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# Were Olduvai Hominins making butchering tools or battering tools? Analysis of a recently excavated lithic assemblage from BK (Bed II, Olduvai Gorge, Tanzania)

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ABSTRACT

A new interpretation of early stone-tool use by hominins at Olduvai depicts them as involved in battering activities (using pounding tools) rather than making cutting butchering tools as is commonly inferred in most other Plio-Pleistocene sites where lithics appear associated to faunal remains. The bulk of this interpretation is based on the recognition of the stigma of percussion activities in anvils and detached by-products. Renewed excavations at BK after more than half a century of the beginning of the digging at the site by M. Leakey have produced a new and unbiased lithic assemblage. The taphonomic study of the faunal assemblage has shown that BK is an anthropogenic site where carcass butchery practices were repeatedly performed over a vast amount of time. The present analysis of the lithic artefacts supports this interpretation by showing that the obtainment of flakes was the principal aim in stone knapping. We argue that a number of technical traits observed in the lithic collection of BK can be best interpreted as the result of bipolar loading rather than the by-products of battering activities. Since BK has provided the second largest collection of hominid-modified bones from Olduvai, it is concluded that detached pieces produced in the course of bipolar reduction might have played an active role in bone modification and that active rather than passive percussion behaviors might have been responsible for the formation of the lithic assemblage. The functionality of the Oldowan stone tools are discussed under the light of the new study.



## Introduction

The function of the early stone tools from Olduvai Gorge has always been implicit in previous lithic categorizations. Leakey (1967, 1971) established a typology mostly based on heavy-duty tools. The subsequent revision undertaken by Toth (1985) argued that flakes constituted the main goal in Oldowan stone knapping. More recently, de la Torre and Mora (2005) have criticized both interpretations and argue that the bulk (>80% of raw material weight) of artifacts in several sites from Olduvai Gorge, during Bed I and Bed II times, are percussion tools (hammerstones and anvils) or the by-product of battering activities (debris, angular fragments). These interpretations, usually made using exclusively the information derived from the analysis of lithic assemblages, have to be reconsidered now within the taphonomic and palaeoecological interpretations of the sites in which those assemblages were found.

Recent taphonomic re-analyses of all the Olduvai Bed I sites have shown that with the exception of FLK Zinj, the remaining sites were palimpsests with minimal hominid input in the accumulation and modification of archaeofaunas (Domínguez-Rodrigo et al., 2007). An extension of this analysis to all Bed II sites has also shown that with the exception of BK, all faunal assemblages in those sites were either too poorly preserved to evaluate or accumulated by biotic agents other than hominins (Egeland and Domínguez-Rodrigo, 2008). Therefore, lithic assemblages would be expected to vary between anthropogenic sites (FLK Zinj and BK) and the other Olduvai palimpsests. The analysis of the lithic assemblage from FLK Zinj has shown a wealth of flakes, as well as of other flaked artifacts, which support the taphonomic interpretation of the site as a place where repeated butchery episodes took place (Domínguez-Rodrigo et al., 2007). The tool kit for the carcass processing history taphonomically identified is present at the site.

A recent re-excavation of BK and the subsequent taphonomic study of the fauna support a similar functional interpretation of the site, with multiple butchery episodes by hominins identified across a much larger stratigraphic sequence than at Zinj (Domínguez-Rodrigo et al., submitted for publication). Therefore, it would

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be expected that the BK lithic assemblage would also reflect this functional interpretation. Recently, a study of selected artifacts from BK by de la Torre and Mora (2005), assuming without proper justification that all of it was highly biased given its fluvial context (*contra* recent evidence in Domínguez-Rodrigo et al., submitted for publication), yielded interesting results. The authors argued that discoid and Levallois methods were common in the exploitation of cores. They also argued that there was a double strategy by knapping hominids to extract small flakes (3–5 cm) and large flakes to be used as blanks for handaxes. The former strategy was more common than the latter. Large nodules and blocks were also used to craft heavy-duty artifacts. In contrast with most of the sites analyzed by these authors, where they inferred battering as the main reason for artifact production and discard, at BK they identified flake production as the target of stone knapping. This initially supports the interpretation that stems form the taphonomic study of the faunal assemblage where butchery is the sole activity inferred and cutting tools must have been necessary to accomplish it.

The BK (Bell's Korongo) site was found in 1935 at the top of Bed II in lateral connection with a tuff (Tuff IID) that was dated to 1.2 Ma (Leakey, 1971; Hay, 1976). It was the first site selected by the Leakeý s for extended excavation in search of a living floor or camp base (Leakey, 1965). The clay, silts and sands that contain the archaeological deposit represent the fillings of a riverine system responsible for the erosion of Tuff IID, which the site overlies. Several visits, minor excavations and selective surface and *in situ* collections were carried out in 1952, 1953, 1955, 1957 and eventually in an extensive and less selective excavation in 1963. The excavations (totaling 10 trenches) revealed a very rich assemblage of stone tools and bones amounting to over 6800 lithic pieces, including 652 whole flakes, 721 tools and almost 400 pieces of utilized material, according to Leakey (1971). Despite the presence of handaxes, this assemblage was classified as belonging to the Developed Oldowan B complex (Leakey, 1971, 1976). About 2900 faunal remains were also unearthed, of which Bovidae, Equidae and Suidae are the most abundant groups. Pieces of ostrich eggshell were unusually plentiful.

In the summer of 2006, our team resumed excavations at BK. A 10 m × 3 m trench was opened between Leakey's Trench 4 and the Trench 5–6–7 set (Figs. 1 and 2). The excavation was conducted with small hand tools during the excavation of the fossiliferous levels and with larger tools in the sterile sections of the sequence. Sediments were completely sieved and every visible fragment was collected. We retrieved more than 6000 bones and 1500 flaked stone specimens, i.e., many more faunal remains than Leakey recovered in all trenches combined, compared to our much smaller

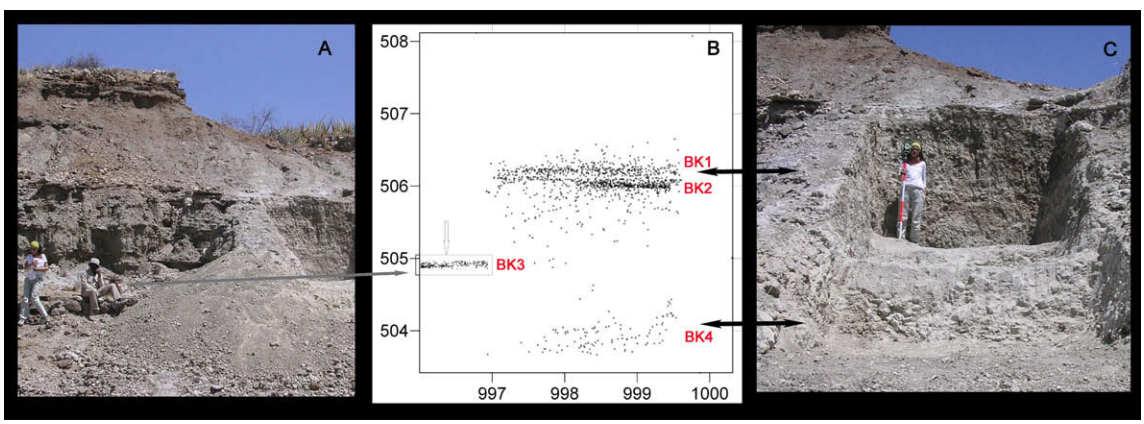


**Fig. 1.** Spatial distribution of the archeological materials excavated at BK. A: Leakey's trench on the left (people are sitting at exhibit level, BK3), and our trench on the right. B: spatial distribution of artifacts and fossils as seen from the front of our trench showing the four levels: the exhibit level (corresponding to BK3) is shown in a rectangle on the left to indicate the level at which it was found outside the trench. C: the profiles of BK and the location of each level.

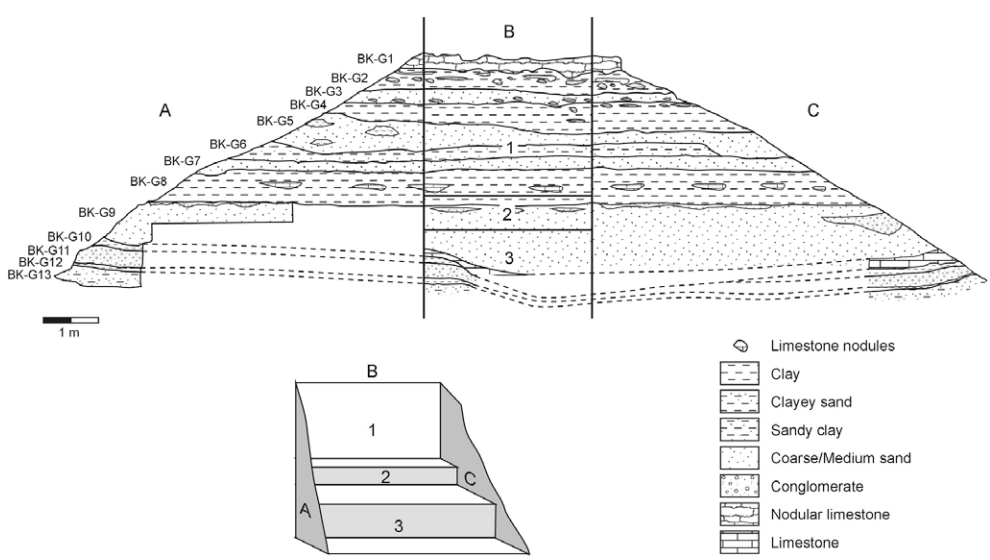


**Fig. 2.** Geological column in the excavated trench.

trench. This suggests selective collection of materials by prior excavations. This is supported by Kyarás (1999) remark that of the 12,000 original lithic pieces retrieved from BK only slightly more than 4000 were stored in the Nairobi National Museums of Kenya. Leakey himself (1965) admits that selective recovery took place at BK given the limitation of resources.

Leakey (1971) reported that the average thickness of the archaeological deposit at BK was 5 ft. (ca. 1.5 m). In our excavation, we documented the overall depth of deposit as 3 m; twice that reported previously (see further description of levels in Domínguez-Rodrigo et al. (submitted for publication)). Furthermore, a total of three clearly differentiated archaeological levels were detected in our trench during excavation (BK1, BK2 and BK4). A possible fourth level (BK3), represented by the exhibit level exposed by Leakey in the adjacent trench, did not occur in our trench because of the presence of the main body of the channel upon which it rests at the exhibit level. If we consider this as a separate level, then initially four archaeological levels can be distinguished. We do not know if the exhibit level is different from what we identified as the *Pelorovis* level in our trench. It certainly occurs above it and the channel sediments in which it is embedded barely contain any fossils in the excavated part of our trench. For the sake of objectivity and given that it was not located in our trench, we keep the exhibit level separate in the present analysis.

It is difficult to classify Leakey's BK collection according to these newly-documented levels, but it surely comprises the lowermost two levels – the *Pelorovis* level (BK4) and the exhibit level (BK3) – since they span 1.5 m in depth as reported by Leakey (1971), and they present similar taphonomic properties to those levels documented by our field research.

In the present study we report the results of our study of the artifact assemblage from the recent excavation at BK. The bulk of the assemblage was found in BK3 and BK4. Our study confirms only partially de la Torre and Mora's conclusions on BK. Their study was based upon a re-examination of a selected sample of Leakey's collection and, therefore, it is incomplete. Our re-excavation of the site has shown the significant role of bipolar technique within the stone reduction strategies implemented at BK, a technological trait not reported nor mentioned by these authors. Furthermore, in line with our experience with the BK bipolar materials, we argue that there are reasons to claim that the objects and technical traits interpreted by Mora and de la Torre (2005) in other Bed I and Bed II sites (such as FLK North, TK, and FC West) as passive percussion tools (anvils) or the by-product of battering activities (debris, angular fragments) can be alternatively also interpreted as part of the bipolar reduction universe. The diagnostic features of both processes may overlap significantly. Untangling this equifinality may be of paramount importance to interpret the Olduvai lithic assemblages. Our interpretation of the BK assemblage has important technological and behavioral implications for the recognition of the central role played by the bipolar technique in those ESA sites where tabular quartz blocks were very abundant (as is the case in Olduvai Gorge). Raw material characteristics might have encouraged hominins to use this reduction technique as an expedient, but efficient solution for producing cutting tools, probably aimed at meat processing.

## The lithic industry of BK

A total of 1575 lithic artifacts were unearthed from our excavation at BK. Table 1 shows the distribution of these objects sorted out by archaeological level and raw material type. Contrary to what is documented with fossil bones (Domínguez-Rodrigo et al., submitted for publication), almost 67% of the lithic sample studied here comes from the two lowermost levels, the exhibit level (BK3, 40%) and the *Pelorovis* level (BK4, 27%). As it is also shown in Table 1, the predominant raw material type documented in the four levels is quartz (ranging from 92.12% of the lithic sample recovered in BK1 to 97.9% in BK4). We have included in this category very few fine-grained specimens that show evidence of metamorphization and that we have defined as quartzite (0.53% of the total objects counted in the quartz category). Other raw materials such as hyaline quartz (representing a mean of 2.05% per level), basalt (2.44%), nephelinite (1%) contribute in a much lower percentage to the general count. The representation of chert and gneiss is marginal. Petrographic characterizations, outcrop sourcing and experimental studies on the flaking properties of the main rock types found at Olduvai have been already reported elsewhere (Hay, 1976, Jones, 1994). The main outcrops for quartz come from the Precambrian formations of Naibor Soit (about 3.5 km to the north of the confluence of the two gorges) and Naisiusiu Hills (12 km away). Most quartz is hard and coarse-grained, and occurs in tabular blocks or slabs with laminations (Hay, 1976: 11). Hyaline quartz comes from quartz dikes and was probably originated from hydrothermal deposits. Among the volcanic-lavic rocks, basalt outcrops can be found in the river channels that flow from the slopes of the volcano Lemagrut, located to the south of the Gorge. They occur in pebbles and boulders that vary substantially in flaking properties. Nephelininte comes from the Sadiman volcano, to the south of the basin, and occurs in cobbles found in river channels flowing towards the east.

The main artifact categories recognized in our analysis are the following (Fig. 3): (1) Manuports/hammerstones. Manuports include natural pebbles of various materials not showing traces of human modification but retrieved in archaeological contexts in absence of evidence of physical transportation by geological processes. Hammerstones include cobbles showing percussion stigma such as pitting, scaring or crushing in part of their surface. Two different knapping methods have been recognized at BK, freehand and bipolar. Since the by-products obtained by the use of both methods show fundamental differences concerning fracture mechanics and technical traits, the objects have been studied separately. The freehand technique artifact set includes (2) cores/fragments, and (3) detached objects. Detached objects consist of plain flakes, flake fragments and retouched flakes. Flake fragments are those pieces in which some diagnostic traits of conchoidal freehand fracture can be recognized (dorsal patterns, flat ventral sur-

**Table 1**
Distribution of raw materials by archaeological levels at BK.

| | BK 1 | | BK 2 | | BK 3 | | BK 4 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| Quartz | 199 | 12.63 | 297 | 18.85 | 578 | 36.69 | 415 | 26.34 | 1489 | 94.53 |
| Hyaline quartz | 9 | 0.57 | 12 | 0.76 | 2 | 0.12 | – | – | 23 | 1.46 |
| Basalt | 4 | 0.25 | 10 | 0.63 | 21 | 1.33 | 6 | 0.38 | 41 | 2.6 |
| Nephelinite | 3 | 0.19 | 2 | 0.12 | 13 | 0.82 | 1 | 0.06 | 19 | 1.2 |
| Chert | – | – | – | – | – | – | 2 | 0.12 | 2 | 0.12 |
| Gneiss | 1 | 0.06 | – | – | – | – | – | – | 1 | 0.06 |
| Total | 216 | 13.71 | 321 | 20.38 | 614 | 38.98 | 424 | 26.92 | 1575 | 100 |

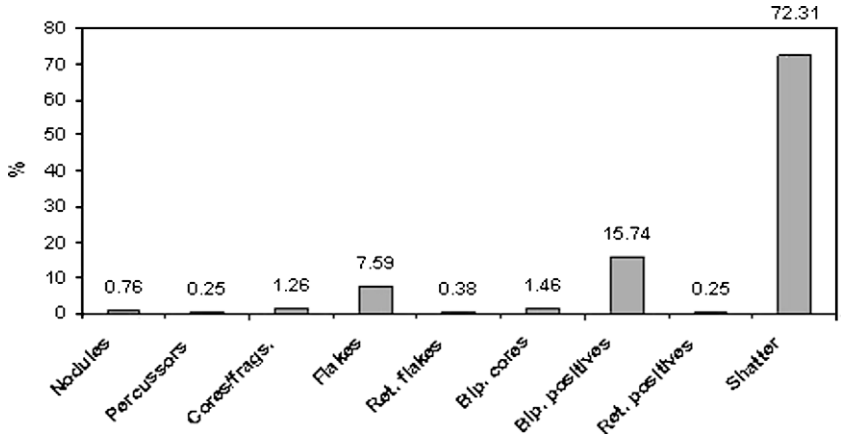


**Fig. 3.** Percentages of artifact types from the BK lithic assemblage.

faces, unidirectional compression rings, striking platforms or bulbs of percussion), and have been classified, depending the location of the fracture (proximal, distal or lateral), into nine different types according to Bernaldo de Quirós et al. (1981): Fig. 9). Bipolar objects have been classified as (4) bipolar cores and (5) bipolar flakes/positives (including complete flakes, undetermined bipolar flakes larger than 25 mm, and secondary modified bipolar flakes). A last category, (6) shatter, includes the by-products of knapping activities smaller than 25 mm. Shatter, that is, angular fragments (Leakey, 1971), debris (Sullivan and Rozen, 1985) or blocky debris (Bradbury and Carr, 2004), include mainly angular detached products lacking basic diagnostic attributes (such as the identification of ventral and dorsal faces). Shatter is, thus, a distinctive category, different from flake fragments or undetermined bipolar positives (where both the knapping method and artifact category have been recognized), and from core fragments (Isaac and Harris, 1997). Shatter ($n = 1139$) represents 72% of the collection retrieved in the recent excavation. About 11.23% of shatter comes from BK1, 11.41% from BK2, 44.51% from BK3, and 32.83% from BK4. All these specimens have been individually examined, and included in one of the four dimensional groups established: 52.32% of angular fragments are $\leqslant$10 mm, 26.86% $\leqslant$15 mm, 12.37% $\leqslant$20 mm, and 8.42% $\leqslant$25 mm. All the objects included in this category are made of quartz. As has been reported by experimental work, blocky debris are quite common by-products for both freehand and bipolar reduction methods. Both techniques produce similar percentage of shatter, ranging from 20% to 40% (Amick and Mauldin, 1997; Bradbury and Carr, 2004; Kuijt et al., 1995). Taking into account this percentage range, it seems that shatter is overrepresented in BK and shows a much less disturbed depositional context for the site than inferred by de la Torre and Mora (2005). Provided that bipolar and freehand techniques produce shatter in similar proportion, it would be a spurious task to assign each of these items to a particular reduction method. Since both of them are represented in the sample excavated by us, shatter may refer indistinctly to bipolar of freehand reduction. Therefore, we have not included shatter in our technological study.

About 99% of the collection retrieved by us from BK is mint fresh, showing no signs of abrasion and polishing in edges and surfaces. Even shatter shows mint fresh breakage patterns, clearly distinguishable from those natural rounded gravels reported by other authors in collections made up of similar rock types and located in analog alluvial deposits (de la Torre, 2004). We therefore infer a fairly undisturbed context for the lithic assemblage from a post-depositional point of view.

The detailed technological analysis presented here, thus, has been undertaken with a total number of 436 lithic objects (Table 2). According to the representation of all artifact categories (except shatter) sorted out by raw material type, quartz, in agreement with its predominance in the four levels, is dominant in all the artifact classes and reduction methods (Fig. 4). However, quartz was barely used for percussion activities. Although this material is well represented in freehand knapping, it appears that it was the exclusive rock selected by hominins for undertaking bipolar reduction (see below). Conversely, lavas have been widely used in percussion activities and in freehand reduction, being absent in the bipolar knapping sample. This is in agreement with other authors who have already pointed out that lavas are not suited for bipolar reduction (Toth, 1982: 126).

## Manuports and hammerstones

A total number of 16 objects have been included in this category. Non-modified objects include six natural chunky nodules/manuports on porous basalt recovered in BK2–BK4, and one small basalt pebble from BK2. Another small natural pebble from BK2 shows clear *de visu* damage patterns of thermo-alteration, such as deep fissures, cracks and external surface decoloration Clemente-Conte,

**Table 2**
Number of analyzed artifacts distributed by lithic category, level and raw material.

| | NODS/HAMMERSTONES | | | | CORES/FRAGMENTS | | | | FLAKES/RET. FLAKES | | | | BIPOLAR CORES | | | | BIP. POS./RET. POS | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BK1 | BK2 | BK3 | BK4 | BK1 | BK2 | BK3 | BK4 | BK1 | BK2 | BK3 | BK4 | BK1 | BK2 | BK3 | BK4 | BK1 | BK2 | BK3 | BK4 | |
| Quartz | – | – | 1 | – | 1 | – | 7 | 2 | 14 | 22 | 33 | 15 | 3 | 6 | 7 | 7 | 55 | 139 | 23 | 17 | 352 |
| Hyaline Q. | – | – | – | – | – | – | – | – | 2 | 1 | 2 | – | – | – | – | – | 7 | 11 | – | – | 23 |
| Basalt | 1 | 5 | 5 | 1 | – | – | 4 | 1 | 1 | 5 | 12 | 4 | – | – | – | – | – | – | – | – | 39 |
| Nephelinite | 1 | – | 1 | 1 | – | – | 4 | – | 2 | 2 | 8 | – | – | – | – | – | – | – | – | – | 19 |
| Chert | – | – | – | – | – | – | – | – | – | – | – | 2 | – | – | – | – | – | – | – | – | 2 |
| Gneiss | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Total | 2 | 5 | 7 | 2 | 2 | – | 15 | 3 | 19 | 30 | 55 | 21 | 3 | 6 | 7 | 7 | 62 | 150 | 23 | 17 | 436 |

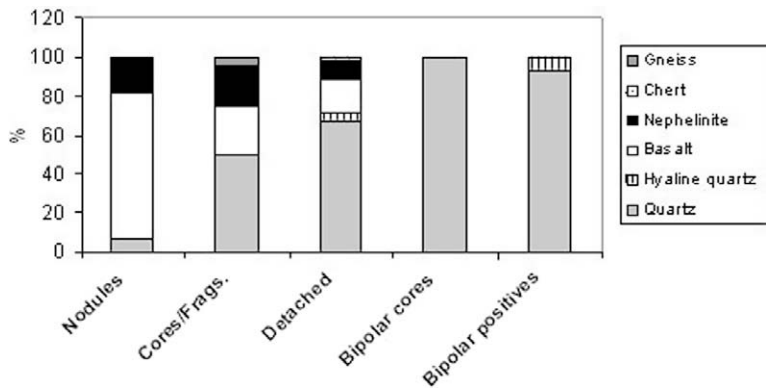


**Fig. 4.** Percentages of raw material sorted out by artifact category.

1997; Gómez de la Rúa, 2006). Another four nodules (all of them lavas from BK1 and BK4), despite showing good ergonomic conditions for their use as hammerstones, do not bear any pattern of percussion damage, such as surface scars or battered areas. We have unearthed four items for which percussion activities can be inferred and whose mean dimensions are 82 × 59 × 52 mm and 400 g of weight. This meager sample includes a quartz spheroid from BK4, a well-known classic type in normative Oldowan typological lists that is now interpreted by some authors as the final morphological stage of a recurrent pounding process that generates intense scarring and battering of the external angular/rounded surface of the original blank (Jones, 1994; Sahnouni et al., 1997; Schick and Toth, 1994). Two other lava items from BK3 and BK4 show clear battering signs in discrete cortical areas and some isolated surface scars probably detached by impact. Finally, another object recovered from BK3 has attracted our attention. It is a sub-rectangular basalt cobble, whose dimensions are 83 × 52 × 45 mm and 319 g of weight that presents intense and concentrical battering and pitting on its flattest, central, and most stable surface. While hammerstones used for freehand knapping tend to show battering on the edges, bipolar hammerstones show this kind of modifications on their flat surfaces (Honea, 1965: 264). This object could have been used as a hammerstone involved in bipolar percussion or could have even acted as a stationary anvil (Fig. 5).

*Freehand knapping*

*Cores and fragments*

A total of eight fragments have been retrieved from BK2–4, being this sub-category most abundant in BK3. Most of these items (62.5%) are made in lavas, although some quartz and one gneiss fragment have also been recorded. The bulk of the identified specimens are small core fragments and it has not been possible to identify the reduction model from which these objects were made. Another specimen that shows some traces of battering might correspond to a hammerstone fragment.

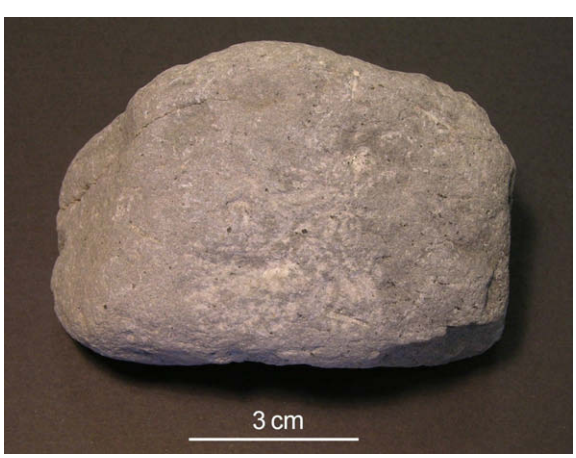


**Fig. 5.** Hammerstone/anvil from BK3.

Freehand cores include 12 artifacts. Table 3 shows their percentage according to each level and their mean dimensions and weight. In general, cores show traces of intensive exploitation. This is a pattern that is most evident in BK3. The mean number of negative scars per core is 9.8. The mean dimensions of these scars are 33.63 × 28.81 mm, well in accordance with the mean dimensions observed in freehand detached products. The reduction strategies have been defined according to two complementary attributes: faciality (the number of faces or knapping surfaces that have been subject of exploitation) and polarity (the number of poles or directions observed in the negative scar patterning). The combination of these two attributes has permitted to recognize the following reduction models (Fig. 6):

*Multifacial/multipolar.* This reduction strategy is commonly known as polyhedrons in classic Oldowan typologies (Leakey, 1971). These are cores showing a multifacial and multipolar reduction of the blanks, including negative scars in, at least, three different planes or faces organized in a minimum of three different directions. These cores constitute the most abundant reduction model, contributing to 58% of the sample studied here. Polyhedrons have been found in the three levels that have yielded freehand cores and include the largest items of the category (mean dimensions and weight are 73 × 64, 57 × 56 mm and 404 g). The rock types selected for carrying out the multifacial/multipolar reduction strategy are quartz (42%), basalt (29%) and nephelinite (29%). All the polyhedrons retain some cortical areas on their exploited surfaces.

*Unifacial multipolar centripetal.* These cores show a discoid or centripetal exploitation in the whole perimeter of one flaking surface of the cobble. This reduction strategy shows no need of preparation of striking platforms and, therefore, the exploitation takes place from a natural, non-prepared and non-hierarchizied surfaces. The

**Table 3**
Mean sizes (mm) and weight (g) of freehand cores sorted by level.

| | % | Length | Width | Thickness | Weight |
|---|---|---|---|---|---|
| BK1 | 8.33 | 79 | 75 | 63 | 448 |
| BK2 | 75 | 58.44 | 49.22 | 41 | 254 |
| BK3 | 16.66 | 75 | 63 | 49.5 | 295.5 |
| Total | 100 | 70.81 | 62.4 | 51.16 | 332.5 |

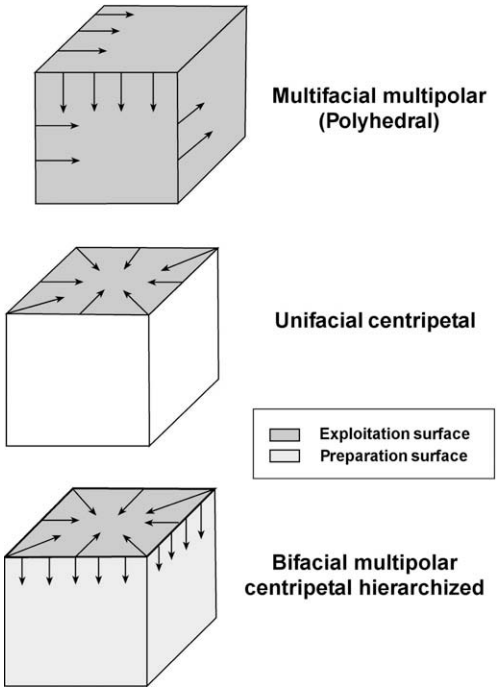


**Fig. 6.** Schematic representation of the freehand reduction models recognized in BK.

intersection of the non-prepared striking platform and the exploitation surface shows a simple angle. One quartz artifact from BK4 has been included in this reduction model (83 × 63 × 48 mm).

*Bifacial multipolar centripetal hierarchized.* According to Boëda (1995: 46), the volume of these cores is divided into two asymmetrical convex surfaces. The intersection of both surfaces generates a plane. Both surfaces are hierarchized; that is, the upper surface is aimed at the production of flakes while the lower surface serves for preparing the striking platforms. The role of both surfaces is not reversed and the intersection plane created by the two surfaces is perpendicular to the flaking axis of the predetermined flakes. Four small quartz cores thus knapped have been retrieved from the exhibit level (BK3). The main dimensions and weight of these centripetal hierarchized nuclei are 40.25 × 32.25 × 22.5 mm and 37 g. Two of them are completely exhausted. Negative scars of the preferential flakes exhibit a mean dimension of 22 × 21 mm. The exploitation or the upper surface shows a simple angle with respect to the intersection plane, while the preparation or lower surface shows an abrupt angle (Fig. 7).

*Detached objects*

*Flakes and flake fragments*

A total of 119 objects have been included in this group: 70 whole flakes (6 of which are core tables), 16 flake fragments and 33 debris or flakes whose main dimension is always ⩽20 mm. The mean dimensional values and weight of whole flakes and the percentage of these objects sorted out by level are shown in Table 4. Most flakes have been detached from quartz cores (65.54%), followed by basalt (18.48%), nephelinite (10%) and hyaline quartz (4.2%). Two chert debris (1.6%) have been retrieved from BK4. These pieces, together

**Table 4**
Mean sizes (mm) and weight (g) of freehand whole flakes sorted by level.

| | % | Length | Width | Thickness | Weight |
|---|---|---|---|---|---|
| BK1 | 15.96 | 27.8 | 28.46 | 9.33 | 10 |
| BK2 | 22.68 | 31.25 | 28.68 | 9.47 | 15.36 |
| BK3 | 44.53 | 34.69 | 30.65 | 10.82 | 14.55 |
| BK4 | 16.8 | 33.36 | 27.09 | 9.09 | 10.33 |
| Total | 100 | 31.77 | 28.72 | 9.67 | 12.56 |

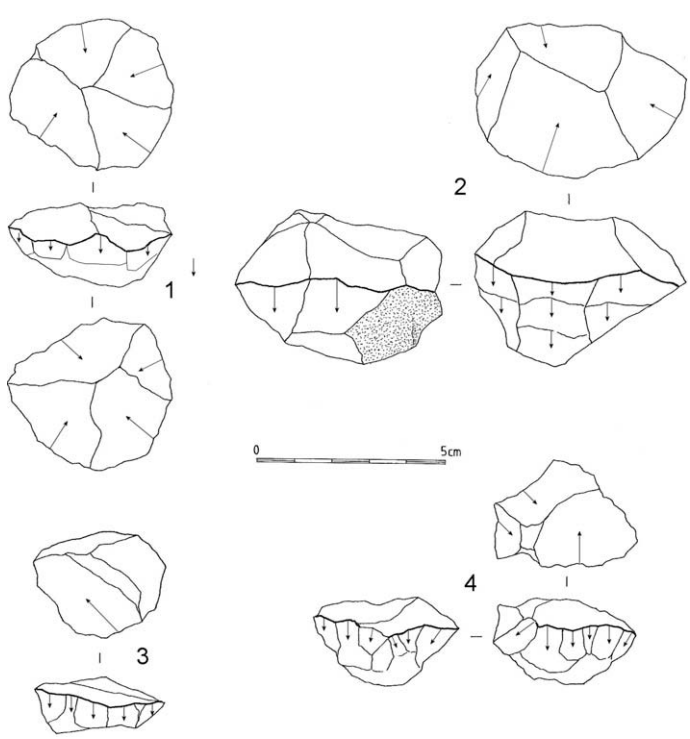


**Fig. 7.** Bifacial multipolar centripetal hierarchized cores from BK3.

with the core fragment retrieved by M. Leakey in her excavations (Leakey, 1971: 221), are the sole evidence of chert manipulation at the site. Most of the flakes retrieved from BK fall within a similar dimensional pattern; that is, detached pieces are slightly larger than wider, mainly ranging from 28 to 35 mm of length. When sorted out by raw material type, no apparent variations can be observed in the dimensions of flakes. However, larger flakes have been detached from basalt nodules (mean 35 × 32×10 mm), while the smallest and thinnest come from hyaline quartz (mean 27 × 22 × 9 mm.). The mean dimensional values of flakes detached from the various types of rocks show, therefore, variation ranges that cannot be considered representative of different dimensional objectives. Hominins at BK were recurrently obtaining small freehand products (a range of 20–40 mm of length) regardless of the type of raw material and the reduction strategy selected. Although the core sample is not representative enough (due to the small number of specimens and the fact that some of them are already exhausted blanks), the mean length and width of the negative scars measured by us seem to be in agreement with this pattern. The platform location of the flakes obtained at BK tend to be, by this order, irregular side-struck (60%), elliptical (43%) and end-struck (42%) (Bisson, 1990).

With regard to their position in the reduction sequence, 73% flakes do not show cortical areas on their dorsal surfaces, while only 4% belong to the initial reduction stages. According to Toth's (1982) classification of flakes, Type VI predominates, followed by Type V, while the other types are very scarce (Fig. 8). This pattern applies to all the rock types and it seems that the knapping processes carried out at the site (intensive flaking and reorganization of core volumes, as evidenced by the presence of rejuvenation flakes) do not include the initial phases of the reduction sequence. These activities should have taken place elsewhere. The striking platforms documented support this idea (Fig. 9). Most are non-cortical platforms (plain and dihedral), while non-cortical lineal and point platforms are quite abundant. Regarding dorsal patterns (Fig. 10), most flakes show irregular dorsal scars in one and two directions (Bisson's types 3 and 4). However, 12.65% of the sample show more complex directionality patterns, in which scars and ridges are arranged in one parallel direction (type 1) or in a centripetal or radial manner (type 6).

*Retouched flakes*

Retouched flakes represent only 5% ($n = 6$) of the detached objects and 4% of all the artifacts included in the freehand reduction model. Flakes with intentionally modified edges have been found in levels BK2–4. All of them are quartz flakes. Recognizing human-made retouch on the edges of a material such as quartz is a difficult task. The coarse-grained crystalline structure of quartz frequently prevents a clear diagnosis of retouching. Pseudo-retouching (produced during or after the knapping process) and post-depositional damage might have played a role in many archaeological assemblages creating unintentional modifications of natural edges. Therefore, we have been cautious and restrictive when ascribing artifacts to this category. For instance, we have found a number of objects that present a single-blow notch. The interpretation of

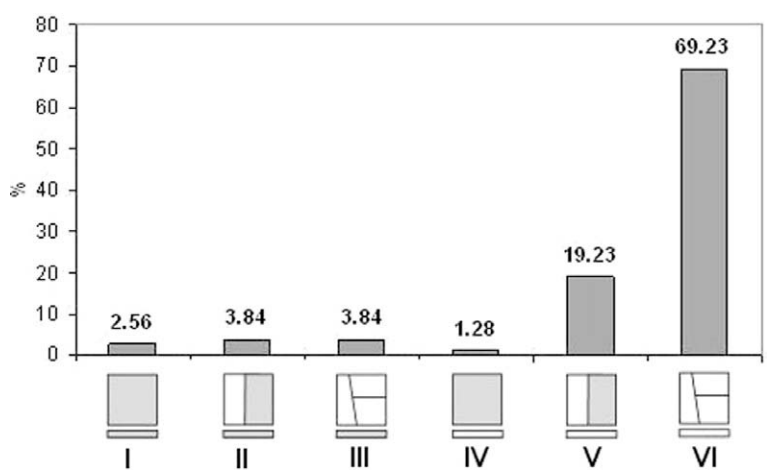


**Fig. 8.** Percentage distribution of flake types according to Toth (1982).

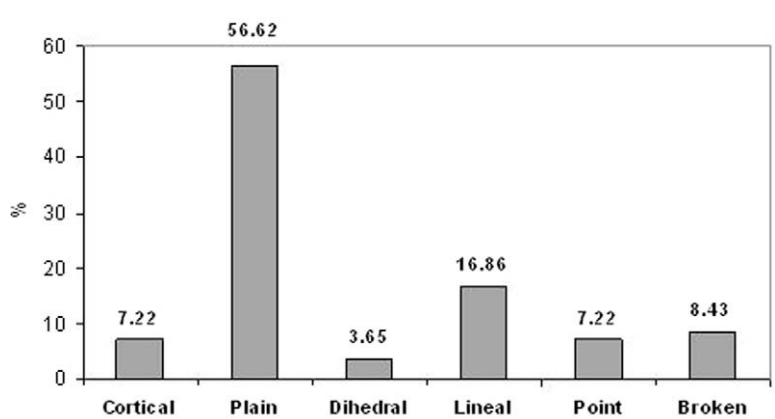


**Fig. 9.** Percentage distribution of striking platforms.

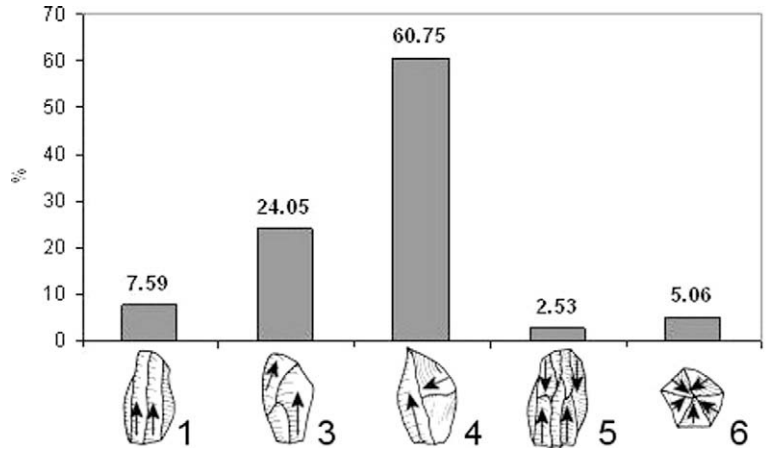


**Fig. 10.** Percentage distribution of dorsal patterns according to Bisson (1990).

these objects is problematic provided that such a concavity, in which no traces of recurrent configuration can be found, might be due to natural breakage of the edge or to a knapping accident. These objects have not been considered in this study as intentional configured tools. Retouched flakes are slightly larger, thicker and heavier than plain flakes (mean 39 × 26 × 11 mm and 16 g). However, all the technical traits mimic those already mentioned for unretouched products. Most of these artifacts belong to Toth's flake type VI, exhibit plain or uni-faceted striking platforms, irregular end-struck plan forms, and irregular uni- or bi-directional dorsal patterns. When it has been possible to identify any retouch, it is equally continuous and denticulate, simple and semi-abrupt, marginal and deep. Typologically, we have included retouched objects in the following types: side scraper ($n = 3$), denticulate ($n = 1$), and awl ($n = 1$). Another object shows a convergent denticulate retouch on both sides. This form, in fact a convergent denticulate or a denticulate convergent scraper, is analog to the Tayac points described in the classical typological lists of the European Lower Paleolithic (Merino, 1980).

*Bipolar knapping*

Bipolar knapping consists of placing a core on a stationary anvil and striking it in perpendicular planes from the top with a hammerstone. Proceeding this way, the applied loading produces two opposing points of impact and fracture directions (Crabtree, 1982; Jeske and Lurie, 1993; Leaf, 1979; Shott, 1989). The bipolar technique, then, differs substantially from the freehand technique in terms of fracture mechanics. It has been technically defined as a fracturing model that includes wedging initiation, compression–propagation and preferential axial terminations (Cotterell and Kamminga, 1987). Depending on the form of the selected raw material, the potential core can be placed on the anvil horizontally (horizontal bipolar) or vertically (vertical bipolar), producing different types of detached pieces during the reduction sequence (Barham, 1987; Honea, 1965; Toth, 1982). Taking into account that at BK the quartz type that was available at the site was tabular and that it exhibited numerous planes of stratification, a horizontal bipolar method seems to have been the most suitable procedure to undertake reduction. In situations where the available raw material shows numerous planes of stratification or where natural formats are tabular, bipolar reduction would have been the most efficient way to overcome raw material constrains and to avoid constant knapping accidents (Crovetto et al., 1994).

Apart from shatter (probably related to a great extent to bipolar reduction, as it will be mentioned later), we have identified 275 objects that can be linked to bipolar knapping (63% of the studied sample). Among them, 23 bipolar cores, 248 detached pieces and 4 retouched flakes have been included.

*Bipolar cores*

As other authors have already stressed, the identification of bipolar traits on cores is more reliable than of bipolar detached pieces (Jeske and Lurie, 1993: 140). However, cores might not always be discarded before complete exhaustion (showing in that case patterns that can facilitate their identification). Conversely, cores may undergo a subsequent series of reduction stages until they are broken in many amorphous fragments. A bipolar core might end up being angular shatter (Andrefsky, 1998; Kobayashi, 1975; Prous and Lima, 1990) and, therefore, recognizable bipolar cores might be underrepresented in any given lithic sample. There are a number of technical attributes derived from bipolar knapping that can be read on cores. In bipolar knapping, the striking angle tends towards 90°, although acute and obtuse angles may be produced in order to reorganize volumes and to prepare new knapping series (Mourre, 2004: 30–31). Therefore, in bipolar knapping, detachments are originated, not from a striking platform *sensu* freehand knapping, but from a rather small interaction surface that in occasions can be a ridge or a point (Curtoni, 1996). The mechanical interaction between hammerstone, core and anvil produces two series of opposed detachments, one from the striking platform (the surface that is struck with the hammerstone) and another from the base of the core (the surface that rests on the stationary anvil). This pattern is representative of opposite loading application. Leaf (1979) has suggested that crushing appears mainly at the base of the core, although (as it happens with flakes) the presence of crushing on either platform is not always a good indicator of bipolar knapping. However, in our experience, the presence and intensity of crushing on ridges, discrete areas or points is frequent and it depends on various factors such as the raw material type, the force applied and the rotation degree of the exploited volume.

Recognizing different series of detachments and the organization of the reduction on a bipolar core is very difficult. This is why some authors tend to simply include these objects in a generic category, such as that one proposed by Prous and Lima (1990) as nucleiforms. However, in an already classic study of bipolar cores, Binford and Quimby (1963) classify bipolar cores into different types according to the modifications produced by core rotation. Percussion axis rotation might be a valid indicator, if not the only one, of the *chaîne opératoire* of bipolar cores. Certainly, in order to eliminate irregularities and to enhance the stability of the base during the reduction process, platforms may be subject of some sort of preparation by rotating the core and using previous negative scars as new striking platforms and bases. Core rotation might

respond both to exploitation intensity and the particular characteristics of the raw material available at the site. That being said, in this study we have classified cores according to two variables, core rotation and alternation in the use of core platforms. From this perspective, a gradual loss of interaction surface during bipolar reduction can be adjusted by rotating the core in three ways: opposed, orthogonal and multipolar. Then, three bipolar groups have been established (Fig. 11):

C1. Cores show a reduction model in which the relationship between platform and base remains stable. Cases in which the blank may be turned over during the process are also included here. Negative scars show a linear, semi-circular or circular exploitation of the cobble.
C2. A series of core rotation and alternation of platforms can be observed on these cores. This alternation is arranged orthogonally in most cases.
C3. More than two series of platform rotation can be observed on these cores. The arrangement of negative scars tends to generate cubic or polyhedral final forms.

A total of 26 bipolar cores have been identified at BK. The mean dimensions and weights of bipolar cores sorted out by level are shown in Table 5. Several authors have pointed out that the bipolar technique might be used to maximize the reduction of raw material to the point of exhaustion (Goodyear, 1993; Shott, 1989).

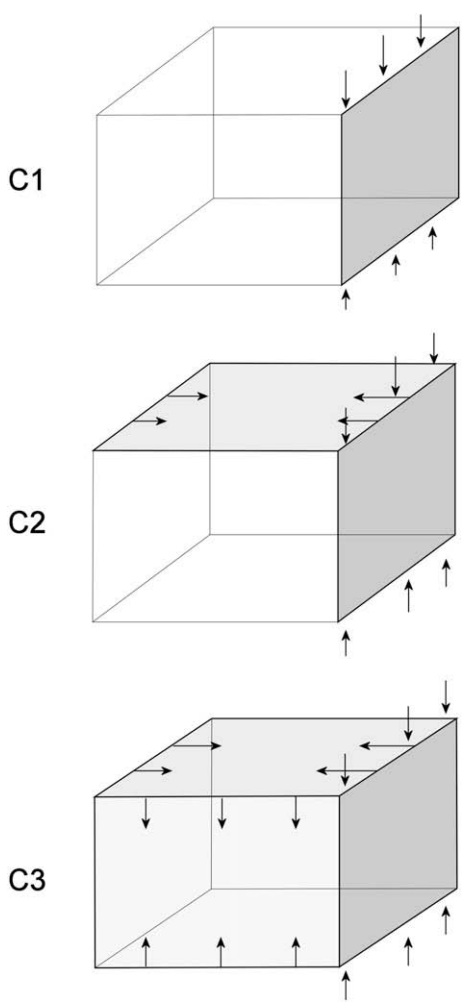


**Fig. 11.** Schematic representation of bipolar core rotation and core types.

**Table 5**
Mean sizes (mm) and weight (g) of bipolar cores sorted by level.

| | % | Length | Width | Thickness | Weight |
|---|---|---|---|---|---|
| BK1 | 13.04 | 41.33 | 31.66 | 26 | 56.33 |
| BK2 | 26.08 | 30 | 20.83 | 17.33 | 16.66 |
| BK3 | 30.43 | 39.14 | 26.85 | 24.28 | 35 |
| BK4 | 30.43 | 36.42 | 24.85 | 20.42 | 25.87 |
| Total | 100 | 36.21 | 25.30 | 21.52 | 30.21 |

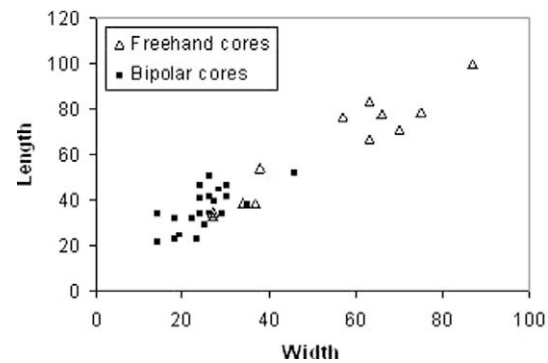


**Fig. 12.** Scatterplot of length and width of bipolar and freehand cores.

Therefore, some studies show that bipolar cores are significantly smaller than freehand specimens (Andrefsky, 1998). A comparison between Tables 5 and 3, shows that this is the case at BK. The mean dimensional values of bipolar cores are clearly smaller than those from freehand cores. This point can be more clearly seen in the scatterplot of Fig. 12. Freehand cores that overlap with the bipolar group correspond precisely to the sample of exhausted and intensively exploited cores from BK3 (where a bifacial multipolar centripetal hierarchized exploitation has been observed). Regarding volumetric shape, a scatterplot has been generated in which the lengthening index (LI, the length/width ratio) and carination index (CI, the ratio of minimum dimension between length and width/thickness) of both bipolar and freehand cores is shown (Fig. 13). The ellipses seen in the diagram indicate the probability at 90% of the bivariate standard deviation of the two related variables. Freehand cores show a high variability in their CI (this could be expected in a sample that includes the reduction models and volumetric patterns recognized at BK), while for bipolar cores, it seems to exist a clear correlation between length and thickness. Both types are represented by medium-sized cubic formats, although bipolar cores tend to be slightly larger and thicker.

In our sample, C2 cores are the most abundant (58.82%), followed by C3 (29.41%) and C1 (11.76%) cores. This indicates that bipolar reduction at BK has been carried out through volumetric rotation and that such an axis rotation might have been intense in order to produce a considerable percentage of C3 types.

*Bipolar flakes*

The application of loading in the course of bipolar knapping is badly controlled (Shott, 1989). This means, for instance, that the knapper cannot control the results of the process and that flakes and fragments can be unintentionally detached from an area that is not being subjected to reduction (the opposite face to the one the knapper is exploiting, for instance). At the same time, due to internal irregularities of the raw material, a variety of fractures easily occur during the process. Quartz breakage, for instance, produces a high percentage of step and hinge fractures (Mourre, 2004). As a result, the bipolar technique on quartz will produce a high variety of non-standardized by-products such as chunks, with

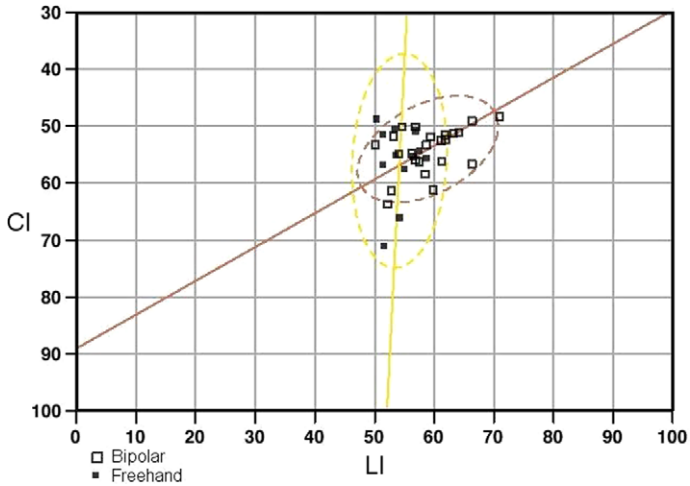


**Fig. 13.** Scatterplot of lengthening index (LI) and carination index (CI) of bipolar and freehand cores.

different shapes and dimensions, basal and parasitic detached fragments, and irregular fragments (Leaf, 1979: 39), most of them neither intended nor controlled by the knapper. The fact that bipolar detached pieces show a great morphological variability frequently encourages analysts to include most of these by-products into the generic category of shatter (Andrefsky, 1998). Bipolar knapping does not always produce a standard set of diagnostic technical attributes in flakes. This might cause some sort of confusion in the course of lithic analysis. Furthermore, attributes often cited in the literature on this topic do not seem to show statistical significance (double bulbs of percussion, battering on two edges, step or hinge terminations, and irregularity of flake outline), as Jeske and Lurie have already pointed out (1993: 138). Bipolar attributes recorded on flakes very much depend on the type and quality of the selected raw material and the type of bipolar reduction carried out (vertical or transversal). Most of the bipolar attributes cited in literature (based mainly on studies and experimentation with chert) do not apply for quartz, as has been remarked by several authors (Lombera, 2004; Mourre, 1994). This point is neatly confirmed by our own experimentation. At the moment, we are involved in an experimentation program of bipolar transversal technique on quartz. Research is in progress and results will be published in a forthcoming article (Diez-Martín et al., in preparation). However, many of the observations and data retrieved in the course of our experimentation have been of much help in interpreting the archaeological sample studied here.

At BK, the opposing striking forces have produced irregular and thick detached products, with no sign of bulbs of percussion, no compression rings, ventral edges that show the intersection of two opposed planes of fracture (sometimes accompanied by opposed scars) and frequently torsioned ventral surfaces. Battering on the platform and/or the base is not always detectable. Contrary to what has been previously stated (Shott, 1989: 2), and confirmed by our own experiments on transversal bipolar reduction on quartz materials, some detached pieces produced by heavy loading bear traces of the two opposite platforms. Transversal bipolar flakes have been classified according to the progressive loss of the striking platform surface during the knapping process. Therefore, flakes may preserve a clear platform surface (F1) or a linear/point striking area (F3). Flakes for which the stage of platform reduction cannot be assessed with confidence, have been classified in a intermediate group (F2).

A total of 81% of the artifacts included in the category of bipolar detached pieces are undetermined pieces larger than 2.5 cm. Although these pieces have been interpreted as the by-products of bipolar reduction, only ambiguous traits of such a technique have been observed on them. The remaining 47 pieces bear evident signs of bipolar shattering. Table 6 shows the mean dimensions and weight of bipolar flakes sorted out by level. Bipolar detached pieces show similar sizes as freehand flakes (slightly sorter and narrower), although they are thicker. The scatterplot of Fig. 14 shows the LI and CI of bipolar and freehand products. As already seen in Table 6, bipolar pieces tend to be thicker (showing a tabular carinated morphology) than freehand flakes, in agreement with the characteristic acceleration of reduction and mass loss reported for bipolar technique. While freehand flakes show a stable CI pattern, bipolar flakes tend to increase their CI in agreement with length values. The frontal morphology of bipolar detached pieces is mostly trapezoidal and triangular. Most pieces show no traces of cortical retention on their dorsal areas. When platform and base

**Table 6**
Mean sizes (mm) and weight (g) of bipolar positives sorted by level.

| | % | Length | Width | Thickness | Weight |
|---|---|---|---|---|---|
| BK1 | 24.59 | 30.46 | 26.07 | 19.92 | 16.63 |
| BK2 | 60 | 27.47 | 23.95 | 11.42 | 10.56 |
| BK3 | 8.87 | 37.81 | 27.31 | 15.06 | 21.43 |
| BK4 | 6.54 | 29.33 | 26.66 | 12.66 | 13.08 |
| Total | 100 | 30.27 | 25.35 | 12.24 | 13.95 |

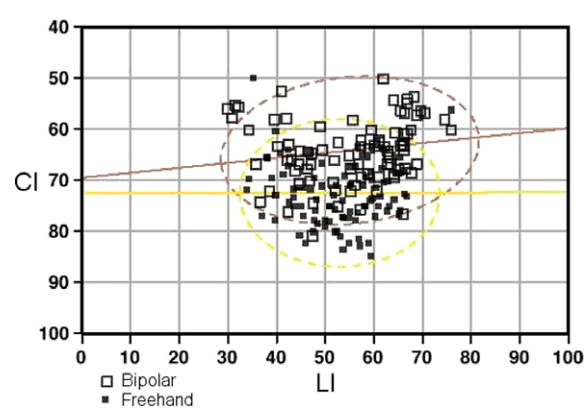


**Fig. 14.** Scatterplot of lengthening index (LI) and carination index (CI) of bipolar and freehand flakes.

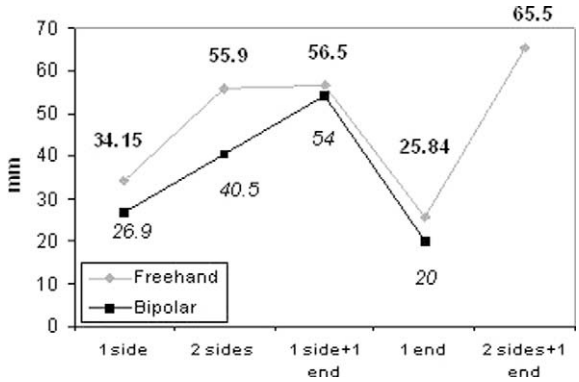


**Fig. 15.** Mean length (mm) of potentially usable cutting edges on freehand and bipolar products sorted by the location of the edges.

have been recognized, 37.83% of the flakes have been included in the F1 group, while 35.13% are F3 pieces and 27% are F2.

The maximum edge length has been measured in bipolar and freehand flakes. The latter show good natural sharp edges ($\geqslant$10 mm), ergonomically placed and potentially selectable for use. A total of 50% of all freehand flakes retrieved at BK show potentially usable sharp edges, while this trait has only been observed in 7.25% of all bipolar detached pieces. Fig. 15 shows the mean length of potentially usable edges on measured freehand and bipolar products sorted out by the location of the edges. The mean lengths show that, at the same location of the edge, freehand blanks always produce higher amount of edge. This again suggests that bipolar reduction produces a high amount of chunky positives and a much smaller amount of blanks with sharp edges.

*Retouched bipolar pieces*

A total of four bipolar flakes (retrieved from the four levels) have been subject of secondary modification. These tools include one denticulate, one pointed specimen and two objects showing a bipolar abrupt retouch on one side opposed to a natural and non-transformed edge.

## Interpreting flaking by-products: passive percussion or bipolar reduction

A remarkable characteristic uncovered by our study is the important role played by bipolar reduction at BK. In Mary Leakey's study, most of the artifacts classified as *outils écaillés* come from Developed Oldowan sites in the upper part of Bed II (47%). BK contains a larger sample, although these objects only represent 5.13% of tools (Leakey, 1971: 222). The French terms *outils écaillés* or *pièces esquillées* are typological categories that refer, in a rather broad way, to bipolar objects and to the evidence of the use of bipolar reduction in archaeological contexts, as a number of specialists argue (Barham, 1987; Shott, 1989, 1999). Although remarkably different in percentage and in the lithic categories involved, our study confirms and documents the important role played by bipolar reduction at BK.

Because of the acknowledged difficulties of recognizing technical traits related to bipolar knapping (repeatedly noted by a number of authors in the basic literature on this topic), this technique might pass unidentified in several lithic collections. We are persuaded that bipolar reduction was a common technological behavior during most of the Paleolithic and that it can be widely represented throughout the Oldowan sequence. An example of the controversial diagnosis linked to the bipolar universe can be found in a recent paper by Mora and de la Torre (2005) devoted to the analysis of percussion tools at Olduvai Beds I and II. These authors account for the existence of what they call passive percussion elements throughout the whole Bed I and II sequence, in sites such as FLK North, TK and FC West. These authors describe those objects as cuboid tabular blocks with two flat surfaces: one of them acting as the percussion platform that receives the impacts and showing intense battering, particularly on the edges; and the other one, positioned in the ground and adding stability to the object. The area of the block exposed between the two flat surfaces described, shows percussion modifications in the form of hinged and stepped scars. Mora and de la Torre interpret these pieces as anvils and the reported modifications as the result of percussion activities in which elongated elements (bone diaphyses or wooden branches) were interposed between the edge of the anvil and the ground. While this could be an explanation, alternative null hypotheses have not been disproved. We think that some of the cases that they are describing could potentially be bipolar cores resulting from opposed horizontal bipolar knapping. A brief comment of the arguments to support this interpretation is presented here.

A first point of disagreement comes from the fracture traits described for these objects and the misunderstanding of the way in which fracture mechanics affects bipolar reduction. Mora and de la Torre report that the surface that rests on the ground (which does not receive direct impacts with a hammerstone) "*experiences écaillés and fractures given the force transmitted to the block and being in contact with the ground, especially on the edges of the piece*" (ibid.: 184). Certainly, the attached illustrations of two implements from TK and FLK North (ibid.; Fig. 5) show two series of opposed points of impact and fracture directions. As we have already stressed, this pattern is also representative of the opposed loading application that defines bipolar reduction (Fig. 16). However, as a basic understanding of rock fracture mechanics shows, for this pattern to be produced it is necessary that the manipulated object rests on a hard surface (a stationary anvil, for instance), and not directly on the ground. When force is applied, the stationary stone that interacts with the base of the manipulated object generates a set of scars resulting from the compressing effects of such interaction. An object placed on a soft solid like the ground would absorb most of the force unidirectionally applied and, then, the described opposed compressive pattern would not be produced. This is so because the ground, with a different density and structural composition, has an elasticity index and a hardness non-comparable to other solids such as rocks, less elastic and harder (Baena, 1998: 41) (Fig. 17). The only way in which we imagine this could happen through the interaction hammerstone/block/ground would be by turning over the block and using both surfaces alternatively as percussion areas. Another possibility could be carrying out the percussion activities interpreted by these authors by placing the anvil on a big block or rock outcrop located at the vicinity of the site. However, it would be necessary to explain the functional advantages of such a battering behavior, since the rock itself could act as an anvil.

Mora and de la Torre (2005) acknowledge the appearance of involuntary detachments on the surface of the purported anvils and the generation of a number of fragments as a result of the intensive percussion activities in which they were involved. Certainly, at FLK North or TK they have recognized "*a high number of objects classified as flakes or flake fragments* which *are actually positives spontaneously detached from the anvils*" (ibid.: 185). All these objects show a number of common formal traits such as traces of battering, no butts or compression rings. The authors think that these positives cannot be actual flakes obtained from a bipolar technique. However, they do not mention which are the characteristics that generically define bipolar flakes and which are the technical or morphological criteria allowing them to separate the positives they refer to from bipolar positives. In fact, that would

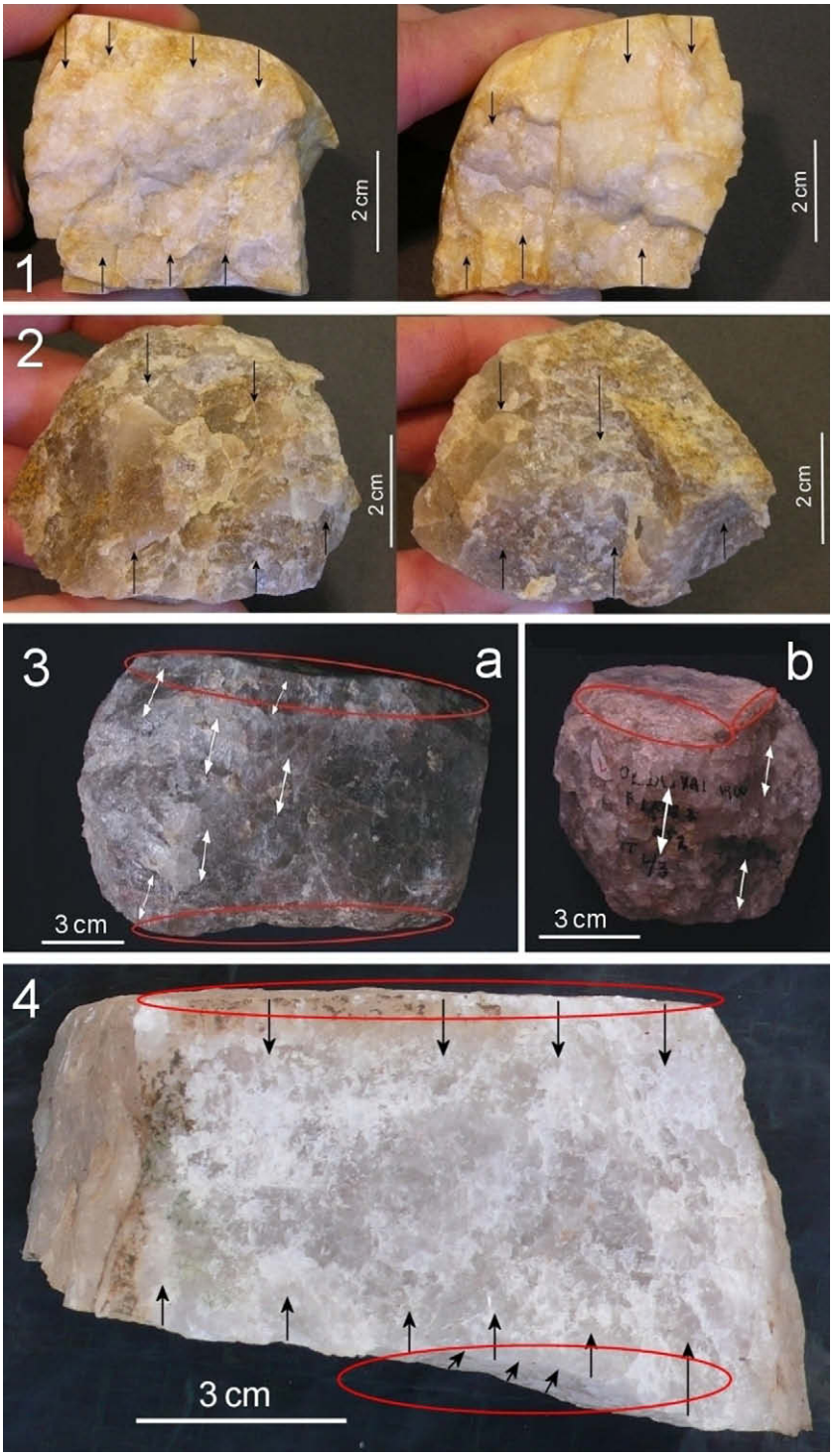


**Fig. 16.** 1. C1 bipolar core on quartz (experimental replication) showing traits of opposed loading application. 2. Bipolar core from BK1 (C2 type) showing the same pattern. 3. Quartz items from TK and FLK North interpreted as anvils by Mora and de la Torre (2005: modified from Fig. 5). Note that both specimens show the same two series of opposed points of impact and fracture directions seen in the exploitation planes of bipolar cores. 4. C1 bipolar core on tabular quartz from Naibor Soit (experimental replication). The same traits observed in photographs 1, 2 and 3 can be seen here. Note the presence of step-like negative scars at the base of the core (the surface directly interacting with the anvil). In bipolar reduction, and due to the lack of elasticity of quartz (Mourre, 1996), the base area that receives the impact breaks up producing small, right-angled basal flakes (Leaf, 1979). Similar step fractures can also be detected in the base of the A specimen in photo 3 (Mora and de la Torre, 2005).

be a rather difficult task. As we have already pointed out, and as is redundantly mentioned in most of the literature dealing with experimental work and technical analysis of bipolar knapping, a basic trait of bipolar reduction of paramount importance here is precisely that the application of force is poorly controlled. This fact produces in many occasions the shattering rather than the clear fracture of the core. A main consequence of this fact is the detachment of a high number of flakes with quite variable origins and morphologies, which are unintentionally obtained in the process of reduction. As described above, the morphology of the section of bipolar detached pieces is mostly trapezoidal and triangular; these are precisely the features that Mora and de la Torre (2005)

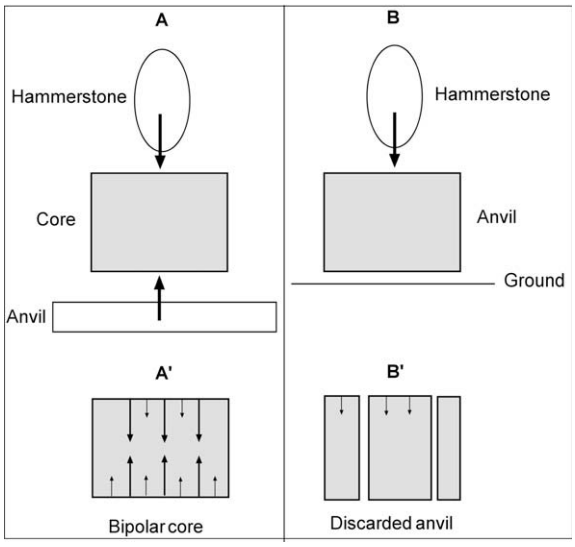


**Fig. 17.** Schematic representation of the effects produced by (A) bipolar loading application (where the interaction hammerstone/core/anvil occurs) and (B), by passive percussion activities (where the interaction hammerstone/processed material/ground occurs). A′, Opposed compressive patterns of bipolar cores result in bipolar negative scars and a variety of fractures at the core base (i.e, step, hinge). B′, When a stationary anvil rests on the ground (high elasticity index and low hardness), unidirectional load application results in the final breakage of the anvil in various pieces and, when this is produced, small and unidirectional negative scars appear on the ridges.


**Fig. 18.** Non-diagnostic (absence of bulbs, no identification of dorsal/ventral surfaces and striking platform) angular fragments produced during the process of bipolar reduction of a single quartz nodule (experimental replication).

identify as anvil corners and ridges detached through battering. Particularly in quartz rocks, where a number of fractures are quite common, it is possible to obtain bipolar flakes and fragments with no bulbs of percussion, no attributes indicating the direction of the blow, and unidentifiable ventral or dorsal areas (Fig. 18). We are referring to shatter here, and we know through experimental studies that bipolar reduction produces a high amount of it. Furthermore, we question that (even after the experience acquired through repeated experimental work) a lithic analyst would be skilled enough as to refit confidently fragments of shatter to the area of the block from which they originally might have shattered on the basis of morphological observations only, as Mora and de la Torre actually do (ibid.: Fig. 6).

If Mora and de la Torre's hypothesis is correct, then hominins were involved in a type of battering activities that produced an intensive reduction of the anvil volume and an enormous number of fragments and chips. This progressive loss of mass (focused on what looks like a discrete plane of percussion and difficult to link to the functionality of an anvil) fits more within a pattern of rock exploitation rather than the purported battering behavior, even if the percussion activity tends to be localized mostly on the ridge of the anvil. We are not aware of such modifications produced on anvils when processing bone, nuts or vegetal tissues, where the interaction hammerstone/processed material/anvil/ground is always produced. Experimental, archaeological and ethological references of anvils used for bipolar reduction (Honea, 1965: 264; Jones, 1994: 288–289) or nut/vegetal tissues processing (Beaume, 2004; Boesch and Boesch, 1993; Goren-Inbar et al., 2002; Joulian, 1996; Kortlandt, 1986; Mercader et al., 2002; Willoughby, 1987) show nothing of the sort. In the course of our own experimentation with bipolar technique, using Naibor Soit quartz (Diez-Martín et al., in preparation), we have widely confirmed that the alterations produced on the anvil (where the manipulated object is a rock, by far harder than bone, nut or vegetal materials) do not replicate the kind of massive reduction of the anvil volume suggested by Mora and de la Torre (2005). In our experiments we have repeatedly and intentionally located the point of loading both on the center and on the ridges of the anvil. After various sequences of core reduction, the whole anvil finally tends to break up into a number of fragments. Battering marks on the surface show very clearly the various points of loading application (including edges), but we do not see any transformation of the edges in the whole perimeter of the anvil (Fig. 19).

We are very much aware of the important role that percussion elements should have played in archaeological sites such as BK, where it is evident that hominids were intensively breaking long limb bones. This is not the case in several of the sites where Mora and de la Torre (2005) have reported the existence of such type of anvils (Domínguez-Rodrigo et al., submitted for publication). Our opinion is that it is crucial to found such interpretations upon actual experimental work in order to replicate the effects of both bipolar knapping and various battering activities using the local quartz available for Oldowan hominins (Fig. 20). Only this procedure will shed light on the issue of the functional implications of bipolar reduction, which still presents many unresolved questions. An important point related to this problem is, as Shott (1999) has nicely put it, the equifinality of bipolar knapping. The dilemma of bipolar knapping is therefore that different causes might have produced identical results. A number of scholars have suggested different functional meanings for bipolar reduction: it could be used when small nodules or low quality rocks are locally available (Berman et al., 1999; Kuijt and Russell, 1993), or in a context of low regional mobility and maximization of local resources (Jeske, 1992; Shott, 1989), or in a context in which an expedient reduction would suffice (Curtoni, 1996), or for producing certain types of tools (Kimball, 1992; Jones, 1994) for processing organic substances, in reference to the controversy by which bipolar objects have been interpreted as the result of a knapping strategy or as wedges (see Shott, 1989, 1999, and references therein). Ethnographic accounts however, describe that the goal of bipolar manipulation of rocks is always the production of flakes/positives (Shott, 1989, 1999). At BK, although we have observed that freehand knapping would produce a much higher percentage of good flakes and more suitable cutting edges for potential use, bipolar reduction has produced a larger number of items suitable for meat processing. The efficiency of bipolar products in a number of activities has been pointed out by Crovetto et al. (1994: 194). However, an unresolved contradiction arises here. If at BK bipolar reduction is best suited to somewhat expedient knapping activities using near-

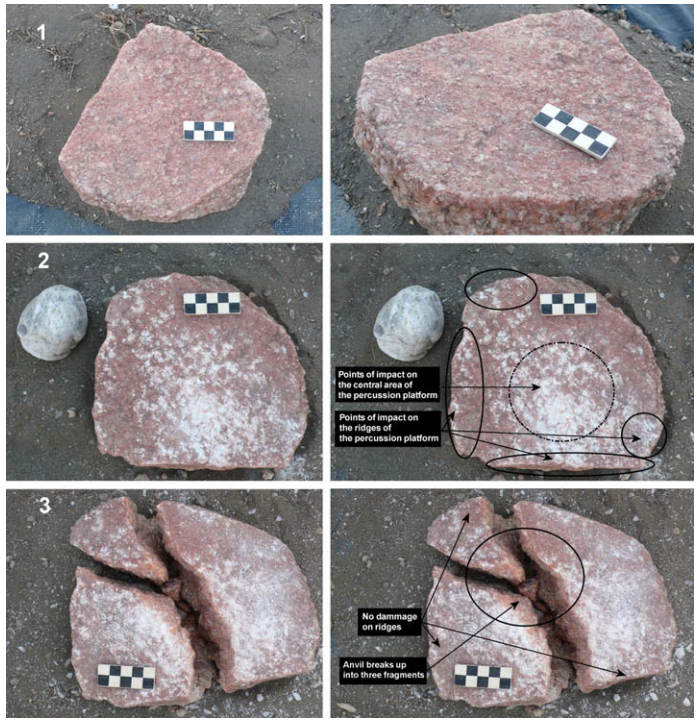


**Fig. 19.** Effects of bipolar reduction on an anvil replicated by experimentation on Naibor Soit quartz (Diez-Martín et al., in preparation). 1. Initial characteristics of the block selected as an anvil; 2. Distribution of points of impact (battering) on the surface used as percussion platform after the complete bipolar reduction of three quartz slabs used as cores. Note that points of impact are randomly located on the percussion platform (center and the edges of the surface) and that ridge transformation and/or ridge mass loss is not observed. 3. Discarded anvil. During the reduction process of a fourth core, the anvil breaks up into three fragments. Intense battering on the three fragments indicates their implication in passive percussion activities. No damage can be observed on the ridges of the whole perimeter of the anvil. No recurrent mass loss (angular fragments, chips or shatter) has been produced in the course of the experiment.

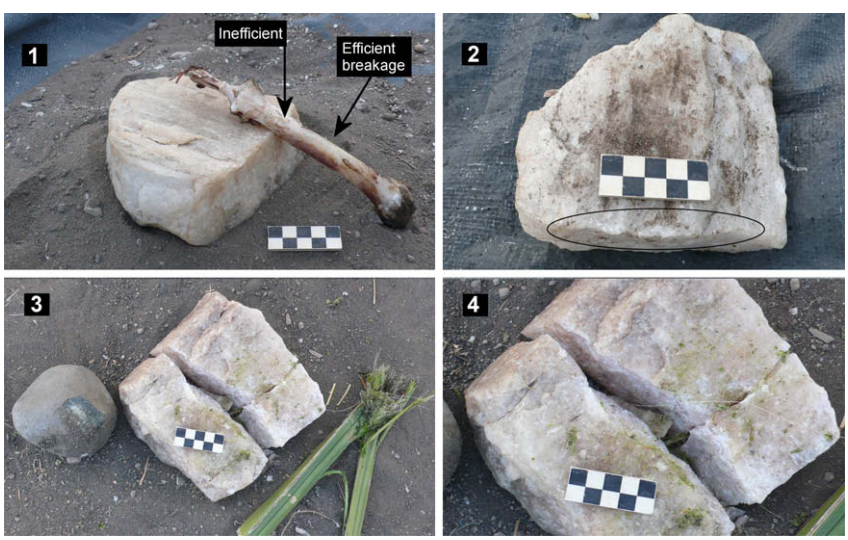


**Fig. 20.** Battering activities replicated by experimentation (Diez-Martín et al., in preparation). Effects of organic materials (bone epiphysis and *Sansevieria ehrenbergii*) processing on Naibor Soit quartz anvils (where the interaction hammerstone/tissue/ground occurs). 1. Our experiments show that processing this kind of materials by interposing the items on the ridge of the anvil (as proposed by Mora and de la Torre, 2005) is remarkably inefficient. 2. Recurrent bone breakage produces no effect on ridges (related to mass loss). 3. *Sansevieria ehrenbergii* leaves can be much more efficiently processed by crushing them in the center of the stationary anvil. 4. Discarded anvils tend to break in several pieces (particularly in the case of *Sansevieria ehrenbergii*, a very hard and fibrous plant) and show no damage on the ridges.

by coarse-grained and tabular quartz, why have we recorded a number of quartz cores exploited in a centripetal hierarchized manner, a much more complex reduction model that implies a certain degree of curation? Experimental work in progress will be instrumental in our functional interpretation of bipolar reduction at BK.

## Conclusions

At BK, a total number of 1575 lithic artifacts have been recovered. Quartz is the predominant raw material type, accounting for 94.53%, while lavas only represent 3.8% of the sample. Artifacts are mint fresh, exhibiting no signs of abrasion or post-depositional

damage. A high percentage of shatter accounts for the majority of the sample (72%). Two reduction models have been recognized, freehand (36.92%) and bipolar knapping (63.07%). Bipolar reduction is predominant in the four archaeological levels, while freehand knapping is remarkably more abundant in BK3. In fact, 48% of all the freehand objects come from the exhibit level and here, the larger collection of freehand flakes and cores has been retrieved.

Freehand reduction strategies are represented by polyhedral and centripetal schemes. An important percentage of the cores, most of them exhausted, show traces of a centripetal hierarchized reduction model. Flakes produced at BK were small, with a range of 20–40 cm of maximum length. The knapping processes preserved at the site do not include the initial phases of the reduction sequences. Toth's flake Types VI and V are predominant, while most striking platforms are uni-faceted. Dorsal patterns are mainly irregular, although a number of flakes were detached from cores rotated in a centripetal manner. Retouched flakes are very scarce, representing 5% of all the detached objects, including scrapers and denticulates.

Bipolar knapping is predominant through the whole sequence, including cores, detached pieces and a low number of retouched objects. A large amount of shatter was produced in the course of bipolar reduction. Horizontal bipolar reduction of tabular quartz slabs would have taken place by rotating the core and using different surfaces as platforms and bases. Most bipolar cores show signs of such a rotation and, from a dimensional perspective, they are significantly smaller than freehand cores. Small and relatively thick bipolar flakes were produced in the course of this kind of rock reduction. While 50% of freehand flakes show good natural cutting edges, only 7% of bipolar products could be potentially selectable for use. A very small number of bipolar flakes show secondary modification. Despite the lower percentage of bipolar usable edges, this technique might have played an important role in meet processing at BK. However, the presence of percussion marks related to dynamic loading on bone (Domínguez-Rodrigo et al., submitted for publication) indicates that hominins were using hammerstones to produce this kind of bone modification. We conclude that there are not mechanical reasons to claim that the items interpreted here as the by-products of bipolar reduction (cores, positives and angular fragments), whose technical traits indicate bipolar loading, might be the by-products of passive percussion activities (where bipolar loading application is absent by definition).

One further controversial question would be: why are hominids using a bipolar technique to produce cutting tools if such a small percentage thus produced is potentially functional? The answer that comes to mind and which needs testing in the future is that only if raw material at or near the site was abundant and hominins could afford to waste so much of it, would this strategy have been an efficient way of reducing quartz tabular slabs. Also, the large amount of waste makes 7% of usable bipolar products a small percentage, but maybe that is translated into enough cutting tools for butchery when a ratio of number of flakes: number of carcasses (or carcass parts) is established. The location of quartz at Naibor Soit, some 3.5 km away from the site would disprove the first part of the answer. However, the interpretation that hominins at BK were wastefully using bipolar technique for knapping and the discovery in the vicinity of the site of several extremely large pieces of tabular quartz (also retrieved by Leakey at the nearby site of SHK), suggests that maybe a closer source to BK could have been available during the formation of Bed II currently covered by overlying sediment.

Another consequence of the present study is that it cast some doubts on the massive battering activities identified by de la Torre and Mora (2005) in the Olduvai lithic assemblages. This is of crucial importance to understand hominin Plio-Pleistocene subsistence. The elaboration of butchering tools has been identified as the main cause explaining Plio-Pleistocene lithic assemblages in most East African sites. According to de la Torre and Morás (2005) interpretation, Olduvai would stand as an exceptional oddity, since hominids would have been involved in battering activities unrelated to butchery over thousands of years. Thus, the identification of battering and its differentiation from bipolar knapping is of utmost relevance to the interpretation of Oldowan stone tools. We argue that a lot of the signatures used to identify battering are subjected to equifinality and that others can be better identified as resulting from bipolar artifact stone-tool making.

The identification of bipolar technique at BK in order to produce cutting tools supports recent interpretations of the site as an anthropogenic assemblage created by repeated butchering episodes over a vast amount of time (Domínguez-Rodrigo et al., submitted for publication).

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