill. The fifth, Tabya Hassaniya (SBK.W.SS-18), constitutes a large habitation site situated on a former Nile terrace, ca. 6 km to the southwest of the mountains and ca. 1.5 km west of the Nile. All these sites have also remains of occupation during the Early Khartoum (Mesolithic) Culture and earlier and/or later periods. One gouge was found at an off-site location in the Lake Basin area (Table 1).

The gouges collection from Sabaloka consists mostly of surface finds and includes 360 artifacts. Of these, 321 pieces come from Fox Hill and the remaining from the other five locations. The finds from Fox Hill were collected during systematic surveys that focused on searching for gouges; the finds from the other five locations were collected during a reconnaissance survey and casual visits. Only three gouges from the Fox Hill location originated from excavated deposits, but none were found in a context that would indicate primary position. For this reason, the excavated gouges are treated in the same way as the surface finds. The Donkey site, Grove site, and Lake Basin area are excluded from detailed analysis and the discussion that follows because their sample of finds is very small. As a result, the total number of gouges from Sabaloka included in this study is 355, and these come from Fox Hill, Rhyolite, and Tabya Hassaniya.

The collection from Shaheinab comes from Arkell's excavation conducted in 1949–1950 (Arkell 1953). It includes 642 gouges currently stored in the Sudan National Museum in Khartoum. It is impossible to ascertain at the moment the excavated areas where these artifacts were collected, so these pieces are treated as one group. The collection from Wadi Soba originated from Sheikh el-Amin, the only gouge-bearing site explored in the Blue Nile Project directed by Víctor M. Fernández in 1990–2000 (Fernández 2003). From this site, situated 80 km to the southeast of Jebel Sabaloka and 17 km to the north of the Blue Nile, ten gouges and two flakes were available for our study out of the total of 26 pieces collected from the surface and excavated deposits (Fernández et al. 2003).

Methods

In our study, we did not keep to the division between gouges and celts suggested by Arkell (1953, p. 32) and instead focused our attention on sizes, raw materials, and technologies of production. We treated the proportionality of objects, based on their metrics, as a useful indicator of the production process. Each artifact from Sabaloka and Sheikh el-Amin was therefore weighed, and the following six different types of measurement were taken (in millimetres): maximal length, width, and thickness; the width of the cutting edge and the base; and the thickness of the base. Of course, it was only possible to take a limited number of measurements from broken or incomplete tools. Also, measurements were recorded on only selected artifacts in the Shaheinab collection.

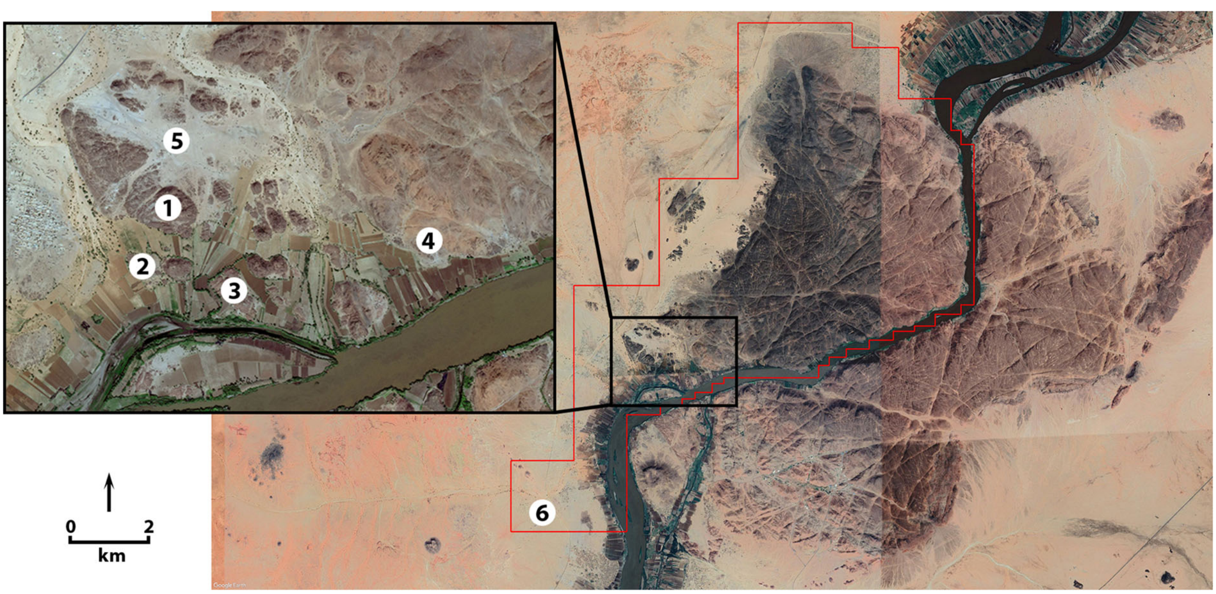


Fig. 2 Sites with gouges in the Sabaloka (West Bank) research area: 1—Fox Hill (SBK.W-20), 2—Donkey Site (SBK.W-24/25), 3—Grove Site (SBK.W-56), 4—Rhyolite Site (SBK.W-58), 5—isolated find within the Lake Basin area, 6—Tabya Hassaniya (SBK.W.SS-18). Background: Google Earth 2016, 2019 ©. Illustrated by: L. Varadzin and L. Varadzinová

Table 1 Locations in the western part of Jebel Sabaloka with gouges documented between 2011 and 2018

Site name (site code)	Size	Description	Method of exploration	Represented periods	No. of gouges documented	Bibliography
Fox Hill (SBK.W-20)	11,650 m^2	Approximately oval-shaped granite outcrop (ca. 110,000 m^2) ca. 1.2 km from the Nile, with 16 platforms of varied size situated 2–29 m above the surrounding terrain; the platforms are set within exposed bedrock and granite boulders and constitute well-delimited occupation areas	Repeated surface survey, large-scale excavation on *Terraces 1* (12 trenches, ca. 155 m^2) and *3* (6 trenches, 38.5 m^2), small test pits on the remaining platforms (9 trenches, ca. 8 m^2), and 46 total counts of lithics	ESA; MSA; LSA; EK; EN; LN; PM; IP; UHP	321	Suková and Varadzin (2012); Varadzinová et al. (2018)
Donkey Site (SBK.W-24/25)	1,500 m^2	Lower-lying platform (ca. 3 m above the surrounding terrain) on the western side of a smaller granite outcrop (ca. 18,000 m^2) ca. 0.4 km from the Nile	Basic surface survey, 1 test pit (1 × 1 m), and 3 total counts of lithics	EK; EN; UHP	3	Unpublished
Grove Site (SBK.W-56)	Not estimated	Trapeziform granite outcrop (over 37,000 m^2) ca. 0.2 km from the Nile, with many little occupation platforms between granite blocks and boulders	Basic surface survey and 2 test pits (1 × 1 m each)	EK; EN; UHP	1	Unpublished
Rhyolite Site (SBK.W-58)	12,800 m^2	Elevated corner spur on a former Nile terrace ca. 250 m from and 16 m above the Nile; the site is distinguished by the presence of a massive vein of red rhyolite and abundant quantities of rhyolite on the surface	Basic surface survey, 1 test pit (1 × 1 m), and 3 total counts of lithics	EK; EN; LN; PM; CP/IP	11	Suková and Varadzin (2012)
Tabya Hassaniya (SBK.W.SS-18)	Not estimated	Remains of a large late prehistoric habitation site situated on a former Nile terrace ca. 1.5 km from and 16 m above the Nile, largely affected by erosion and erection of numerous large gravel tumuli	No systematic survey performed, only random finds collected during repeated visits	EK; EN; PM	23	Unpublished
Lake Basin area (no code)	Not estimated	Flat basin surrounded by granite outcrops ca. 1.1–1.7 km from the Nile whose bottom was occupied by a lake or marshland in late prehistory; the area features loosely scattered prehistoric finds (Early Neolithic) and several tumuli (PM, or UHP)	No systematic survey performed, only random finds collected during repeated visits	n/a	1	Suková and Varadzin (2012)

ESA Early Stone Age, *MSA* Middle Stone Age, *LSA* Late Stone Age (Terminal Pleistocene), *EK* Early Khartoum (Mesolithic), *EN* Early (Shaheinab) Neolithic, *LN* Late Neolithic, *PM* Post-Meroitic, *CP* Christian Period, *IP* Islamic Period, *UHP* unspecified historical period

In addition, we macroscopically identified the minerals of the lithic artifacts. We ascertained that all the gouges were made of rhyolites. These were divided into variants according to color. In considering the quality of raw material, we recorded and described visible defects which have affected the knapping procedures. Moreover, the geological characteristics of the rhyolite outcrops at Jebel Sabaloka were defined, and the variants of rhyolite described in the field were collected for microscopic description to more precisely distinguish the mineral composition of the gouges.

A detailed study of wear and fracture was also carried out to better understand the technological processes of production, following the procedures outlined by Inizan et al. (1999). For the Sabaloka and Sheikh el-Amin collections, the presence or absence of weathering, patina, polish, and cortex was recorded, and their percentage on the total surface of the artifact was estimated. We not only identified the evidence of polishing, which played a key role in Magid's (1989) typology, but also considered the method of polishing, its quality, and position on different sides of gouges. In every case, the degree of completeness, methods, and phases of production, as well as traces of use (finished/unfinished, traces of reworking, visible repairs) were recorded and described. Special attention was given to the level of technical skill of production and its variability within collections. The wear and damage patterns observed on the artifacts were compared with those described on other lithic collections (e.g., Aubry et al. 2008; Pelegrin 2012; Pétrequin et al. 1998).

Furthermore, in 2017 and 2018, a detailed survey was carried out in Jebel Sabaloka to locate and compare the remains of production and consumption of gouges at different sites within the source area (Varadzinová et al. 2018). Given the extremely high quantities of surface finds of lithic artifacts (at some places exceeding 3,500 pieces per m^2; see Fig. 3c, d), we used the method of total counts in delimited areas to estimate the distribution density in the larger area (e.g., Sobotková et al. 2010). All lithic finds were collected and described based on typological and technological categories (tool, core, flake, blade, and its fragments), size of artifacts (below 2 cm^2, 2–5 cm^2, and more than 5 cm^2), and raw materials. The goal was to identify the functional activities at different sites.

Analytical Categories

The post-field analyses were undertaken to understand the technology and economy of gouge production and consumption. To start, we grouped the artifacts into twelve analytical categories: (1) whole finished pieces, (2) reworked gouge fragments, (3) pieces that broke during use and (4) during production, (5) gouges that were intentionally broken and (6) broken by natural causes, (7) indeterminate fragments, (8) retaken pieces, (9) pieces knapped by novices, (10) unfinished pieces, (11) half-finished products, and (12) reworked artifacts from other periods. The goal of this classification is to understand the stages of production or use in the life cycle of each artifact. These analytical categories are subsequently used to discuss processes of production, reworking, and discard, followed by observations on the morphometric characteristics. We then summarize our observations on the selection and utilization of raw materials at Sabaloka. Finally, we compare the three sites to understand the distribution of gouges and rhyolites in central Sudan.

Whole Finished Pieces

This category includes gouges that have complete functional parts but lack traces of repairs and use-related damages (Fig. 4). Minor traces of use are present, but not on all pieces. The usual length of these pieces is 10–12 cm, and their average width and thickness is 4 cm and 2 cm respectively. Of importance is the ratio of width to thickness which shows that the proportions of the gouges in the various assemblages were standardized (Fig. 5). Altogether 32 pieces were identified, of which 12 came from Sabaloka (3%) and 20 from Shaheinab (3%). None are known from Sheikh el-Amin. All are flaked but only three pieces from Shaheinab show polishing. The quality of these pieces shows that all of them were a product of a high level of technical skills.

Reworked Gouge Fragments

The pieces in this group resulted from re-sharpening of worn gouges and reworking of broken artifacts. While basal parts dominate this category (Fig. 6), there is enormous variability in shape and size. Generally, they are usually conical in shape and show varying degrees of polishing. The polish was usually partial, covering only small surfaces of the pieces, and was mostly

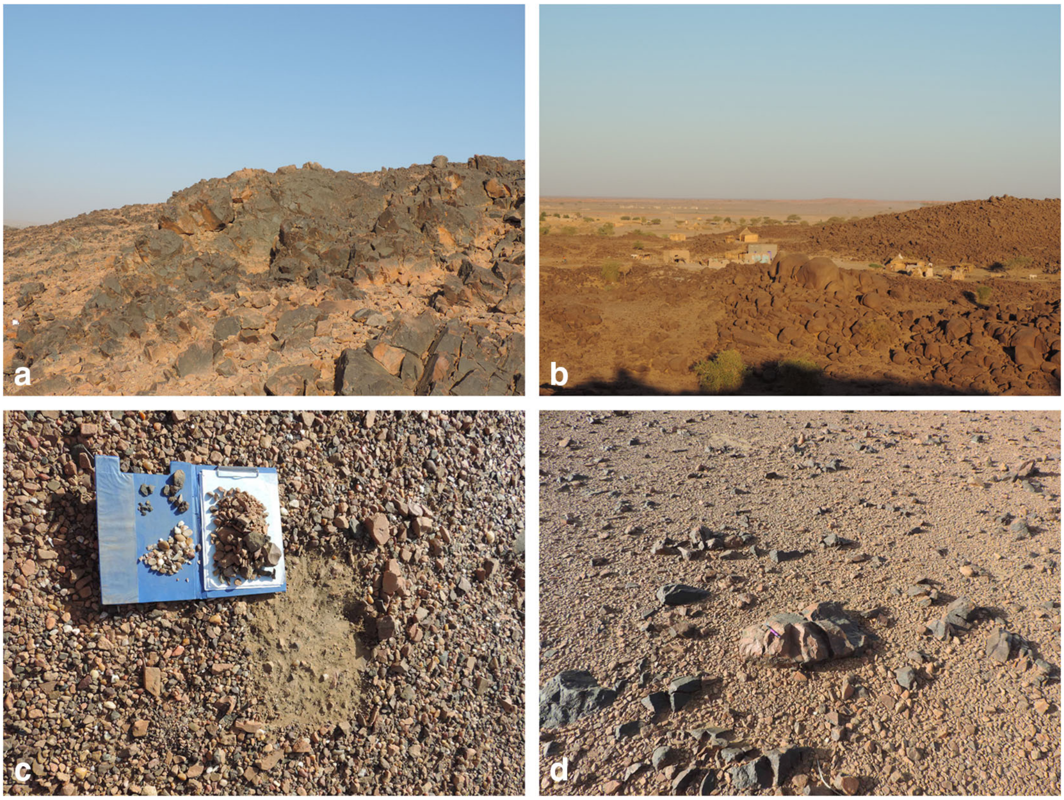


Fig. 3 Archaeological landscape. **a** Rhyolite Site: raw material sources. **b** Fox Hill: workshop for gouge production. **c** Fox Hill: example of total count in the area of the workshop. **d** Block of raw material found in the area of the workshop at Fox Hill

limited to one side (preferably the convex; Table 2). The ratio of polished pieces at different sites is quite variable

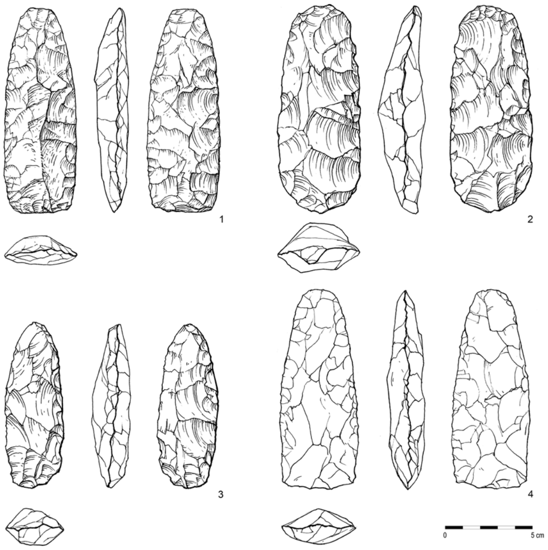


Fig. 4 Gouges: whole finished pieces. 1–3: finds from the site of Fox Hill, 4: example of experimental production. Drawn by M. Černý

(Fig. 7). It appears that gouges were always polished on the reworked side. This suggests that polishing was part of the reworking process as it facilitates re-sharpening or repair. The reworked gouge fragments are found in all the three regional collections. In Sabaloka, they accounted for 24% of the gouges at Fox Hill and 35% at Tabya Hassaniya (they are present in other sites except for the Rhyolite Site). They are present at Shaheinab as well (38%) and dominate the finds at Sheikh el-Amin (70%). There are signs that these pieces were used after reworking because their size is quite variable. It seems they were reworked several times, especially as we move further from the source of the raw material. The average length of these pieces in Sabaloka is about 7 cm, whereas the average length is less than 4.5 cm at Sheikh el-Amin.

Breakage During Use

This category includes gouges that show a particular type of fracture in the shape of a step ridge that very probably happened by accident during use (Fig. 8). This

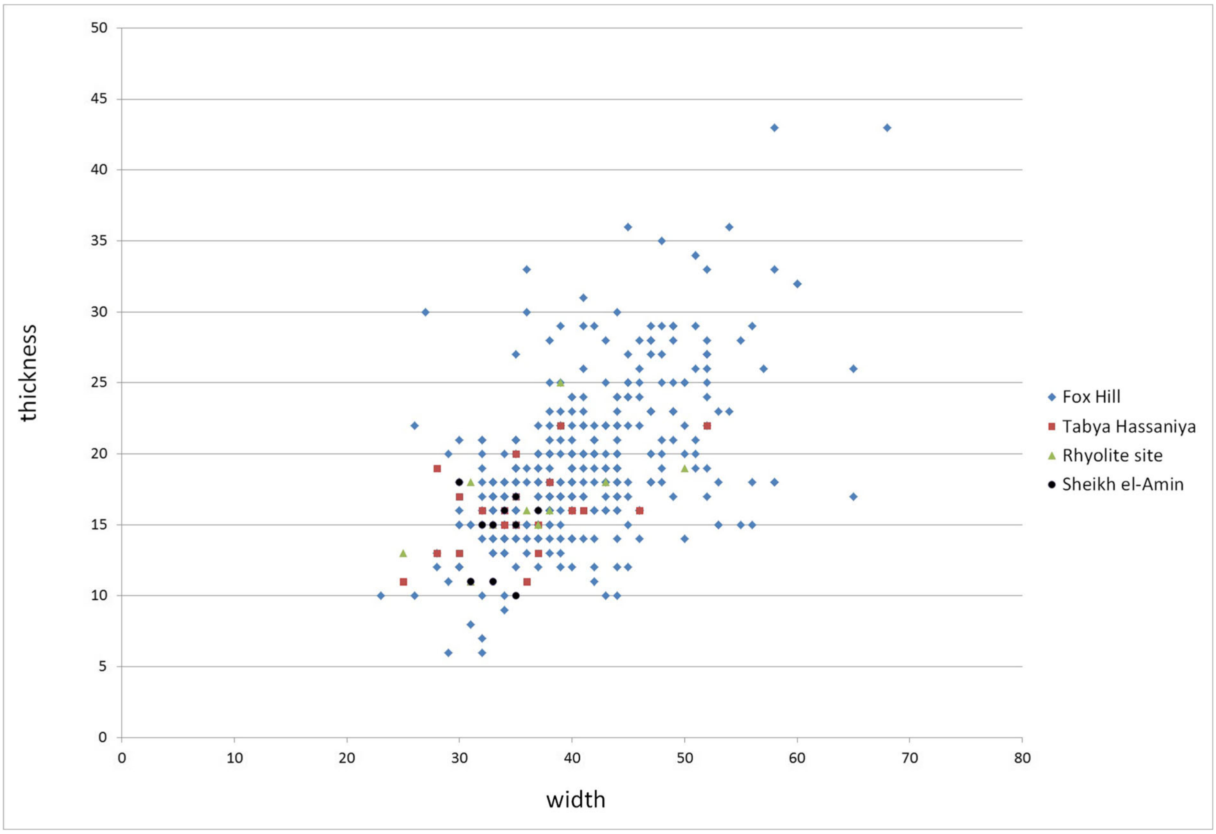


Fig. 5 Ratio of maximal thickness (mm) and maximal width (mm) on gouges from Fox Hill, Rhyolite Site, Sheikh el-Amin, and Tabya Hassaniya

type of fracture was already described on bifacially worked pieces by J. Pelegrin (1984). In our sample, this category is present at Fox Hill (12%) and Tabya Hassaniya (9%), in Sabaloka, and at Shaheinab (6%). In Sabaloka, 19% of the pieces that broke during use are polished, compared with 71% at Shaheinab. The patterns of breakage provide clues about the functions of the gouges. For example, the step ridge fracture is indicative of a high speed activity such as wood or soil working (for an earlier discussion of the function of gouges, see Caneva 1988; Haaland 1982; Magid 1989, 2003).

Breakage During Production

Sometimes, visible fractures can be associated with the production process. Breakage was usually caused by poor control of the force or direction during knapping or heterogeneity within the raw material (Fig. 9: 1). These fractures are quite difficult to identify and can sometimes be confused with intentionally broken pieces (see below). Production-related fractures can be detected by looking at the direction of the strike that caused the breakage. We were able to identify these patterns only at sites where other indications of production were present (e.g., big flakes from primary shaping of the blank, and small flakes from final shaping of the tool). The gouge fragments that broke during the production process are present at three sites in Sabaloka: Fox Hill (4%), Rhyolite Site (9%), and Tabya Hassaniya (9%). They are also present at Shaheinab (6%). None of the pieces from Sabaloka are polished, while most of those from Shaheinab are polished (75% of all pieces broken during the production process). Gouges, accidentally broken during production, provide insight into the site and methods/stages of production. For example, the percentage of pieces with polish in the Shaheinab collection is much higher than the other sites, indicating that those pieces at Shaheinab likely broke during reworking or the repair process.

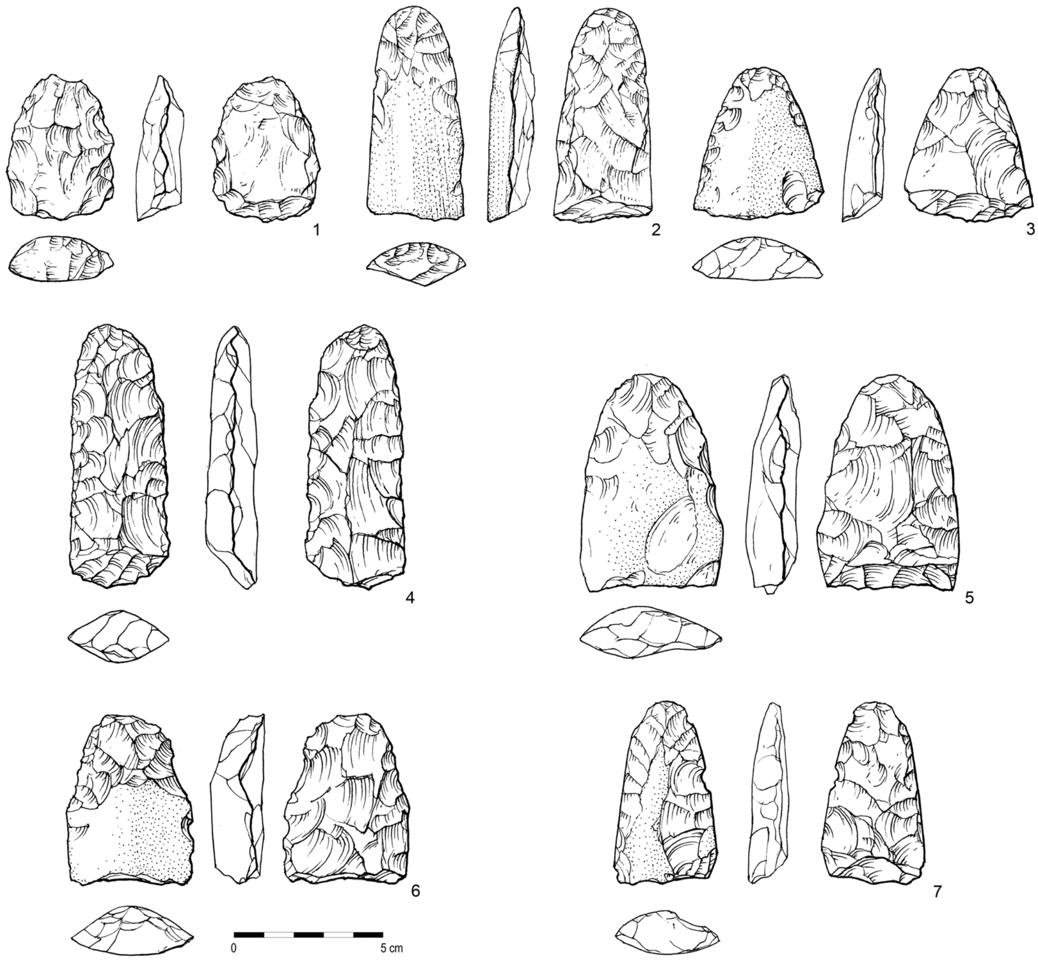
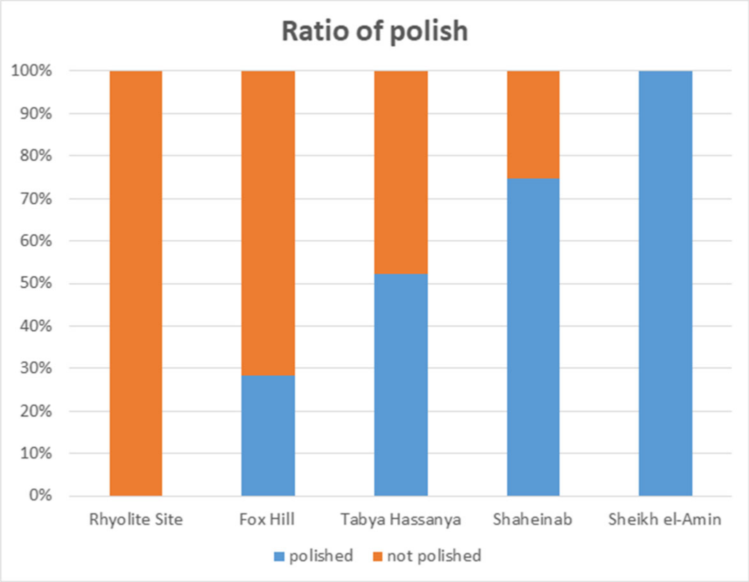


Fig. 6 Gouges: reworked fragments; polished 2, 3, 5–7 from Fox Hill. Drawn by M. Černý

Table 2 Position of polish on gouges in the Sabaloka region

Sabaloka	Not polished	Polished from convex side	Polished from flat side	Polished from both sides	Total
Whole pieces	12	0	0	0	*12*
Reworked broken pieces	14	68	1	2	*89*
Broken during use	33	7	0	1	*41*
Broken intentionally	13	6	0	0	*19*
Broken during production process	17	0	0	0	*17*
Indeterminate broken pieces	70	13	0	0	*83*
Knapped by novices	9	0	0	0	*9*
Retaken pieces	6	0	1	1	*8*
Unfinished	48	2	0	0	*50*
Broken due to natural causes	12	1	0	0	*13*
Half-finished pieces	4	0	0	0	*4*
Other	14	0	0	0	*14*
Total	*252*	*97*	*2*	*4*	*355*

Fig. 7 Ratio of polished and not polished pieces at mentioned sites



Intentional Breakage

Intentional fractures have been described in some of the gouges that show high-quality production (Aubry et al. 2008; Fig. 10). J. Pelegrin (1984, 2013) has described this type of fracture on leaf points. There is evidence of gouges that were intentionally struck in the middle in the attempt to break an almost finished piece. They are quite difficult to determine, and to ascertain this type of breakage, one must find a piece that shows signs of skilled production and a fracture that is unrelated to production or use. To ascertain intentional breakage, it is important to compare the suspected fracture with pieces which were broken voluntarily during experimental production. In our study, we were able to match these fractures (usually in the middle) with some of the intentionally broken pieces described by Pelegrin (2013) and also found in experimental samples. They are present at Fox Hill (5%) and Tabya Hassaniya (9%) in Sabaloka as well as at Shaheinab (6%).

The fragments of gouges with evidence of intentional breakage support the idea that master knappers had an ideal objective shape in mind during production and that the fulfilling of this objective required a combination of mental and manual skills. When a piece (in-production) deviated from these expectations, however, some master knappers could decide to break it (which would have involved a considerable amount of effort). The presence of these intentionally broken pieces at sites distant from the source of the raw material (e.g., at Shaheinab) shows that skilled knappers were working far away from the source of the raw materials.

Breakage Due to Natural Causes

This category includes pieces that were broken mostly by heat or due to heterogeneities in the raw material (Figs. 11 and 12) or by a combination of factors. Pieces broken by heat are easy to recognize, thanks to their typical surfaces,

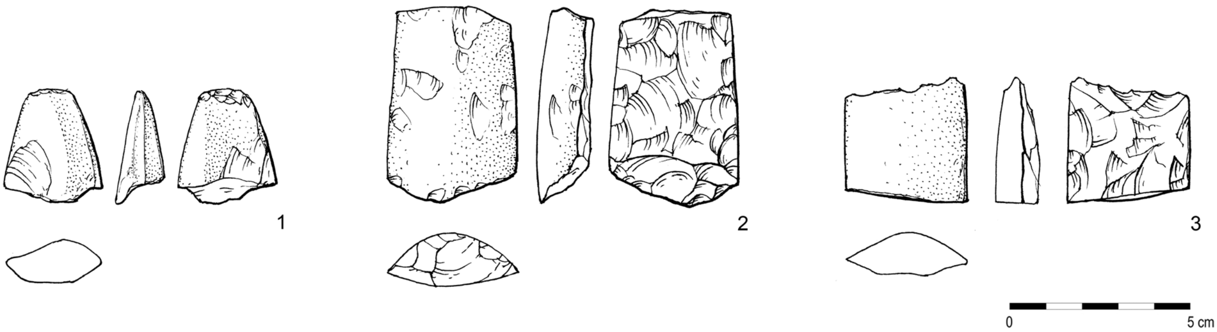


Fig. 8 Gouges: broken during use, Fox Hill. Drawn by M. Černý

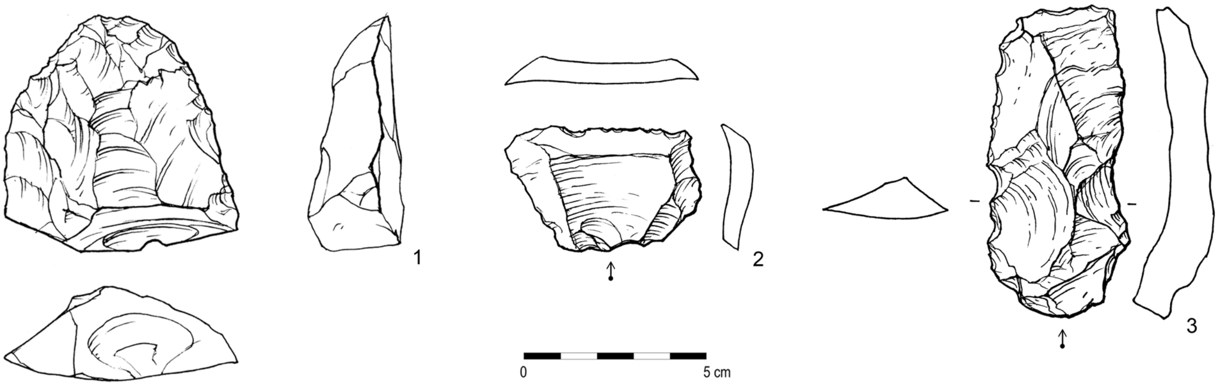


Fig. 9 Gouges: piece broken during production (1) and pieces which confirm production (2, 3), Fox Hill. Drawn by M. Černý

covered by small bowl-shaped pits modified by heat. These nature-induced fractures are usually the result of a quick change in temperature (see Fig. 12a). Heat-broken pieces could have also resulted from being thrown into the fire, but there is no way to know if they were thrown there willingly or by chance. For the pieces that broke due to mineral heterogeneities (Fig. 12b), the breakage could result from the fact that the knapper did not initially see problems within the raw material and so the piece was broken during production or during use. A skilled knapper who saw the problem early and determined that the raw material was good enough could work around the problem and produce a gouge of medium quality. The gouges in this category were identified only in the Sabaloka collection at Fox Hill (3%) and at the Rhyolite Site (9%). It seems that those with defects were sorted out in the source area, and only the good quality ones were transported to more distant regions, so this type of fracture did not often occur in areas located farther from the raw material source. As far as heat-related breakage is concerned, none was identified in the collections outside Sabaloka, although Arkell (1953) reported finding several complete and fragmented gouges in three hearths uncovered at Shaheinab.

Indeterminate Breakage

As there are many possibilities on how a piece could break, it is difficult to determine every fracture. Some characteristics of different types of fractures overlap. Hence, it is sometimes impossible to determine the exact cause of breakage. Because of this, we used this category in all collections where we were not able to determine the reason for breakage. Indeterminate breakage is represented in the samples from Fox Hill (23%), Rhyolite Site (9%), and Tabya Hassaniya (30%) in the Sabaloka area, as well as in the collections from Shaheinab (28%) and Sheikh el-Amin (30%). They form 48% of all the broken pieces in Sabaloka, 61% at Shaheinab, and 100% at Sheikh el-Amin.

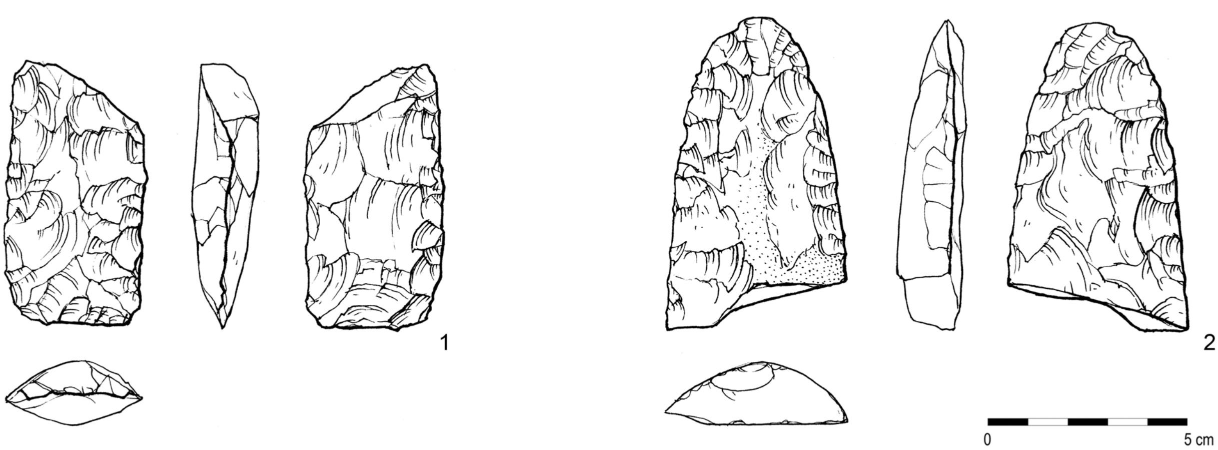


Fig. 10 Gouges: intentionally broken pieces, Fox Hill. Drawn by M. Černý

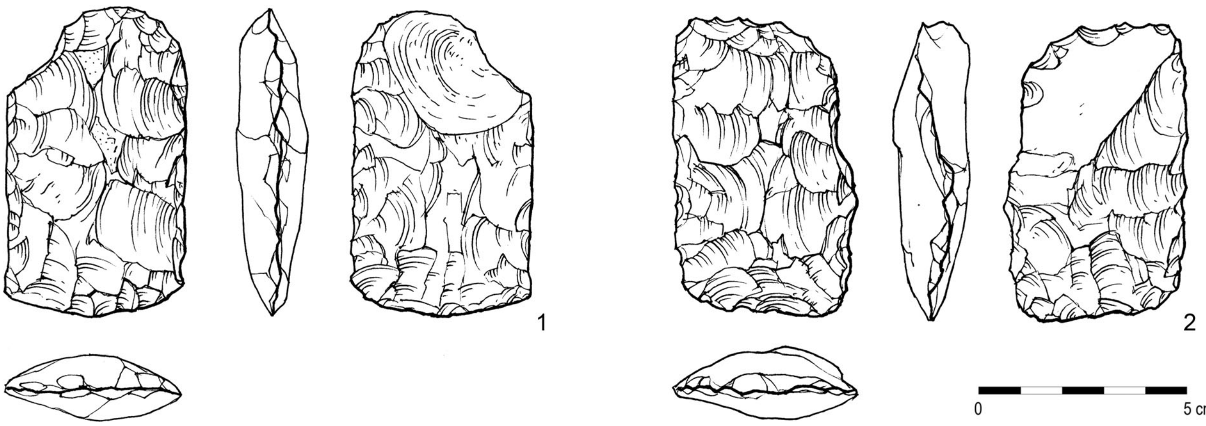


Fig. 11 Gouges: pieces broken by natural causes, Fox Hill. Drawn by M. Černý

When we compare Shaheinab and Sabaloka, in particular, it is apparent that when a collection is studied in greater detail some of the fractures which are difficult to determine could be assigned to one of the more precisely described categories. For example, the presence of polish is an indication that a gouge was used and most likely reworked. In Sabaloka, 16% of the indeterminate broken pieces were polished, whereas 72% of the indeterminates in the Shaheinab collection were polished. So it seems that at Shaheinab, a higher percentage of these pieces were used and reworked before they broke while in Sabaloka it seems that the gouges had a much shorter life and were discarded after the breakage in the early life of the artifact.

Retaken Fragments

This category includes fragments of gouges that were knapped by at least two different individuals. As the level of technical skills necessary for gouge production was quite high, it is sometimes possible to detect when pieces were repaired or worked on by two or more people with different levels of skills and experience. It is much easier to identify these pieces when the level of skill of two individuals was considerably different than when the pieces were worked on by two or more different artisans at similar levels of proficiency (Fig. 13). These pieces, dubbed "retaken fragments," were identified at Fox Hill (2.5%) and Shaheinab

Fig. 12 Gouges. **a** Burnt gouge. **b** Heterogenous material. **c** Piece broken during utilization. **d** Gouge made by reshaping of thin block

(2%). The presence of this type is likely underestimated because they are identifiable only in specific and subjective conditions. The gouges with this characteristic can indicate repairs in a "do it yourself" way or even a learning process. If it is the learning process, we include such gouges in the category of "pieces knapped by novices" (see below). The distinction between the learning process and different level of skill is not always easy. The difference is usually accounted for by the absence of major mistakes in retaken pieces. Such mistakes are however prominent in the pieces made by a novice. In an example of a retaken piece, there is a regular sequence of original negatives, with approximatively the same length and width (left and right edges). But the middle edges are covered by a series of negatives that are not regular, showing that the edge of the tool was not finished with the same level of regularity as in the original manufacture (Fig. 13: 1, 4). The piece must have been repaired by someone who had a different level of technical skill from the original knapper. Although this person achieved the purpose of the repair, he/she was not a very skilled knapper. Hence, differences in the level of technical skill by two or more knappers are the main markers for identifying retaken gouges.

Pieces Knapped by Novices

Two different groups of finds fall into this category: finds with technical traces attesting playfulness rather than learning (Fig. 14: 3 and 4) and finds with traces attesting a lack of skills to obtain proper results (Fig. 14: 1–3) (for more details see Pelegrin 1991, 2007). There are two indicators to help us observe that the knapper was unskilled: repetitive mistakes and irregularities. These indicators are easier to detect in large-sized collections, and they account for 2% of the assemblage at Fox Hill, 9% at Tabya Hassaniya, and 7% at Shaheinab. The presence of these characteristics shows that there was a learning process involved in gouge manufacture, and it also provides insights into the nature of on-site production. The best visible marker of inexperience is lack of planning during production, which is usually demonstrated by a sequence of severe strikes to the same place (Fig. 14: 3). These strikes often damaged the tool before the final product was realized. All of these markers of novice production indicate the inability of the knapper to achieve the objective of the different steps of production. One challenge that novices faced was keeping the convexity necessary for successful knapping as the piece in Fig. 14: 4 illustrates. As a result, this piece was damaged and could not be repaired to the intended shape and was, therefore, abandoned. The low number of this category at Fox Hill could be a result of a high proportion of specialized/experienced knappers. In contrast, the high percentage of this category at Shaheinab and Tabya Hassaniya is indicative that although production activities took place there, there was a higher percentage of novice or inexperienced knappers.

Unfinished Pieces

These are pieces with visible natural defects (heterogeneities of the raw material of different quality). For example, the illustrated piece in Fig. 12b has a black spot in the middle; this is a type of inclusion typical of volcanic rock, and it complicates the production process. As a result, the knapper(s) decided to discontinue the production (Fig. 15). These finds inform us that production took place at or very near where the artifacts were found. There are 51 pieces of this type present in the Sabaloka collection, specifically at Fox Hill (13%) and the Rhyolite Site (73%). In the Shaheinab collection, they form only one percent.

These pieces indicate several things. First of all, they are mostly abundant near the raw material source, especially at the Rhyolite Site—the location of the main raw material outcrops—where they represent 73% of the collection. This abundance indicates that the rates of discard of blanks and prepared pieces that did not match expectations were higher in the raw material source area than elsewhere. The rate of discard of unfinished gouges significantly declines as the distance from the raw material source increases. Hence, only 13% of this category constituted the Fox Hill assemblage (2 km from the raw material source), whereas at Shaheinab (30 km from the source), only 1% of the collection is unfinished. None of these unfinished discards was found at Sheikh el-Amin, the most distant of the sites from the raw material source. All of these support the idea that prepared blocks, rather than unfinished pieces, were transported to distant sites. This implies that the transport of raw material from Sabaloka (specifically the Rhyolite Site) was subject to quality control. We also noticed that the heterogeneities in the raw materials and unfinished pieces are much lower the greater the distance from

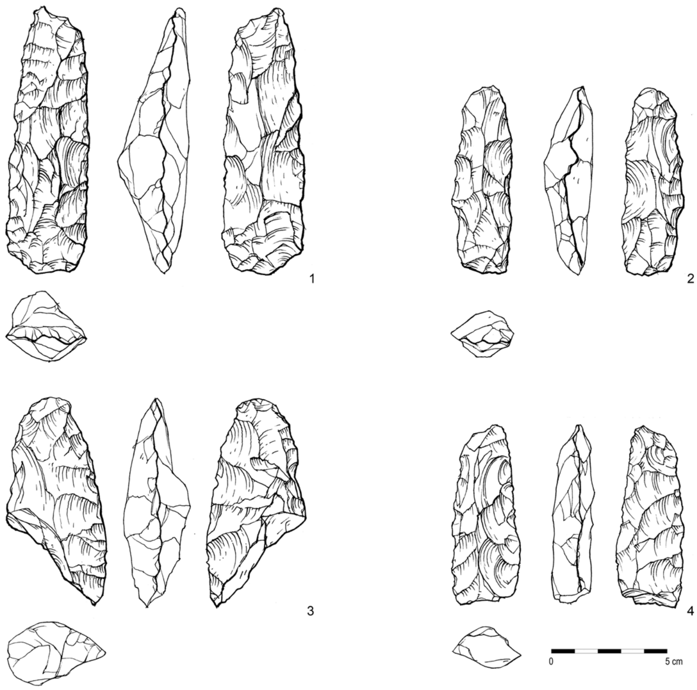


Fig. 13 Gouges: pieces retaken and knapped by at least two different persons, Fox Hill. Drawn by M. Černý

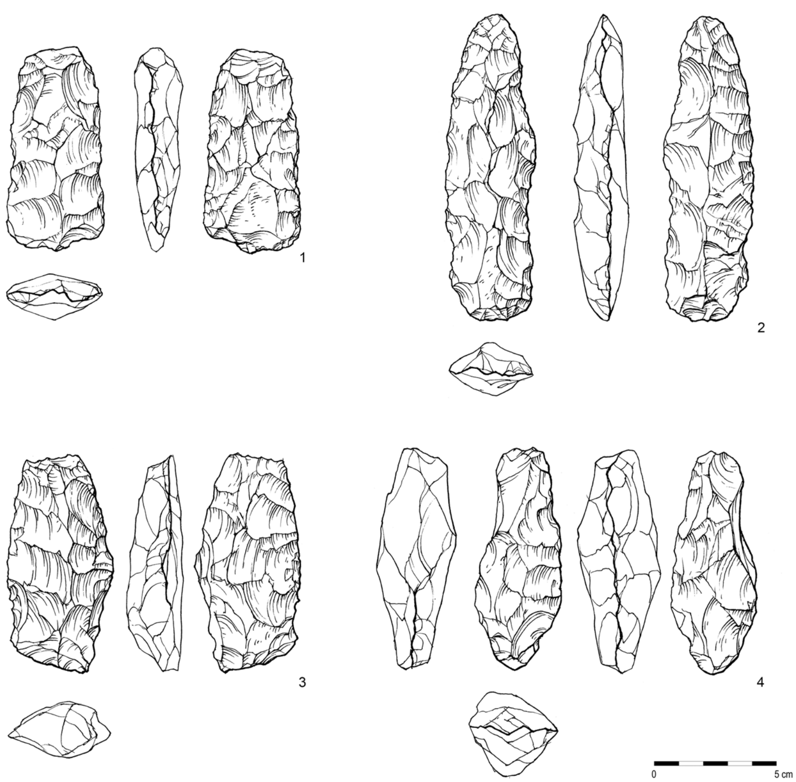


Fig. 14 Gouges: pieces knapped by novices or not very skilled knappers, Fox Hill. Drawn by M. Černý

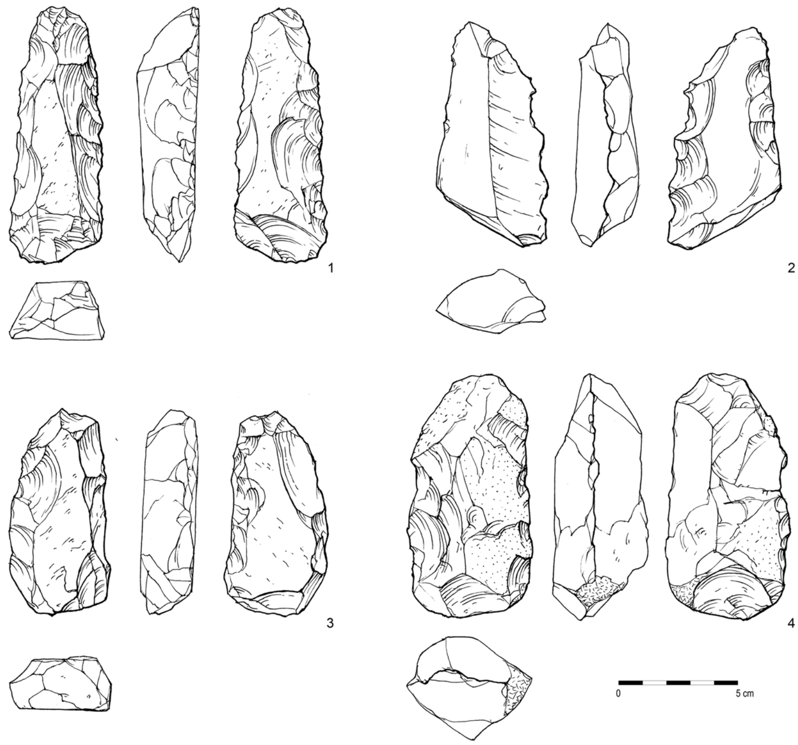


Fig. 15 Gouges: unfinished products, Fox Hill. Drawn by M. Černý

the raw material source. So it seems that the most suitable raw material was transported from the source of rhyolite to other production sites.

Half-Finished Gouges

This category covers pieces of raw material prepared to the shape of a blank for gouge production. However, such pieces are extremely rare in the collections. They are found only at Fox Hill, accounting for only 1% of the assemblage (Tables 3 and 4). It is possible to distinguish half-finished pieces meant for gouge production based on the absence of heavy patination, which is typical for the Middle Stone Age handaxes.

Gouges Reworked from Artifacts of Other Periods

This category includes gouges made from recycled pre-Neolithic rhyolite artifacts. Such artifacts are especially known at Shaheinab, where recycling was described in more detail by Arkell (1953), and at Fox Hill where older artifacts, especially Middle Stone Age handaxes, were recorded (Varadzinová et al. 2018, 2019). The identification is more evident in cases where the gouges are not yet finished, and some of the original characteristics of the older tool are present. It is also noticeable in cases where the surface of the previous artifact being reworked was heavily worn or patinated, and this pattern remains even after the processes of retaking and reshaping that produced the gouge. But when such patinas are absent, it is usually not possible to detect that the gouge was made from another tool. For this reason, these finds cannot be quantified with precision, and are therefore included in the "Other" category in Tables 3 and 4.

Places of Production

To evaluate the production process and technology of manufacture, we use the analytical categories of: finished whole pieces; unfinished; half-finished; intentionally broken; accidentally broken during the production process; reworked pieces; reworked artifacts from different periods; pieces knapped by novices; retaken pieces; and production waste. The analytical categories

Table 3 Gouge production stages present at Fox Hill, the Rhyolite Site, and Tabya Hassaniya

Site	Fox Hill			Rhyolite Site			Tabya Hassaniya			Total		
Polish	Not polished	Polished	Total	Not polished	Polished	Total	Not polished	Polished	Total	Not polished	Polished	Total
Whole finished pieces	12	0	*12*	0	0	0	0	0	0	12	0	*12*
Reworked broken pieces	14	63	*77*	0	0	0	0	8	8	14	71	*85*
Broken during use	32	7	*39*	0	0	0	1	1	2	33	8	*41*
Broken intentionally	11	6	*17*	0	0	0	2	0	2	13	6	*19*
Broken during production process	14	0	*14*	1	0	1	2	0	2	17	0	*17*
Indeterminate broken pieces	65	10	*75*	1	0	1	4	3	7	70	13	*83*
Knapped by novices	7	0	*7*	0	0	0	2	0	2	9	0	*9*
Retaken pieces	6	2	*8*	0	0	0	0	0	0	6	2	*8*
Unfinished	40	2	*42*	8	0	8	0	0	0	48	2	*50*
Broken due to natural causes	11	1	*12*	1	0	1	0	0	0	12	1	*13*
Half-finished products	4	0	*4*	0	0	0	0	0	0	4	0	*4*
Other	14	0	*14*	0	0	0	0	0	0	14	0	*14*
Total	*230*	*91*	*321*	*11*	*0*	*11*	*11*	*12*	*23*	*252*	*103*	*355*

Table 4 Gouge production stages present in the Shaheinab and Blue Nile collections, compared to the total number in the Sabaloka region

Site	Sabaloka			Shaheinab			Sheikh el-Amin			Total		
Polish	Not polished	Polished	Total	Not polished	Polished	Total	Not polished	Polished	Total	Not polished	Polished	Total
Whole finished pieces	12	0	*12*	17	3	*20*	0	0	0	29	3	*32*
Reworked broken pieces	14	71	*85*	12	234	*246*	0	7	7	26	312	*338*
Broken during use	33	8	*41*	11	27	*38*	0	0	0	44	35	*79*
Broken intentionally	13	6	*19*	15	26	*41*	0	0	0	28	32	*60*
Broken during production process	17	0	*17*	9	27	*36*	0	0	0	26	27	*53*
Indeterminate broken pieces	70	13	*83*	49	128	*177*	0	3	3	119	144	*263*
Knapped by novices	9	0	*9*	36	7	*43*	0	0	0	45	7	*52*
Retaken pieces	6	2	*8*	0	11	*11*	0	0	0	6	13	*19*
Unfinished pieces	48	2	*50*	6	1	*7*	0	0	0	54	3	*57*
Broken due to natural causes	12	1	*13*	0	0	*0*	0	0	0	12	1	*13*
Half-finished products	4	0	*4*	0	0	*0*	0	0	0	4	0	*4*
Other	14	0	*14*	7	16	*23*	0	0	0	21	16	*37*
Total	252	103	355	*162*	*480*	*642*	*0*	*10*	*10*	414	593	1,007

attesting to production were recorded at Fox Hill, Rhyolite Site, Tabya Hassaniya in Sabaloka, and at Shaheinab and Sheikh el-Amin (see Tables 3 and 4). These finds indicate different phases of production, starting from shaping a preform into the form of a gouge. Blocks of raw material were found only at Sabaloka sites. Slightly shaped preforms, rather than raw materials, may have been transported to locations outside the source area.

Production waste was identified at Fox Hill and the Rhyolite Site. Where present, early stage production (the shaping of blocks of raw material) is obvious due to the flakes with the presence of cortex. These are almost missing at Shaheinab, but it should be noted that only a small amount of production waste from this particular site is present in the Sudan National Museum and our observations are based on these materials. Of the three gouge-bearing sites surveyed in Sabaloka, production waste was found at Fox Hill and the Rhyolite Site (Table 5). These were studied in detail at Fox Hill. In the western part of the site, we identified a workshop for the production of gouges based on the presence of waste from the early-stage shaping and much higher percentages of red rhyolite within lithic concentrations. This debitage contrasts sharply with the insubstantial representation of lithic waste in the settlement terraces of the extensive site.

In the collection from Shaheinab, even the small sample of production waste helped us to understand what may have been happening at the site. There are several examples of larger flakes that can be associated with gouge shaping. Their shapes and sizes confirm that some preforms for gouge production, rather than raw materials, were transported to the site. No evidence of primary production waste is evident in the collection from the Blue Nile (Fernández et al. 2003). The foregoing shows that gouge production took place in Sabaloka from the very initial phases and at Shaheinab from phases of prepared blocks of raw material or preforms. There is no evidence of gouge production at Sheikh el-Amin; only reworking processes took place as suggested by the flakes with traces of polish (Table 6).

Technology of Production

Production sequences and technological aspects of gouge production have not been described

Table 5 Basic information on total counts

Site	Total number of total counts	Average number of pieces per m^2	Raw materials (number)												Lithic categories (%)				
			Red rhyolite			Other rhyolite			Quartz			Other			Waste	Waste from production process	Blanks	Finished products	Raw material
			< 2 cm^2	2–5 cm^2	> 5 cm^2	< 2 cm^2	2–5 cm^2	> 5 cm^2	< 2 cm^2	2–5 cm^2	> 5 cm^2	< 2 cm^2	2–5 cm^2	> 5 cm^2					
Fox Hill	46	654	524	442	198	118	125	1	1,885	1,104	92	13	8	1	83	11	< 0.1%	2	4
Rhyolite Site	3	3,631	800	180	139	23	4	2	223	78	15	0	24	1	82	10	< 0.1%	< 0.1%	8

Table 6 Percentage of polish on gouges from Fox Hill (SBK.W-20)

Fox Hill	Polished from convex side				Polished from flat side	Polished from both sides	Total
	< 10%	10–25%	25–50%	> 50%			
Reworked broken pieces	9	11	14	26	1	2	*63*
Broken during use	0	0	3	3	0	1	*7*
Broken intentionally	3	1	0	2	0	0	*6*
Indeterminate broken pieces	4	2	3	1	0	0	*10*
Retaken pieces	0	0	0	0	1	1	*2*
Unfinished	2	0	0	0	0	0	*2*
Broken due to the natural causes	0	1	0	0	0	0	*1*
	18	*15*	*20*	*32*	*2*	*4*	*91*

systematically in published works. According to our experimental observations, the preferred raw materials for gouge production—red rhyolite—is an extremely hard rock, compared to most of the other knappable rocks (except for quartz). Another important characteristic of this volcanic rock is its large number of heterogeneities, inclusions, and areas of varied qualities, which often constrained or complicate their use for production.

Gouges were mostly produced from big flakes of rhyolite which were knapped by direct hard hammerstone percussion from a block of raw material (Inizan et al. 1999; Tixier 1962). Sometimes, they were produced from plaquettes of raw material (Fig. 16). It is also possible that even smaller blocks of suitable dimensions were used as a starting point for the production. However, we were not able to show this on finished pieces. Pieces of raw material which were suitable blanks are present at several sites in

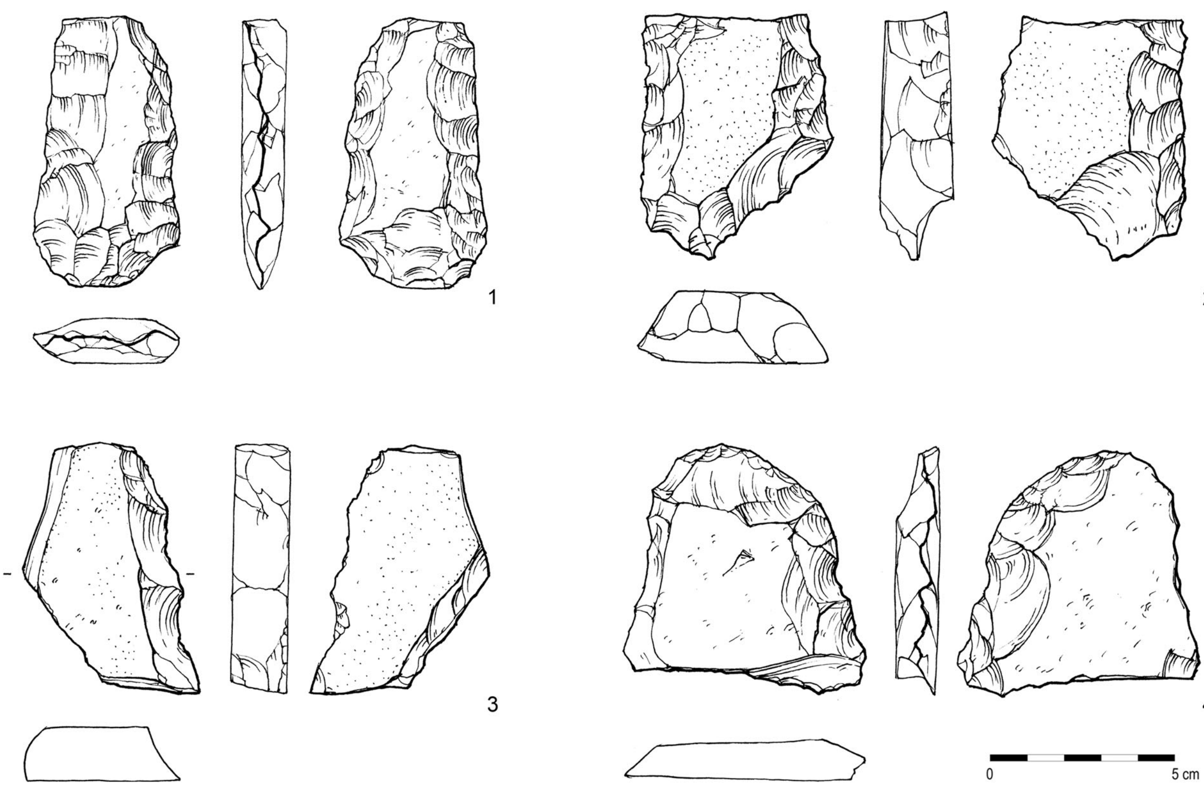


Fig. 16 Gouges: examples of production from tabular form of raw material, Fox Hill. Drawn by M. Černý

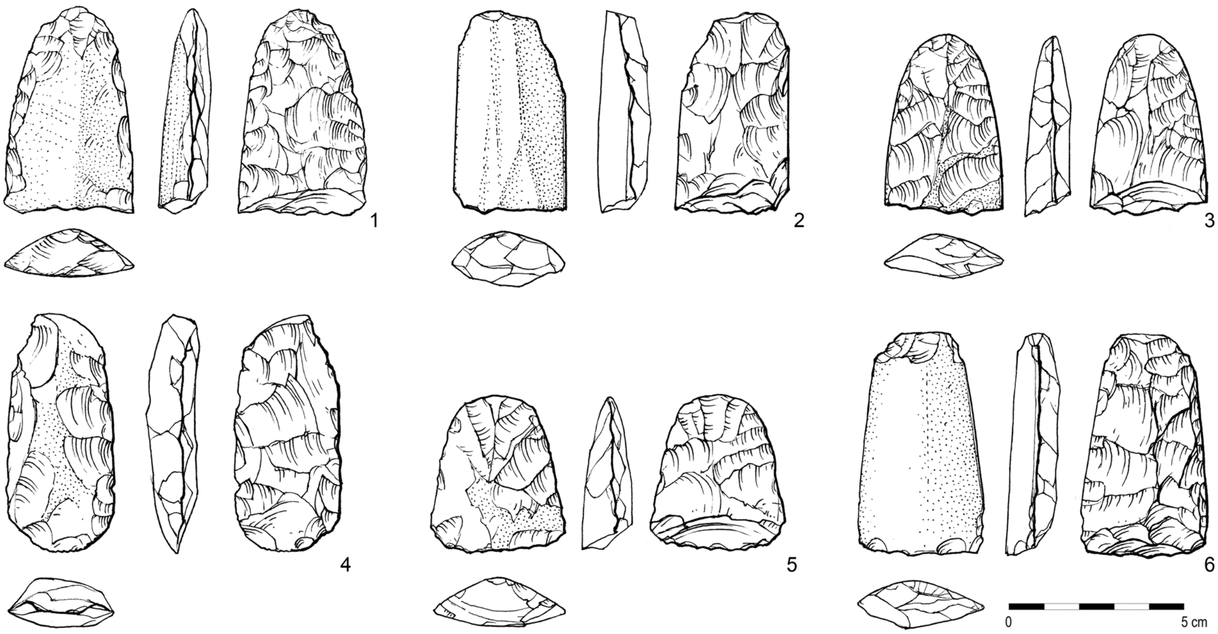


Fig. 17 Gouges: broken reworked polished basal parts, Fox Hill. Drawn by M. Černý

Sabaloka, but it is not always possible to prove their direct relation to gouge production. This is especially true of sites where production from red rhyolite from other periods is present. For example, gouge production was taking place at Fox Hill, but there is also the evidence for the earlier production of Middle Stone Age handaxes at the site.

Further shaping of the prepared blanks may have had different operational chains. It is possible to shape a gouge to its final form with soft hammerstone percussion. We proved this experimentally with the example in Fig. 4: 4. This piece is very similar in its production traces and shape to Fig. 4: 1, so it is possible that some of the pieces were accomplished using only soft hammerstone. However, this was not the only possibility, as evident in the production waste. There were many knapping techniques used for gouge production. Pieces were often shaped using direct organic percussion, as evident in the production waste shown in Fig. 9: 2–3. This waste was detected not only at the Sabaloka sites but also at Shaheinab. For sure, most of the pieces were made using soft hammerstone or direct organic percussion. Another technique which was used for gouge production is the pressure technique. Although it was not an integral part of the production process, its occasional presence is evident by great regularity and parallel orientation of the negatives (e.g., Figs. 9: 7 and 12: 2). Overall, high-quality production was important to the Early Neolithic societies of central Sudan, but levels of perfection could differ. There is evidence of specialized knappers and quality control as well as learning on-site, represented by retaken pieces or pieces knapped by novices. These processes are well documented at Fox Hill and are also evident at Shaheinab.

Reworking

The main evidence for re-sharpening of worn pieces and reworking of broken gouges includes: reworked parts; gouges that broke during use and production; retaken pieces; and flakes from reworking and repair. Reworking of gouges is attested in all the three regions. In Sabaloka, it is present at all sites except the Rhyolite Site: Fox Hill (n = 79 and numerous flakes from different stages of reworking process), Donkey Site (n = 2), Grove Site (n = 1), Lake Basin (n = 1), and Tabya Hassaniya (n = 8). At Shaheinab, reworking is visible on 246 pieces and some of the production waste. At Sheikh el-Amin, all the gouges have reworked base, and two flakes also represent the reworking process. Reworked gouges outnumber those that were broken during utilization but were not repaired—39 gouges at Fox Hill and two pieces at Tabya Hassaniya (Sabaloka) and 38 pieces at Shaheinab. The basal part tended to be repaired more often than the apical part. The latter was reworked only when it was long enough, and these cases were quite rare, but the basal parts were often reworked until the very end of the tool's use life (e.g., Figs. 9: 1, 3 and 17: 3).

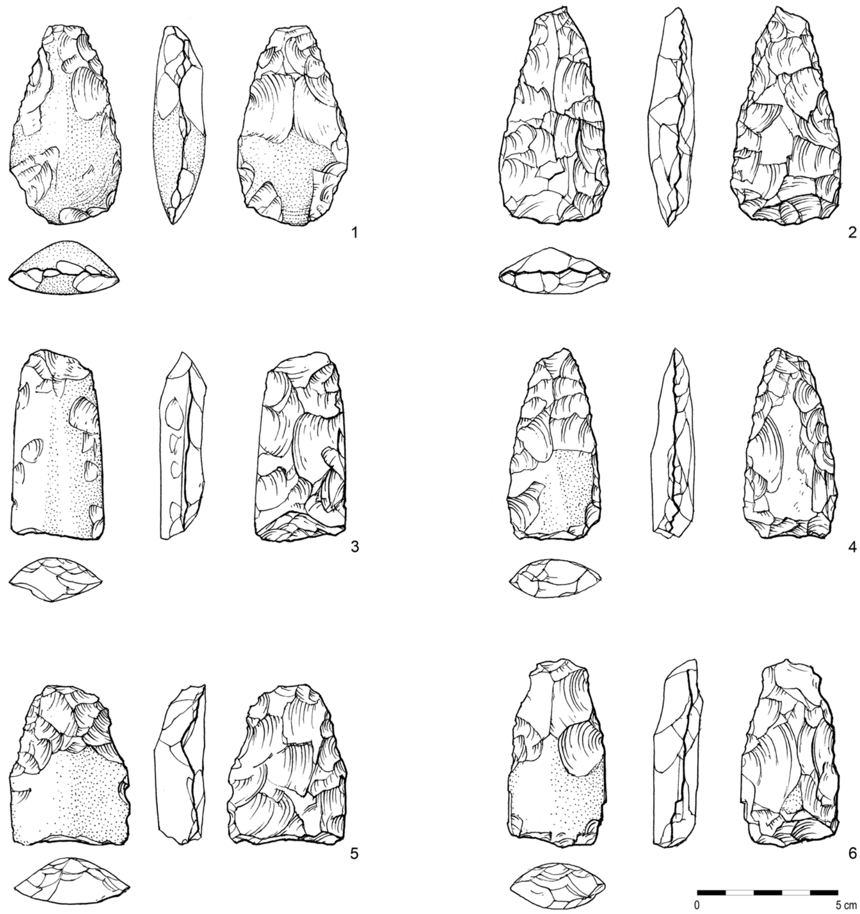


Fig. 18 Gouges: broken reworked non-polished basal parts, Fox Hill. Drawn by M. Černý

Repairs often involved polishing. In Sabaloka, polishing is mostly present on reworked pieces (see Table 4), and it seems that broken gouges were often polished to facilitate smoother reworking of a piece. Polish tends to be partial. It was not necessary for repairs, but it made repairs more efficient. Therefore, it was often used. According to the patterns of defects visible on the polished pieces, they were polished on a coarse rock with the polisher holding them by hand. We infer this from the fact that the direction of polishing traces differs and sometimes they are even convergent.

In the Shaheinab collection, the situation is different, as there are whole finished pieces as well as pieces broken during production which were intentionally polished. It is not possible to determine for this site to what extent polishing constituted an integral part of production or whether it was only part of reworking activities. Although reworking played some role in Sabaloka (Fig. 18), it seems that this was more critical and necessary at distant sites where raw materials were scarce as shown in the extensive collection from Shaheinab and even more so in the Sheikh el-Amin collection where all the pieces were reworked. These polished pieces were utilized until the limit of their usefulness (Fig. 19).

Discard

Discarded gouges are the most challenging to evaluate. The farther we are from the source of raw material, the more gouges were reworked. Only a few cases can be interpreted convincingly as discards (Schiffer 1987). The first of these are pieces that are too short or too thin to facilitate the preparation of the working edge and the base that cannot be attached. In either case, the artifacts were discarded when they had become unworkable. These discards could be edges, middle parts, basal parts, or pieces that broke longitudinally. The number of

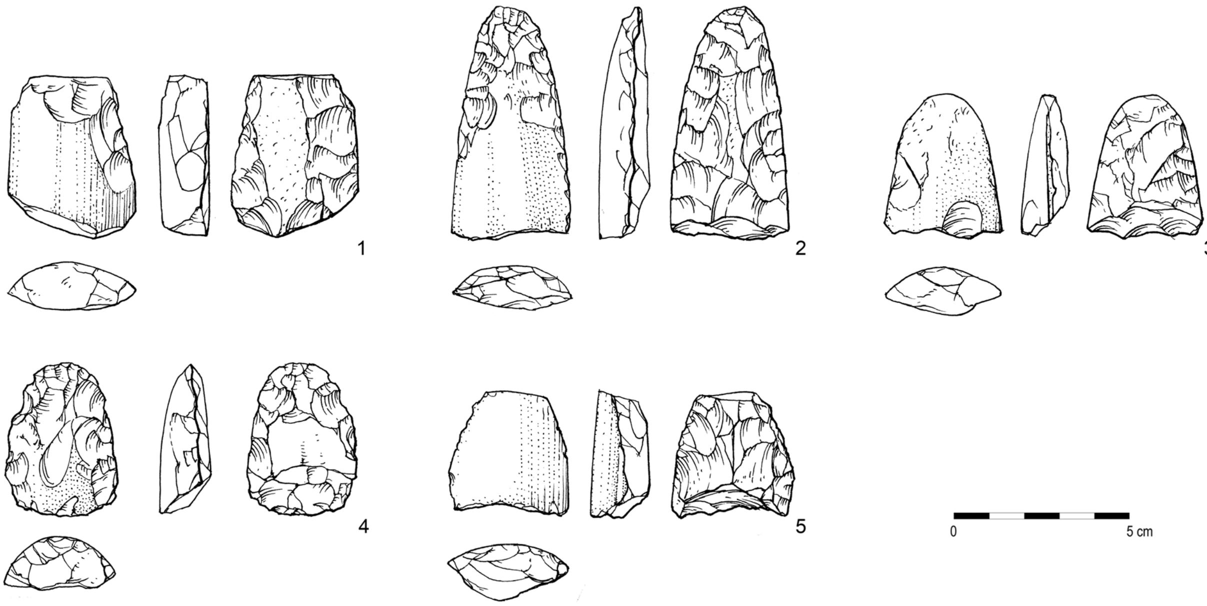


Fig. 19 Gouges: reworked basal parts of the gouges, finds from the sites on the Blue Nile. Drawn by M. Černý

discarded pieces is low in all the assemblages. These include 38 pieces in Sabaloka and one piece at Sheikh el-Amin (basal part). For Shaheinab, the evidence is not detailed enough to ascertain which parts were discarded.

Some pieces that were no longer of use were, however, retained and subjected to recycling. In the Shaheinab collection, we noticed the reuse of discarded gouges as cores for the production of blanks for crescents, while Arkell (1953) mentioned their reuse for production of scrapers. This type of reuse of discarded gouges was found in other collections as well and must have been a common practice, especially outside the raw material zone (Caneva 1988). The possible discard of finished or reworked functional pieces can be deduced from the finds of complete and broken gouges in hearths, reported by Arkell (1953) from Shaheinab. Some of the pieces identified macroscopically in the Sabaloka collection seem to have been modified by heat, due to their characteristic shiny gloss.

Morphometric Characteristics

The metrical analysis of the gouges was done systematically with the collections from Sabaloka and Sheikh el-Amin and only selectively for the Shaheinab collection. In all assemblages, we noticed a strong emphasis on regularity and symmetry. There is a visible tendency for an ideal shape (e.g., Fig. 4: 1, 4). First of all, the form of these artifacts has longitudinal edges slightly curved to withstand the impact during use. This is also the reason most of the artifacts have the widest point, not at the cutting edge or in the middle but usually near the

Table 7 Summary of the basic characteristics of the mentioned sites

Site	Total number of gouges	Red rhyolite (%)	Red rhyolite (number)	Grey rhyolite (%)	Grey rhyolite (number)	Evidence of production	Distance from the RM source (km)
Sheikh el-Amin	10	90	9	10	1	None	80
Shaheinab	642	95	610	5	32	Clear	30
Fox Hill	321	88	282	12	39	Clear	1.5
Rhyolite Site	11	100	11	0	0	Clear	0
Tabya Hassaniya	23	83	19	17	4	?	6

cutting edge. If the longitudinal edges are straight, it is more probable that the artifact will break during use, so this seems to be the reason the preferred shape was an oval narrowing towards the basal part. Sometimes, the maximal width and the width of the cutting edge might be equal.

The basal part seems to be standardized as well. Tixier (1962) published his view on the basal part of adzes as a marker of typology. According to our observation, the basal part had the ideal oval shape, which was the objective of production, and other shapes are the result of error or accident. When the shape is trapezoidal, it is the result of the partial shaping of the basal part (evident at Fox Hill, Rhyolite Site, and Shaheinab), and this tends to be the original shape of blanks prepared for gouge production. Pointed basal parts are rare and tend to result from the accidental breaking of a piece. It was not usually possible to correct this error and rework the base into a regular oval shape. The standardization of the basal part of gouges is evident in Fig. 5, showing that the ratio of width to thickness of the basal part is similar in most of the pieces and clustering only in one group. The shape of the cutting edge was also important to the knappers. The objective was to get a slightly curved cutting edge to make the piece more effective. Most of the gouges have this curved cutting edge. However, there are a few gouges with a straight edge.

It seems there was a preference for proportions and size, according to the cluster analysis of the morphometrics of gouges from Sabaloka sites (Fig. 5). All values cluster in one group, showing similar characteristics. Most of the gouges (whole finished pieces) from all the sites and regions have a maximum length of 100–120 mm, and their proportions were also very similar. However, at some sites, we recorded pieces (less than 10% of the collection) which are considerably larger or smaller than the usual size. The smaller pieces may be artifacts for some other kinds of activity for which higher precision is needed. On the other hand, the very big pieces, which never show any traces of use, were probably some emblematic pieces not meant for practical use, but heirlooms aimed to demonstrate the skill and prestige of the knapper.

Selection and Use of Raw Materials

All the gouges from the three regions were made from rhyolite of the same varieties. In all, red and grey rhyolite were represented, with the red variant being predominant, 90% in Sabaloka (360 pieces), 95% at Shaheinab (642), and 90% at Sheikh el-Amin (10 pieces) (Table 7). This suggests a strong preference for red color. Unfortunately, we were not authorized to do destructive thin sections on the archaeological materials and so the petrological study of the gouges was done macroscopically.

During the geological survey in the western part of Jebel Sabaloka, two types of rhyolite were identified:

A) very fine-grained reddish rhyolite turning, in some parts, into fine-grained rhyolite with phenocrysts and banded reddish rhyolite (Fig. 20); and
B) fine-grained red microgranite with phenocrysts (Fig. 21)

The field observations show that the high variability of rhyolitic rock is the product of metamorphosis which occurred in a quite limited area. Therefore, the color or mineralogical differences of these varieties is not useful for determining provenance. Six varieties of rhyolite were observed during our microscopic study of the samples collected in the source area, especially at the Rhyolite Site. A detailed description of these varieties is provided below to guide the future study of gouge production, technology, and regional distribution.

(1) Aphanitic rhyolite (Fig. 20: 1A, B): a very fine-grained, reddish rock, locally with fluidal texture. Groundmass consists of a devitrified felsitic mass (grain size < 0.1 mm) composed of anhedral quartz and subhedral feldspars, together with minor opaque minerals. Both plagioclase and K-feldspar are strongly affected by hydrothermal alteration (clay minerals). Feldspar phenocrysts, up to 0.5 mm, are present. Quartz veins and fine-grained elongated aggregates composed of quartz are also present (up to 0.5 mm in thickness). Its magnetic susceptibility is high (1.03–1.19). This type of rhyolite is the most preferred for gouge production. It has excellent knapping characteristics and pleasing aesthetic qualities. It is present in different variants, as shown in Fig. 20.
(2) Banded rhyolite of a very fine-grained, reddish rock variety (Fig. 20: 2A, B). On the weathered surface, alternation of red and yellow flow bands is visible (0.3–1.0 mm thick). Quartz and plagioclase phenocrysts (up to 0.4 mm) are sometimes present

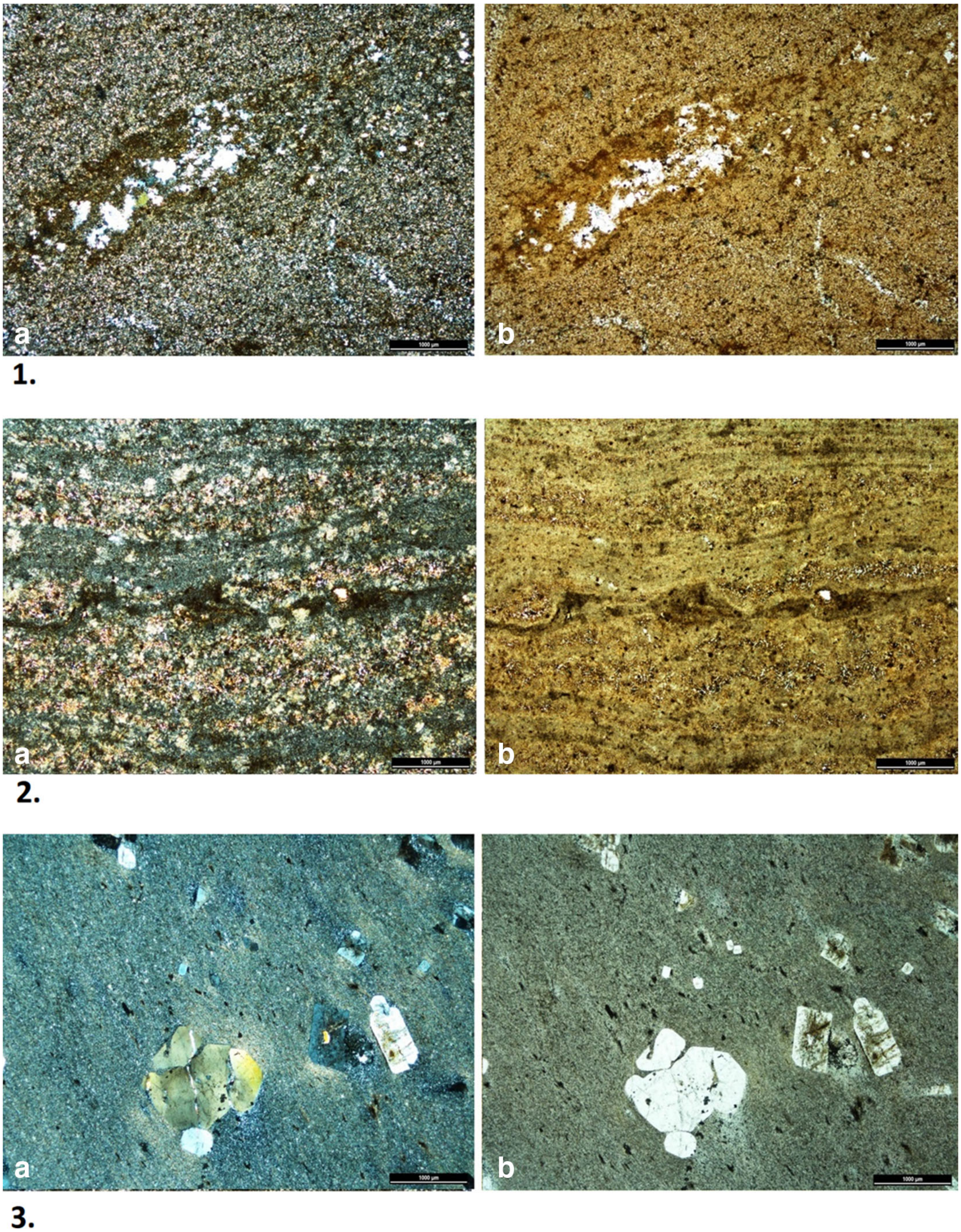


Fig. 20 Textural features of the rhyolites: (1) Aphanitic rhyolite samples 6 and 8, with elongated aggregates of quartz, a: XPL (cross-polarized light), b: PPL (plane polarized light). (2) Banded rhyolite sample 14, a: XPL, b: PPL. (3) Porphyritic rhyolite (sample 10) with K-feldspar, plagioclase and quartz phenocrysts a: XPL; b: PPL (photo by D. Buriánek)

but rare. Plagioclase phenocrysts exhibit relict compositional zoning. Groundmass consists of a devitrified felsitic mass (grain size < 0.1 mm) composed of anhedral quartz and subhedral feldspars. Some layers contain spherulites (intimately intergrown quartz and feldspar) up to 1 mm in diameter. Magnetic susceptibility is low (0.21–0.27).

The following two varieties of rhyolite are less suitable for knapping and were rarely used for gouge production. And, when their geological characteristics are very pronounced, they were not used for gouge production. Otherwise, their use involved a much higher risk and was unlikely to deliver the desired final product.

(3) Porphyritic rhyolite, an aphanitic, dark-grey rock with twinned K-feldspar, plagioclase, and quartz phenocrysts, varies between 0.6 and 1.0 mm (Fig. 20: 3A, B). Its very fine-grained groundmass (grain size < 0.1 mm) with fluidal texture consists of anhedral quartz and feldspars together with minor biotite. Locally present are embayed quartz phenocrysts. Opaque minerals and apatite are present as accessory minerals. Rock is affected by secondary alteration. Kaolinization and sericitization of plagioclase are stronger than in K-feldspar. Magnetic susceptibility is low (0.21–0.28).

(4) Rhyolite porphyry—microgranite pinkish brown rock with pink euhedral to subhedral K-feldspar (locally perthitic) and quartz phenocrysts up to 4 mm in size (Fig. 21: 2A, B). Typical characteristics are embayed quartz phenocrysts and glomeroporphyritic aggregates, opaque minerals, and quartz up to 1 mm in diameter (probably pseudomorphs of a euhedral mafic mineral). Fine-grained groundmass consists of anhedral quartz, K-feldspar, plagioclase, and minor opaque minerals. Between phenocrysts, several spots with granophyric texture are present. Secondary alteration is visible mainly in the groundmass (clay minerals, white mica). K-feldspar phenocrysts are weakly altered to clay minerals and white mica. Magnetic susceptibility is high (0.72–1.32).

(5) Rhyolite porphyry—microgranite consisting of reddish groundmass and pale pink elongated K-feldspar phenocrysts, up to 14 mm long (Fig. 21: 2A, B). Embayed quartz phenocrysts and granophyric rim along K-feldspar phenocrysts are typically present. Its granophyric texture shows intimate intergrowth of quartz and alkali feldspar. Plagioclase occurs rarely as euhedral inclusions (up to 1 mm long) in dominant K-feldspar phenocrysts. Chlorite progressively replaced the mafic phases (amphibole). Fine-grained, strongly altered groundmass contains quartz, plagioclase, K-feldspar, chlorite, and opaque minerals. Magnetic susceptibility is low (0.36–0.55).

(6) K-feldspar phenocrysts (yellowish), 5–12 mm, accompanied by smaller phenocrysts of plagioclase, quartz, and amphibole (Fig. 21: 3A, B). Euhedral to subhedral, perthitic K-feldspar is often rimmed by the intimate intergrowth of quartz and alkali feldspar (granophyric texture). Plagioclase and some parts of K-feldspar phenocrysts are affected by kaolinization. Amphibole is accompanied by opaque minerals and is strongly affected by secondary alteration (chloritization). Fresh amphibole is almost exclusively present as inclusion in K-feldspar phenocrysts. Chlorite is locally accompanied by clinozoisites. Strongly altered, fine-grained, granophyric groundmass consists of quartz, feldspars, and opaque minerals. Magnetic susceptibility is low (0.24–0.29).

To sum up, the geology of the study area shows several outcrops of rhyolite varieties in the Sabaloka region, but so far, only two of them have been found to overlap with evidence of occupation, at Fox Hill, which features a minor vein in its westernmost part and at the Rhyolite Site which is situated on a massive vein several hundred metres in width. There is evidence of the production of gouges on both sites. Three forms of rhyolite are present at Sabaloka as raw material suitable for lithic production: blocks, tabular forms, and cobbles. Of these, blocks were the most preferred for gouge production. There is also evidence of the use of tabular rhyolite, the pieces of which are sometimes modified only on their edges to obtain gouge-like shapes (see Figs. 12d and 16). There is no evidence that gouges were produced from rhyolite cobbles whose shape is more convenient for other lithic types.

Regional Distribution

It is clear from the collections studied that red rhyolite was nearly exclusively preferred for production of

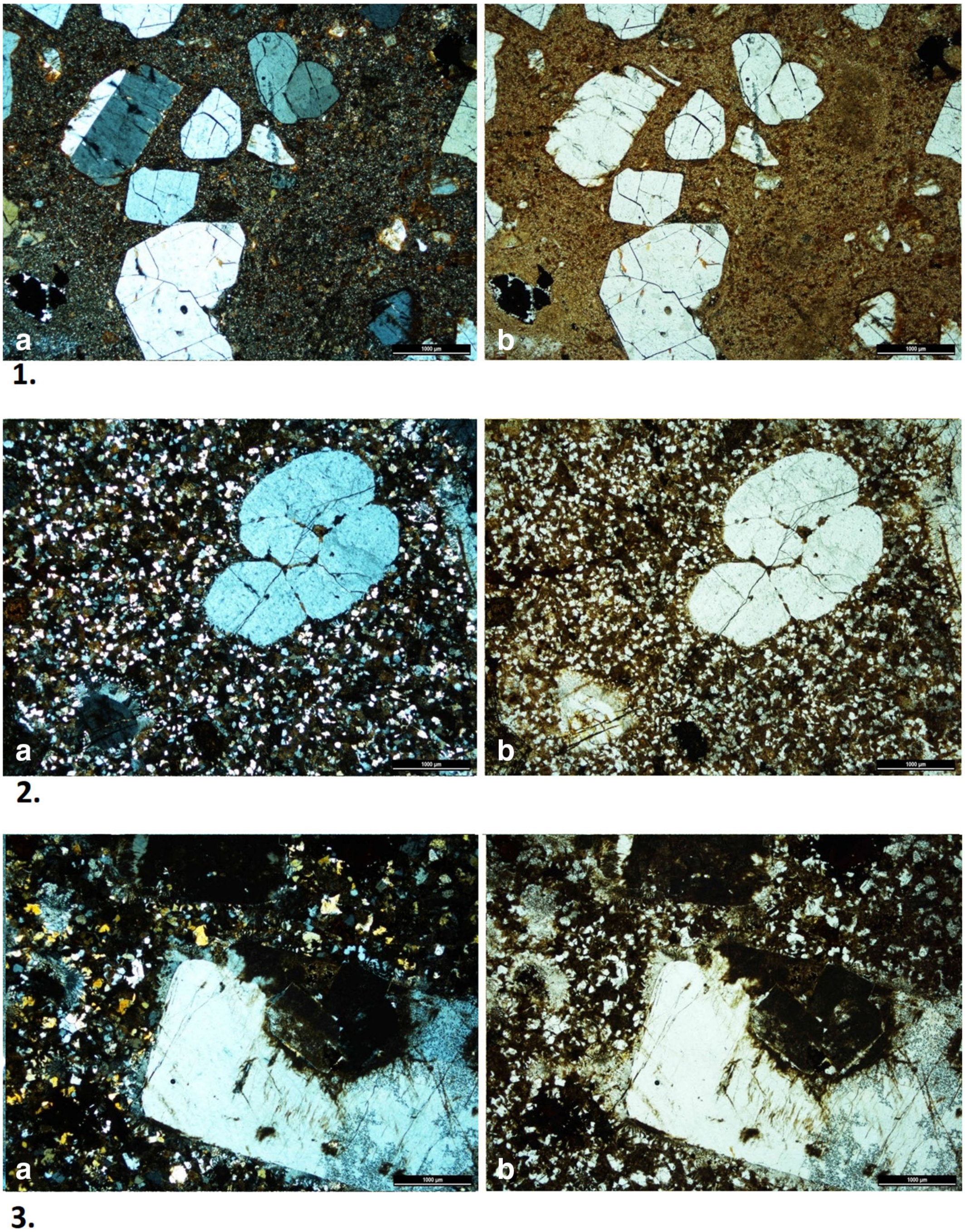


Fig. 21 Microgranite (rhyolite porphyry): (1) Microgranite sample 6 with K-feldspar and quartz phenocrysts, a: PPL, b: XPL. (2) Microgranite sample 3 with embayed quartz phenocryst a: PPL, b: XPL. (3) Microgranite sample 8 wit typical granophyric texture, a: XPL, b: PPL (photo by D. Buriánek)

gouges, a pattern that is confirmed for other Neolithic sites in the Khartoum province (e.g., Arkell 1953 for el-Qoz; Caneva 1988 for Geili; and Kobusiewicz 2011 for Kadero). However, in central Sudan, the sources of red rhyolite are confined only to the Sabaloka Inlier (Vail 1982), which means they would have had to be transported to all the other locations outside Sabaloka, including Shaheinab and Sheikh el-Amin (30 km and 80 km from Sabaloka, respectively). This very fact opens the question of distribution and exchange of gouges or rhyolite in the Early Neolithic of central Sudan.

The analytical categories defined in our research are well-suited for inter- and intra-regional comparison. The categories can be seen as markers of diverse activities falling mostly into two main stages of the life cycle of gouges. First, the half-finished, unfinished, and retaken pieces, as well as the pieces knapped by novices, intentionally broken, and broken accidently during production, are all connected with production. The production wastes at the gouge-bearing sites in Sabaloka and in the Shaheinab collection are also indicative of on-site production of gouges. Second, the pieces broken during use, reworked fragments of gouges, and flakes from resharpening or reworking of broken tools are indicative of consumption. The remaining categories—complete gouges, pieces broken due to natural causes, and gouges reworked from other lithic artifacts—could fit in either of these two groups. The presence/absence and frequency (ratio) of these categories show the kinds of activities taking place in each of the three study areas and at the sites within them (see Tables 3 and 4).

In Sabaloka, the starting point of our research, we have evidence of the production and consumption of gouges. But there are differences between the individual sites. The two locations with a single find each (Grove Site and Lake Basin) attest only to consumption of gouges. The Rhyolite Site, on the other hand, was a production site, based on the total counts made (see Table 5), as well as by the presence of massive outcrops of rhyolite which made this place highly convenient for production. The site was where the half-finished pieces were prepared and from where they were transported to the nearby settlements to finish the manufacturing process. However, this extensive site requires systematic archaeological survey.

At the other three locations in Sabaloka, there is evidence for both production and consumption. This is not surprising with Fox Hill, the most prominent Early Neolithic site in the area. Here, a broad spectrum of activities associated with gouges is indicated not only by the size and diversity of the gouge collection but also by the presence of a local workshop for gouge production in the western outcrop area near the local source of rhyolite (see Fig. 22). Abundant evidence indicates that the finishing processes for gouges production took place near or at this particular site. At Tabya Hassaniya, located some 6 km upstream from the major rhyolite outcrops, the presence of reworked pieces and pieces broken during use strongly indicates consumption. Pieces that were broken intentionally or accidentally during production and those knapped by novices also suggest some degree of production at the site. At the Donkey Site, one unfinished piece out of three gouges collected during reconnaissance suggests that the finishing processes for the manufacture of gouges also took place, but this was a minor habitation site rather than a site of full-scale production.

In Sabaloka, the morphometry of the whole finished pieces (their regularity and symmetry) indicates high levels of craftsmanship. These complete tools and the presence of intentionally broken pieces indicate that specialized knappers engaged in high-quality production. At the same time, the raw material does not seem to have been used in the most economical way in this region. For example, big pieces of gouges were unfinished (e.g., compared to Sheikh el-Amin). Also, there were a large number of gouges which were broken during use and were not repaired or reworked (11.4% in Sabaloka vs 5.9% at Shaheinab). In addition, the size of reworked pieces in Sabaloka was larger compared with the other two sites (for example, 7 cm on average in Sabaloka vs 4.5 cm on average at Sheikh el-Amin). This suggests that gouges in Sabaloka were discarded before being totally exhausted.

At Shaheinab, situated some 30 km from the source area, we find evidence of both intensive consumption and production of gouges based on the presence of half-finished products and production waste in the form of flakes from the final shaping and reworking of the lithic artifacts. Shaheinab has approximately the same ratio of complete gouges (3.3%) as Sabaloka (3.11%). But between the two, Shaheinab shows a slightly higher percentage of gouges that were broken intentionally (6.4% vs 5.3%), accidentally broken during production (5.6% vs 4.7%), and knapped by novices (6.7% vs 2.5%). All of these suggest that while an idea of what a good gouge

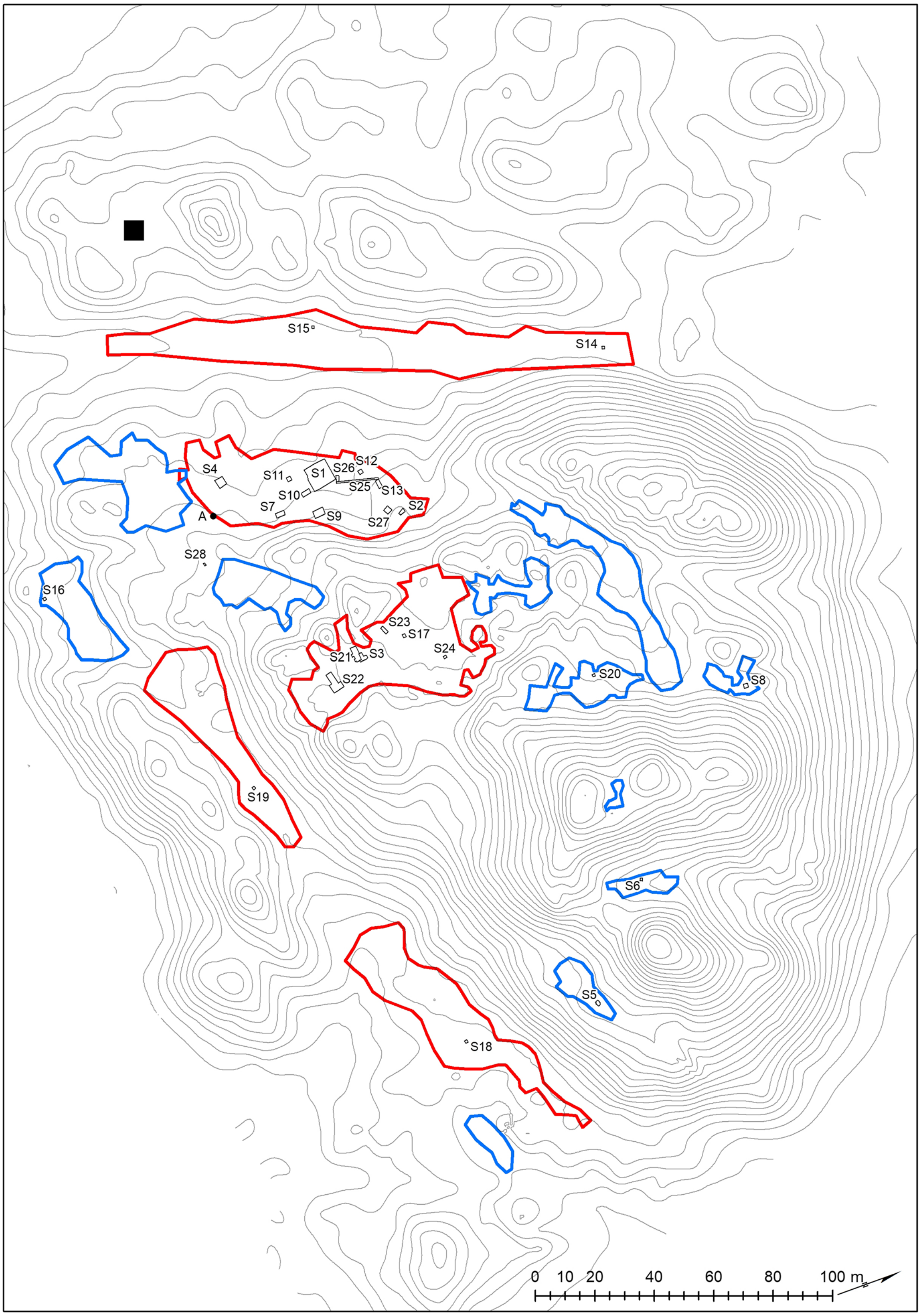


Fig. 22 Plan of Fox Hill (SBK.W-20). Excavated trenches (empty squares and rectangles marked S1 to S28), gouge production area (solid black square), primary settlement areas (red outline), and less important settlement areas (blue outline). Authors: J. Pacina, L. Varadzin and L. Varadzinová

should look like was apparently present and aspired to by specialized knappers, the local production also included processes of learning.

It seems that different aesthetical norms and considerations influenced the production of gouges outside the raw material-source area. This is demonstrated on three finished and polished gouges from Shaheinab. In the Sabaloka area, finished whole pieces are never polished and polishing is connected only with reworking of gouges. The higher number of reworked pieces at Shaheinab, compared with Sabaloka (38.3% vs 24.7%), and a lower number of pieces broken during utilization (5.9% vs 11.4%) seems to testify that far more effort was exerted at Shaheinab than in Sabaloka for a maximum exploitation of the raw material to produce functional gouges. The raw materials certainly had a high and premium value outside the source area as indicated by the extensive recycling of gouges for the production of other artifacts in Shaheinab (see above and Arkell 1953). At Sheikh el-Amin in the Blue Nile region, the most distant gouge-bearing site from Sabaloka, we have no evidence of local production. Moreover, the gouges and two flakes collected from this site are the only pieces of lithics made of rhyolite (Fernández et al. 2003). They show evidence of intensive consumption and continuous reworking and repairing of gouges until the limit of their usability.

Hence, interesting trends are visible from the comparison of the three regions. First, the farther from the source area of the raw materials, the greater and more intensive the reworking of gouges, the higher the number of pieces exploited until the limits of their usability, and the shorter the average length of gouges. Second, the number of polished gouges, linked to re-sharpening or reworking of broken pieces also increased with distance from the raw material area. Third, the further from the source, the greater the symmetry of the gouges, indicating a more precise and higher skill of production and reworking. This implies that the value of the red rhyolite and finished gouges increased farther away from the raw material source area and that only master knappers were involved in the production/reworking of gouges outside Sabaloka. All of these enrich our understanding of the mechanisms of distribution of gouges. It appears that half-finished products were transported from Sabaloka to Shaheinab, possibly along with some finished products. The apparent lack of gouges broken due to natural causes at the latter site suggests that only good quality material or products were selected for transport. For the area of the Blue Nile, on the other hand, the lack of evidence for production of gouges and the absence of this raw material on other types of lithic tool supports the hypothesis of the transport of only finished products to Sheikh el-Amin. So it seems that the Sudanese Neolithic society operated on some of the fundamental economic principles in which scarcity drives value and that this affected the degree of quality, maintenance, and reuse.

Conclusion

On the basis of our study of 1,012 gouges and gouge-like artifacts from three areas of central Sudan, we confirm Arkell's (1953) hypothesis that gouges were produced in Sabaloka by identifying easy-to-exploit surface outcrops of rhyolite and, in their context, evidence of the different gouge production stages. In contrast to Arkell (1953), however, we also provide evidence of gouge production at Shaheinab. Rhyolite constitutes the only raw material identified in the collections studied. The rhyolite characteristics of gouges at Shaheinab and Sheikh el-Amin do not differ in any respect from those found in Sabaloka. Grey and red rhyolite were used, with the red being more predominant. This could indicate that aesthetic aspects, which are often omitted in the study of lithic collections, could have played an important role in the social lives of the Early Neolithic culture of central Sudan. We found that rhyolite could contain a greater amount of defects due to heterogeneity in the material, and this must have made the gouges prone to breakage during manufacture and utilization. These heterogeneities were prevalent in Sabaloka gouges but not attested at Shaheinab. The latter is indicative of the careful selection of raw materials intended for distribution to areas that are remote from the raw material source location.

Despite some evidence of inexperienced knapping, the finds from Sabaloka (artifacts and production waste) suggest high-quality production of gouges evident in coherent, homogenous, and symmetrical production that cannot be achieved by average knappers. However, the abundance of raw materials also provided opportunities for learners and novices to knap and improve over time. Symmetry within collections appears to increase with the growing distance from the source area, which could suggest that the best possible pieces might have been distributed or exchanged. Also, Sabaloka may have been the primary supplier of skilled and master gouge manufacturers to the surrounding region. The evidence from the three study areas shows that the distribution of gouges from the source area need not have concerned only finished products (Sheikh el-Amin) but must have also included prepared blocks of raw material and half-finished products intended for finished products elsewhere (especially, Shaheinab). In Sabaloka, we also proved that whole finished gouges were not polished and that polishing was connected explicitly with reworking of worn-out or broken tools.

Using the collection from Sabaloka, it was possible to define analytical categories associated with diverse stages of the life of gouges, from raw material preparation, production, use, reworking, and maintenance, to reuse (recycling) and discard. These analytical categories can be applied to the study of any lithic collection. And, unlike the typological approach, they also offer the possibility of comparison between regions through the study of the uneven representation of these categories at individual sites. While Arkell (1953) avoided the issue of typology (he found the pieces in the Shaheinab collection to be too individual and therefore defy grouping), Tixier (1962) used the shape of the gouge base to distinguish different types, and Magid (1989) discerned five types based on the presence and degree of polishing. Our findings do not support multiple types of gouges. Rather, we conclude, based on the study of whole finished pieces from Sabaloka, that the knappers sought to produce only one type of gouges. These findings eliminate some of the long-lasting ambiguities about gouges and set a new point of departure for further research. Gouges represent a complex product that has a significant potential for addressing a whole spectrum of issues, from raw material sourcing, technological developments, and distribution of skills to the patterns of exchange, processes of social differentiation, and dynamics of regional interactions in the early Neolithic communities of central Sudan.

Acknowledgments We thank Abdelrahman Ali Mohamed (General Director of the National Corporation for Antiquities and Museums of the Sudan), Ghalia el-Nabi (Director of the Sudan National Museum in Khartoum), Sarah Abdulatif and other curators of the Sudan National Museum, and Víctor M. Fernández (Department of Prehistory, University Complutense of Madrid, Director of the Blue Nile Project). Our research would not have been possible without their help and cooperation.

Funding Information The research for this paper was conducted as part of the *Communities and resources in late prehistory of Jebel Sabaloka, central Sudan: from analysis to synthesis* project supported by the Czech Science Foundation (no. GAČR 17-03207S). Our research was also supported by the Institute of Geology CAS, Prague RVO 67985831, and the Institute of Archaeology CAS, Prague RVO: 67985912.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

Almond, D. C., & Ahmed, F. (1993). *Field guide to the geology of the Sabaloka Inlier, Central Sudan*. Khartoum: Khartoum University Press.

Arkell, A. J. (1949). *Early Khartoum. An account of the excavation of an early occupation site carried out by the Sudan Government Antiquities Service in 1944–5*. London: Oxford University Press.

Arkell, A. J. (1953). *Shaheinab. An account of the excavation of a Neolithic occupation site carried out for the Sudan Antiquities Service in 1949–50*. London: Oxford University Press.

Aubry, T., Bradley, B., Almeida, M., Walter, B., Neves, M. J., Pelegrin, J., Lenoir, M., & Tiffagom, M. (2008). Solutrean laurel leaf production at Maîtreaux: An experimental approach guided by techno-economic analysis. *World Archaeology, 40*(1), 48–66.

Caneva, I. (Ed.). (1988). *El Geili: The history of a Middle Nile environment, 7000 B.C.-A.D. 1500*. BAR International Series, 424. Oxford.

Caton-Thomson, G., & Gardner, E. W. (1934). *The Desert Fayum*. London: Royal Anthropological Institute of Great Britain and Ireland.

Fernández, V. M. (Ed.). (2003). *The Blue Nile Project. Holocene archaeology in Central Sudan*. Complutum 14. Madrid: Servicio de Publicaciones, Universidad Complutense.

Fernández, V. M., Jimeno, A., & Menéndez, M. (2003). Archaeological excavations in prehistoric sites of the Blue Nile, Central Sudan. In V. M. Fernández (Ed.), *The Blue Nile Project. Holocene archaeology in Central Sudan* (pp. 273–344). Complutum 14. Madrid: Servicio de Publicaciones, Universidad Complutense.

Haaland, R. (1982). *Migratory herdsmen and cultivating women: The structure of Neolithic seasonal adaptations in the Khartoum Nile environment*. Ph.D. Thesis. University of Bergen, Bergen.

Inizan, M. L., Reduron, M., Roche, H., & Tixier, J. (1999). *Technology and Terminology of knapped stone*. Meudon: Cercle de Recherches et d'Etudes Préhistoriques.

Kobusiewicz, M. (2011). Lithic implements. In M. Chłodnicki, M. Kobusiewicz, & K. Kroeper (Eds.), *Kadero. The Lech Krzyżaniak Excavations in the Sudan* (pp. 267–297). Poznań: Poznań Archaeological Museum.

Krzyżaniak, L. (1995). Late prehistory of the Central Sudan: A summary of the results of the last thirty years. *Cahiers de* *recherches de l'Institut de papyrology et d'égyptologie de Lille, 17*(1), 117–122.

Magid, A. A. (1989). *Plant domestication in the Middle Nile Basin. An archaeoethnobotanical case study*. British Archaeological Reports 523, Cambridge Monographs in African Archaeology 35. Oxford.

Magid, A. A. (2003). Exploitation of food-plants in the early and middle Holocene Blue Nile area, Sudan and neighbouring areas. In V. M. Fernández (Ed.), *The Blue Nile Project. Holocene archaeology in central Sudan* (pp. 345–372). Complutum 14. Madrid: Servicio de Publicaciones, Universidad Complutense.

Pelegrin, J. (1984). Experiments in bifacial work: About 'laurel leaves'. *Flintknappers Exchange, 4*(1), 4–7.

Pelegrin, J. (1991). Aspects de la demarche expérimentale en technologie lithique. In *25 ans d'études technologiques en Préhistoire: Bilan et perspectives (XIémes rencontres internationals d'Archéologie et d 'Histoire d'Antibes)* (pp. 57–63). Juan-les-Pins: APDCA.

Pelegrin, J. (2007). Réflexions sur la notion de «spécialiste» dans la taille de la pierre au Paléolithique. *Documents Préhistoriques, 16*, 315–318.

Pelegrin, J. (2012). Observations sur la taille et le polissage de haches en silex. In P.-A. de Labriffe & É. Thirault (Eds.), *Produire des haches au néolithique: De la matière première à l'abandon* (pp. 87–106). Saint Germaine en Laye: Musée d'Archéologie Nationale.

Pelegrin, J. (2013). Les grandes feuilles de laurier et autres objets particuliers du Solutréen: Une valeur de signe. In *Le Solutréen… 40 ans après Smith. Revue archéologique du Centre de la France* 47 (pp. 143–164). Tours: ARCHEA-FERACF.

Pétrequin, P., Pétrequin, A.-M., Jeudy, F., Jeunesse, C., Monnier, J.-L., Pelegrin, J., & Praud, I. (1998). From the raw material to the Neolithic stone axe. Production processes and social context. In M. R. Edmonds & C. Richards (Eds.), *Understanding the Neolithic of north-western Europe* (pp. 277–312). Glasgow: Cruithne Press.

Schiffer, M. B. (1987). *Formation processes of the archaeological record*. Albuquerque: University of New Mexico Press.

Sobotková, A., Ross, S., Nehrizov, G., & Weissová, B. (2010). Tundzha regional archaeological project Kazanluk survey: Preliminary report. Spring 2009 and 2010. *Studia Hercynia, 14*, 56–66.

Suková, L., & Varadzin, L. (2012). Preliminary report on the exploration of Jebel Sabaloka (West Bank), 2009–2012. *Sudan & Nubia, 16*, 118–131.

Tixier, J. (1962). Le "Ténéréen" de l'Adrar Bous III. In H. J. Hugot (Ed.), *Missions Berliet Ténéré*, (pp. 353–362). Paris: Arts et Métiers graphiques.

Vail, J. R. (1982). Geology of the central Sudan. In M. A. J. Williams, M. A. J. Adamson, & D. A. Adamson (Eds.), *A land between two Niles. Quaternary geology and biology of the Central Sudan* (pp. 51–63). Rotterdam: A. A. Balkema.

Varadzinová, L., Varadzin, L., Kapustka, K., & Pacina, J. (2018). Výzkum lokality Liščí kopec (SBK.W-20) v pohoří Sabaloka: poznatky z výzkumné sezóny 2017. *Pražské egyptologické studie, 20*, 35–45.

Varadzinová, L., Varadzin, L., Crevecoeur, I., Kapustka, K., McCool, J.-P., & Sůvová, Z. (2019). Výzkum pravěkého osídlení v pohoří Sabaloka v centrálním Súdánu: poznatky z výzkumné sezóny 2018. *Pražské egyptologické studie, 22*, 43–53.