



## New insights into hominin lithic activities at FLK North Bed I, Olduvai Gorge, Tanzania

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### ABSTRACT

Recent work at FLK North (FLK N) has unearthed a new archaeological assemblage recovered with precise control of its stratigraphic position. In the present work, the technological study of the new lithic sample is described. The results show the co-occurrence in the same site of different technological behaviors. At FLK N, hominins were involved in both percussion/battering activities and, through freehand and bipolar knapping, in core reduction. However, the reconstruction of the operational sequences shows that core reduction was probably a marginal behavior, while percussion/battering activities occurred more regularly throughout the sequence. If hominins were not involved in regular carcass processing, as recent taphonomic studies suggest, then hominins' sporadic and low-impact visits to the site over a long period of time must have been driven by other activities probably linked to the exploitation of alternative resources. Plant processing could have been a plausible explanation for hominin presence at FLK N.

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### Introduction

FLK North (FLK N), located on a ridge about 60 m north of the FLK site, was first excavated in 1960 (Leakey, 1971). Fieldwork unearthed a sedimentary sequence spanning ~7.31 m in depth, which included three fossil-bearing horizons in Lower and Middle Bed II sediments and six more levels in Upper Bed I, right below the marker Tuff 1F, dated to 1.79 Ma (Walter et al., 1991). The 1.52-m-deep sequence excavated in the Bed I sediments of FLK N revealed rich accumulations of fossil bones and artifacts.

In her landmark work on the lithic industry of Olduvai, Leakey (1971, 1976) provided a detailed account of the lithic collections retrieved from this site. The material excavated at FLK N totaled 2019 objects. Leakey (1971) concluded that at this site the main knapping goal was chopper production, as 46.5% out of the total tool sample retrieved was included in this type. A high percentage of débitage (>50% of the total sample) indicated that hominins were involved in intense knapping activities probably related to carcass processing, a behavioral pattern that seemed to be in agreement with the functional

scenario of living floors and butchering sites (but see Leakey 1971, 1976).

Since Leakey's work, other researchers have used parts of the FLK N lithic dataset (Bower 1977; Roche, 1980; Willoughby 1987; Potts 1988; Sahnouni, 1993; Brantingham, 1998). Apart from Leakey's work, two other studies have been devoted to re-examining the complete lithic collection of FLK N (Ludwig 1999; de la Torre and Mora, 2005a). De la Torre and Mora's work is of particular interest, as it constitutes the only published comprehensive reassessment of the entire FLK N collection retrieved by Leakey. De la Torre and Mora's diagnosis differs drastically from the ones previously proposed (Leakey 1971; Potts, 1988). These authors suggest that here, hominins were preferentially involved in battering activities. They argue that knapping activities were residual and they depict an alternative scenario in which hominins were basically involved in the intense percussion of a variety of organic materials, particularly long bone shafts. However, no evidence of hammerstone-broken bones has been found in most of the FLK N sequence (Domínguez-Rodrigo et al., 2007).

Recent work at FLK N undertaken by our team has unearthed a new archaeological assemblage (Domínguez-Rodrigo et al., 2010). This paper presents the technological study of the new lithic sample retrieved. Our diagnosis of the hominin behavior observed at this site concludes that archaeological items related to battering activities are

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somewhat over-represented in de la Torre and Mora's analysis (2005a) even if battering is the main activity inferred at the site. Our study shows some key differences with de la Torre and Mora's interpretation of several technical traits present in artifacts. These differences are of utmost importance, since they reveal a more diversified set of technological actions, some of them not recognized in previous analyses. This study, considered within the framework of the most recent taphonomic (Domínguez-Rodrigo et al., 2007) and paleo-environmental interpretations (Ashley et al., 2010), helps us to provide new insight into the role played by lithic artifacts at FLK N and to better understand the purpose of lithic manipulation at this spot.

## Materials and methods

In 2007, our team resumed excavation at FLK N, opening two new trenches (I and II). Work is in progress and the details of this new archaeological investigation and stratigraphic data at the site are reported elsewhere (Domínguez-Rodrigo et al., 2010). We present here the lithic collection retrieved from the 6 m<sup>2</sup> exposed in Trench 1, excavated between 2007 and 2008. A total of 168 lithic objects have been retrieved from this trench.

Studied artifacts have been included in four general categories: (1) Irregular basalts—amorphous in shape, mostly vesicular basalts, with no good ergonomic qualities for precision-grip nor hammering, nor do they have textural qualities for knapping. (2) Percussion elements—items included here show varied patterns of percussion damage on their surface (such as battering and/or scarring). We have also included several nodules that bear no sign of battering but that are very well-rounded cobbles, showing very good ergonomic conditions for potential use. (3) Cores—in handheld cores, reduction models have been defined according to three parameters: facial exploitation (the number of knapping surfaces exploited, i.e., unifacial, bifacial, trifacial, multifacial), polarity (the number of striking platforms identified, i.e., unipolar, bipolar, multipolar) and the relationship between different knapping series (linear, opposed, circular, orthogonal, centripetal). As we have already explained elsewhere in more depth (Díez-Martín et al., 2009), we have classified bipolar cores according to the combination of two variables: core rotation (Binford and Quimby, 1963) and alternation of striking platforms. (4) Products—we have included in this category all detached specimens and shatter, assuming that most of them are the by-products of freehand and/or

bipolar knapping reduction techniques. We have also included here the meager collection of retouched flakes.

In order to overcome statistical problems related to sample size and sample bias in a relatively small population, all the samples were bootstrapped 1000 times prior to the application of any statistical test. Sample sizes used for statistical comparisons and analysis can be observed in Table 1.

## Results

Table 1 shows the distribution of lithics sorted by category and raw material type. Quartz is the main rock type used and it has been basically directed to exploitation processes: 99% of quartz items have been classified as part of the débitage or core categories. Conversely, most volcanic rocks have been included in the percussion category (60%), while 84% of amorphous basalts show no traces of anthropogenic modification.

### Irregular basalts

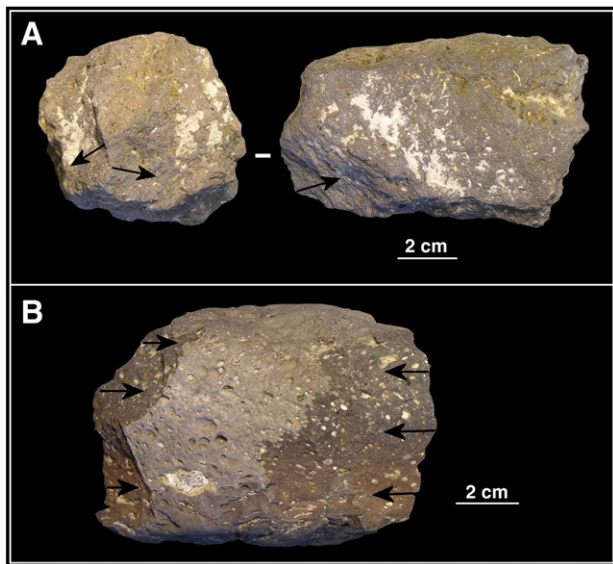
Other authors have already provided explanations for the presence of amorphous basalts in some Olduvai Gorge archaeological contexts (de la Torre and Mora, 2005b), alternative to the manuport hypothesis supported by Leakey (1971) and other researchers (Potts, 1988, 1991). However, two of the irregular vesicular basalts retrieved by us might have been fractured due to percussion, while another might exhibit negative scars (Fig. 1). The poor quality of these materials and their amorphous shape make it difficult to identify with confidence any marginal sign of hominin manipulation on their surface (Leakey, 1967). In our collection, we have included, albeit in very low numbers, some vesicular basalts in the categories related to percussion and exploitation processes (Fig. 1, Table 1).

### Percussion elements

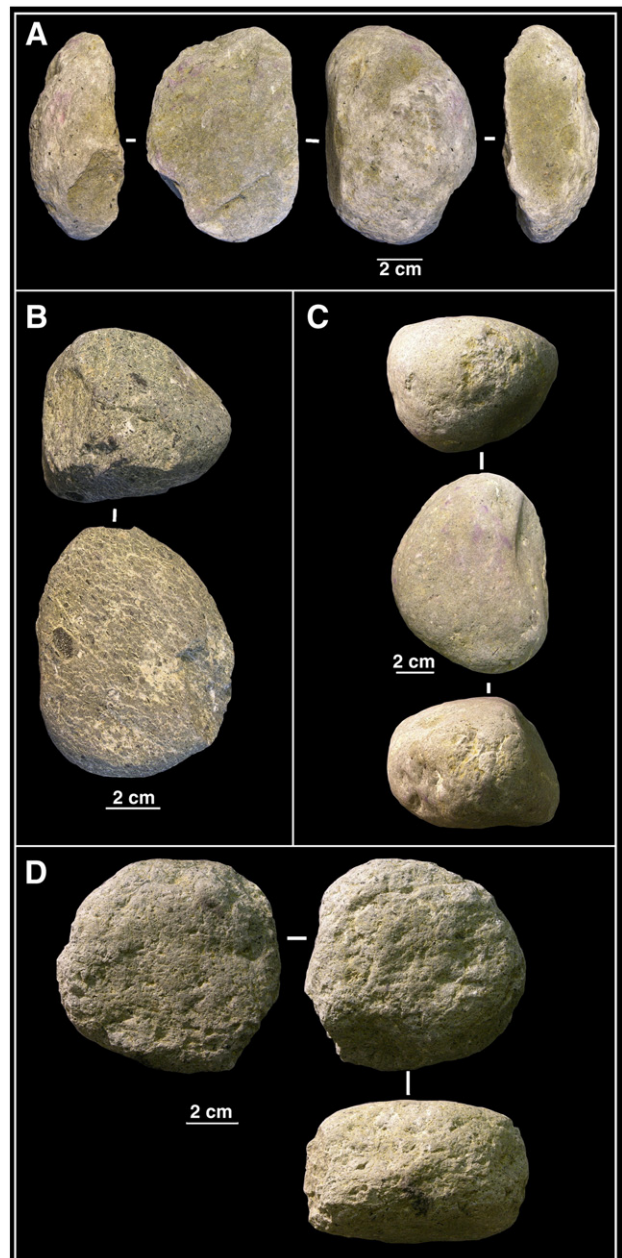
Specimens bearing percussion stigma have been classified in different groups in accordance with the type of percussion damage observed on their surface (Table 1): Hammerstones are rounded or oval nodules showing clear pitting or battering caused by pounding (Willoughby, 1987; Pickering and Egeland, 2006). Seven objects show this kind of stigma (Fig. 2C), while another, showing battering on an

**Table 1**  
FLK North lithic collection retrieved from our Trench 1. Technical categories are sorted by artifact group and raw material.

Category/type	Basalt	Vesic. Bas.	Phonolite	Quartz	Gneiss	Total	%
IRREGULAR BASALTS						20	11.9
Amorphous/irregular	4	16	–	–	–	20	
PERCUSSION ELEMENTS						31	18.45
Nodules	3	–	–	1	–	4	
Hammerstones	7	–	–	–	–	7	
Anvils	–	–	1	–	–	1	
H. with surface scars	5	–	2	–	–	7	
H. with battered dihedral	3	1	1	–	1	6	
Broken hammerstones	4	–	1	–	–	5	
Positives of percussion	–	–	1	–	–	1	
CORES						21	12.5
Freehand	7	1	4	3	–	15	
Bipolar	–	–	–	6	–	6	
DETACHED PRODUCTS						96	57.14
Flakes	4	1	3	15	1	24	
Fragmented flakes	–	–	2	1	–	3	
Bipolar flakes	–	–	–	13	–	13	
Secondary modified	–	–	–	3	–	3	
Indetermined positives	–	–	–	11	–	11	
Shatter (≤25 mm)	–	–	4	38	–	42	
Total raw material	37	19	19	91	2	168	
% raw material	22.02	11.3	11.3	54.16	1.19		100



**Figure 1.** (A) Amorphous vesicular basalt showing two opposed negative scars. (B) Vesicular basalt exploited in a unifacial bipolar opposed manner.



**Figure 2.** (A) Longitudinally fragmented hammerstone showing very intense battering (basalt). (B) Hammerstone with battered dihedral edge (phonolite). (C) Hammerstone showing battering on two opposed edges (basalt). (D) Basalt anvil showing circular pitting on one flat surface and battering around the edges.

edge, has been considered to be a stationary anvil (Fig. 2D). Another type of percussion damage recorded here is surface scarring produced when nodules, due to intense impact, lose mass in the form of thin percussion positives. Two objects show surface negative scars on one edge, while another five items show this pattern on one edge in combination with battering on the opposite edge. Another type of percussion damage identified in our sample is represented by what we have called “hammerstone with battered edge.” In this particular case, negative scars produced on one edge of the nodule form a dihedral angle, an acute and irregular angle. This ridge shows intense alteration produced by percussion, sometimes clearly blunted by the intensity of load application. Other authors refer to these items as “hammerstones with fracture angles” (de la Torre and Mora, 2005a). De la Torre and Mora consider that this damage pattern is spontaneously produced in the course of hammering. Although this might be an explanation, we suggest that some of these items might be fragmented nodules, test cores or barely-exploited cores. In that case, hominins might have taken advantage of an already existent acute edge in order to reinforce blow damage and enhance the desired percussion task. One object shows this kind of battered dihedral angle on one side, while another four combine this pattern with battering and one with surface scars on the opposite edge (Fig. 2B). Another type considered in this category are nodules broken off in the course of percussion. Intense load application have caused some cobbles to split longitudinally (Fig. 2A). Finally, the last group included in this category corresponds to positives of percussion. We have found one phonolite positive revealing battering on its dorsal surface and showing a concave ventral area. These patterns indicate that this piece has been detached from a hammerstone. Raw material distribution shows a remarkable bias towards volcanic rocks in the objects directed to percussion tasks (Table 1).

Metric variables were used to determine volume (length, breadth, and thickness), weight and raw material types for the artifacts included within the percussion category (Table 2B). To undertake the statistical analysis we have used the different types as referred to above. For comparative purposes we have included irregular basalts in our study (Table 2A). A factorial multiple analysis of variance (MANOVA) was performed following a log-linear model and using Levene’s test for the homogeneity of variances. The variable width showed a departure from normality and had to be log-transformed. The results show that the types of nodular artifacts and their raw materials are homogeneous, showing no significant differences,

except when compared with irregular nodules. Box’s M test of equality of covariance matrices (32.065, sig. 0.259) indicates that matrices do not differ. Wilk’s lambda values are <1 and non-significant, showing that none of the effects are significant.

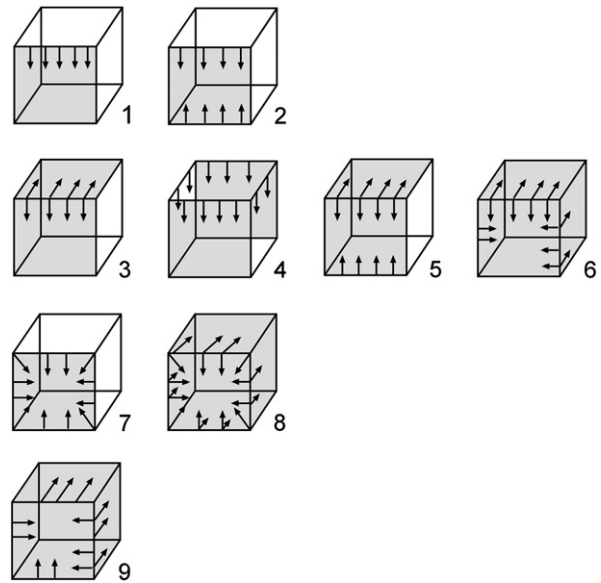
Post hoc tests such as Tukey and Dunnett T3 were selected to create pairwise comparisons in which differences may be detected. The Tukey HSD test was selected because of the number of groups in the factor variables. Dunnett T3 was also used under the assumption of no variance equality, although this was confirmed by Levene’s test. It was also used to add more strength to pairwise comparative inferences. Both post hoc tests show that the only significant differences lie in the weight of hammerstones when compared to irregular basalts (Tukey 0.908, sig. 0.18; Dunnett T3 detected no significant differences) and the weight of hammerstones with battered dihedral edges and irregular basalts (Tukey 1.5, sig., 0.016;



**Table 2**

Mean size (mm) and weight (gr) of the lithic categories: (A) Irregular basalts ( $n = 20$ ); (B) Nodules with percussion stigma ( $n = 25$ ); (C) Freehand cores ( $n = 15$ ); (D) Bipolar cores ( $n = 6$ ); (E) Freehand flakes ( $n = 24$ ); (F) Bipolar flakes ( $n = 13$ ).

	Minimum	Maximum	Mean	Standard dev.
(A) Irregular basalts				
Length	55	97	74.85	11.82
Width	43	75	61.3	9.77
Thickness	28	69	48.5	10.52
Weight	26	421	235.6	104.9
(B) Nodules with percussion stigma				
Length	47	100	78.36	13.47
Width	43	91	62.93	11.02
Thickness	26	73	51.3	12.4
Weight	95	689	363.13	162.79
(C) Freehand cores				
Length	46	93	75.26	13.17
Width	45	71	59.13	9.15
Thickness	30	59	43.33	9.17
Weight	48	441	240.8	126.6
(D) Bipolar cores				
Length	35	72	52.83	14.66
Width	32	60	44.5	9.73
Thickness	30	57	39.66	9.79
Weight	48	274	155.16	102.81
(E) Freehand flakes				
Length	17	49	31.78	9.1
Width	13	49	29.34	7.57
Thickness	5	17	11.28	3.54
Weight	3	48	13.86	9.79
(F) Bipolar flakes				
Length	19	49	32.92	9.67
Width	16	57	27.71	10.51
Thickness	11	38	18.07	6.66
Weight	6	159	26.85	39.7



**Figure 3.** Schematic representation of core types in FLK N. Unifacial: 1. Unifacial unipolar lineal; 2. Unifacial unipolar opposed. Bifacial: 3. Bifacial unipolar lineal; 4. Bifacial unipolar circular; 5. Bifacial bipolar opposed; 6. Bifacial multipolar orthogonal. Centripetal: 7. Centripetal unifacial; 8. Centripetal bifacial. Trifacial: 9. Trifacial/multifacial multipolar.

Dunnett T3 1.5, sig. .005). No significant differences in all the typometric groups were detected when comparing raw material type, length, breadth or thickness. These results show that hominins were selecting basalt nodules that were fairly homogeneous in shape and volume in order to undertake the percussion tasks performed at FLK N. The tendency for irregular basalts to fit within the same volumetric parameters would at least favor the idea that hominins were occasionally interacting with these items (i.e., minimally selecting, transporting and using some of them), even if these rocks were naturally present on the paleo-surface when hominins visited the spot.

**Cores**

We have identified both freehand and bipolar reduction strategies (Table 1). No previous study has recorded the presence of bipolar technique at FLK N. Freehand cores represent 71% of the core collection ( $n = 15$ ). Freehand knapping was undertaken preferentially on volcanic supports (80%): most of them are good-quality basalts and phonolite, although we have recorded one core made of a vesicular basalt support. Although less abundant, quartz blocks were also used for freehand knapping. Table 2C shows the mean size and weight of freehand cores. According to the combination of the three attributes mentioned in Materials and methods, we have identified four exploitation models (Fig. 3):

**Unifacial**

Cores in which negative scars are arranged in one single surface account for 40% ( $n = 6$ ) of the collection. Most unifacial cores show only one striking direction or platform. However, we have included in this group one unifacial bipolar specimen, in which two opposed and parallel striking platforms show negative scars in two directions. All unifacial specimens are made of volcanic rocks. Three cases have been exploited using basalt supports and two more using phonolite

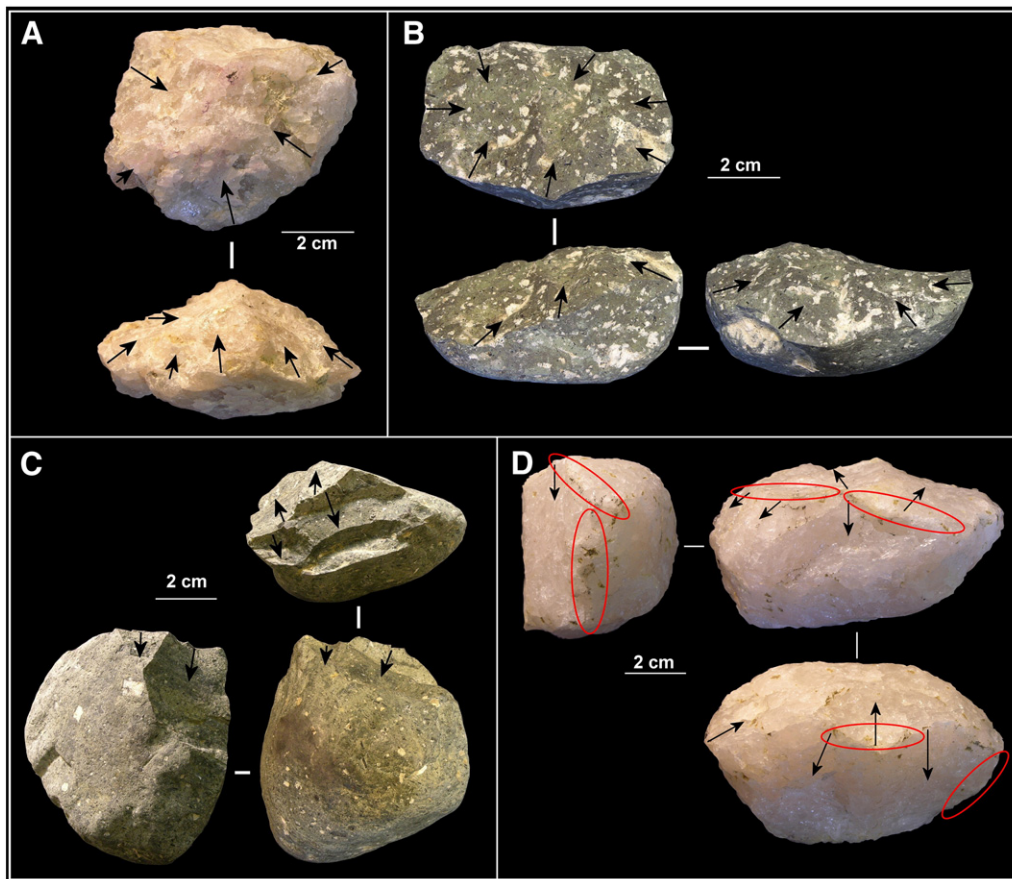
nodules. The unifacial bipolar opposed specimen has been exploited in vesicular basalt (Fig. 1B). Unifacial cores are the largest and heaviest of the collection, a pattern that agrees with a less intense volume exploitation and a lower ratio of detached flakes per item. The mean dimensions and weight of this group of cores are  $82 \times 64 \times 45$  mm and 298 g. The mean number of negative scars observed is five, while mean negative scar dimensions are  $33 \times 26$  mm.

**Bifacial**

Specimens in which exploitation has been conducted in two different striking surfaces account for another 40% ( $n = 6$ ) of the studied sample. According to the relationship observed between both striking surfaces, we have identified the following sub-groups: bifacial unipolar ( $n = 1$ ), where two surfaces of the original nodule have been exploited from a single striking platform. The specimen included in this sub-group has been knapped in a phonolite nodule and could be classified as a chopping-tool, following Leakey's typology (1971) (Fig. 4C); bifacial unipolar circular ( $n = 1$ ), a quartz whose bifacial reduction pattern is continuous and eventually circular (Fig. 4D); bifacial bipolar opposed ( $n = 1$ ), a basalt specimen showing the exploitation of two opposed parallel striking surfaces in two different planes ( $n = 1$ ); and bifacial multipolar orthogonal ( $n = 3$ ), two basalts and one quartz whose negative scars are present on two surfaces and whose negative scar sequences are arranged orthogonally (forming an angle close to  $90^\circ$ ). Cores exploited bifacially tend to show signs of more intense exploitation and volume reduction, although none of these cores has been exploited to exhaustion. The mean size and weight of bifacial nuclei are  $78 \times 60 \times 46$  mm and 249 g. They retain a mean number of 9.2 negative scars per core, with a mean dimension of  $35 \times 25$  mm.

**Trifacial**

In one case (7% of the total sample), the exploitation of a phonolite nodule has been carried out in three different surfaces and from multiple striking platforms. This item could be classified as a polyhedron, following Leakey's typological list (Leakey, 1971). The item measures  $46 \times 46 \times 39$  mm and weighs 125 g. Seven negative scars can be recognized on its surface, the largest of which measures  $34 \times 39$  mm.



**Figure 4.** (A) Bifacial centripetal core (quartz). (B) Unifacial centripetal core (phonolite). (C) Bifacial unipolar core/ chopping-tool (phonolite). (D) Bifacial unipolar circular (quartz) with signs of crushing on the edges.

#### Centripetal

We have identified in our collection two centripetal cores (13.33%) that comply with the technical criteria identifying centripetal or discoid cores (Boëda, 1995). One of them is a basalt core that shows a centripetal distribution of negative scars on a single knapping surface (Fig. 4B). The other is a quartz specimen in which a bifacial centripetal reduction has been carried out on two secant surfaces (Fig. 4A). Both centripetal cores have been intensively exploited. They are the smallest cores in our sample (mean  $62 \times 50 \times 31$  mm and 298 g) and show the highest core/negative scar ratio (10.5 per core). The flakes detached from these nuclei, in agreement with their higher level of exploitation, are the smallest (mean of  $28 \times 25$  mm).

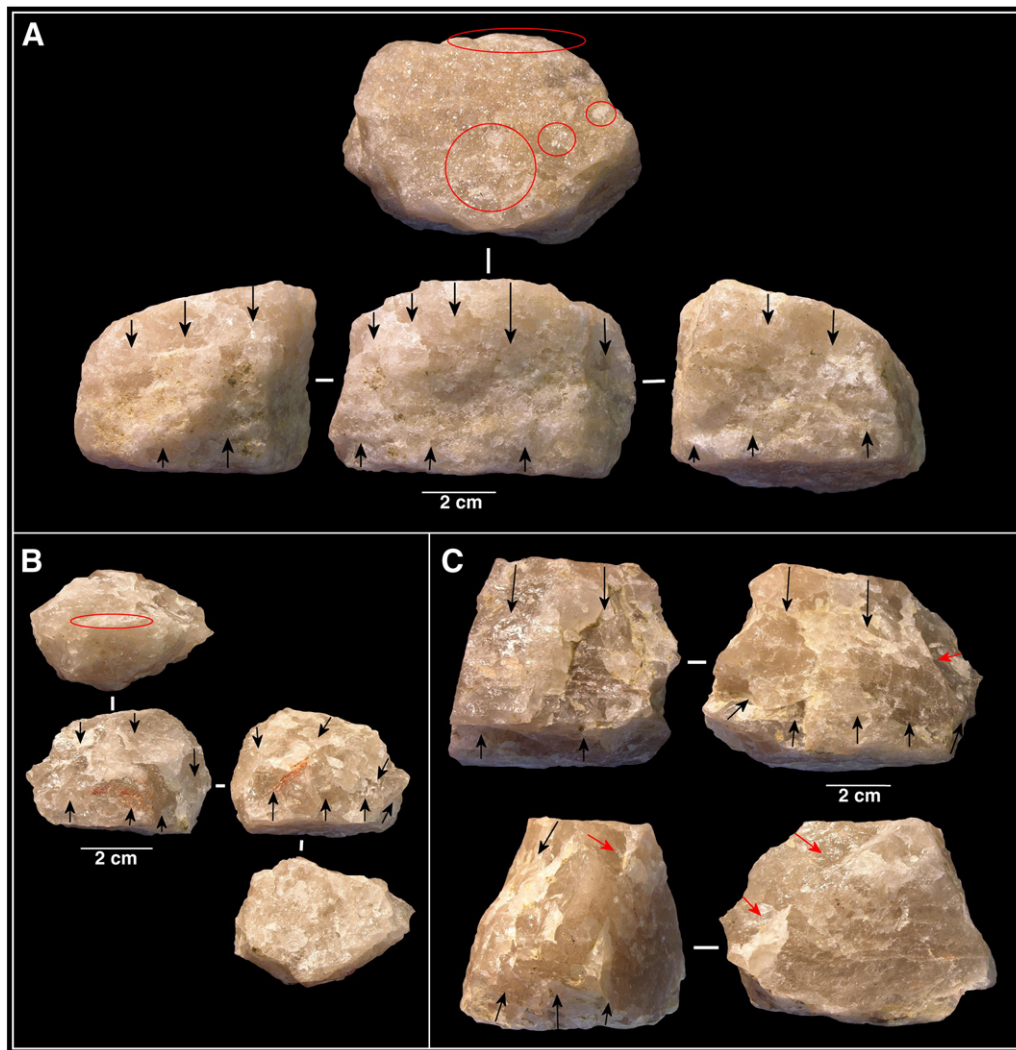
Bipolar knapping is present in our sample throughout 28% of the core collection, and it has been performed exclusively on quartz slabs. As a result of the progressive mass reduction related to bipolar knapping at FLK N, four bipolar cores can be classified as C1 (the platform and base remain stable during the whole reduction process). In two cases, continuous rotation from a single axis has produced a characteristic circular exploitation of the cobble, producing quintessential examples of C1 bipolar circular reduction (Fig. 5A, B). A third example of our C1 core sample is a good example of technological transfer from bipolar to freehand strategies (Fig. 5C). Finally, other specimens have undergone different series of core rotation and platform alternation (C2 and C3). An independent sample T test on both freehand cores and bipolar cores showed metric differences in length ( $t$  3.43, sig 0.003) and width ( $t$  3.45, sig 0.004) between both types, confirming that the bipolar technique tends to maximize the exploitation of the support,

taking it almost to the point of exhaustion (Table 2D) (Shott, 1989; Goodyear, 1993).

#### Detached products

In all, the result of core exploitation accounts for almost 58% of the lithic collection (Table 1). In our sample we include four phonolite debris items ( $\leq 25$ ). Most debris plus undetermined positives ( $\geq 25$  mm) lack diagnostic attributes and cannot be related to any particular knapping method (Suillivan and Rozen, 1985, Bradbury and Carr, 2004). Debris, shatter and undetermined positives represent almost half ( $n = 53$ , 54.6%) of the product category and 32% of the whole studied assemblage. A remarkable characteristic of shatter is that 92% has been produced from quartz.

Detached objects produced in the course of freehand reduction represent 30% of this category and include 24 flakes (two of which are volcanic rejuvenation specimens), three fragmented flakes and two retouched flakes. When we see the percentage contribution to flakes of the various raw material types, a remarkable imbalance exists. This imbalance can best be detected when we compare our core and flake collections sorted by raw material type. Table 3 shows the minimum expected core/flake ratio according to the number of negative scars observed in cores and the actual core/flake ratio observed in our collection. The three raw material types to which we refer do not fulfill theoretical expectations. In particular, basalt flakes are remarkably underrepresented in our collection according to our core sample. Other authors have already underlined this trait in the FLK N lithic collection, particularly in level 1-2 (Brantingham, 1998; de la Torre and Mora, 2005a). The higher amount of quartz



**Figure 5.** (A) Bipolar circular core (C1), showing sings of opposed load application and crushing on the platform. (B) Bipolar circular core (C1) in which the platform has ended up being a ridge (with signs of crushing) and the base still is recognizable. (C) Bipolar core showing sings of opposed load application. However, two series of freehand knapping have been identified (arrows in red).

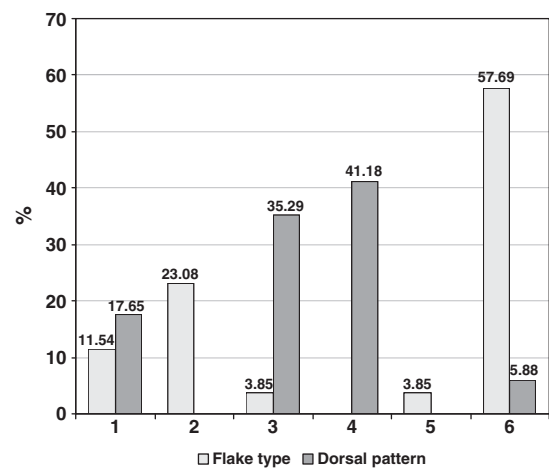
shatter is certainly related to the breakage properties of this raw material (Brantingham, 1998), but also to the presence of bipolar reduction (Kobayashi 1975; Shott 1989; Prous and Lima 1990; Goodyear 1993; Andrefsky 1998).

Hominins at FLK N were obtaining small- and medium-sized flakes from their freehand exploitation strategies (Table 2E). According to Toth (1982) classification, the most abundant flakes correspond to Type VI (~58% of the flake collection), followed at a distance by Types II and I (Fig. 6A). 54% of the striking platforms retrieved are uni-faceted, while 35% are cortical. Most flakes resulting from the last stage of reduction have been detached from quartz cores (80%). The predominance of first generation flakes

**Table 3**

Imbalance between cores and flakes in FLK N, sorted by raw material type: number of cores, mean negative scars counted per core, minimum expected flakes (calculated from mean negative scars in cores), number of flakes actually present in the sample, core/flake ratio.

	Freehand cores		Freehand flakes			Debris <20 mm
	Cores	Scars/core	Expected	Found	Core/flake	
Basalt	8	6.5	52	5	0.62	–
Phonolite	4	5.75	23	6	1.5	4
Quartz	3	9	27	19	6.3	38



**Figure 6.** (A) Percentage contribution of flake types (Toth, 1982). (B) Percentage contribution of dorsal pattern types (Bisson, 1990): 1. One parallel direction; 2. One convergent direction; 3. One irregular direction; 4. Two irregular directions; 5. Two opposed directions; 6. Radial (analysed sample = 27 specimens).



on basalt and phonolite tallies with the exploitation by means of these rock types of all unipolar blanks. Although the sole centripetal bifacial core retrieved is made of quartz, no radial dorsal patterns have been observed in any quartz flake. In all events, dorsal patterns preferentially tend to show an irregular arrangement of scars in one or two directions (Fig. 6B).

Identified bipolar positives account for 14% of the category of detached products. All these items have been produced exclusively in quartz. We have explained elsewhere the basic technological traits allowing identification of positives detached in the course of bipolar knapping on Naibor Soit quartz (Diez-Martín et al., 2009, in press). We will only reiterate here that, as a result of the particularities of fracture produced by two opposed forces, bipolar positives show a number of traits that differ significantly from freehand flakes: for instance, a variety of striking angles, no bulbs of percussion or ripple marks, the intersection of two opposed planes of fractures on ventral surfaces, opposed scarring at the platform and base on ventral surfaces, twisted ventral surfaces, remnants of two opposite platforms and crushed and/or absent platforms. These traits are not necessarily present in every specimen, and therefore the identification of bipolar positives might occasionally be difficult (Andrefsky, 1998). The items identified here as bipolar positives bear some or all of the technological traits mentioned. However, since in many instances bipolar reduction tends to be poorly controlled, a variety of angular fragments may occur. Therefore, unidentified positives, fragments and shatter, which constitute 50% of our collection, may be related in great numbers to bipolar load application (Diez-Martín et al., in press).

We have compared dimensional values recorded in both bipolar and freehand flakes (Table 2F). An independent sample T test analysis, using Levene's test for equality of variances, yielded non-significant differences for most bipolar and freehand flake dimensions (length and width) and weight. However, significant differences in thickness were detected when comparing both samples ( $t = -4.38$ , sig. .000), which matches our observation that the opposed striking of quartz slabs produces rather thick products due to the enormous and badly controlled mass loss experienced by the core.

Three quartz artifacts included in this category bear signs of retouching. Two are freehand flakes showing a denticulate and an abrupt retouch opposed to a natural cutting edge, respectively. The third one might be a bipolar positive in which two concave blows have produced a pointed edge.

## Discussion

### Technological interpretations

The two major published works on the FLK N material are Leakey's (1971) and de la Torre and Mora's (2005a) re-examination of Leakey's material. Each work presents a different typological and/or technological diagnosis that can reveal alternative behavioral scenarios. In order to look more deeply into the rationale of such different perspectives, we find it useful to compare Leakey's and de la Torre and Mora's conclusions with ours. Table 4 shows the percentage distribution of lithic objects within these categories, sorted by levels 1–6 according to Leakey's (1971) and de la Torre and Mora's (2005a) interpretations. Figure 7 shows the general percentage distribution of categories seen at FLK N following Leakey, de la Torre and Mora, and this study. The present study is closer to the data provided by Leakey's work. In both cases flakes constitute the most abundant category in terms of number of specimens (cores and flakes account for 66% in Leakey's collection and 68% in ours).

In contrast, de la Torre and Mora (2005a) present quite a different picture. For these authors the bulk of the lithic materials retrieved at this site are related not to knapping processes but to battering elements. For them the collection reflects intensive percussion behavior. The rationale behind this statement is based on the fact that de la Torre and Mora

include most of the materials interpreted by Leakey as débitage within the percussion elements. What is certain is that, although this is not done explicitly in their classification lists, they are very much inclined to incorporate most of the quartz material included in the lithic categories identified by them as “fragments <20 mm,” “possible flake fragments” and “angular fragments” (de la Torre and Mora, 2005a,b: Tables 4.1, 4.2, 4.4, 4.6 and 4.8) within the percussion elements. Their decision seems evident when, talking about the collection retrieved in level 5 they write “...it may seem reasonable to interpret a substantial part of the purported flake fragments as the result of battering activities and, therefore, as being positives detached from anvils...” (ibid: 63). The same impression is apparent when they refer to the collection retrieved from level 6. Thus, following de la Torre and Mora's diagnosis only artifacts included in the lithic categories of “whole flakes” and “retouched pieces” and non-quartz waste could be classified unambiguously as the by-products of knapping activities. This is why, following the most restrictive scenario (that in which all the possible flake fragments, angular fragments and fragments <20 mm made of quartz would be considered percussion by-products), it is possible, for instance, to calculate ~83% of items related to percussion activities in FLK N level 6 (Table 4).

We disagree with de la Torre and Mora's interpretation of the quartz operational sequences, as we conclude that a number of traits observed in some of the objects classified as quartz anvils by de la Torre and Mora can be alternatively considered to be bipolar cores and that some of the quartz angular fragments documented may consequently be the by-product of bipolar knapping (Diez-Martín et al., 2009). Our perspective implies, thus, a significant difference in the percentage distribution of categories. By identifying quartz bipolar cores as anvils (the most relevant artifact category in level 6 to de la Torre and Mora, 2005a) and by including a great amount of shatter as unintentional by-products of percussion activities, these authors are over-estimating the percussion category. Our objections to de la Torre and Mora's “anvil hypothesis”, which has been the object of a more in-depth discussion elsewhere (Diez-Martín, et al., 2009), is summarized in Table 5.

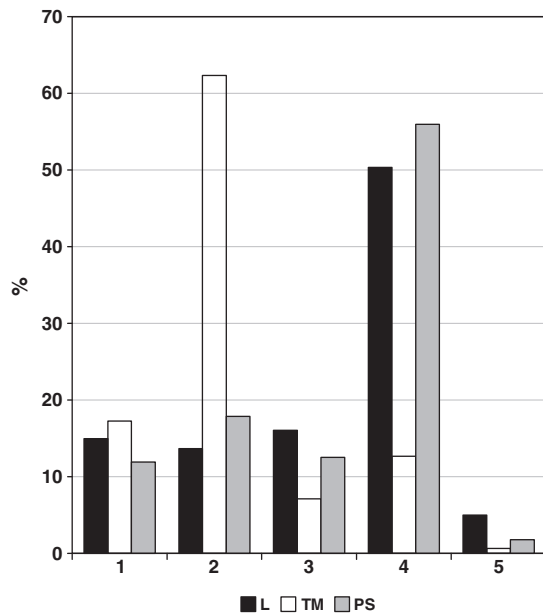
### Reconstructing operational sequences at FLK N, level 1–2

As we can see in Figure 8 and Table 6, the uppermost section, coinciding with level 1–2, was particularly rich, as it alone account for ~61% of the whole sample studied here. This over-abundance of lithic

**Table 4**

Percentage distribution of lithic findings within the steps included in the manufacture stage of the operational sequence, according to Leakey's (1971) and de la Torre and Mora's (2005a) data. (A) Using Leakey's (1971) data: non-modified stones (manuports), cores (choppers, polyhedrons, discoids, heavy-duty scrapers, proto-bifaces, core fragments), products (flakes, broken flakes and chips, retouched and trimmed flakes), percussion elements (hammerstones, anvils, spheroids/sub-spheroids, cobblestones, nodules and blocks). (B) Using de la Torre and Mora's (2005a) data: non-modified stones, cores, products (flakes, retouched flakes, <20 mm fragments on lava, possible flake fragments on lava, inform fragments on lava), percussion elements (percussors, hammerstones with fracture angles, anvils, <20 mm fragments on quartz, possible flake fragments on quartz, inform fragments on quartz, fragments with battering).

Level	Unmodif.	Percussion	Cores	Flakes	Ret. flakes
<b>Leakey (1971)</b>					
1–2	14.84	11.17	14.7	53.42	5.86
3	18.57	19.05	14.76	42.38	5.23
4	20.24	35.71	17.86	23.8	2.38
5	15.11	16.67	30.56	36.66	-
6	5.38	13.85	11.54	65.38	3.84
<b>de la Torre and Mora (2005a,b)</b>					
1–2	16.9	61.99	6.94	13.6	0.54
3	20.56	59.34	7.48	11.21	1.4
4	33.73	48.19	9.64	8.43	-
5	20.25	57.05	9.81	12.26	0.61
6	1.55	82.82	3.1	7.75	0.77



**Figure 7.** Mean percentage distribution of categories following Leakey (1971) (L), de la Torre and Mora (2005a) (TM), and this study (PS).

remains in the uppermost part of the section is coincident with Leakey's figures (Leakey 1971). Due to the scarcity of materials in other parts of the section, we will analyze here only the operational sequences observed in level 1–2 (Fig. 9).

In this temporal–depositional unit, battering activities have been very intense. All the types of percussion artifacts recognized by us (almost exclusively composed of volcanic rocks: basalt, vesicular basalt and phonolite) are present here. It is also possible that some of the irregular basalts, vesicular in most cases, have been used in percussion activities, showing that these materials might have entered the process of anthropogenic use. It is interesting to point out that 43% of the hammerstones included here have lost some lithic mass in the course of percussion. However, it is remarkable that the by-products of percussion activities are almost absent, as we have only found a positive of percussion in phonolite. Volcanic rocks have similarly been the object of freehand knapping. We have found a very abundant collection of basalt and phonolite cores, representing the variety of reduction strategies present at FLK N. In contrast, the products of this reduction process are lacking. A rejuvenation flake in basalt might suggest some knapping at the spot but, in spite of the variety of core types, only the earliest and the latest stages of the reduction process (Toth's types 1, 2, and 6) have been found. Only 16% of the phonolite flakes expected in theory have been retrieved. This imbalance is more acute in the case of the basalt flakes, since 88% of the flakes theoretically produced at the site in this raw material, based on a minimum number of pieces estimated, are missing.

At FLK N 1–2, quartz slabs have been directed exclusively to exploitation. Freehand cores show bifacial models, one of them centripetal. Again, only the first and the last phases of the reduction sequence are present here, and again there is an imbalance in the operational sequence of freehand quartz reduction, as only 44% of the expected flakes have been found. Retouching is present in two quartz flakes (a denticulate and an item with an abrupt retouch). Quartz blocks have also been directed to bipolar reduction (mostly without core rotation), although one bipolar core shows a series of freehand knapping and some sort of transfer between quartz reduction strategies. The relation between bipolar cores and products seems to be more balanced, as the greater number of quartz positives and shatter is in agreement with the bipolar technique. It seems plausible that the bipolar manipulation of quartz is more closely related to on-

site reduction. It would be reasonable to think that the lack of freehand positives shows the off-site transfer of these products. Alternatively, some cores already exploited elsewhere may have entered the site to be used in tasks alternative to knapping (Kimura, 1999). As an example supporting this interpretation, one freehand core on quartz, exploited following a bifacial circular strategy, shows battering on two edges. This evidence confirms that some material, after being subjected to freehand reduction (not necessarily on-site), may have been used in battering activities. In sum, we have identified behaviors linked to percussion and knapping activities, despite most of the latter being highly fragmented.

#### *The behavioral meaning of the lithic sample*

Recent excavations undertaken at FLK N have produced a new lithic collection that can shed more light on hominin presence and activities at this spot, a dry promontory located within an extensive wetland (Ashley et al., 2010). This specific spot attracted both carnivores and, more marginally, hominins. Moreover, vertical reconstruction of the depositional sequence in our excavation provides evidence for the existence of a refuse continuum, probably tinged by some sort of vertical migration of materials within the clay deposit (see Dominguez-Rodrigo et al., 2010), over a long period of time. The intensity of this discard activity is difficult to assess, as it could be formed by the accumulation of a variety of short-term episodes or more continuous activity.

The lithic sample retrieved in the course of our fieldwork has shown the co-occurrence at the site of different technological behaviors. Hominins were definitely involved here in varied and intense battering activities. These nodules, selected for their dimension, shape, and ergonomic suitability for hammering, must have entered the site by anthropogenic means. Other basalts, mostly vesicular and amorphous, might have been brought to the area by natural processes (de la Torre and Mora, 2005b). However, it seems reasonable to assume that, in a place where intense percussion activity has been detected, some sporadic use of a number of these amorphous items by hominins might have occurred. The idea that hominins occasionally took advantage of these irregular stones can be inferred by the similarity in size to that of good cobbles and hammerstones, and by some possible hominin interaction with a number of these items. Knapping activities have also been documented at the spot. Volcanic rocks were also directed, more marginally, to freehand knapping while quartz slabs were used in both freehand and bipolar reduction strategies.

We have observed that the operational sequences related to knapping activities are highly fragmented. Clear breakages in the freehand exploitation continuum have been detected. Imbalances in core/flake ratios show that a high number of freehand flakes related to the whole reduction sequence might have existed at (or never entered) the site. This pattern is most evident when the raw material is a volcanic rock (mainly basalt), although it can also be observed in the case of quartz. Fragmentation in the freehand reduction operational sequence of quartz is also confirmed. Some authors have argued that at FLK N quartz materials might have been subject to more on-site knapping activity (Brantingham, 1998). We believe that the closest case, albeit problematic, to on-site reduction is bipolar knapping. Although we have detected cases in which the operational sequence of bipolar knapping is also fragmented, it seems that the by-products of the bipolar technique observed at the site are more coherent with a situation of on-site manipulation. The different pattern observed in freehand and bipolar reduction might be related to the expedient and low-mobility character of the latter, as a number of authors have pointed out (Shott, 1989; Jeske, 1992; Curtoni 1996). It certainly seems that the products of freehand reduction have been subjected to more intense mobility in the area (Potts, 1988, 1991). Alternatively, it is possible to suggest that some cores might have



**Table 5**  
The anvil hypothesis purported by de la Torre and Mora (2005a) and main objections to this perspective following our alternative interpretation (Diez-Martín et al., 2009).

Torre and Mora's interpretation (2005)	Technical traits observed	Alternative interpretation
<b>QUARTZ ANVILS</b>		
<p>“... one of the flat sides to be used as a percussion platform (A) whilst the opposite side (B) is positioned on a stable ground... platform A is full of impact marks, especially by the edges... Platform B, although it does not receive direct blows, also experiences écaillés and fractures given the force transmitted to the block and being in contact with the ground (de la Torre and Mora, 2005a,b: 60).</p>	<p>M. Leakey (1971: 7) defined anvils as: “... cuboid blocks or broken cobblestones with edges of approximately 90° on which there is battered utilization, including plunging scars”.</p> <p>This definition is assumed by de la Torre and Mora, 2005a,b: 60).</p> <p>As a result of the whole process, the surface of the block exposed between the two natural planes (C) is modified by percussion, generating numerous scars with hinged and stepped morphologies throughout the whole periphery of the block (de la Torre and Mora, 2005a,b: 60).</p>	<p>In bipolar core reduction it is common for the striking angle to tend towards 90° (although non-axial striking angles can also be produced, Mourre, 2004).</p> <p>Presence and intensity of crushing and battering on ridges, areas or points, is a common trait in bipolar knapping.</p> <p>Bipolar reduction of cores results in two series of opposed detachments from the striking platform (Torre's A) and from the base (Torre's B), representative of opposed load application (Leaf 1979; Crabtree, 1982; Shott 1989; Jeske and Lurie 1993).</p> <p>An object placed on the ground (high elasticity index) would absorb most of the unidirectional force, which makes it improbable that the described pattern would be produced (Baena, 1998; Diez-Martín et al., 2009).</p> <p>- Hinged and stepped morphologies are common both in bipolar and freehand cores, due to the opposed force producing involuntary detachments generated at the base of the core (Leaf, 1979, Mourre, 2004).</p>
<b>SHATTER, ANGULAR/BLOCKY FRAGMENTS, IRREGULAR DEBRIS</b>		
<p>“Several small fragments were detached from anvils due to percussion during battering activities... the purported débitage fits the functional interpretation resulting from our study” (de la Torre and Mora, 2005a,b: 60).</p>	<p>The purported flake fragments lack typical features of flakes: bulbs, dorsal faces with previous scars, butts... (de la Torre and Mora, 2005a,b: 60)</p> <p>... the battering traces in some of them... would indicate that most of these fragments could be the involuntary result of battering activities (de la Torre and Mora, 2005a, b: 60).</p>	<p>Quartz breakage produces many step and hinge fractures (Mourre 2004). Application of both freehand and bipolar reduction on quartz produces a high variety of non-standardized by-products: chunks, blocky debris, basal fragments (Leaf, 1979; Sullivan and Rozen, 1985; Kuitj et al., 1995; Amick and Mauldyn, 1997; Bradbury and Carr, 2004).</p> <p>Bipolar reduction often produces positives with no bulbs of percussion, no butts, no compression rings, no dorsal scars, twisted ventral surfaces and signs of battering on striking surfaces (Diez-Martín et al., 2009).</p> <p>Load application in bipolar knapping is badly controlled and it can produce positives, fragments and chips that are neither controlled nor pursued by the knapper (Shott 1989).</p>
<p>... the so-called quartz débitage, which would, in fact, be nothing but fragments detached from anvils...” (de la Torre and Mora, 2005a,b: 77).</p>	<p>... Finally, Level 1-2 has 25 anvils, accounting for over 10 kilograms of raw material, approaching the total volume of débitage (de la Torre and Mora, 2005a,b: 77)</p>	<p>The intensive mass loss produced in the anvil suggested by Torre and Mora is in disagreement with available actualistic data. Experimental, observational and archaeological work suggest that stationary anvils used in the course of stone (bipolar knapping) or organic material processing do not show such an intense mass loss (Honea, 1965; Jones, 1994; Joulian, 1996; Goren-Imbar et al., 2002; Mercader et al., 2002; de Beaume, 2004; Diez-Martín et al., 2009).</p>

entered the site in their final form, that is, having already been exploited elsewhere. We have found one freehand quartz core showing evidence of battered edges (Fig. 4d) and other authors (de la Torre and Mora, 2005a) have also reported such items. This evidence suggests that a number of already exploited nodules could have been brought into the site to perform other tasks not related to core exploitation but linked to battering. This evidence indicates that at FLK N, hominins were quite flexible in their use of material. The same way that some transfer in knapping methods are documented, functional transfers (cores used as hammerstones or anvils) may have occurred.

The imbalance of flakes and core fragments in our collection would permit us to entertain the idea that a minimal exploitation of lava cobbles might have taken place on site and that hominins were interested in these cores for other purposes. Fragmentation of the knapping operational sequence is related to the idea that the presence of hominins at this spot might have been driven by short, sporadic and non-intense visits by hominin groups over a vast time span.

Fragmented operational sequences might indicate fragmented tasks (with a high rate of functional transfer), interests or aims of hominins at this precise spot, that is to say, a low, non-organized hominin impact on the site and its resources.

Some authors have argued that at FLK N percussion activities not related to knapping processes were the main task performed by hominins (de la Torre and Mora, 2005a). Although we attribute more relevance to knapping than these authors do (including bipolar reduction, a knapping strategy previously unreported at this site), we agree that percussion activities are the most representative at FLK N. We have, however, reached this conclusion not because of a high percentage of lithic artifacts related to percussion activities (which our study does not support), but because of the fact that percussion operational sequences seem to be fairly complete. In a framework in which hominin activities tended to have a low impact, percussion seems to be the most coherent and complete form of behavior recognized at the site.

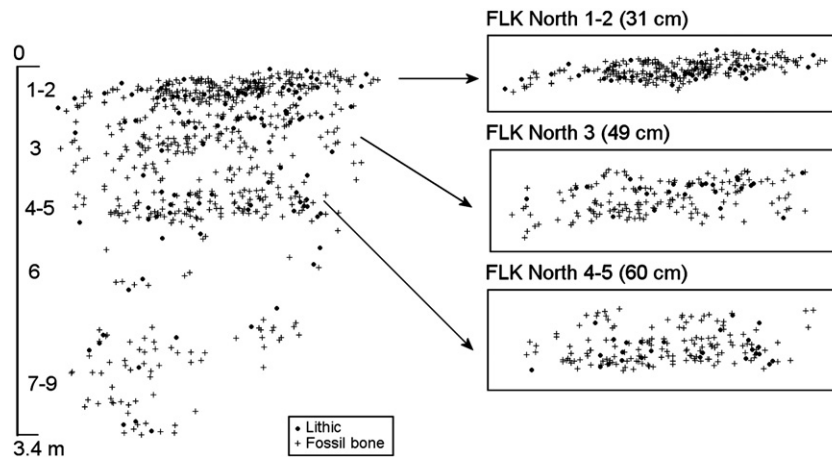


Figure 8. Vertical distribution of archaeological remains plotted in FLK N Bed I sediments.

Although bones and stones co-occur at the same spot, it is difficult to infer a clear hominin involvement in this association. We rely on adequate information to interpret this site mostly as a palimpsest of non-related animal and hominin behavior. Data retrieved in the course of re-examination of the fossil collections excavated by Leakey (Domínguez-Rodrigo et al., 2007; Egeland 2008), and confirmed by our excavation (Domínguez-Rodrigo et al., 2010), cast doubt on the active role played by hominins in bone accumulation at FLK N. The scarcity of bones with hominin surface modification or percussion breakage patterns suggests that hominins were not involved in bone accumulation and fragmentation. On the contrary, felids seem to have been primarily responsible for bone accumulation and consumption at FLK N.

If hominins were sporadically, but over a long period of time, visiting the site to undertake a variety of tasks, among which percussion activities seem to be the most consistent behavior, and if they were not involved in breaking long bones for obtaining marrow or butchering the herbivore carcasses mostly accumulated by felids, what were they doing at this site? What kind of advantages afforded by the site encouraged them to keep visiting this place on a long-term basis? What types of tasks can be inferred from the identified operational sequences? What is certain is that they were interested in producing cutting edges through the implementation of rather simple reduction strategies (amongst which bipolar knapping was the most expedient and localized). However, the operational sequences show that core reduction was probably a marginal behavior, reconstructed through the chaotic accumulation of fragmented parts of the knapping continuum. This fragmentation and the transfer of a large number of flakes off-site are at odds with intensive butchery activity at the spot. On the other hand, percussion tasks seem to have taken place on-site,

so hominins were actively performing the processing of undetermined materials, other than bones. Vegetal tissues, nuts, roots and plants, could be candidates for these alternative activities (Toth 1985; Willoughby 1987; Goren-Inbar et al. 2002; de Beaume 2004). Our study of the lithic sample would favor this hypothesis of plant exploitation through battering activities, as we are convinced that the array of percussion damage observed in hammerstones and nodules cannot be related exclusively to the possible knapping activities undertaken at the spot. The core exploitation documented in our trench produced a very small number of flakes, mostly concentrated in level 1-2 (Table 7), which is where most of the evidence of hominin involvement with carcasses, even if marginal, is documented (Domínguez-Rodrigo et al., 2007).

**Conclusions**

Paleoecological reconstruction suggests that FLK N might have been a dry land in the middle of a marshy area, probably characterized by a closed-vegetation habitat (see Ashley et al., 2010). The strategic characteristics of this location might have encouraged the co-occurrence of different agents related to different activities and behaviors. Hominins, as well as carnivores, are among the most recognizable agents that visited the spot. However, it seems that hominin impact was low and unclear over what seems to be a long period of time. Hominin visits were probably mostly driven by the presence of undetermined non-animal resources that needed processing by intense battering. Non-elaborated cutting edge production at the spot was probably a secondary, less important task, presumably linked to the processing of the same resources or for the butchery of the few carcass remains documented to have been hominin-modified.

**Table 6**  
Lithic collection sorted by level, raw material and category.

Categories	Level 1-2				Level 3				Level 4-5				Level 6				Level 7-9			
	P	B	Q*	Total	P	B	Q	Total	P	B	Q	Total	P	B	Q	Total	P	B	Q	Total
Irregular bas.	–	13	–	13	–	2	–	2	–	1	–	1	–	1	–	1	–	3	–	3
Nodules	–	1	–	1	–	1	1	2	–	2	–	2	–	–	–	–	–	–	–	–
Hammerstones	4	16	1	21	–	1	–	1	–	–	–	–	2	–	–	2	–	–	–	2
Anvils	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–
Perc. fragments	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Freehand cores	2	7	3	12	–	1	–	1	1	–	–	1	–	–	–	–	–	–	–	1
Bipolar cores	–	–	4	4	–	–	1	1	–	–	1	1	–	–	–	–	–	–	–	–
Shatter	–	–	20	20	–	–	10	10	3	–	14	17	1	–	1	2	–	–	4	4
Freehand flakes	2	5	13	20	3	–	1	4	–	–	3	3	–	–	–	–	–	–	2	2
Bipolar flakes	–	–	10	10	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–
Total level	9	42	51	102	3	5	16	24	5	3	18	26	3	1	2	6	1	3	6	10
% level	8.8	41.2	50	60.7	12.5	21	66.5	14.3	19.2	11.5	69.2	15.5	50	16.6	33.3	3.6	10	30	60	5.9

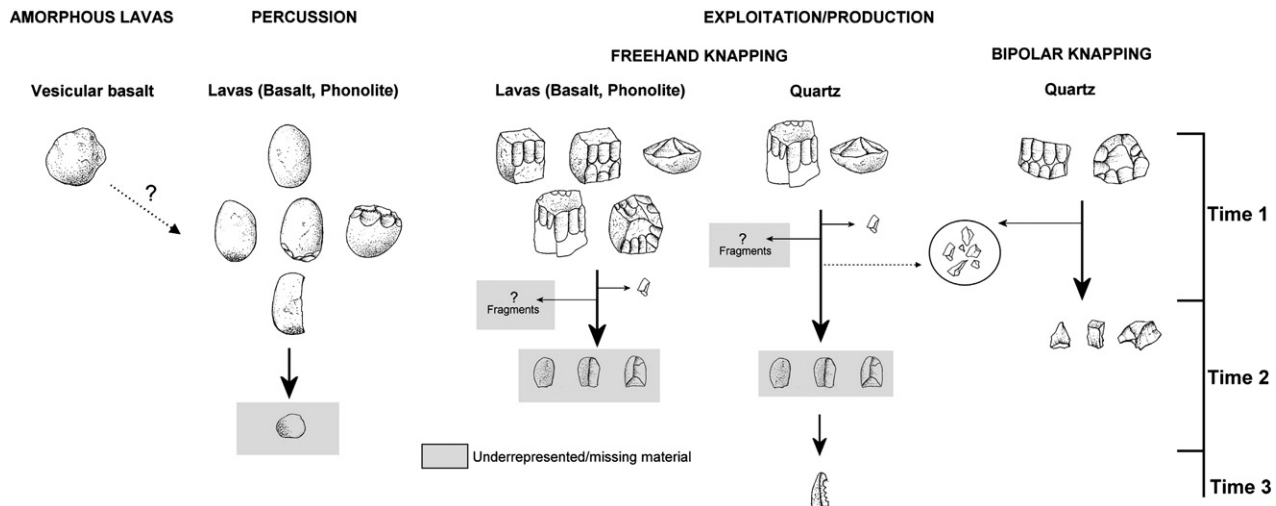


Figure 9. Operational sequence reconstructed in FLK N 1-2.

Battering must have targeted the exploitation of plant resources since not a single bone retrieved from Trench 1 bore any traces of hammerstone percussion, despite the excellent preservation of their cortical surfaces (Dominguez-Rodrigo et al., 2010). Most of the battering was carried out by volcanic nodules. Quartz was used for core exploitation, though both bipolar and freehand techniques. The reduction sequences documented are very incomplete and seem to respond better to behavioral rather than taphonomic causes. The few cutting tools documented in our excavation could have been used for butchering the few carcass remains documented to have been exploited by hominins, since they cluster in level 1–2 where more of this evidence is also found. Battering is documented across the whole stratigraphic sequence. Disentangling the types of resources processed by hominins at this particular spot would be critical to understand the predominance of battering activities not related to marrow extraction.

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