Chapter 3

Technological Assets for the Emergence of the Acheulean? Reflections on the Kokiselei 4 Lithic Assemblage and Its Place in the Archaeological Context of West Turkana, Kenya

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Abstract On the western side of the Turkana basin, the sedimentological members of the Nachukui Formation expose a unique succession of archaeological site complexes ranging from 0.7 to 3.3 Ma. Following the analysis of the oldest and most remarkable lithic assemblages, we propose a model clarifying the chronology and possible operative modes of the first stone knappers; the technological components which around 1.76 Ma led to a new method in stone working: shaping. It appears that they gradually substituted newly mastered technical advances for the initial selection of blocks or cobbles naturally displaying a suitable shape. The alternating of conceptual advances, first concretized in the appropriate selection of natural block shapes, then in major technical innovations, seems to have been the rhythm of a very slow and hesitant tempo, leading to the formalization of the oldest Acheulean lithic assemblages then to a new technological world from 1.0 Ma.

Keywords Oldowan • Early Acheulean • Lithic technology • Earliest technologies • Concept of tool

3.1 Pluralist Tool Makers, a Single Technological Framework

The relationship of wild chimpanzees with tools, currently observed by primatologists, is that of a single living species (*Pan troglodytes*) evolving in a natural environment where the plant component is a key element. The fossil evidence for the relationship with the stone tools of this great ape is poor and only gives us information limited to the use and the economy (transport and reuse) of a material, non-transformed except by use.

Conversely, we are interested here in the knapped stone objects that are together with faunal remains the relics abandoned by representatives of several extinct fossil species. In the Late Pliocene/Early Pleistocene context in which these ancient hominins evolved, any possible vegetable component of their equipment has not been preserved to date.

Current data indicate that from 3.3 to 1.0 Ma, several species belonging to several genera of hominins dedicated themselves to hard stone knapping. The oldest lithic assemblages we will consider are geographically relatively concentrated, but could have been produced by representatives of different species, or even of a different genus: *Kenyanthropus* and/or *Australopithecus* (Harmand et al. 2015). Besides, we know that from 2.3 to 1.5 Ma, representatives of the *Paranthropus* and *Homo* genera could have interacted on the western shores of Lake Turkana (Prat et al. 2005).

Whatever the level of expertise, hard stone knapping is only possible by combining several well-identified parameters that come within the province of solid-state physics; this forms a rigid framework to which none of these operators could deviate. Therefore, we will not discuss here the stages of a continuous technological evolution that would have resulted from a single species, but, based on concrete remains, we will discuss how the inescapable technical obstacles to the development of the first known bifacial forms have been overcome between 3.3 and 1.0 Ma, by one or more hominin species. If several of them were able to provide, with or without continuation, a technical solution to the overcoming of the first obstacles met, a single lineage, one that led to the only species present around 1.0 Ma, *Homo erectus s.l.*, was able to overcome them all.

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3.2 Origin of the Term “Acheulean”

Gabriel de Mortillet first used the term “Acheulean” in 1872 to refer to industries with handaxes (which he then referred to as “coup de poing”) from the middle terrace of the Somme River, near the village of Saint-Acheul and the town of Amiens. But the term “biface” (handaxe) was coined by Vayson de Pradenne to describe the first large pieces shaped on each of their faces, with more or less pronounced bilateral and bifacial symmetry, which had been unearthed in unquestionably very ancient sediments in the terraces of the Somme River (Vayson de Pradenne 1920).

For the archaeologists of the time, handaxes represented the oldest known material evidence left by those considered as the very first protagonists of prehistory. Easy to identify, relatively easy to “read”, the handaxe naturally emerged as the most representative tool of the new Acheulean culture. It remains “the first truly shaped object that is known, the first shape completely invented by mankind”[1] (Tixier and de Saint-Blanquat 1992: 8). It thus became the undisputed techno-typological marker of a culture that subsequently proved very widespread in Africa, the Middle East, Eurasia and equally widely spread over time. In Africa, the Acheulean handaxe is often associated with the cleaver on flake, another emblematic large cutting tool, whose bifacial symmetry, however, is not the first morphological characteristic. In Europe, cleavers are often lacking from the considered Acheulean lithic assemblages. We will also see that this other marker of the African Acheulean always seems to have appeared with a chronological discrepancy with regard to the handaxe. This delayed first appearance is an important factor to consider in the research on the mechanisms and chronology of the emergence of the Acheulean. The main reason is the minimum level of predetermination required to make possible the manufacturing of a cleaver on flake (Roche and Texier 1996).

So far, prehistorians have agreed on an eastern African origin of the Acheulean, but at a time that still remains unclear because sites with bifacial objects reliably dated over a million years were, and still are, particularly rare (de La Torre and Mora 2005; de la Torre et al. 2008; Gallotti 2013). The discovery and the very ancient dating of two of them, by partially filling this gap (Kato et al. 2000; Lepre et al. 2011; Beyene et al. 2013), are just restarting the debate.

The diffusion of this culture can be followed quite easily thanks to the considered typo-technological markers. Thus, it is commonly accepted that the Acheulean left Africa in several waves toward the Middle East, before gradually reaching Europe and Asia in a succession between 1.7 and 0.8 Ma (Bar Yosef and Goren-Inbar 1993; Goren-Inbar et al. 2000; Petraglia 2003). However, other researchers favor a Near Eastern re-emergence of bifacial shaping (Chevrier 2012).

We propose here to examine the determining technological milestones (Fig. 3.1) that must have punctuated the path leading in 2.3 million years from the first known knapped objects (3.3 Ma) to the first certain bifacial shapes (1.76 Ma), then to the stereotyped forms of an ancient African Acheulean (0.98 Ma), already technologically mature like that of Isenya in Kenya (Durkee and Brown 2014).

3.3 The Concept of Tool

The use and often reuse of stone tools consisting in natural and unmodified shapes have been frequently observed and well documented by numerous primatologists with regards to modern chimpanzees (Mc Grew 1992; Joulian 1996; Boesch and Tomasello 1998) and moreover demonstrated for fossil chimpanzees (Mercader et al. 2002, 2007). But intentional manufacturing of stone tools was never documented.

However, the modern knapping of flakes by chimpanzees (*P. troglodytes* or *P. paniscus*), often born and bred in captivity and that never engage in such activities in the wild, appears as an artifact introduced by modern experimenters and should therefore be considered with caution. If the experiments that have been attempted in this direction show the existence of some potential of these species in this domain, they also allow apprehending the duration of the necessary learning process and the very quickly reached limits of its technical expression (Toth et al. 1993; Texier 2012).

The production of flakes, at will and in series or the shaping of stone objects by direct or indirect percussion, remains the prerogative of one or more representatives of the sub-tribe of Hominina that includes all the species of the genera *Homo*, *Australopithecus* and *Paranthropus*. However, the identification of one or several of them as the author of these productions will always remain a problem.

Unearthed in stratigraphic context, the remains of the first lithic productions of the hominins who occupied the African Rift in the Late Pliocene and Early Pleistocene mark in an almost unchanging and “readable” manner the crossing of a milestone in the history of the human lineage:

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[1] “Le premier objet vraiment façonné que l’on connaisse, la première forme totalement inventée par des hommes.”

Fig. 3.1 Sketch map showing the location of the sites mentioned in this paper

the manufacturing of stone objects, hitherto unknown, using basic tools (hammers or anvils), natural but carefully chosen, and raw materials selected according to their morphologies, their mechanical properties, and their module.

It is clear through these first but already abundant productions, that the elementary principles of fragile fracturing and knapping were assimilated straight away, because the technical gesture and its consequences only become repeatable at will under this condition.

3.4 The Oldest Knapped Tools, the Early Acheulean

The oldest knapped tools currently listed were unearthed in about twenty sites of the Ethiopian or Kenyan sections of the East African Rift (Table 3.1). Their ages range from 3.3 to 2.0 Ma. These sites have yielded early Oldowan and Oldowan lithic assemblages, consisting in several dozens to several hundreds, or even thousands of objects (Roche and Tiercelin 1977; Delagnes and Roche 2005; Semaw 2005; Semaw et al. 2010; Hovers 2012).

To the west of Lake Turkana in Kenya, at the base of the Lomekwi member of the Nachukui Formation, the recent discovery of numerous knapped objects from a stratigraphic context dated to 3.3 Ma (Harmand et al. 2015) has dramatically thrown back in time by 0.7 Ma (Roche and Tiercelin 1977) the first concrete manifestation of the crossing of what some consider as the threshold of hominization. It can then be assessed by the ability to make stone objects recurrently, as simple as they are, with all the underlying ability for anticipation, minimal understanding of the conchoidal fracturing of rocks and manual dexterity.

Moreover, the great age of the Kokiselei 4 site (KS4, West Turkana, Kenya) that yielded many large unifacial and bifacial objects as well as picks shaped on cobbles or split cobbles was recently confirmed by a date at 1.76 Ma (Lepre et al. 2011).

In Ethiopia, in the vast and rich Acheulean complex of Konso Gardula, a lithic assemblage (KGA6-A1), very similar in nature and size to that of KS4 (Table 3.2), could avail of an equivalent age (Beyene et al. 2013, 2015). If this is the case, the presence of three cleavers on flakes in this assemblage suggests looking for the origin of the Acheulean of KGA6-A1 even further in time because of the technological mastery this implies.

Finally, let us remember that the experimental manufacturing of series of large cutting tools (LCTs) in phonolite allowed identifying clearly the range of available techniques and the committed know-how necessary for the working of such raw materials. These experiments also allowed establishing and characterizing the phasing of the making of these tools, evaluating the execution times and the amount of generated knapping wastes. Anticipation is clearly emerging at that level through the selection of the module and the quality of the raw materials, in the obtaining of some handaxe blanks and of all the blanks for cleavers on flakes (Roche and Texier 1991, 1996; Texier 1996; Bouthinon 2002).

Based on the spectacular dating recently conducted by researchers working in East Africa and on the contribution of the technological analysis of the new unearthed lithic assemblages, it seems legitimate to wonder about the mechanisms that have led from the very first knapped objects to the formalization of new "chaînes opératoires" oriented toward bifacial shaping. This forms a long journey

Table 3.1 Size of the assemblages and distribution of the raw materials within the main lithic groups of the Late Pliocene constituted from systematic surface and in situ collecting. Data from de la Torre 2004; Stout et al. 2005; Hovers 2009; Semaw et al. 2010; Harmand et al. 2015

	LOM3	EG10	EG12	OG7 (2000 excavation)	AL 894	LA2C	Omo 123
Age	3.3 Ma	2.6 Ma	2.6 Ma	2.6 Ma	2.36 Ma	2.34 Ma	2.3 Ma
Surface	130	1551	309	65	–	492	1014
In situ	19	685	445	188	–	2122	767
TOTAL	149	2236	754	253	4828	2614	1781
Raw materials	Phonolite 34.2% Basalt 34.9%	Trachyte 79.0% Rhyolite 11.4%	Trachyte 66.1% Rhyolite 17.7%	Trachyte 29.3% Rhyolite 26.3% Aphan. volc. 15.8%	Rhyolite 71.0% Basalt 24.0%	Phonolite 74.7% Basalt 14.2%	Quartz 96.4% Chert 2.2%
w.f. = whole flakes	Trachyphon 23.5% Others 7.4%	Basalt 7.0% Others 2.6% (w.f.)	Basalt 6.5% Others 9.7% (w.f.)	Latite 10.6% Vitr. volcanic 5,0% Basalt 3.5% Others: 9.5% (w.f.)	Trachyte 3.0% Others 2.0% (w.f.)	Trachyte 9.7% Others 1.4%	Lava 1.4%

Table 3.2 Distribution of the main categories of tools within the two oldest Acheulean lithic assemblages (aPhon. is used as a short for aphyric phonolite)

Site	Age	Cleavers	Handaxes	Picks	Others	Main raw material	Total
KS4	1.76	0	3	11	14	aPhon.	28
KGA6-A1	1.75	3	4	11	10	Basalt	28

whose stages are punctuated by the development of new concepts and decisive technical innovations. Still deeply rooted in the Oldowan, the new emerging “chaînes opératoires” marked the Early Paleolithic with their technological footprint in a lasting or recurring manner, depending on whether one chooses the model of a unique Acheulean that was to spread latter out of Africa, or whether one is a supporter of the local invention or reinvention of the bifacial object.

However, the question does not arise here as abruptly, as we propose to look at the very roots of the bifacial phenomenon and to discuss the nature and chronology of the conceptual advances and technological knowledge that have gradually made possible the manufacturing of the earliest bifacial pieces.

3.5 Detaching Flakes …

Detaching one or more flakes, even at an elementary technological level, remains an operation of great complexity, as evidenced by the difficulties encountered by many researchers and modern manufacturers to try (implied as on the edge of a block of raw material) to interpret and put this marginal phenomenon of fracturing into equations (Cottrell and Kaminga 1979; Bertouille 1989; Zarzycki 1991; Tsirk 2014).

Such an approach first requires the selection of a cobble or a block of dense and tenacious rock (to act as a hammer or anvil), whose natural convexities allow concentrating and returning on impact the energy imparted to it, on a limited area, at a preselected and then reached position.

This also implies the selection of blocks of materials identified as suitable for knapping by their homogeneity, texture, and hardness. The project can be modified depending on the sizes of the available blocks or corollary, a selection of blocks of specific morphology or module can be done according to the planned project and the technical background of the knapper.

Thus, the incidence of the trajectory followed by the hammer toward the block, or by the block toward the anvil, its weight, the speed imparted to it, the location of the point of impact on the edge of the worked block, the geometry of the block in the impact area, and the topography of the surface to be knapped are all factors that the experienced knapper should take into account simultaneously during each technical gesture, to achieve a result in line with his/her expectations.

Often, the naturally irregular shape of the worked blocks only allows knappers with an elementary technology to obtain very limited series of flakes, isolated, possibly adjacent, or alternating.

The early Oldowan, Oldowan, and early Acheulean knappers did not always have the necessary technology to carry out their projects directly. Thus at first, they favored the choice of blocks with a natural morphology that allowed them to avoid an obstacle, of which they were aware, but which was still technically insurmountable for them.

3.6 Sketching the First Stages of Knapped Stone Technology

The knapping of hard stone is applied to a volume of raw material suitable for knapping. It is expressed in the three dimensions of space. If the selected material is simply knapped, then some flakes are the desired products. They can be used as tool without any modification. They are, or have been in this case, accompanied by many by-products resulting from their preparation. Conversely, when the material is gradually shaped to manufacture one single artifact, in that case the flake only has the status of a by-product, possibly usable (Texier and Roche 1995; Roche 2007).

Schematically, the débitage may be represented by a system with three X, Y, and Z axes of the same origin. Meanwhile, bifacial shaping can be represented by two sets of arrows, possibly alternating and arranged in opposition. Thus, in the case of a débitage, we propose to refer to the X and Y axes to symbolize the part of the volume of a material that can be exploited without reworking the initial geometry of the worked block/core. The third axis is used to schematize the activation of a preexisting natural striking platform or the creation and management of an unnatural striking platform (Fig. 3.2).

In the case of bifacial shaping, the mutual arrangement of the arrows reflects the quality of the sequence of removals and potentially, the relative chronology of the series of technical events that occurred during shaping (Fig. 3.3).

Where it appears to the technological analysis that the control of the sub-volumes to work is uncertain (systematic

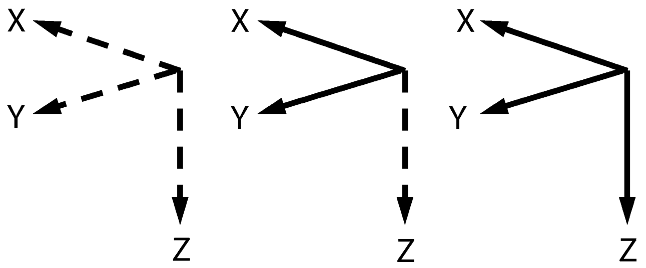

Fig. 3.2 Sketching the ability to control each of the three directions of space when flaking (dotted lines: uncontrolled direction; continuous lines: controlled direction)

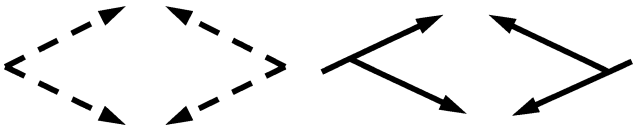

Fig. 3.3 Sketching the ability to control in space the direction and the mutual organization of the removal of flakes when shaping (dotted lines: uncertain control and uncertain organization of the flakes removal; continuous lines: controlled and mutually organized series of flakes removal)

and non-“repaired” knapping accidents), the directions that illustrate its exploitation are shown as dotted lines. Conversely, when it appears that the control of this space has become the norm, the concerned axes are then represented by a continuous line.

3.7 West Turkana: The Unity of Place

The twenty years of presence in the field of the Mission préhistorique au Kenya in the context of the West Turkana Archaeological Project[2] has brought together in a locally and chronologically tightened context, at the same time geologically and archaeologically exceptionally favorable, a unique documentation of the technological developments of the first lithic productions, benefiting in a way from the unity of place.

We suggest to look in these chronologically well-determined lithic assemblages for the diagnostic elements of the technological knowledge (and the processes of their acquisition) that enabled some knappers to venture conceptually, then concretely, in the first recorded attempts at bifacial shaping.

3.7.1 *The Nachukui Formation*

The main levels of volcanic ash (tephra) that punctuate the Nachukui Formation divide this thick sedimentary deposit (712 m) in eight separate members that bear the names of the intermittent streams that are eroding it (Roche et al. 2003). The geochemical signature of these volcanic ashes allows correlating them with some of those from other formations in the Omo group (these are directly dated tephra deposits): the Shungura Formation to the north and the Koobi Fora Formation to the east (Haileb et al. 2004). Moreover, a correlation of the Turkana basin tephra deposits (especially the KBS and Chari Tuffs) with those of the Konso Formation has been proposed (Katho et al. 2000; McDougall and Brown 2006; McDougall et al. 2012; Beyene et al. 2013).

To date, four members of the Nachukui Formation (members of Lomekwi, Kalochoro, Kaitio, and Nariokotome) have yielded 10 archaeological complexes for a total of 59 sites with ages ranging from 3.3 to 0.7 Ma (Table 3.3).

Our approach is specifically based on data from the preliminary study of the artifacts collected on the surface or in stratigraphy at Lomekwi 3 (Harmand et al. 2015), and from the in-depth technological analysis of the lithic assemblages of three sites; two Oldowan sites, Lokalalei 2C and Kokiselei 5, were excavated exhaustively (Delagnes and Roche 2005, Texier et al. 2006); at Kokiselei 4, the excavation was more limited in extension but with systematic surface collecting for the early Acheulean (Lepre et al. 2011).

The last three of these sites have notably in common comparable raw materials (aphyric phonolite) while the numerous refits that could be done confirm and refine the technological reading.

Table 3.3 Members of the Nachukui Formation (West Turkana, Kenya). Time intervals, thicknesses of sedimentary deposits, coding of the name of the sites complexes and corresponding number of sites (after Roche 2011)

Members	Age (Ma)	Thickness (m)	Archaeological complexes	Number of archaeological sites
Nariokotome	1.30–0.7	70	KL; NK; NAD	18
Natoo	1.65–1.30	75		
Kaitio	1.90–1.65	169	KS; KLD; NY	30
Kalochoro	2.35–1.90	72	LA; NAS	8
Lokalalei	2.50–2.35	42	NAS	2
Lomekwi	3.35–2.50	159	KUS; LOM	1
Kataboi	4–3.35	34		
Lonyumum	>4	91		

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[2] The West Turkana Archaeological Project (WTAP) is a joint program of the National Museums of Kenya (National Museums of Kenya) and of the Mission préhistorique au Kenya (MPK). Created and directed by H. Roche from 1994 to 2013, the WTAP is now directed by S. Harmand and J. Lewis. This program yearly benefits of the institutional (Commission consultative des recherches archéologiques à l’étranger) and financial support of the French “Ministère des Affaires étrangères et du Développement international.”

Other sites, older than Lokalalei 2C or contemporary, were discovered in Hadar in Ethiopia. The lithic assemblages of some of them have recently been the subject of technological studies (Hovers 2009, 2012; Stout et al. 2010). However, they can account for substantially different technical behaviors than those other knappers have shown, living around the same time a thousand kilometers away, west of Lake Turkana. To benefit in some way from the unity of place and from a narrow range of raw materials, the diachronic evolution model of the technologies presented here will refer exclusively to the sites of West Turkana.

3.7.1.1 Lomekwi 3 (LOM3)

LOM3 site was discovered during surveys carried out in 2011 by the WTAP team at the base of Lomekwi member (3.35–2.5 Ma). Some artifacts and skeletal remains, some of which in situ, were then collected. At the end of the field campaign that followed, along with the discovery of new relatively poorly preserved bone remains attributed to six species of mammals, 149 lithic pieces were collected, including 19 in an indisputable stratigraphic context (Harmand et al. 2015). They are essentially flakes or flake fragments bearing indisputable knapping traces, relatively bulky worked blocks of an average weight of about 3 kg, and elements that were used in active or passive percussion. The worked blocks mostly evidence flake scars terminating as hinge and step fractures (Fig. 3.4). The raw materials are in equivalent proportion, phonolites (35%), and basalts (34%) and to a lesser extent, trachyphonolites (23%). They are still currently available in modules compatible with the artifacts from LOM3, in gravel from the dismantling of ancient alluvial formations surrounding the site. The well-argued age of 3.3 Ma that is proposed (Harmand et al. 2015) makes it the oldest archaeological site known to date. In the current state of knowledge, this discovery finally demonstrates conclusively that hominins other than those

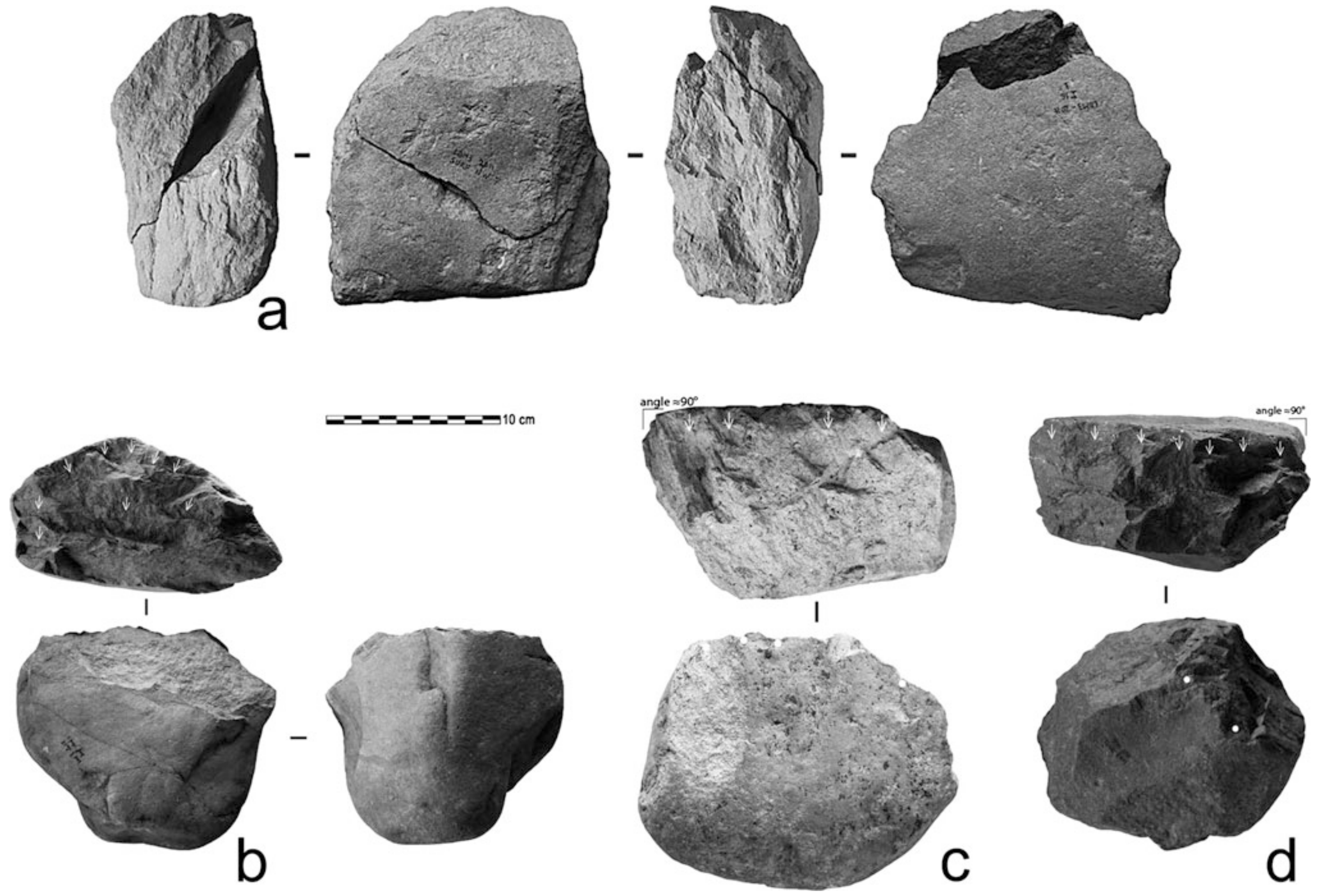


Fig. 3.4 Lomekwi 3. **a** Refitting surface flake and in situ unifacial core worked using passive hammer and bipolar technique (1.85 kg). These two conjoining artifacts show series of percussion marks on cortex documenting a prior use for different purpose; **b** Unifacial passive hammer core (2.04 kg); **c** and **d** Unifacial bipolar cores, respectively, 3.45 and 2.58 kg. Impacts due to the countercoups are localized on the opposite edge from the striking platform. All these cores show numerous knapping accidents due to assessing errors and to the poor quality of the raw material (Harmand et al. 2015). (Photographs courtesy of MPK-WTAP)

related to the *Homo* genus, which appears at the earliest at 2.8 Ma (Villmoare et al. 2015), also knapped hard stone. *Kenyanthropus platyops* and/or *Australopithecus afarensis* and/or *Australopithecus deyiremeda* (Haile-Selassie et al. 2015), whose presence is confirmed at Lomekwi or more widely in East Africa, could therefore be the makers.

In light of these recent findings, a thorough re-evaluation of the prehensile and manipulative abilities of these hominins from the Late Pliocene and of the gestures related to the manufacturing of stone tools is required (Harmand et al. 2015, supplementary information). Questioning the relevance of the morphological characteristics used till now to evaluate "precision", a study conducted by Pouydebat et al. (2006) demonstrated that a hand that does not seek to be precise does not necessarily lack the ability in tool making. Working on the primitive hand of *Australopithecus sediba* (Kivell et al. 2011) or on the wrist remains of *Homo floresiensis* (Tocheri et al. 2007, 2008) anthropologists came also to the conclusion that more than one type of hominin hand can be responsible for stone tools.

The technological analysis of the currently available lithic assemblage indicates that raw material blocks poorly adapted to knapping were intentionally modified and/or knapped by unifacial or semi-peripheral alternating direct percussion, with hard hammer, or by percussion of the blocks on passive hammer or again by bipolar percussion on anvil.

We can retain from the lithic productions of this exceptionally ancient site that if their knapping schemes are extremely simple, using elementary knapping techniques, their quantity, together with the butts and the characteristic traces observed on the lower face of the flakes, indicate that the basic knapping principles were sufficiently assimilated to be reproducible at will. However, in LOM3 numerous knapping accidents and percussion traces also show assessing errors of the involved parameters, the still uncertain mastery of the knapping gestures, both partially due to the poor suitability of the raw materials flaked, as well as to the ambivalence of some blocks, knapped after having been used in percussion.

Elementary knapping schemes have resulted in short series of removals or in the creation of very irregular cutting edges. Due to the low technical level shown by those first craftsmen of prehistory, the initial morphology and morphometry of the blocks were major constraints. Multiple step fractures and hinge terminations observed on the flakes or on their negatives of removal and the presence of numerous impact or percussion marks behind the core edges are all elements indicating the limited knapping capacity of the selected materials and the low control of the percussive gestures (Fig. 3.5). The most elementary knapping principles were assimilated, but the three directions of space were still awkwardly controlled when working blocks.

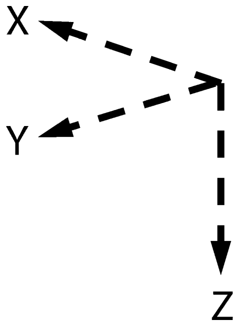


Fig. 3.5 LOM3: an awkwardly control of the three directions of space when flaking

3.7.1.2 Lokalalei 2C (LA2C)

A lack of technological elaboration was especially assumed about Lokalalei 1 site (Roche 1989), also emphasized by Kibunjia (1994, 1998). With the discovery of the neighboring LA2C site, it was later put forward that at 2.34 Ma hominin groups displayed distinct levels of skills as, at a lesser level, variations of quality in the locally available raw materials would also have had a significant role.

The Lokalalei 2C site (LA2C) was discovered during surveys conducted in the deposits of the Kalochoro member in 1998. The presence under the LA1 and LA2C sites of two tuffs, Kokiselei and Ekalalei, correlated with the tuffs E and F-1 of the Shungura Formation (Ethiopia), respectively, dated at 2.40 ± 0.05 and 2.34 ± 0.04 Ma, allowed to assign an age of 2.34 ± 0.05 Ma to the latter (Roche et al. 1999). This age is still relevant despite a reviewing of the local lithostratigraphy conducted more recently (Brown and Gathogo 2002).

The LA2C site was excavated exhaustively on about 17 m^2 that had been spared by erosion. LA2C yielded 2,614 lithic pieces associated with relatively poorly preserved skeletal remains.

Besides its age, which made it one of the oldest known archaeological sites at the time of its discovery, one of the remarkable aspects of the lithic assemblage is that over 13% of refits were possible. Often complete and sometimes combining several dozen pieces (Fig. 3.6), they allowed an exceptionally fine technological reading of the sequence of the technical gestures done by the knappers (Delagnes and Roche 2005).

This sequence can be outlined as follows:

- Choosing a specific raw material in the range of locally available volcanic materials in LA2C (mainly trachyte and phonolite).
- Choosing in these materials small blocks with a dihedral angle formed by the intersection of two surfaces, cortical

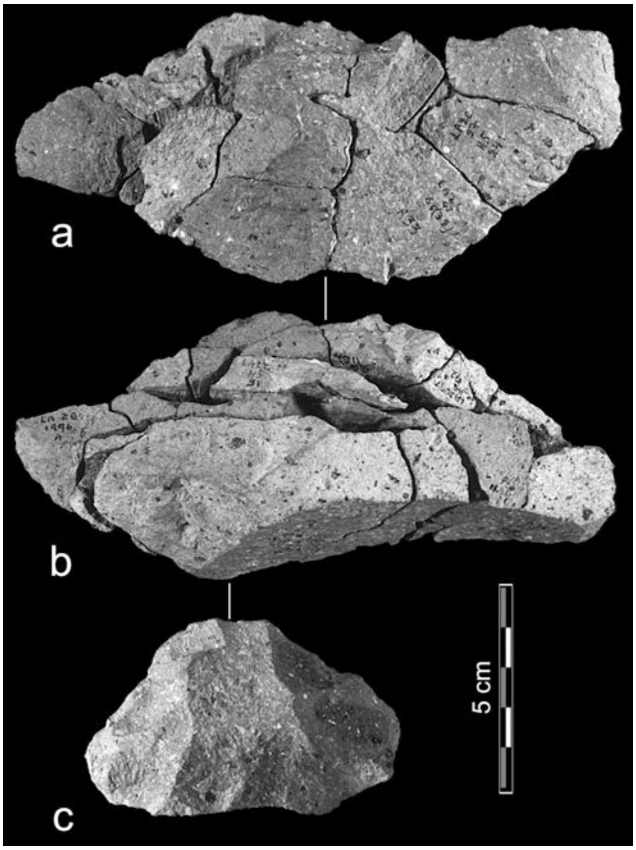


Fig. 3.6 LA2C. Upper (a) and lateral (b) view of an intermediate reconstruction of refitting group 33 reassembling 38 items. View from the flaked surface of the residual core (c). These images show the characteristic geometry of the majority of the cores at LA2C. The faces of the original dihedral that played the role of striking platforms during the exploitation of the cores result from the intentional fracturing of a fine-grained basalt block. (Photograph P-JT—MPK/WTAP)

or from fracturing, which are alternately used as natural striking platform throughout the débitage of a succession of short series of 2 to 5 flakes.

A careful selection of a material with very similar mechanical properties from one block to another and offering natural or summarily created forms (fractured blocks), according to what we know from all the available lithic assemblages on the technical background of early Oldowan and Oldowan knappers (Fig. 3.7), is what allowed the LA2C craftsmen to easily bypass the major handicap that still was their poor technical command of the third dimension of space.

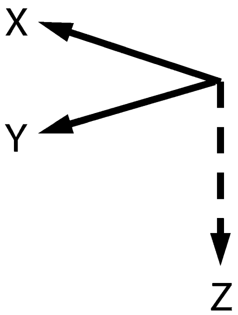


Fig. 3.7 LA2C: a good technical control of two directions of space and an indirect control of the third one obtained by flaking rigorously selected blocks

3.7.2 The Kokiselei Sites Complex

Currently, 10 sites were found in the archaeological complex of Kokiselei (KS), which takes place in its entirety in the Kaitio Member. Their stratigraphic place clearly showed that the KS1 and KS6 sites, especially, are among the oldest in the complex, with a slightly younger age than the KBS Tuff (1.87 Ma). Furthermore, the stratigraphic position of KS5 can be compared with that of the Oldowan site KS6.

Located in the flood clays that mark the top of the sequence of the complex, KS4 is significantly different from this first group of sites. An age of 1.76 Ma was calculated for the early Acheulean of KS4 (Lepre et al. 2011) that comes from sediments located 4.5 m above the Olduvai/Matuyama reversal.

KS6 and KS1 yielded typically Oldowan lithic assemblages, both typologically and technologically. The study of the Oldowan assemblage of KS5, stratigraphically very close to KS6, clearly shows, especially thanks to several refits, that its authors had already acquired the technical skills needed to deal with the same efficiency with sufficiently homogeneous and isotropic materials in all three dimensions of space. A very roughly shaped piece on a cobble could be the evidence of a still very timid attempt toward other materials modules and toward another knapping method, shaping (Texier et al. 2006).

3.7.2.1 Kokiselei 5 (KS5)

The unique archaeological level of KS5 only showed a very slight vertical dispersion of the material. It was excavated extensively on a 65 m^2 surface. It yielded a few bone remains (n = 280), relatively poorly preserved. The 1,727 pieces of the lithic assemblage that included several decisive diagnostic refits was the subject of a thorough technical analysis.

It appears from this study that the KS5 knappers used a wider variety of raw materials than at LA2C and KS1, sometimes very poor in quality.

The analysis of three refits, I, J, and F in particular (Fig. 3.8), clearly shows that the KS5 knappers had managed to cross a critical threshold in the conduct of débitage. This analysis reveals in particular that the technological level

Fig. 3.8 Three refitting groups from KS5 (a = refitting I; b = refitting F; c = refitting J) documenting a negative (n) or a positive (p) way the redirection of flake removals during the cortex removal phase or the core débitage phase of various raw materials. (Photograph P-JT. MPK/WTAP)

reached allowed them to create at will and to maintain the necessary striking platforms to continue and/or reorganize the débitage (Texier et al. 2006). This is the first and most finely recorded evidence for sequences of flake removals technically and angularly outstandingly well controlled in the three dimensions of the worked volume. This advance, which is a real technological leap, enabled them to dispense in a large measure with the selection, so far unavoidable, of the morphology of the blocks to be worked. Sorting of the lithic assemblage by raw materials and by worked blocks confirms that the KS5 knappers were able to use a much wider range of materials. This predate from about 0.3 Ma the diversification of débitage methods like at Garba IVD (Melka Kunture) where it was recently demonstrated (Gallotti and Mussi 2018) that among several available methods the choice of a specific one was both influenced by raw material geometry and by technical purposes.

The knappers of KS5 had understood the importance of the role played in a débitage by the ability to create at will a new striking platform to redirect, reorganize, and continue a flake production (Fig. 3.9). Several refits show that these knappers had reached the required level of technological expertise. Therefore, any block of a raw material suitable for knapping that could be handled had now become workable.

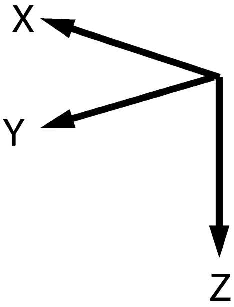


Fig. 3.9 KS5: a good control of the three directions of space reached in flaking when the ability to create at will new striking platforms is acquired

All the elements were already in place in KS5 to allow the mental construct and the formalization of a new concept: bifacial shaping. It materialized gradually (see the examples of Kokiselei 4 and Isenya below) by a succession of knapping operations whose aim was to make one single object by sculpting the raw material (Inizan et al. 1995) to create a specific morphology by successive removals of invasive, alternate, or alternating flakes.

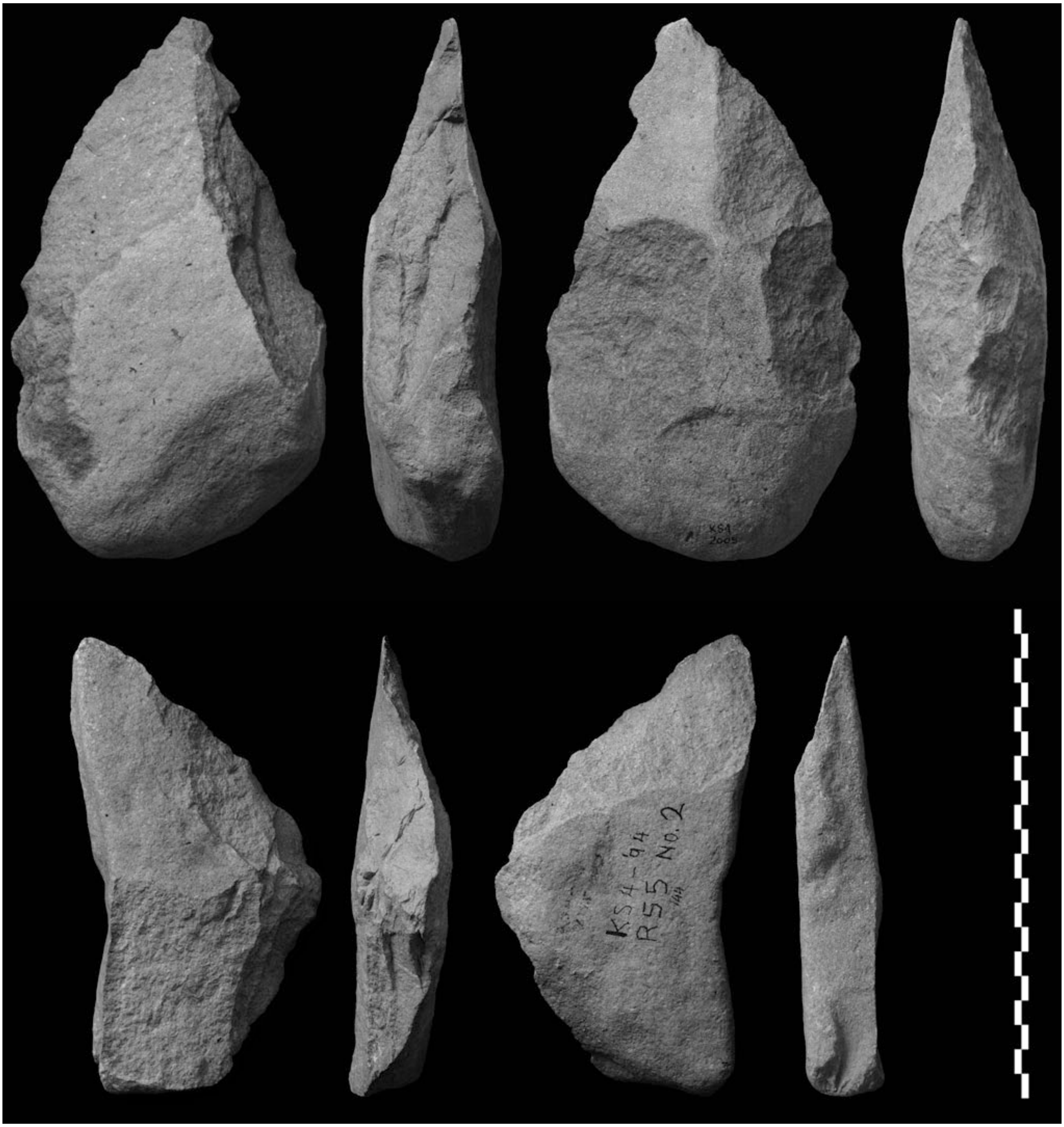


Fig. 3.10 KS4: basic bifacial shaping of a flat cobble and partial bifacial shaping of the half of a split cobble. Direct hard hammer percussion on aphyric phonolite. (Photograph P-JT. MPK/WTAP)

3.7.2.2 Kokiselei 4 (KS4)

The flood clays that yielded the artifacts from KS4 were quite largely depleted by erosion. For this reason, and also because of the low concentration of artifacts, the KS4 site could only be the subject of limited excavations. However, extensive surface collecting was regularly carried out. Numerous refits between the material collected on the surface and the material collected in stratigraphy have validated the consistency of the resulting assemblage (Lepre et al. 2011). Furthermore, these refits are contributing very significantly to the technological analysis of the assemblage, especially by allowing the reconstruction of voluminous objects and the study of their fracturing mode.

The KS4 site is only a few hundred meters away from KS5. It punctuates remarkably the end of the Kokiselei complex, for which all the sites are situated in the Kaitio Member between 1.87 and 1.76 Ma.

The KS4 lithic assemblage presently contains 202 items. Made for 85.3% of aphyric phonolite (for 6.3% of basalt and 8.4% of trachyte), it shows a certain monotony at the petrographic level. This only reflects the sought after module for the blanks, mostly present among the available phonolite cobbles (Harmand 2005, 2012). This assemblage is essentially characterized by the presence of large flakes and heavy tools. These were obtained by débitage, splitting of large aphyric phonolite cobbles and by shaping of the fracturing products, or by direct shaping, unifacial or bifacial, of flat phonolite cobbles (Fig. 3.10). Several refits tell us about the dimensions of the initially selected slabs or cobbles. Overwhelmingly in aphyric phonolite (74%), they reach or exceed 30 cm in length in their long axis (Table 3.4). Direct percussion with heavy hammer of large cobbles resting on an anvil was an effective way to split pieces of this module. The lower faces of flakes or flake fragments bearing the characteristic traces of intentional knapping evidence it, but surprisingly flat, including in areas close to the points of impact.

In the absence of hammers and alongside the heavy fashioned toolkit, the rest of the KS4 assemblage consists of cores and untreated flakes, very variable in size (up to 20 cm), showing, without particular organization, the use of materials often poor in quality.

The heavy shaped equipment of KS4, with 28 elements, includes in particular picks with trihedral (n = 8) or square (n = 3) sections, unifacial (n = 8) or roughly shaped handaxes (n = 3), as well as pieces left as rough outs (n = 6).

The metric and technical characteristics of the large shaped pieces from flat, split, or fractured cobbles on anvil put the lithic assemblage of KS4 in technological discontinuity with the Oldowan in general and with the lithic groups of the sub-contemporary or slightly older sites of the Kokiselei complex.

The technological level revealed by the refits of KS5 is perfectly compatible with that required in the production in its simplest form of a new knapping method, shaping. Thus, this event can be considered as the new milestone of technological developments taking root locally in the Oldowan and remained with or without a future.

In the new area of exploration that opened to the KS4 knappers, the raw material supply was again decisive. Indeed, we will see that the methods of acquisition and standardization of the blanks to be shaped needed tens of thousands of years to take form and establish themselves as techno-cultural markers of the Acheulean.

Thus, the need to bypass obstacles up to then technically insurmountable forced the KS4 knappers to seek new supply sources rich in large module cobbles, flat if possible, which they found in their close environment (Harmand 2005).

KS4: Techniques

The choice of large cobbles is obviously compulsory for those who want to shape tools about twenty centimeters long in their bigger axis. But the selection of large flat cobbles or

Table 3.4 Main metric attributes of the KS4 major tool types; raw materials determination after Harmand (2005)

Shaped tool types	n.	Mean length (mm)	Mean weight (g)	Length range (mm)	Weight range (g)	Raw materials
Trihedral picks	8	197.6	1310.1	160–248	857–2010	aPh2
Diamond section picks	3	202	1356	170–222	1260–1463	aPh1-aPh2
Uniface/cortical str. plat	5	198.2	1124.2	172–220	824–1390	aPh2-aTr1qz
Uniface/fracture str. plat.	3	189.3	1078	170–200	876–1423	aPh2
Bifacial rough out	6	196.6	1210.6	178–227	491–2120	aPh2
Biface	3	216.6	1388.6	195–235	766–1950	aPh2
Total or metric range	28	196–216	1078–1388	160–235	491–2120	74% aPh

the splitting up in the thickness of thick cobbles, with heavy hammer and resting on anvil, have this time allowed the KS4 knappers to overcome a major technological gap to meet the new situation created by the realization of a new concept.

The bifacial or unifacial working, even summary, of halves of thick cobbles previously split and/or fractured on anvil, or of large flat cobbles, involves the use of three variants of the same technique: direct percussion with heavy hammer, direct and passive hammer percussion, direct hard hammer percussion.

The double impact caused by percussion on passive hammer allows fracturing thick cobbles, otherwise unusable, and generates remarkably flat fracture surfaces.

KS4: Sequences

The large flat cobbles, blocks, or split cobbles are then summarily worked by direct unifacial or alternate or alternating bifacial removals of short series of flakes. The study of the heavy KS4 toolkit reflects a rudimentary sequence of removals, whose number never reaches more than 12 on the most elaborate pieces. At KS4, the very basic aspect of the shaping is due to the still deficient representation the KS4 knappers had of the order of the removals to achieve, as well as to a lack of precision in the execution of the technical gestures, and to a lesser extent, to the sometimes very average quality of the raw material worked.

In an attempt to realize a new concept, despite the limits imposed by their know-how of the moment, and the technical space in which they lived, the KS4 knappers followed a similar approach to that of the LA2C knappers. Access to new sources of raw material in terms of morphology and module, if necessary by resorting to splitting the larger cobbles on anvil with heavy hammer, enabled them to acquire and summarily shape the large tools they needed and that their technology did not yet allow them to acquire by débitage.

Technological control of débitage in the three dimensions of space could be demonstrated in KS5. Some tens of thousands of years later, the partial transformation of blanks by bifacial shaping appeared around 1.76 Ma in the neighboring site of KS4. This was another way for the knappers of the time to express technologically their appropriation of three-dimensional space. The selection of a specific module for cobbles and their possible fracturing enabled them once again to overcome their technological deficiencies (Fig. 3.11). Direct percussion with hard stone was then the only technique available at this stage of the chaîne opératoire. It is much later than the sequences were organized, then became standardized and that other techniques appeared in the chaîne opératoire of bifacial shaping.

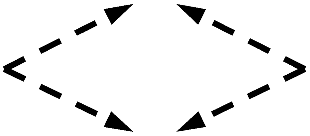


Fig. 3.11 KS4: an uncertain control of the direction of flakes removal and of their mutual organization in bifacial shaping

3.8 Gw1-Isenya Acheulean Site

The multilayered Acheulean site of Isenya is located in the Kajiado district (Kenya), 65 km south of Nairobi, in the Pleistocene sediments overlying the Tertiary volcanic entablatures that border the left bank of the Gregory Rift. Excavated thirty years ago, the seven main levels of Acheulean occupation have yielded an abundant archaeological material. This site is taken as an example here because of the technological characteristics of its lithic assemblages, of their size and their age that has recently been distinctly increased (Durkee and Brown 2014). This recent review now makes it both one of the best-dated Acheulean sites and the most richly documented with regard to the systematic and recurrent use of direct ironwood hammer percussion for shaping large bifacial objects in phonolite(s).

Numerous LCTs (Table 3.5) were collected in seven of the main archaeological layers (Va, Vb, Vla, VIb1, VIb21, VIb22, and VIc1) that succeed each other in the 80 cm thick alluvial deposits of the Pleistocene sequence, and that are topped by recently dated volcanic ashes in the western sector of the excavation.

Based on a substantial experimental program, their technological study (Roche and Texier 1996; Bouthinon 2002) has provided many indications about the acquisition modes of the blanks of these LCTs, their degree of predetermination and the techniques used in the various phases of the representative chaînes opératoires of what can be considered as an Acheulean in full technical maturity. In particular, it was shown that the chaînes opératoires of the two major categories of LCTs widely represented in Isenya are closely intertwined at the level of the acquisition phase of the blank flakes with heavy stone hammer directly on the phonolite outcrops.

3.8.1 Predetermination of Some Blanks

Handaxes: when the shaping has not completely obliterated the knapping traces of the original blank and prevents its interpretation (95%), it appears from this study that the

Table 3.5 Isenya: count and metric characteristics of the LCTs from the main archaeological levels. Handaxes: mean value of the number of removals per face: dorsal (A) and ventral (B). According to data from P-J. Texier and M. Millet (lengths in mm; weight in grams)

Layer	Va	Vb	VIa	VIb1	VIb21	VIb22	VIc1	Total
N. handaxes	90	111	239	108	57	68	5	678
Handaxes mean length/weight	188/624	191/689	199/770	200/817	182/737	166/645	138/402	193/740
Mean removals A/B	9/10	9/10	9/10	9/10	7/9	6/8	4/6	8.6/9.7
N. cleavers	20	97	302	207	217	247	66	1156
Cleavers mean length/weight	167/695	177/897	172/900	168/807	176/850	176/877	165/820	173/857
Total LCT per layer	110	208	541	315	274	315	71	1834

handaxe blanks in Isenya have mostly been flakes with a partly predetermined morphology (Fig. 3.12a). These flakes are both broad and short, with a convex lower side and often hinge termination. 13.6% of them are short flakes, wide, and déjeté, whose butt was often kept in proximo-lateral position at the end of a shortened shaping time (Roche and Texier 1996).

Cleavers: the cleaver on flake cannot be made in series without the perfect control of predetermining flake removals. Thus whatever the ancient age considered, the presence of cleavers on flakes is clearly indicative of the mastery of the predetermination concept, and of a higher level of anticipation to that required to obtain a handaxe, even the most carefully executed (Roche and Texier 1991). The presence of three cleavers on flakes in the lithic assemblage of KGA6-A1 in Konso Gardula could indicate the existence in Ethiopia of an even older Acheulean than at KS4 if the age of 1.75 Ma was confirmed. The cleaver on flake is an asymmetric tool, mostly obtained at Isenya at the expense of a short flake, broad and with a convex lower face, laterally overlapping the negative of removal of a flake predetermining its future terminal bevel. Its final shape is in most cases determined by the rapid implementation by direct hard hammer percussion of a series of alternating removals to take out the plane of the supporting flake butt, then to summarily rectify its delineation (Fig. 3.12b). A distal series of often limited direct removals, also aimed at regularizing and strengthening this edge, fashion the final shape of the tool. The morphological axis of the final piece is perpendicular to the technological axis of the original blank. The bevel created by the removal of the predetermining flake is for the most part spared of any modification, but sometimes voluntarily reduced when working the edges of the tool. Direct stone percussion is the only necessary technique for producing such a tool. The shaping of 4.1% of them however was continued beyond this stage by then using the systematically implemented technique in Isenya in the later stages of the bifacial shaping: direct percussion with an organic hammer (Texier and Roche 1995).

At Isenya, all layers taken into account, on a sample of 949 cleavers, the orientation of the débitage axis of the original blank is identifiable at 91%. In 81% cases (n = 700), this axis makes an angle equal or close to the perpendicular with the morphological axis of the tool. When the orientation of the technological axis of the flake creating the bevel is identifiable (n = 252), it is always parallel or slightly convergent with the axis of the original blank. Their number and these last observations reinforce in a convincing way arguments for a production in series and predetermination.

3.8.2 Techniques and Sequences

Direct heavy hammer percussion is the only technique applied in the unique method of obtaining the LCT blanks in Isenya. It is the only technique that allows to obtain, on the very outcrop of phonolite, flakes whose weight should vary between 1 and 2 kg to make handaxes of a mean weight of 740 g (n = 621, all layers combined) and cleavers with a mean weight of 857 g (n = 948, all layers combined). A skilled knapper can manipulate with two hands with satisfactory accuracy a 5–10 kg stone hammer (Petrequin and Petrequin 1993; Madsen and Goren-Inbar 2004).

The initial phase of the shaping that consists in removing the major imperfections of the blanks (cracks, protuberances, planes, etc.) is done by hard stone hammer direct percussion. It is common to both chaînes opératoires of these two LCTs. This is an essential prerequisite to a bifacial shaping such as that carried out at Isenya because it makes possible the coming into play of the new technique, essential to the smooth running of the following phases. A bifacial balance of the volumes begins to be sketched in this first stage in the selection, direct or inverse, and the location of the very first shaping flakes.

In the presence of characteristic knapping traces of a working by organic hammer direct percussion, reinforced by the results of a large program of experimentation with local raw materials (Roche and Texier 1996; Bouthinon 2002), and in the absence in sub-Saharan Africa of Cervidae whose antlers could provide an alternative solution, percussion with ironwood is the only possible technique to interpret the fine working of these phonolite blanks previously prepared with stone.

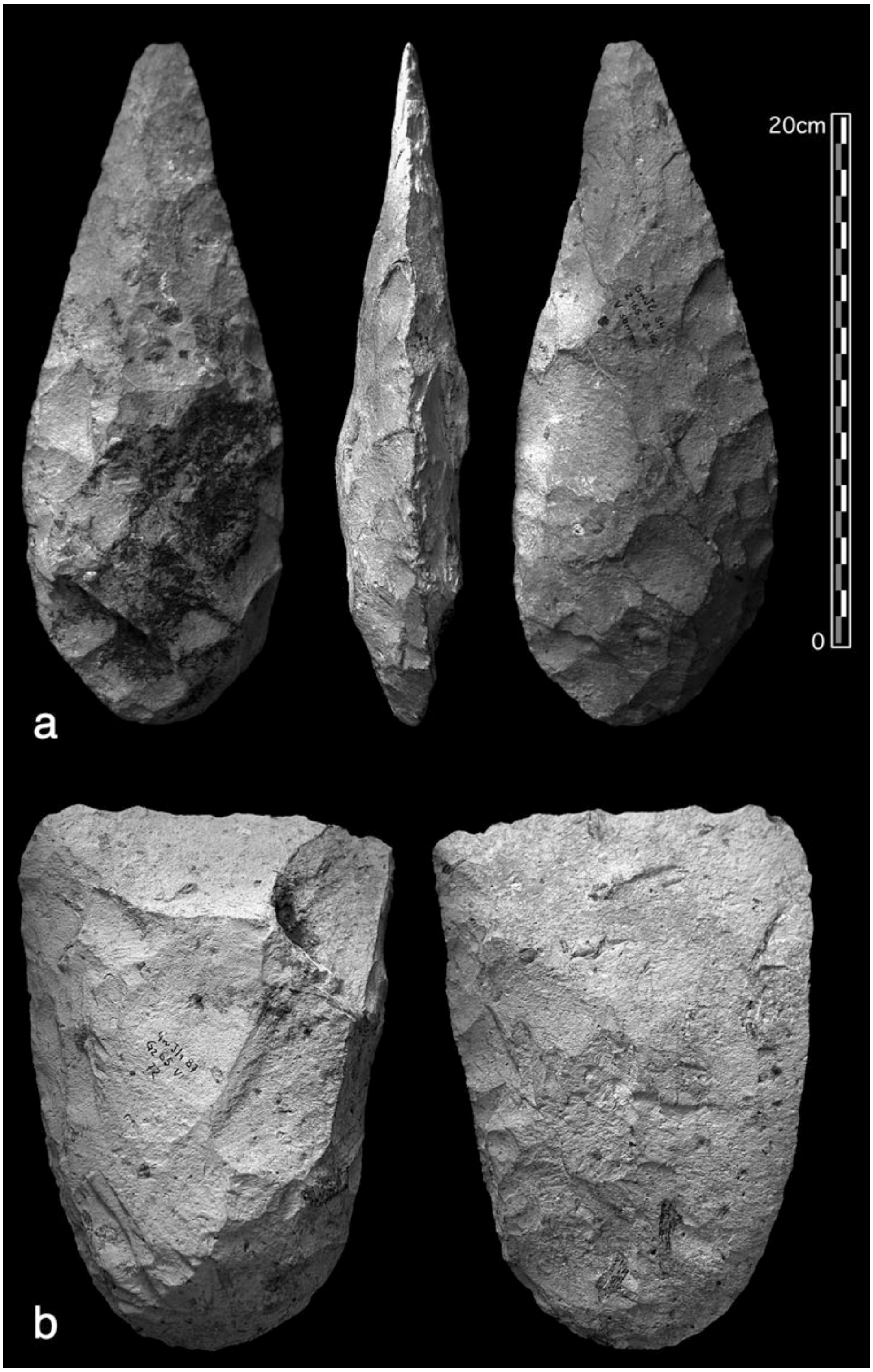


Fig. 3.12 Isenya GwJl1. LCTs in phonolite: lanceolate handaxe (a) and cleaver (b) shaped on flake blanks. Fine-grained phonolite from Kapiti. (Photograph P-JT—MPK/WTAP)

The coming into play of ironwood hammer direct percussion is in itself indicative of a high degree of anticipation from the knappers. One to three generations of thin covering flakes, with concave lower face, were detached. The bifacial balance of the worked piece was permanently established; as for its bilateral balancing, it appeared in the final stages of the shaping. If the worked material allowed it (fine grain), the delineation and the cutting edge of the worked object could be regularized by the carefully controlled removal of small flakes, precisely localized and limited in extent.

At Isenya, the joint production of bifacial pieces and cleavers on flakes was planned up to the choice of the raw material outcrop. The mental images in three dimensions that the knappers had were of great precision. From the outcrop to the finished object, the technical gestures were perfectly controlled, the field of application of the techniques used on these materials was precisely known, and their starting time scrupulously controlled. The shaping of handaxes roughouts by direct percussion with ironwood hammer was a routine operation in GwJl1, while completion by direct percussion with ironwood hammer for 4.1% of the cleavers can be considered as technically over-finished.

Carefully planned knapping operations, a very precise anticipatory vision of the consequences of the technical gesture in three-dimensional space, a perfect mastery of the knapping techniques and their field of application, a well-thought-out scheduling of the technical gestures, and their seriation alternating from one face to another, from one edge to the opposite edge (Fig. 3.13), enabled the knappers of Isenya to realize accurately the mental image of objects made by the hundreds.

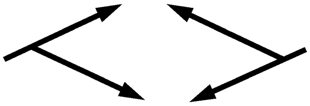


Fig. 3.13 GwJl1: a high level of control is reached removing flakes by mutually organized series in bifacial shaping

3.9 Conclusion

From 3.3 to 1.5 Ma, the species of several types of hominins have rubbed shoulders west of Lake Turkana, in a geographic area corresponding at minimum to that of the sedimentary deposits that have yielded their remains. Since the discovery in Lomekwi 3 of undoubtedly knapped objects, we also have the confirmation that many of these species have practiced hard stone knapping there. These knappers, whose anonymity will probably never be lifted, left behind indisputable evidence, but scattered both in the geographical area concerned and within the time encompassed by the sedimentary deposits involved. However, their technology could only be expressed in a constraining context governed by the laws of solid-state physics. In this context, there were not many alternatives for these early craftsmen, whatever they were, when crossing the technological threshold that could lead to more sophisticated knapping or to the first bifacial shaping. This is what gives cohesion to scattered knapping products and leads us to seek there the regularities that could govern their production mode.

Their examination shows that the slow appropriation of parameters and elementary methods of fracturing rocks suitable for knapping was done according to a recurring mechanism (Fig. 3.14). From LOM3 to KS4, the selection in the near environment of raw materials with specific morphology and module allowed the hominins who were able to develop new knapping concepts to overcome the obstacles that the previously acquired techniques and their field of action at the time did not allow to overcome yet.

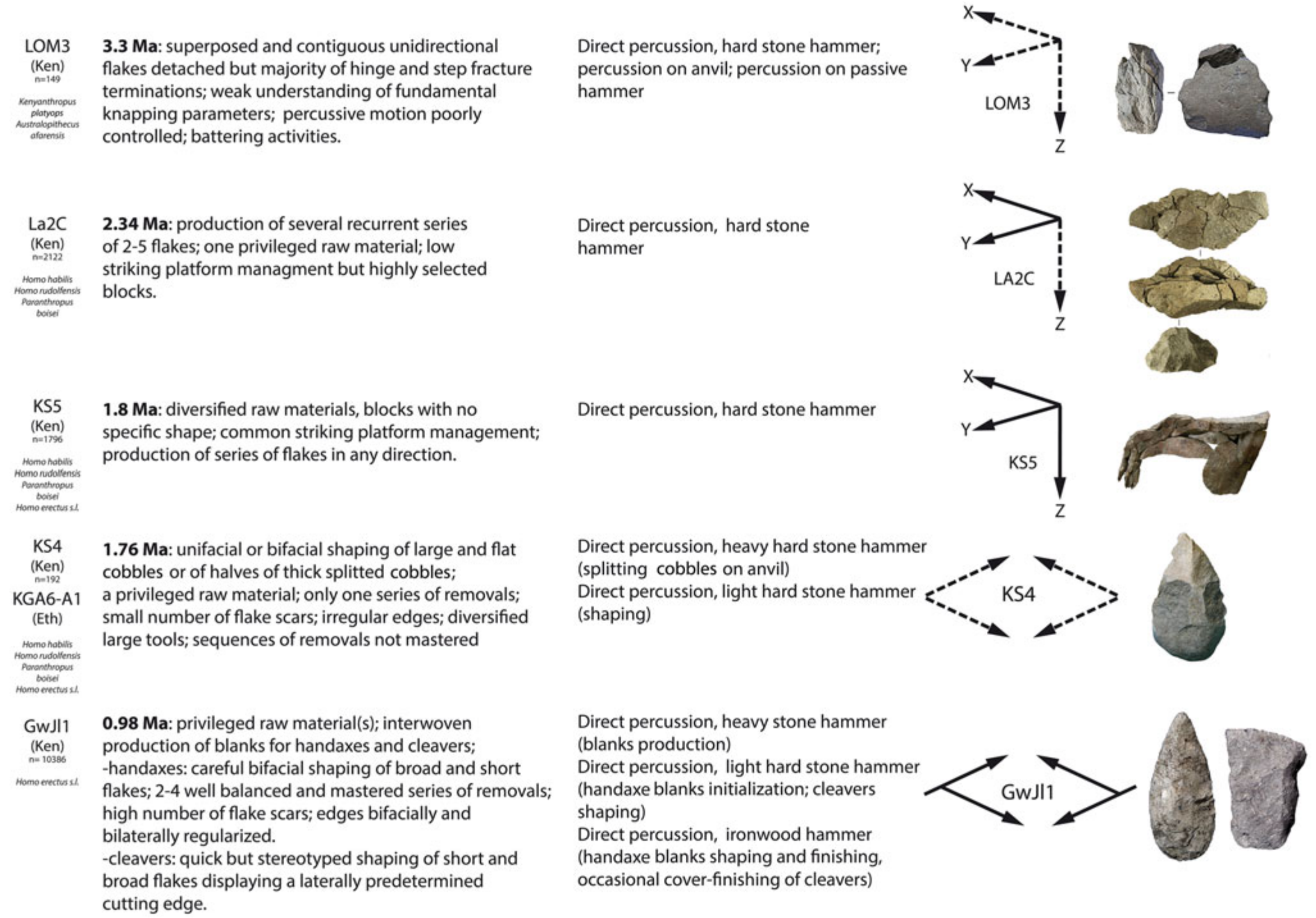
At LOM3, the selection of materials and blocks/cobbles with favorable angulation has allowed, despite a still obviously very uncertain control of the technical gestures, to get the very first short series of flake removals ever done by direct or block on block technique.

A million years later, the rigorous and systematic selection of the morphology of blocks of the best materials available on site, made it possible for the LA2C knappers who had already acquired a remarkable precision in the percussion gestures, without particular preparation or reworking of the cores, to produce short but numerous recurring series of flakes.

Six hundred thousand years later, the KS5 knappers left us concrete evidence of their complete control of the sequence of the technical gestures in the three dimensions of space. A decisive step was taken because it is an essential knowledge to the development of a concept such as bifacial shaping and to the early stages of its technological investigation.

Just a few tens of thousands of years apart, in KS4, the descendants or successors of the KS5 knappers did not master yet percussion on anvil and direct hard hammer percussion. They chose large flat cobbles or the splitting on anvil of large thick cobbles to be able to engage into the uncertain sequences of the first bifacial shaping.

During these early and very long stages of industrious humankind that only had at its disposal a few variants of direct hard stone percussion, the basic knapping parameters were gradually integrated. The slow development of simple but efficient débitage methods, then of shaping still at a rudimentary stage enabled them to invest the volume to be knapped in its entirety. Among the available suitable knapping materials, the selection of blocks with specific morphologies reveals the awareness of these basic parameters such as the formalization of new concepts that the



LOM3 (Ken) n=149 *Kenyanthropus platyops* *Australopithecus afarensis*	**3.3 Ma**: superposed and contiguous unidirectional flakes detached but majority of hinge and step fracture terminations; weak understanding of fundamental knapping parameters; percussive motion poorly controlled; battering activities.	Direct percussion, hard stone hammer; percussion on anvil; percussion on passive hammer
La2C (Ken) n=2122 *Homo habilis* *Homo rudolfensis* *Paranthropus boisei*	**2.34 Ma**: production of several recurrent series of 2-5 flakes; one privileged raw material; low striking platform managment but highly selected blocks.	Direct percussion, hard stone hammer
KS5 (Ken) n=1796 *Homo habilis* *Homo rudolfensis* *Paranthropus boisei* *Homo erectus s.l.*	**1.8 Ma**: diversified raw materials, blocks with no specific shape; common striking platform management; production of series of flakes in any direction.	Direct percussion, hard stone hammer
KS4 (Ken) n=192 KGA6-A1 (Eth) *Homo habilis* *Homo rudolfensis* *Paranthropus boisei* *Homo erectus s.l.*	**1.76 Ma**: unifacial or bifacial shaping of large and flat cobbles or of halves of thick splitted cobbles; a privileged raw material; only one series of removals; small number of flake scars; irregular edges; diversified large tools; sequences of removals not mastered	Direct percussion, heavy hard stone hammer (splitting cobbles on anvil) Direct percussion, light hard stone hammer (shaping)
GwJl1 (Ken) n= 10386 *Homo erectus s.l.*	**0.98 Ma**: privileged raw material(s); interwoven production of blanks for handaxes and cleavers; -handaxes: careful bifacial shaping of broad and short flakes; 2-4 well balanced and mastered series of removals; high number of flake scars; edges bifacially and bilaterally regularized. -cleavers: quick but stereotyped shaping of short and broad flakes displaying a laterally predetermined cutting edge.	Direct percussion, heavy stone hammer (blanks production) Direct percussion, light hard stone hammer (handaxe blanks initialization; cleavers shaping) Direct percussion, ironwood hammer (handaxe blanks shaping and finishing, occasional cover-finishing of cleavers)

Fig. 3.14 Overview: sites; size of the lithic assemblages; hominins; age and main technological features of the lithic assemblages; knapping techniques; level of technological control of the three directions of space. Dotted arrows: low technological control of the exploitation of the concerned volumes and sub-volumes; plain arrows: full technological control of the concerned volumes or sub-volumes. This last is a fundamental component of the corresponding technical system of lithic production

know-how of the time did not yet allow to formalize in all circumstances.

Circumvention of the technical barrier by selecting appropriate modules and morphologies is the regularity that characterized the first technological advances for 1.5 Ma. It allowed materializing new concepts with a relatively low technological level but it prefigured the control and the rational ordering of the technical gestures in knapping or shaping methods, which occurred much later.

The study of the large cutting tools from the Acheulean site of Isenya vividly shows how, seven hundred thousand years later, what remained was only an attempt, perhaps without future at KS4, turned into a standardized production. The recently established correlations between the ash deposits bracketing the Acheulean bearing layers from Isenya, Kariandusi, and Olorgesailie Formations shed new light on the chronology and flexibility of the Acheulean technologies toward local raw materials in or on the slopes of the meridional section of the Kenyan Rift Valley. For example, comparing assemblages from Olorgesailie (H9A, DE89B…) and Isenya, one can notice the remarkable knowledge that the Acheulean knappers had of the module, fracturing and splitting properties as well as of the strength, hardness and flakability of specific raw materials. At Olorgesailie, the bifacial chaîne opératoire was adapted to the tendency to split of the local trachyte.

Isenya is undoubtedly both the oldest and best-dated Acheulean site, where an in-depth technological study demonstrated the systematic use of ironwood hammer direct percussion when shaping bifacial roughouts and during the finishing touches (Roche and Texier 1996). This technical innovation denotes an excellent knowledge of the mechanical properties and weaknesses of the large worked phonolite blanks. It is also in itself a very strong assessment component of the level of anticipation that some Acheuleans showed, both in the preparation and maintenance of soft hammers and in the predetermination of the blanks to be worked.

With a still approximate knowledge of the properties of the worked materials and with a limited technical range and know-how, the KS4 craftsmen had to compromise with the module and morphology of the available materials to try to realize new projects that went far beyond their technical capabilities of the time.

The technical behavior of knappers like those of Isenya clearly differentiates them from that of their predecessors from Turkana, in the fact that the obstacle to be overcome to realize such a complex project as the production in series and simultaneously of LCTs was no longer circumvented but technically eliminated. The complexity of the project and the technical innovation (direct percussion with ironwood hammer) that accompanied its realization, are two revealing elements of a profound change in the relationship of the knapper to the raw material. The chaîne opératoire analysis of the Isenya's LCTs clearly shows that from 1 Ma in this part of East Africa, the knappers had already conceptually and technically fully subjected some of the materials suitable for knapping in their environment.

The conceptualization and realization of large shaped Acheulean tools are the result of a long technological exploration deeply rooted in the Oldowan. The accessible evidence, scattered in time, shows us how in a constraining technological context the first craftsmen of humankind have been able to appropriate a three-dimensional knapping space where new concepts could take shape.

A more demanding selection of raw materials, an organized layout of the better controlled technical gestures, looking for better balanced shapes and the ability of the knappers to project in a longer time have created a favorable context for the development of a new technique such as direct percussion with organic hammer.

The control and strict delimitation of the field and time of action of the available techniques, a stereotyped execution of the technical gesture proper to each of them, allowed the mass production of large technically standardized cutting tools. What the refits of KS5 prefigured, that the knappers were not as dependent on the morphology of materials suitable to knapping available in their environment, had become a reality.

Around 1.76 Ma, the formulation of a still technically unfeasible new concept momentarily reactivated this dependency. From 1.76 to 1 Ma, the technical background of the knappers expanded considerably. The field, the area of action, and the starting order of the techniques have gradually been defined. The Acheulean knappers then disposed of the technical knowledge and know-how to engage in the mass production of technically standardized tools. Knapped stone technology shifted into another world, which already was or was about to become that of a single species of hominin: *Homo erectus s.l.*

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