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Limestone percussion tools from the late Early Pleistocene sites of Barranco León and Fuente Nueva 3 (Orce, Spain)

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In recent years, there is growing interest in the study of percussion scars and breakage patterns on hammerstones, cores and tools from Oldowan African and Eurasian lithic assemblages. Oldowan stone toolkits generally contain abundant small-sized flakes and their corresponding cores, and are characterized by their structural dichotomy of heavy- and light-duty tools. This paper explores the significance of the lesser known heavy-duty tool component, providing data from the late Lower Pleistocene sites of Barranco León and Fuente Nueva 3 (Orce, Spain), dated 1.4–1.2 Myr. Using quantitative and qualitative data from the large-sized limestone industries from these two major sites, we present a new methodology highlighting their morpho-technological features. In the light of the results, we discuss the shortfalls of extant classificatory methods for interpreting the role of percussive technology in early toolkits. This work is rooted in an experimental program designed to reproduce the wide range of percussion marks observed on the limestone artefacts from these two sites. A visual and descriptive reference is provided as an interpretative aid for future comparative research. Further experiments using a variety of materials and gestures are still needed before the elusive traces yield the secrets of the kinds of percussive activities carried out by hominins at these, and other, Oldowan sites.

1. Introduction

Interest in the study of hammerstones and the traces they bear has recently been brought to the fore in the literature regarding some key late Early and Middle Pleistocene sites in Africa and Eurasia, for example, Melka Kunturé [1]; Olduvai Gorge [2,3]; Isernia la Pineta [4] and Gesher Benet Ya'aqov [5]. The current assimilation of an inter-disciplinary approach to prehistoric archaeology highlights exploration in percussive technology as a central research axis, not only in lithic studies, but also in the fields of taphonomy, primatology, ethnography, palaeontology and archaeozoology [6–8]. Traces on bones and stones are now closely examined for their value as agents for deciphering percussion-related activities carried out by our early tool-making and tool-using ancestors. Percussive technology has been defined by Whiten *et al*. as: '... the use of tools to strike surfaces and objects, their functionality deriving from the impacts involved' [7, p. 420]. Since the dawn of technology, percussive activities have been carried out with 'tools' that today we commonly refer to by the generic term: 'hammerstones'. But, their morpho-functionality is in fact highly diverse and little is known about their real uses. Hammerstones are an essential part of most early stone toolkits, notably those allotted to the Oldowan (heretofore) or 'Mode 1' techno-complex [9,10]. Oldowan toolkits show a bi-format component distribution of (i) large cobbles, cores and/or core-tools and (ii) debitage. This paper deals specifically with the former, comparatively neglected, *macro* or *heavy-duty* tool component. We focus on the limestone tools from Barranco León and Fuente Nueva 3 (Orce, Spain: heretofore BL and FN3).

This quantitative and qualitative study provides a methodological basis for analysing percussive tools, as a means for future intra-site comparisons. Over the years researchers have encountered difficulties treating this theme, especially in attempts to define criteria to differentiate between 'cores' and 'tools'. This complexity was brought to the fore in the early 1970s, notably following work on the eponymous sites of Olduvai Gorge [9]. It has also been largely treated by specialists working not only in Africa [11–13], but also in Europe [14–16] and, more recently, in Asia [17]. These and other researchers have grappled with difficulties involved in defining 'types' of macro-tools in archaic assemblages lacking the standardization to do so. Although one of the main reasons for this classificatory turmoil lies in the non-standardized nature that is so distinctive of Oldowan industries, it must be stressed that, in light of recent research, *non-standardized* does not necessarily imply *random*. Systematic core reduction strategies do in fact prevail in early toolkits, whose relative sophistication is commonly acknowledged today [18]. The oldest stone industries are African and date to 2.6–2.3 Ma or older [19] at Gona [20,21] and Hadar [18,22] in Ethiopia, in Ethiopia's Omo Basin [12,23–25] and West Turkana [19,26,27] in Kenya. Any morpho-technological dichotomy between macro-tools (hammerstones) and cutting tools (debitage) in these oldest core-flake assemblages does not appear to vary according to raw material type, making it all the more difficult to establish. It has, however, been made clear that the physical and formal qualities anchored in a preferred raw material at these sites are not random [28]. In all cases, the macro component of earliest stone assemblages consists of whole, broken and/or knapped cobbles bearing traces of impact attributed to percussive activities carried out by hominins.

Oldowan assemblages that do show discriminate use of two or more distinct raw materials do not occur in the African archaeological record until *ca* 2–1.9 Ma [29,30]. However, this feature is already present in earliest stone toolkits outside of Africa, at Dmanisi, for example, from *ca* 1.8 Ma [31] or Ubeidiya, from *ca* 1.6 Ma [32]. The significance of this duality (or multiplicity) suggests that the selection of raw materials was effectuated in relation to specific uses or morpho-types within each individual site context. From that point, morpho-functional demarcation became more apparent, heralding the first technological and typological differentiations in relation to raw material types. The rupture from unique raw material exploitation is therefore at the root of an important selective process that involves a complex planning phase wherein raw materials come to be chosen in accordance to their foreseen use(s).

Difficulties related to homogenizing terminology or categorization of macro-tools are further reflective of their polymorphous role in early toolkits as these voluminous items served as cores for flake production, as hammerstones for percussive activities (pounding, bashing, breaking, crushing) or for all of these. This *functional* plurality has sometimes been used to categorize the tools. For example, the denomination 'chopper-core' assigns function to cobbles with knapped or broken edges presenting traces of use [9]. In non-standardized Oldowan toolkits, use-wear visible to the naked eye on natural or knapped edges (crushing, irregular retouch) is regularly cited as a criterion to differentiate cores from core-tools [30,33]. Unfortunately, it is not always easy to determine the origins of such traces on stone edges (taphonomical causes, involuntary knapping-related stigma). In her analysis of the Olduvai Gorge industries, M. Leakey [9] established a category called: 'utilized material' encompassing '... anvils, hammerstones, cobblestones, nodules and blocks, light-duty flakes and other fragments ...', although an anthropic origin for some of this material is contested [33, p. 7].

This paper considers the significance of the macro-tool component of the BL and FN3 stone toolkits in particular, and of Oldowan stone industries in general. We examine the situation and morphology of stigma observed on edges/surfaces of limestone macro-tools from these sites, moving beyond the knapping sequences. This analytic work stems from their abundance and variability observed during our recent re-study of the limestone tools from Orce and the consideration that they are *a priori* revelatory of the uses of these voluminous objects and, therefore also, of past hominin activities. The ultimate goals of this study are to: (i) establish a morpho-technical database; (ii) decipher and catalogue different kinds of traces on the limestone tools; and (iii) ascertain what kinds of activities could have been carried out with macro-tools at these Oldowan sites.

2. Geo-chronological setting of the Barranco León and Fuente Nueva 3 sites

The BL and FN3 sites are located in in the Guadix–Baza basin (Orce, Andalousia, Spain). During the late Lower Pleistocene, the Baza sector of this depression was filled with a saline lake, formed in the Upper Miocene [34]. The endorheic lake system was drained at the end of the Pleistocene (approx. 0.2 Ma) when its waters were captured by the Guadalquivir River and its affluents. Subsequently, the alluvial (Guadix) and colluvial (Baza) basin infill was deeply carved into by erosive and tectonic activity, exposing an imposing depositional succession up to 100 m thick. The Baza sector, where the sites are located, displays successive layers of lacustrine clays, silts, sands and evaporitic limestone crusting and is well known for having yielded a rich fossiliferous and archaeological record in a controlled-stratigraphical and archaeo-chronological context, unique in Europe [35].

At BL and FN3, lithics found associated with large and small herbivore and carnivore fossils attest to the hominin presence. Some bones present cut marks and traces of intentional percussion [35,36]. The age of the sites has been evaluated by correlating data from biochronology, magnetostratigraphy and U-series/electron spin resonance dating (ESR) on quartz grains and tooth enamel ([37,38] and references therein; [39–41]). A hominin infant tooth is documented from BL [42]. The depositional sequences have negative polarities throughout and, in light of the faunal associations, are attributed to the Matuyama Chron, bounded by the Olduvai and Jaramillo subchrons (1.78–1.48 Ma and 1.07–0.98 Ma, respectively). The age for the BL site is evaluated at 1.4 Ma, while that of FN3 is slightly younger at *ca* 1.2 Ma.

Systematic excavations underway since 1995 have spurred continuous multidisciplinary research at the sites for nearly a quarter of a century [35]. Today, BL and FN3 are established as the oldest among a handful of other Western European sites having yielded a significantly large lithic sample of comparable chronology [43–46].

3. The limestone assemblages: preservation and percussive trace frequency

The local raw materials used by hominins at BL and FN3 include flint, used exclusively for knapping small flakes, and limestone, reserved mainly for percussive activities. Subtle behavioural patterns may be discerned from the strictly local raw material sourcing patterns documented at these sites. The toolkits contain a majority of small-sized flint flakes (2–3 cm) with some fragments and a few cores. The larger limestone tools show high morpho-technical diversity and very often display traces of percussion. The limestone assemblages comprise whole and broken cobbles or blocks, cores and some large shaped tools. The correlation between raw material type and tool function is clear: flint was preferred for small flake production and limestone for heavy-duty percussive activities [47]. While the bulk of the limestone was expediently knapped, the flint cores and flakes yield relatively lengthy reduction sequences.

Focusing on the formal and technical aspects of the industries highlights patterns and differences between the two sites that had not been recognized before. It is no longer doubted that the Oldowan hominins were capable of planning and foresight in the selection of their raw materials [48]. The morphometrical dichotomy observed from the Orce industries clearly demonstrates that flint and limestone were collected *from the outset* for very different purposes. This functional dichotomy is interesting to explore as it is the foundation of specific processes with regard to formal and qualitative raw material selectivity. Up to now, petrographical research has focused mainly on the flint, different qualities of which are found outcropping from Jurassic limestone formations and from secondary deposits 5–15 km from the sites [35].

Both sites contain limestone cobbles and blocks whose bearing on anthropic activity is difficult to ascertain. Three types of limestone are documented at BL (silicified, marly, oolithic) and four at FN3 (silicified, marly, marly with fossils, sandy) [35]. Different qualities of limestone were available to hominins both in and around the sites, as cobbles in local channels and blocks in nearby outcrops, in a range of forms and textures that were exploited for knapping and/or hammering. Most cobbles display lightly rolled surfaces and low degree of compaction, suggesting short-distance transport. This surface condition has, in the past, led to unfortunate misinterpretations and even the discard of some pieces, mistaken for natural stones. Indeed, because it is present naturally at the sites, some of this limestone could simply have been displaced or used by hominins. Although further petrographical analysis is presently underway to better deal with this problem, it remains clear that limestone procurement was strictly local in all cases.

At the time of the occupations, the geological setting of the Baza sector of the Guadix–Baza depression was a saline lake environment with fresh water (thermal source) channels feeding locally into it [49]. A remnant of one such palaeo-channel is identified traversing the BL site in its southwesterly sector (level D1). The channel-bank context at BL differs from FN3, where the sedimentary context translates a gradual, evaporitic lakeshore situation, undisturbed by secondary water sources. This does not, however, exclude the likelihood that alluvial sources also existed near the site. Up to now the limestone artefacts have been interpreted as exogenous: in other words, as manuports [35].

There is considerable variability in the size and shape of the limestone artefacts at each of the sites: there are boulders larger than 1 m (at FN3) and smaller-sized blocks, flat quadrangular cobbles exceeding 20 cm in length (at BL), rounded fist-sized cobbles and small angular chunks. The quality also varies: silicified limestone well-suited for controlled flake extraction is found alongside poor quality, altered cobbles. Given the context of the sites and the wide quality and size range of the limestone found there, it appeared unlikely that, as previous studies concluded, all of the limestone was brought into the sites. Furthermore, traces of impact(s) attributed to human activity were identified on much of the limestone, suggesting that it was used *in seeming disregard of the suitability of its petrographical features for knapping and hammering*. In addition, the bulk of each assemblage consists of non-flaked elements, many displaying traces of percussion. Thus, much of the limestone was actually present on or very nearby to the sites. So one of the fundamental challenges we deal with here is to determine whether any selection patterns can be distinguished, or if the hominins at Orce practised an arbitrary process of raw material collection/use.

Post-depositional alteration of the limestone is yet another interpretative hurdle. At BL, numerous tools have been differentially affected by weathering, whose effects reach, in some cases, deep into their volume, sometimes causing *in situ* breakage. Damaged or powdery surfaces pose obvious difficulties for the recognition of anthropic impact traces on the artefacts. Despite this situation, traces of percussion attributed to human intervention have been identified and described on a large proportion of the limestone from both sites based on our comparative experimental protocol and our research to define repeating morphologies (table 1 and figure 1; electronic supplementary material). The kinds of traces range from accidental removals to crush marks, breakage with impact points and even polish. Traces are frequent on both non-flaked and knapped pieces. There are used non-flaked materials and also multi-purpose tools (e.g. cores used as hammerstones). Reliable quantification of used versus un-used is evidently impractical because: (i) much of the material is altered and (ii) experiments show that percussive activities, especially those performed on soft materials (bone, wood), do not always leave traces on stone. In any case, a high combined frequency of 38.4% of pieces with traces indicates that the limestone was intensively used for a range of yet to be determined percussive activities.

4. Methodology

Our broad-scale analysis encompasses morphological and volumetric criteria for macro stone artefact description, with special attention to stigma that may be related to percussion. This study excludes limestone materials $L \lesssim 5$ cm, but this criterion may be adjusted according to different site contexts, depending, for example, on brute raw material size range. First, the surface areas of each limestone artefact were drawn to provide a visual reference. Diachritical schemes were elaborated whenever possible for knapped artefacts. This phase was greatly beneficial to gaining insights into the morphological and technological features of each piece. Next, morphometrical data were systematically collected (figure 2). Given the poorly standardized character of the

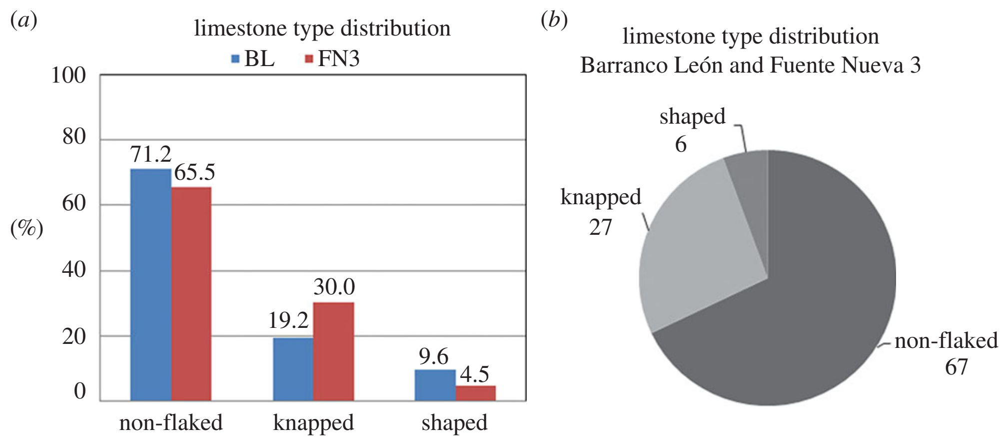


Figure 1. Frequency of the main limestone macro-tool categories. (Online version in colour.)

Table 1. Numerical and relative frequency of limestone macro-tools from Barranco León and Fuente Nueva 3 ($\gtrsim$ 5 cm). PM, with percussion marks

	BL		FN3		total		
category	***N***	**%**	***N***	**%**	***N***	**%**	**global type %**
non-flaked whole	51	32.7	22	7.6	73	16.4	non-flaked whole, 22.6
non-flaked whole PM	12	7.7	14	4.8	26	5.8	
non-flaked whole/anvil	1	0.6	1	0.3	2	0.4	
non-flaked broken	13	8.3	42	14.5	55	12.3	non-flaked broken, 25.8
non-flaked broken PM	8	5.1	42	14.5	50	11.2	
non-flaked broken/anvil	7	4.5	3	1	10	2.2	
non-flaked fragment	12	7.7	39	13.4	51	11.4	non-flaked fragment, 19
non-flaked fragment PM	4	2.6	26	9	30	6.7	
non-flaked fragment/anvil	3	1.9	1	0.3	4	0.9	
core	18	11.5	57	19.7	75	16.8	cores and core fragments, 26.9
sub-spheroid or polyhedron core	3	1.9			3	0.7	
core fragment	4	2.6	16	5.5	20	4.5	
core PM	7	4.5	9	3.1	16	3.6	
core/anvil	1	0.6			1	0.2	
core fragment PM			5	1.7	5	1.1	
chopper tool	5	3.2	5	1.7	10	2.3	configured, 5.7
heavy-duty scraper	7	4.5	8	2.8	15	3.4	
total	156	100	290	100	446	100	100
with percussion marks: non-flaked, 40.5%; cores, 20.8%; configured, 100%							

industries examined by this study, this data collection phase has had the virtue of providing a volumetrical profile for each piece. While maintaining fairly classical measurements currently used in typo-technological analysis (knapping angles, removal size, etc.), the addition of morphological features provides an original metrical–morphological approach to understanding and highlighting the main features of each assemblage. Finally, the morphology of percussive marks and their precise situation on each piece were recorded using a numerical system (box 1, no. 5) in order to observe any systematization in the presence/position/morphology of these traces in accordance with the volumetrical characteristics of the supports (after H. de Lumley, unpublished: Lexique des caractéristiques de l'industrie lithique).

Knapping and butchery experiments accompanied every phase of our work and have been essential to understanding the breakage patterns and stigma present on the archaeological materials. Apart from controlled knapping experiments in a laboratory context, additional knapping experiments were carried out in the field: directly on the outcrop of silicious limestone adjacent to FN3. This allowed us to fully exploit the percussive possibilities in the knapping of Orce limestone, as we freely selected from an abundance of cobbles and blocks with morphologies and petrographical qualities identical to those of our archaeological samples. Direct hammer, bipolar on an anvil and *percussion lancée* are the different techniques that were tested during these experiments.

In earlier publications, results concerning the flint have focused on stigma left on this rock type mostly by bipolar knapping on an anvil [35], but little has been documented about the limestone anvils and hammerstones used during these

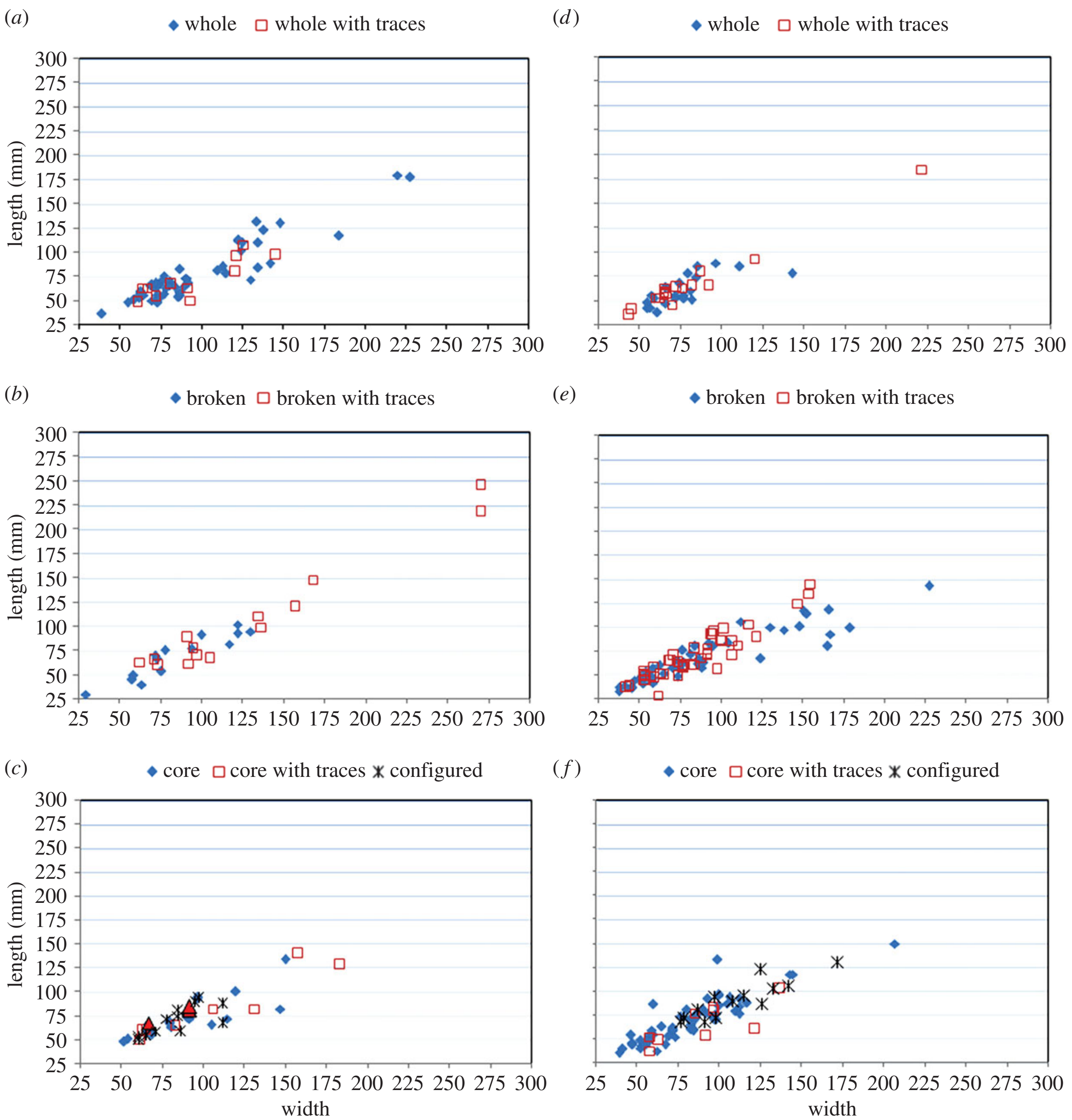


Figure 2. Length and width distribution of the different kinds of limestone items with and without traces of percussion from Barranco León (*a*–*c*) and Fuente Nueva 3 (*d*–*f*). (Online version in colour.)

experiments. Our continued testing of this method produced breakage patterns on limestone slabs used as anvils and also on the hammerstones typically observed at both sites (accidental removals, localized stigma).

A butchery experiment involved breaking cow long bones on limestone anvils and hammerstones. Although results from this experiment are still being processed, the most interesting observations are in fact the lack of traces left on the tools from this activity. So far, percussive activities carried out on soft materials (fresh bone, wood) have been found to leave relatively few traces on limestone. The experiments carried out so far suggest therefore that the kinds of stigma present on the archaeological limestone from BL and FN3 could be mainly indicative of activities involving stone against stone. Accordingly, we are hopeful that new experimental work on stone anvils will yield positive results (e.g. plant processing).

Experimental knapping has been a crucial aid in identifying and defining percussive trace morphologies, their situation in accordance to the size and shape of the supports, and accidental breakage patterns that can only be ascertained by reproducing percussive activities using the same raw materials.

5. The limestone macro-tool assemblages from Barranco León and Fuente Nueva 3

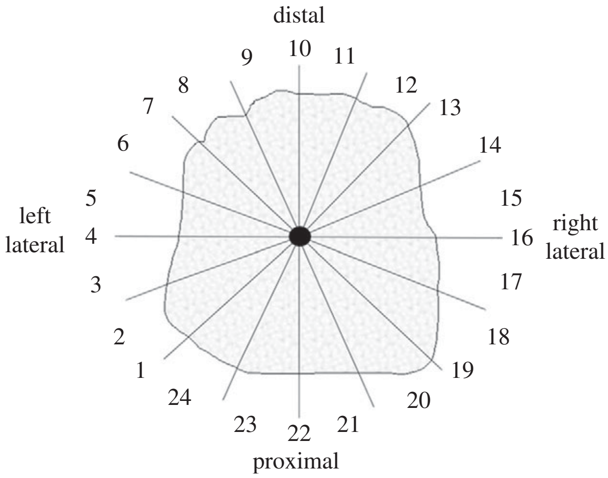
This study includes 446 limestone items: 156 from BL and 290 from FN3 ($L \geq 5$ cm), excavated from 1995 to 2011 (table 1). Non-flaked whole and broken cobbles/blocks make up well over half of the sample. While the BL limestone assemblage contains mainly cobbles, blocks are more characteristic at FN3. At each site, *in situ* reduction is attested with all elements from the reduction schemes represented, including well-struck flakes. Small flakes tend to be non-cortical with dorsal negatives revelatory of at least two extraction directions. Retouch is scarce overall and its tendency to be

Box 1. Methodology for the study of macro-tools.

(1) Generic denomination

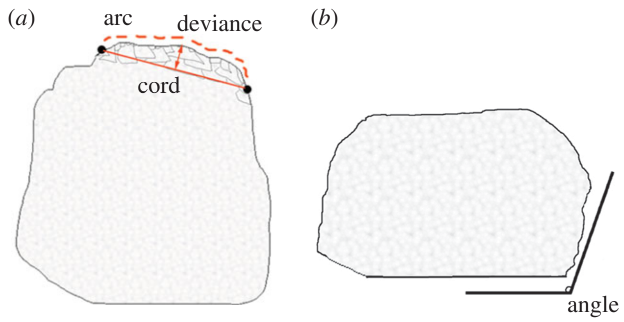
	whole/broken cobbles and blocks	
	without traces	with traces
whole	NFWH	NFWH(T)
broken	NFB	NFB(T)
fragment	NFFRAG	NFFRAG(T)
knapped	CORE	CORE(T)
knapped fragment	COREFRAG	COREFRAG(T)
knapped configured	CHOPPER TOOL; SPHEROID	CHOPPER TOOL(T); SPHEROID(T)

(2) Preservation: 1, not altered; 2, slightly altered; 3, moderately altered and 4, very altered.
(3) Cortical extension: CO, Cortical; CO(NC) $\geq$ 50% cortical; NC(CO) $\leq$ 50% cortical; NC, non-cortical.
(4) Pebble or block morphology
— Volume: Flat (F); Thick (T) + Short (S); Long (L)
— Contour: Round; Oval (O); Triangular (T); Quadrangular ('QS' = square or 'QR' = rectangle); Triangle–rectangle (TR).
— Section: Round; Oval (O); Triangular (T); Quadrangular; Triangle–rectangle (TR).
(5) Attribute localization
Numerical system to homogenize attribute position on a tool (percussion marks, fractures, retouch, removals). Tools are positioned with their flattest surface downwards and their widest extremity in a proximal position (*cf* the following illustration).



(6) Retouch
— Regularity: Regular (R); Regular intentional (RI); Irregular (Ir); Irregular intentional (IrI).
— Type: Marginal (M); Thick (T); Flat (F); Invasive (I).
— Depth: Short (S); Medium (M); Long (L).
— Angle: Abrupt (A); Semi-abrupt (SA); Oblique (O).
— Denticulation: Notch (E); Denticulated (D); Non-denticulated (ND).
— Direction: Direct (D); Inverse (I); Mixed (MX).
— Position: Using the numerical system.
(7) Fracture type: Longitudinal (FL); Transversal (FT); Diagonal (FD); Plane (P); Multiple (FM + description). + Intentionality (presence or absence of single or multiple impacts) and numerical position.
(8) Removal negatives
— Type: Accidental single (As); Accidental multiple isolated (Ami); Accidental multiple associated (Ama); Intentional single (Is); Intentional multiple isolated (Imi); Intentional multiple associated (Ima); Heavy-duty scraper (RC). + number of removals when possible.
— Order: Sequential (S); Non-sequential (NS).
— Size: Length and width (in mm). Averages are calculated in case of multiple removals or the last whole removal is measured ('LR' = last whole removal).
— Angle: Angle (°) between a negative's surface and its platform. Averages are calculated in the case of multiple removals (or the angle of the last whole removal).
— Platform: Cortex (C); Fracture (F); Previous removal negative (PR); Retouched edge (RE).
— Position: Using the numerical system.

(9) Heavy-duty scraper measurements (cf. illustrations *a* and *b*.)
— Arc: Periphery of the convex edge displaying removals/retouch.
— Cord: Shortest distance from the initial point of the modified area to its termination.
— Divergence: Widest extension of the deviation of the arc from the cord.
— Angle: The angle formed by the abrupt convex edge and its flat platform base (°).



(10) Percussion scars: Morphology, description and numerical position.
(11) Observations: Any observations deemed pertinent. A study may focus on specific questions such as: raw material type and quality in relation to technological choices or the elaboration of site-specific morphometrical models.
(12) Experiments: To verify observations made from the archaeological material and test potentiality of activities (carried out with the same raw materials).
(13) Drawings and photos: of experimental and archaeological materials for use as references and in diffusion.

denticulate renders intentionality unclear in most cases [50]. Most limestone flakes are considerably larger than the flint, and they often retain cortical dorsal and platform surfaces. Heavy-duty scrapers (HDS; BL and FN3) and sub-spheroids (BL) are among the loosely 'configured tools' (term referring heretofore to repeating morpho-types that are considered intentionally shaped tools).

About a quarter of the limestone from both sites presents easily discernable traces attributed to percussive activities. Trace morphology is widely variable and flakes and fragments also show features reflective of pounding and crushing activities. We have analysed the relationship between the kinds of traces and their position according to the size and shape of each support. In order to distinguish between natural and anthropic traces on non-flaked artefacts we have (i) compared with cobbles from non-disturbed conglomerates and (ii) sought to identify patterns in the position and morphology of the traces. This methodology is, of course, not exhaustive and further work is required in this area of study: looking for systematic formal selection or shaping processes using morphometrical analysis and comparing archeological materials with cobbles in non-disturbed conglomerates are the first steps in distinguishing natural from anthropically induced traces of percussion.

The average dimensions of the limestone for both sites combined ($L < 5$ cm excluded) are $84.7 \times 67.6 \times 48.8$ mm. With the exception of configured tools, which tend to be larger at FN3, the artefacts from BL have a greater average length (BL: average $L = 94 \times 75.5 \times 49.7$ mm; FN3: average $L = 79.7 \times 63.3 \times 48.4$ mm). Flat, quadrangular cobbles or 'slabs' are the biggest items at BL. They display cupula analogous to those observed on experimental anvils, but a taphonomic origin has not been excluded. The presence of slab fragments with bipolar fracture-impacts and corresponding morphometrical attributes buttresses the anvil hypothesis [33]. There are no such slabs at FN3, where massive polygonal boulders from the local outcrop could have been used as anvils. At both sites these very large items are scarce. Broken non-flaked pieces are generally bigger than whole ones, which are cobbles and tend to be fist-sized and relatively dense. A low degree of core transformation is illustrated by their size correlation with the whole cobbles. All categories combined, chopper-like tools are significantly the largest, while HDS are comparatively smaller.

Fracture planes are very commonly observed on the lateral and transversal extremities of the limestone assemblage. The frequency of multiple fracture planes on the limestone from FN3 is explained by the abundance at this site of blocks with natural breakage planes (versus cobbles). At BL, impact points are observed on 30% of the broken pieces compared with 43% at FN3. The split pebble technique used for creating suitable platforms for knapping is not characteristic at either site. About half of the cores from each site were broken, either before or during knapping or sometimes as a result of their posterior use as hammerstones.

6. Morphometrics and percussive trace relationship

We have compared the morphological features of the artefacts according to the presence/absence of traces and their position on each support, in order to bring to light any anthropic selection processes according to the types defined by our methodology.

(a) Non-flaked whole or broken limestone cobbles and blocks

Non-flaked limestone without traces of percussion is plentiful in both assemblages and its distribution is revelatory of each site's context (mostly cobbles at BL versus chunks at FN3; figure 1). The length/width (L/W) range distribution of pieces with and without traces does not seem to evidence any trends, perhaps reflecting variability in the kinds of percussive activities going on (figure 2). The elongation and flattening indexes also reveal a wide size/shape distribution pattern.

While broken cobbles at BL do not reveal any preferential size distribution, the biggest pieces do tend to show traces of percussion more often. Notwithstanding, whole cobbles with and without traces are distributed into two main L/W groupings: the first corresponds to fist-sized, dense, oval cobbles and the second to larger, angular cobbles. A third, very large size category comprises the cupula-marked slabs.

At FN3, non-flaked items with and without traces are smaller and more cubic than at BL, as is reflected by their L/W grouping (50–75 mm). Elongation and flattening indexes are also grouped. The abundance of blocks rather than cobbles at FN3 explains the relative abundance of broken non-flaked material and the wider size variability. Nearly half of the non-flaked materials at FN3 display percussion marks. Opposite impacts attributed to intentional or accidental bipolar fracture strategies are observed on a large number of fragments from both sites. The use of anvils for core reduction and also for bone breakage is attested at both sites [35]. Fragments thus show a high incidence of percussion and crush marks, either on their edges and/or surfaces (one-third at BL compared with two-thirds at FN3: overall 58.8%). A total of 14 pieces from BL and five pieces from FN3 have been identified either as possible anvils or anvil fragments.

Non-flaked items from BL tend to be flatter and longer than at FN3. Pieces with and without traces reflect the same size range and index patterning, once again suggesting that hominins opportunistically used cobbles and blocks available at the site. As an unknown quantity of limestone was transported to the site by natural agents, it is very difficult to ascertain what, if any human selective processes were applied in the choice of hammerstones. However, volumetric data do indicate that nearly half of the cobbles with percussion marks from BL are thick and long, while those without show an even distribution pattern. At FN3, whole items with and without traces are most often thick and short.

(b) Cores and loosely configured tools

Traces of percussion are often situated on cortical areas of the cores, indicating their use as hammerstones. It is generally impossible to determine at which moment in the operative sequences their use as hammerstones occurred. Nearly a quarter of the cores and core fragments from BL (23%) and one-fifth from FN3 (19%) show traces of percussion unrelated to knapping. Also, numerous cores have fracture impact scars that could result from knapping or percussion-related accidents and/or intentional breakage on an anvil. Fracture planes were sometimes used as knapping platforms but cortical surfaces were preferred overall. Occasionally, flake negatives also served as knapping platforms, a strategy reflective of orthogonal-type knapping schemes. On some cores a combination of knapping platform-use patterns is observed.

We have identified three categories of 'loosely configured' (poorly standardized) tools: chopper-like tools (five pieces from each site), HDS (BL = 7; FN3 = 8) and sub-spheroids (BL only: three pieces). In the context of Oldowan formal heterogeneity, we have used both the dual criteria of repeated morpho-types and the presence of percussion or crush marks on worked edges to distinguish 'tools' from 'cores'. In this context, percussion stigma on tool edges has bearing on interpreting functional aspects: cores with stigma not related to knapping are considered 'multifunctional' tools.

Table 2. Types of percussion marks and their position on the limestone cobbles/blocks from Barranco León and Fuente Nueva 3.

type of percussion marks	localization
accidental removal negatives	cobble extremities
surface scarring; stigmata	cobble extremities and angular points
irregular retouch	sharp fracture or removal negative edges
crushing	fracture plane intersections and polygonal jointures
polish	fracture plane intersections and polygonal jointures
bipolar breakage impacts	plane fracture surfaces
cupula; striations	cobble surfaces
facetted breakage	cobble extremities
fracture angles [33]	cobble crests

The chopper-like tools are cobbles with a few unifacial or (rarely) bifacial removals and with use-wear on worked edges. These large tools owe their denomination to the flatness of the support upon which they were manufactured. They are in fact widely variant tools. HDS are tools with an abrupt convex (or nosed) edge, largely affected by direct abrupt removals, retouch and/or crushing rising up from a plane surface [9]. The percussion/crush marks are present exclusively on the abrupt surface affected by the retouch/removals. The angle formed by the affected edge and its plane platform is always considerably abrupt (BL = 101°; FN3 = 103°). The nosed edges of the HDS from BL show homogeneous size range (approx. 40 mm; average arc = 41 mm) but are widely variant at FN3 (20–125 mm; average arc = 103 mm). The same is true for the degree of convexity: HDS are slightly convex at BL (average cord = 7 mm) and widely convex at FN3 (average cord = 32 mm). The type-specific configuration of these tools is intriguing and raises questions about the kinds of activities that could have resulted in such intense, unifacial stigma on an abrupt, nosed tool. The presence of HDS in other Oldowan sites in Africa and Eurasia is significant and, although they are diversely interpreted as cores or tools, this could suggest some kind of functional–formal continuity [51,52].

The HDS and sub-spheroids tend to be thicker and shorter than the chopper-like tools and their round/oval morphology also distinguishes them from the cores, which are thick and quadrangular or polyhedral. The pieces we attribute to sub-spheroids (three pieces) present residual cortex and, while they do display some intentional removals, most of the negatives are abrupt with fracture angles suggesting that they were intensively used as hammerstones. The average length for all loosely configured tools is 9 cm. The size and characteristics of the negatives on the cores and tools are coherent with the data from the flakes, which are usually short and thick, with cortical platforms (BL: $L = 26 \times$

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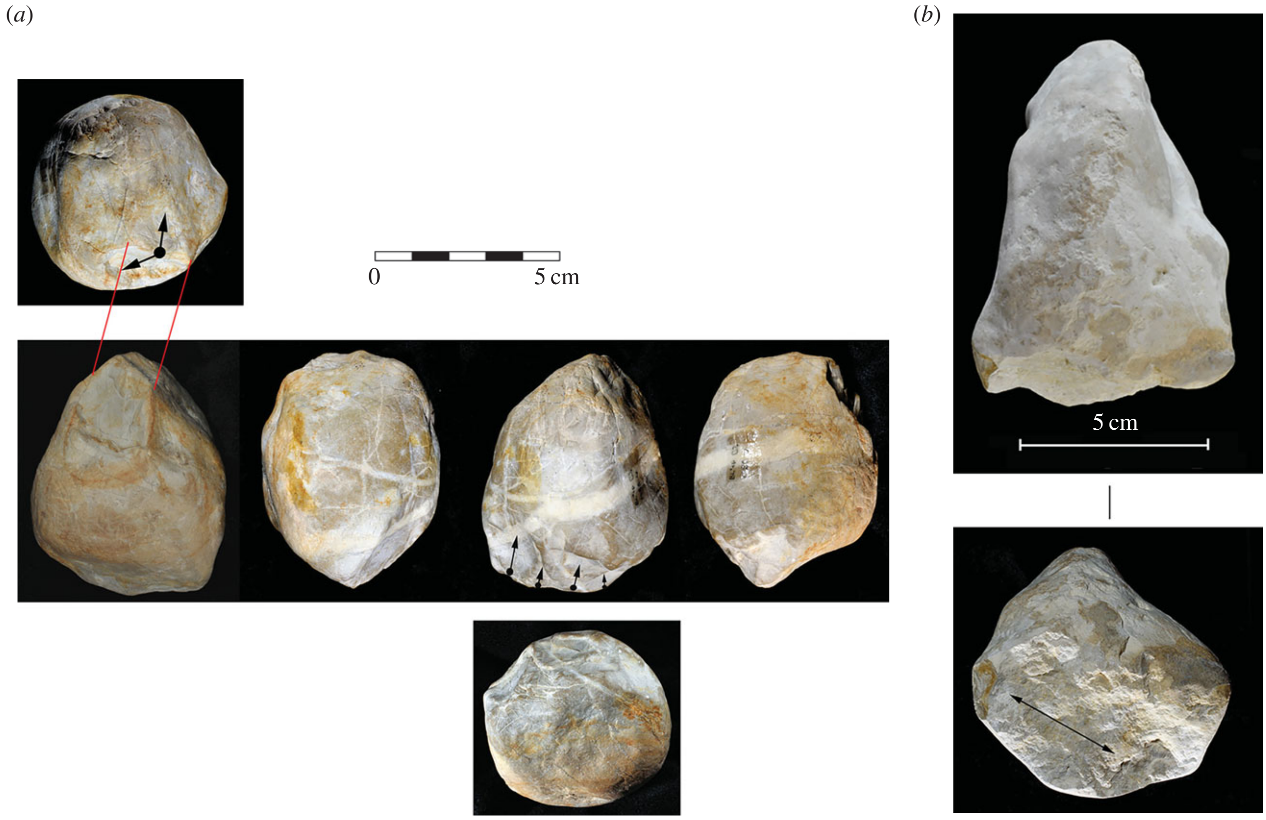

Figure 3. (*a*) Hammerstone and core on a fist-sized cobble from Barranco León with a series of unidirectional abrupt negatives and a double-facetted break on the opposite side. (*b*) Altered, elongated cobble from Barranco León showing bipolar breakage impacts. (Online version in colour.)

28 mm and FN3: $L = 43 \times 40$ mm) [35]. Sub-spheroids and HDS show the smallest average removal sizes. The size of the negatives also fits well within the general volumetric schemes observed for each category and, of course, reflects the intensity of knapping episodes for each tool type.

7. Percussive trace variability

While there is little evidence for prominent morphometrical selective processes in the choice of limestone cobbles/blocks used for percussive activities at BL and FN3, we highlight interesting patterns in the position of the traces in relation to the morphometric characteristics of the non-flaked and knapped limestone artefacts and define specific kinds of traces (table 2). Most heavy impacts are situated on abrupt edges or crests delimited by fracture planes, polygonal intersections or convex termination points on rounded cobbles. Pointed extremities (rounded or angular) were also privileged morphologies for percussive activities, as demonstrated by *facetted breakage* and *accidental removals* (figure 3*a*; figure 5*a*) and *surface scarring* on numerous pieces. *Irregular retouch* or *crushing* is visible on fracture-plane crests (figure 5*b*), pointed extremities (figure 4*a*) and knapped edges (figure 5*a*). At FN3, many small fragments display such scarring. Fracture-plane intersections and polygonal joints show *bipolar impact scars* identical to those obtained in experimental bipolar knapping on an anvil (figure 3*b*; figure 4*a*) [35]. At BL, such breakage scars are present on a number of flat fragments that could be remnants of broken anvils. At BL, some pieces defined as sub-spheroids show *fracture angles* that, as defined by de la Torre & Mora [33], differ from intentional removals in that they lack proximal impact points and concavities typically obtained by intentional impact (figure 5*a*). These items on naturally rounded cobbles were apparently intensively used as hammerstones.

Systematic use of abrupt edges for percussive activities is also underlined in the case of multiple or single *accidental removal negatives*, which were detached with an average angle of 94° at BL and of 91° at FN3. Accidentally produced negatives are usually isolated (sometimes multi-facetted) rather than multiple (BL = 7/11; FN3 = 11/14). When associated on a single support, they may be adjacent on one surface, mixed or on opposing extremities.

Only two pieces present a restricted zone showing *polish*: in one case, situated only on the worked edge of a chopper and in another, on a small protuberant crest (figure 4*b*). The restrictedness and localization of these polished areas suggest that they are not owing to taphonomic causes. A few pieces also display limited areas of *cupula*, which may result from some kind of percussive activity being carried out on a flat cobble surface (figure 5*a*).

8. Conclusion

The Barranco León and Fuente Nueva 3 sites provide the oldest evidence for hominins in Western Europe. The exceptionally rich lithic and faunal series provides data on the activities carried out by early hominins in a lakeside, mixed landscape. At the time of its frequentation by hominins, the Guadix–Baza depression was rich in faunal resources, with thermal springs feeding into the Baza Lake providing a reliable water source. The elemental contextual relationship between fresh water resources and Oldowan sites is well established [13,53,54]. Ancient alluvial systems

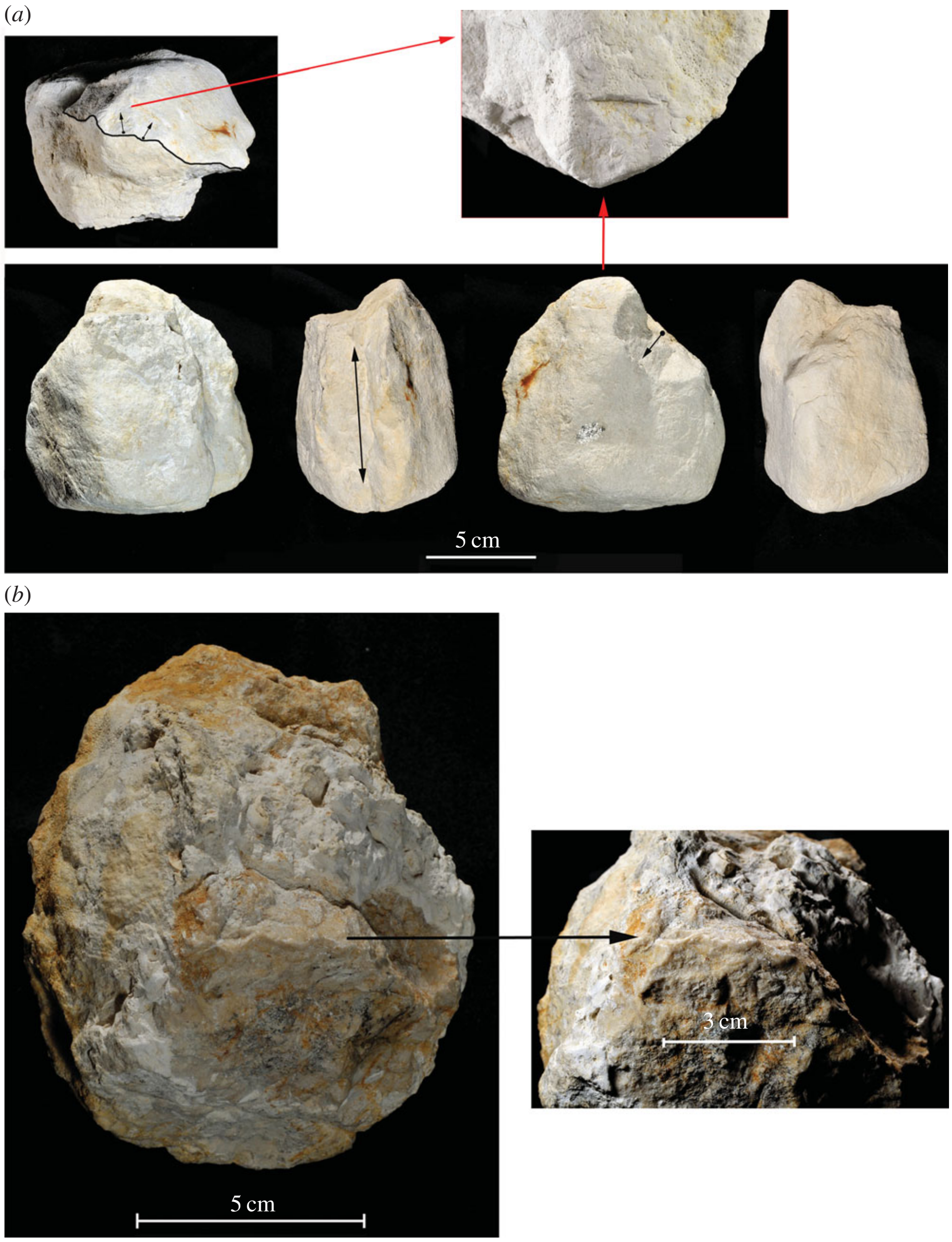

Figure 4. (*a*) Hammerstone and core on a triangular cobble from Barranco Léon with a single removal adjacent to the distal point. There are small percussion-related negatives on the point and a bipolar break along the axis of the piece. (*b*) Polish on a slightly denticulated ridge of a large block from Fuente Nueva 3. (Online version in colour.)

were also a source of lithic raw materials for tool manufacture, an increasingly indispensable hominin survival strategy. Characterized as butchery sites, BL and FN3 have yielded abundant mega-herbivore remains (*Mammuthus meridionalis*, *Hippopotamus antiquus*) with traces of anthropic intervention. There are also numerous carnivore fossils and coprolites, the most conspicuous being from *Pachycrocuta brevirostris*. But apart from butchering activities, is it not possible that other activities were going on at these, and other, Oldowan sites? For example, ethnographical evidence points out the likelihood that woodworking activities would have been carried out with the larger Oldowan chopper-type tools, while smaller flaked items would have been useful for accessing the fleshy parts of carcasses [55]. This question is at the root of the present paper, which was inspired by the wide range of limestone percussion tools found at BL and FN3, and the traces they present. We introduce here a new methodology for their study, contrasting whether or not they were knapped (flake production) or shaped (repeated production of morpho-types whose shaped edges show stigma). The present methodology is intended to provide a basis for future inter-site comparisons, in the aim of identifying common denominators that may perhaps serve as links in better understanding early hominin cognitive capacities and the transmission of their knowhow through the percussion tools they left behind.

In the framework of a local raw material procurement pattern, we hypothesize that hominins at Orce accessed the abundant limestone resources directly from alluvial and colluvial sources within and/or in close proximity to the sites: at BL from alluvial channels and at FN3 from outcrops and a yet to be determined alluvial source. This framework allows us to perceive, for the first time, of the impact of subtle contextual differences on the industries from these sites. At BL, hominins were taking advantage of a sandy channel-bank situated near the shoreline of the Baza Lake. Deposits indicate a dynamic deposition with a succession of lacustrine and alluvial

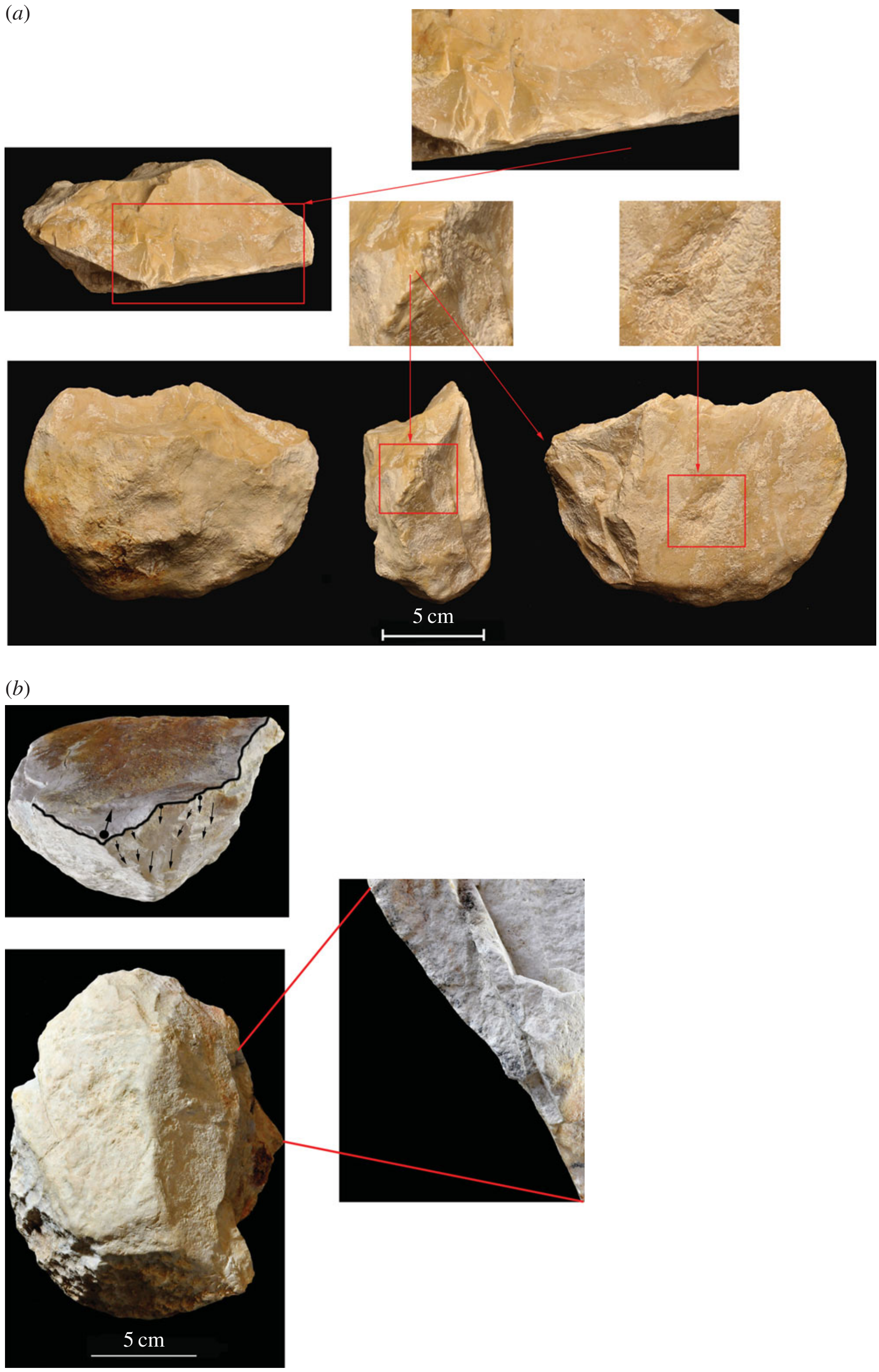

Figure 5. (*a*) Multi-purpose tool from Fuente Nueva 3. The lateral point presents multi-facial, facetted breakage and the knapped distal edge shows crushing. The surface of the cobble presents impact cupula suggesting a possible use as an anvil. (*b*) Multi-purpose tool from Barranco León with a series of impact negatives on a natural edge and irregular retouch on an adjacent lateral fracture edge. (Online version in colour.)

sedimentation. There, they collected and used limestone cobbles from the channel for a range of percussive activities, favouring them over the smaller flint nodules used for flake production. By contrast, the FN3 deposits indicate a low-energy lakeside accumulation where hominins took advantage of fine, silicified limestone blocks outcropping adjacent to the site, while they also collected, knapped and used limestone cobbles from a (nearby) alluvial source. This site-specific context contributes to better understanding limestone qualitative and morphological variability in each assemblage.

At both sites, flint was collected from local secondary deposits, perhaps occasionally from alluvial sources, or extracted from outcrops. The overall size range of the flint material is much smaller than the limestone. Flint assemblage composition also differs from the limestone, with a clear dominance of small-sized flakes (2–3 cm long) and a few cores. Limestone hammerstones and anvils were likely used for the bipolar knapping sequences that are well documented for flint reduction [35]. This limestone/flint size range and functional duality are also documented at other Early Palaeolithic

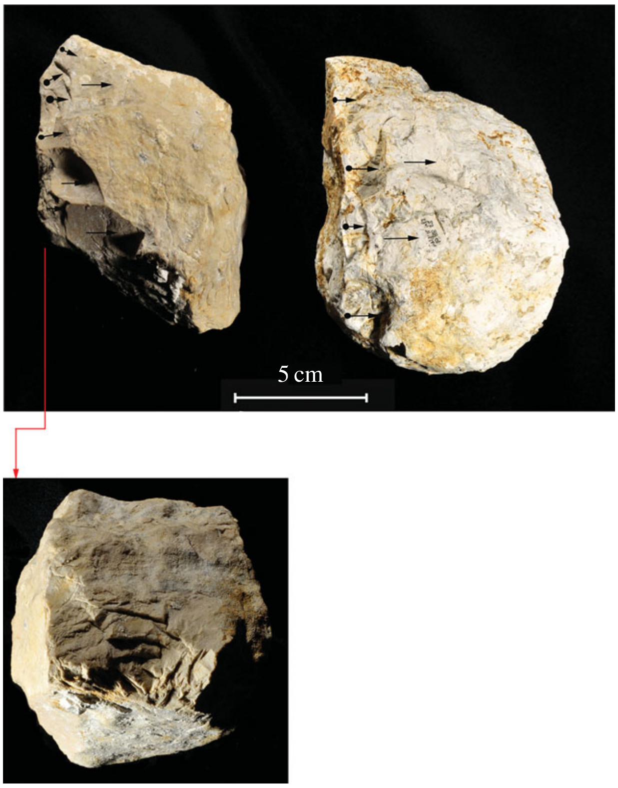

Figure 6. Loosely configured tools from Fuente Nueva 3. The piece on the left displays a stepped negative of a powerful blow on the proximal angle, non-associated to the worked edge (multi-purpose tool). (Online version in colour.)

sites where these two raw materials were used, such as Ubeidiya [32,56] and Aïn Hanech [52].

Analysis of the relationship between the morphometrical features of tools with and without traces has brought to light the multifunctional nature of the artefacts and their different phases of modification and use. The assemblages comprise hammerstones, anvils, multifunctional tools and loosely configured tools, alongside an extraordinary collection of clearly knapped pieces whose systematic trace features reveal selectivity. Our methodology facilitates the identification of repeating morpho-types (recognition of models) that may be elusive in the Oldowan context. While some of these models may be common to other Oldowan toolkits (HDS, sub-spheroids), others are unique in one or another assemblage (figure 6). This distinctiveness may be in part dictated by the morpho-petrographical qualities of the raw materials used, by the activities being carried out, or perhaps even by the traditions practised by specific hominin groups. In any case, the identification of these tools could be indicative of potentially progressive traits in these industries, relative to earlier African occurrences.

More specifically concerning BL and FN3, one of the main features evidenced by our study is that there is systematic use of abrupt edges and preferential use of intersecting plane surfaces. So far knapping experiments have enabled us to reproduce analogous intensive percussion marks to those on the archaeological material, while those performed with bone and wood yielded only limited results. In future, more experimental work is needed in order to ascertain the dynamic behind these percussion tools. Finally, we identify, describe and illustrate an array of percussion stigma, which may serve in future studies of heavy-duty tools in ancient stone toolkits.

Authors' contributions. D.B.: excavations and techno-typological study of the artefacts, elaboration of the methodology, experiments, surveying, data processing and writing of the manuscript. J.-M.V.: elaboration of the methodology, surveying, experiments. R.S.: director of excavations, techno-typological study of the artefacts, elaboration of the methodology, surveying, experiments and writing of the manuscript. L.M.: excavations and techno-typological study of the artefacts. I.T.-M.: excavations, techno-typological study of the artefacts, surveying, experiments.

Competing interests. We declare we have no competing interests.

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