BOREAS An international journal of Quaternary research

Diversity and significance of core preparation in the Developed Oldowan technology : reconstructing the flaking processes at SHK and BK (Middle-Upper Bed II, Olduvai Gorge, Tanzania)

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BOREAS

Sánchez-Yustos, P., Diez-Martín, F., Domínguez-Rodrigo, M., Duque, J., Fraile, C., Baquedano, E. & Mabulla, A.: Diversity and significance of core preparation in the Developed Oldowan technology : reconstructing the flaking processes at SHK and BK (Middle-Upper Bed II, Olduvai Gorge, Tanzania). *Boreas*. 10.1111/bor.12237. ISSN 0300-9483.

Core preparation has been documented in Developed Oldowan assemblages dated between 1.5–1.3 Ma. However, its correct identification and significance is a matter of debate. In order to shed light on this issue, this paper attempts to reconstruct the flake production processes of the lithic assemblages currently recovered in SHK and BK at Olduvai Gorge (Tanzania). The methodological approach applied for the study of these two classical Developed Oldowan sites is based on the analysis and classification of flaking cores through detailed diacritical and technological descriptions, regardless of aprioristic morphological considerations. The flake production processes identified in both assemblages exhibit great technological homogeneity. The most remarkable difference between them is linked with divergences in flake size production. Core rotation and elongation of the perimeter of the flaked surface were the main technical actions implemented to manage core reduction, and seem to be related to reduction intensity. Core preparation, specifically striking platform preparation, was also applied, but to a minor extent, and was linked with a more effective management of blank reduction. It was not carried out through rigid technical and geometric schemes, and the products obtained were not predetermined. Nevertheless, its mere presence in Developed Oldowan sites is very suggestive, as it confirms a strong relationship between the Developed Oldowan and early Acheulean assemblages.

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received 14th November 2016, accepted 18th January 2017.

In recent times, the technological approach has strengthened its relevancy within studies of early African industries (e.g. de la Torre *et al.* 2003; de la Torre 2004; de la Torre & Mora 2005; Delagnes & Roche 2005; Roche 2005; Diez-Martín *et al.* 2009, 2010, 2012, 2014a, b; Stout *et al.* 2010; Gallotti 2013; Sánchez-Yustos *et al.* 2016). Inspired by the 'chaîne opératoire' concept advocated by Leroi-Gourhan (1964, 1971), this approach was initially developed by French archaeologists and applied to the European Palaeolithic record (e.g. Geneste 1985, 1991; Pelegrin 1985, 1990; Pelegrin *et al.* 1988; Boëda 1991; Boëda *et al.* 1990). After a few years, the technological approach was applied to early African industries, but for a long time it played a minor role in lithic studies (Pelegrin 1993; Texier 1995; Roche & Texier 1996; Kimura 2002). This can be explained by the importance that the processual approaches (e.g. palaeoecological and cognitive) have enjoyed in the archaeology of human origins in Africa (e.g. Isaac 1977, 1984, 1986; Toth 1982, 1985; Wynn 1981, 1993, 2002; Kyara 1999; Stout 2002, 2005; Stout *et al.* 2005, 2015; Braun *et al.* 2008a, b, c, 2009; Goldman-Neuman & Hovers 2009; Harmand 2009; Maurin *et al.* 2014).

Both technological and processual approaches have progressively superseded the traditional typological perspective in the study of the Early Stone Age (ESA), generating substantial information about raw material management, modes of lithic production and cognitive complexity, particularly centred on Oldowan assemblages (see contributions in Martínez Moreno *et al.* 2001; Toth & Schick 2008; Hovers & Braun 2009; Schick & Toth 2009). However, the paradigm of the early stages of cultural evolution in Africa is still rooted in culture history postulates from which the typological tradition bloomed (Sánchez-Yustos 2012; de la Torre & Mora 2014). This internal contradiction has constrained the interpretation of the technological development and inter-assemblage variability that characterized the Oldowan-Acheulean gradient (1.7–1.3 Ma), best exemplified in the still-open Developed Oldowan/early Acheulean debate (Semaw *et al.* 2009; Diez-Martín & Eren 2012; de la Torre & Mora 2014).

In order to address the inter-assemblage variability documented in Middle and Upper Bed II at Olduvai, M. Leakey coined the term 'Developed Oldowan' (DO) (Leakey 1967), which was immediately divided into two stages (Leakey 1971): 'Developed Oldowan A' (DOA) and 'Developed Oldowan B' (DOB). The former is stratigraphically below Tuff IIB (*c.* 1.6 Ma) and presents a reduced number of 'protobifaces' and

DOI 10.1111/bor.12237

a relative abundance of light-duty tools (basically retouched flakes) and battering tools (i.e. spheroids, sub-spheroids and modified battered blocks). The DOB assemblages are stratigraphically located above Tuff IIB and present some handaxes and a higher percentage and variety of light-duty tools and battering tools. The distinction between the DOB and the early Acheulean (EA) was more complicated as both contained handaxes and were stratigraphically pene-contemporary (both are located above Tuff IIB). The main criterion employed by M. Leakey to assign assemblages either to the DOB or EA was the relative frequencies of handaxes, which should represent ±40% of the tool types included in the lithic collections (Leakey 1971). In a subsequent work, M. Leakey added typometric and stylistic criteria to differentiate between handaxes of both traditions (Leakey 1975). In sum, Leakey proposed a unilinear evolutive scenario of dual parallel cultural phyla in which the DO (*sensu lato*) evolved from the local Oldowan substrate, whereas she considered the Acheulean as an intrusive culture in Olduvai.

The popularization of the technological and processual approaches has prompted the progressive rejection of Leakey's cultural model. However, paradoxically her terminology and the unilinear evolutionary interpretation of the inter-assemblage variability in the ESA are still in force (Semaw *et al.* 2009; Diez-Martín & Eren 2012; de la Torre & Mora 2014). Based on technological and eco-functional postulates, some authors have pointed out that the DOA does not show any qualitative differences from Oldowan technology at a conceptual or manufacturing level and, therefore, these assemblages could be assigned to the Oldowan cultural tradition (Kimura 1999; de la Torre & Mora 2005; Semaw *et al.* 2009); other authors have suggested that the dichotomy between DOB and EA corresponds to differences in raw material constraints and uses (Stiles 1979, 1980, 1991), site-function (Gowlett 1986), reduction stages or mobility patterns (Jones 1994). As a result, nowadays, DO (*sensu lato*) and EA are conceived as complementary and interrelated parts of the same cultural tradition linked to functional and/or palaeoecological factors (Semaw *et al.* 2009; Diez-Martín & Eren 2012; de la Torre & Mora 2014). Biface frequency and typo-metric and stylistic discriminations are no longer considered cultural markers, and the mere presence of handaxes and/or other Large Cutting Tools (LCTs) is seen as the major indicator of the Acheulean character of the assemblages (e.g. Lepre *et al.* 2011; Beyene *et al.* 2013; Diez-Martín *et al.* 2015), as it implies that knappers had the cognitive and practical skills to manufacture these tools (Gowlett 1988). The production of large flake blanks and the standardization of technical procedures used to shape large preforms according to mental templates have been also considered essential Acheulean hallmarks (Isaac 1972). More recently, some authors have added 'core preparation' (CP) to the list of the early Acheulean markers (de la Torre & Mora 2005; de la Torre 2009, 2011; Gallotti 2013).

CP (striking platform preparation and/or flaking surface preparation) has been documented in DO assemblages dated between 1.5–1.3 Ma and characterized by an absence or rare presence of LCTs and an abundant production of small-sized flakes through simple and complex reduction strategies (Texier 1995; Texier *et al.* 2006; de la Torre *et al.* 2003; de la Torre & Mora 2005; Diez-Martín *et al.* 2009; Gallotti 2013; Sánchez-Yustos *et al.* 2016). However, experimental insights have questioned the presence of complex reduction strategies within these assemblages, challenging the identification and significance of this early evidence of CP (Diez-Martín *et al.* 2012; Moore & Perston 2016). In order to shed light on this major milestone in human technological behaviour, this paper attempts to reconstruct the flake production processes of the lithic assemblages currently recovered in the frame of the archaeological excavations carried out in SHK and BK by The Olduvai Paleoecological and Paleoanthropological Project (TOPPP) (Diez-Martín *et al.* 2014c; Domínguez-Rodrigo *et al.* 2014).

Both sites were classified by M. Leakey as DO (Leakey 1971) and played an important role in the construction and discussion of her cultural model (see de la Torre & Mora 2014). According to the study of the new lithic assemblages, the bulk of the technological processes in both sites was largely devoted to producing on-site small flakes (mostly on quartz); whereas the operational sequences aimed at producing LCTs played a secondary role and are represented by different and isolated knapping events that are spatially and temporally fragmented (mostly on volcanic rocks), and LCTs are thus marginally represented (Diez-Martín *et al.* 2010; Sánchez-Yustos *et al.* 2016).

More specifically, in the present paper we will address the following questions. (i) Is there CP in the studied sample? (ii) If so, how was it carried out, by an orderly sequence of actions following an elaborate plan or by isolated actions? (iii) Does CP imply in this early stage predetermination of products? (iv) Does the DO technology represent an innovation with regard to the Oldowan one in terms of core reduction? The reconstruction of reduction processes will enable a description of the sequence of operational phases, technical actions, reduction rules and methods that guided flaking processes, and assess the impact and significance that CP might have held in these assemblages. Finally, we can assess if DO assemblages show any innovation in core reduction terms with respect to the Oldowan ones and, thus, if CP can be definitively accepted as a derived trait within the Oldowan-Acheulean gradient.

Material and methods

Both sites, SHK (Sam Howard Korongo) and BK (Bell's Korongo), are located in the secondary branch of Olduvai Gorge (Tanzania) (Fig. 1). Stratigraphically, SHK is placed in the upper part of Middle Bed II, directly below Tuff IIC (*c.* 1.5 Ma), while BK is placed above Tuff IID dated at 1.35 Ma (Diez-Martín *et al.* 2014c; Domínguez-Rodrigo *et al.* 2014). In this area of the Gorge, the Middle-Upper Bed II is made up of alluvial, fluvial and flood-plain deposits that correspond to distributary channels that come from the slopes of Lemagrut volcano (Diez-Martín *et al.* 2014c; Domínguez-Rodrigo *et al.* 2014). Thousands of stone tools have been recovered in both sites by TOPPP, some of them are under study and others have already been published (Diez-Martín *et al.* 2010; Sánchez-Yustos *et al.* 2016). In both sites, water disturbance played a minor role in the lithic assemblage composition, but reworking and rearrangement of some remains would have occurred (Diez-Martín *et al.* 2014c; Domínguez-Rodrigo *et al.* 2014).

We present here the cores documented in both sites up to the 2014 field season. We have not sorted the cores according to the geological levels identified by TOPPP at both sites (five levels at BK and two levels at SHK) as such information is not relevant to the objective of the present work. A total of 260 cores has been recognized in both sites (SHK, n = 128; BK, n = 132). However, we have only included 222 cores in

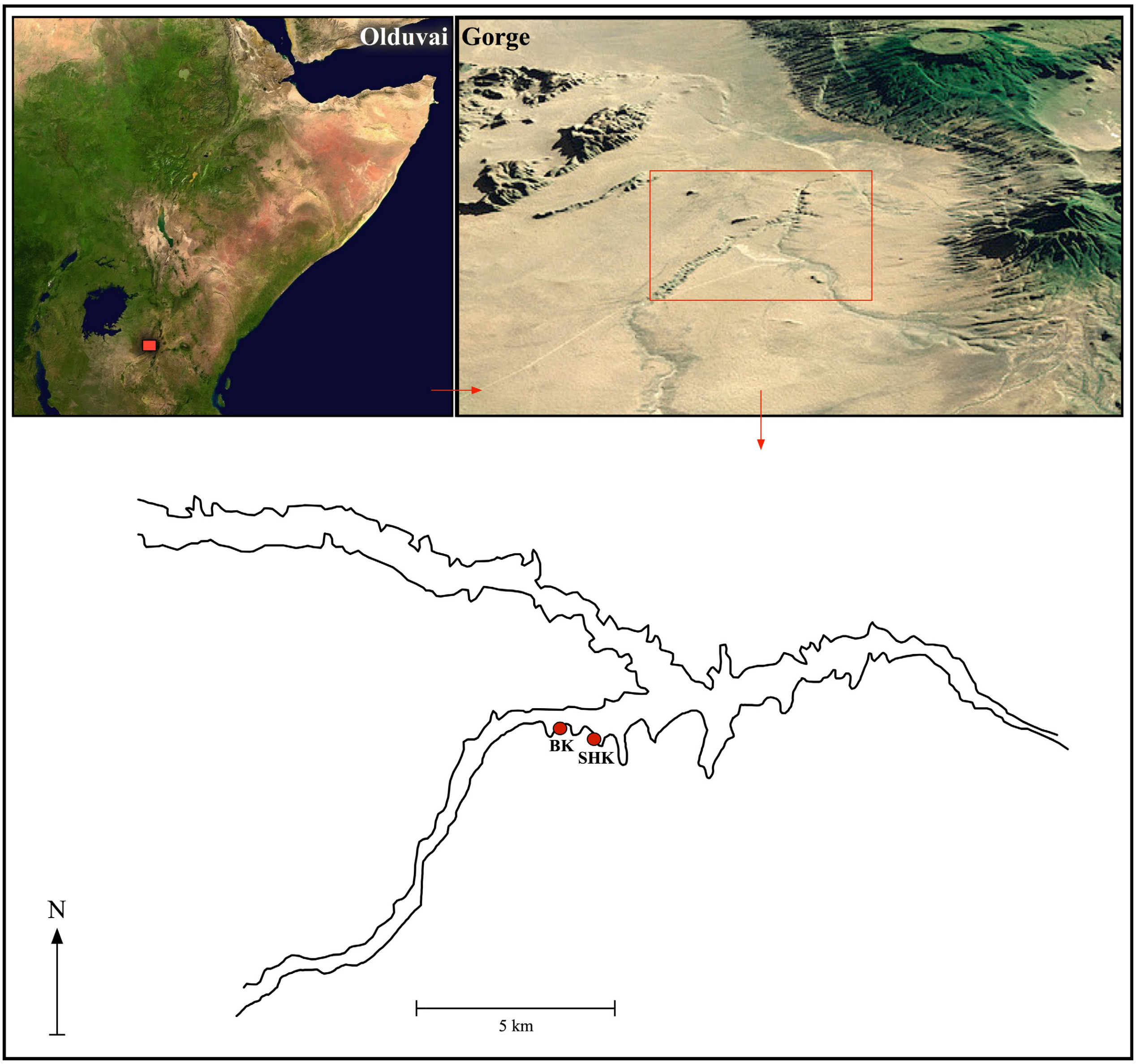

Fig. 1. Location of SHK and BK sites at Olduvai Gorge.

the present study (SHK, n = 106; BK, n = 116); the other 38 cores (SHK, n = 22; BK, n = 16) were not included because, for different reasons (fluvial abrasion, fragmentation or intense battering damage), they do not allow a detailed and complete reconstruction of their reduction sequences.

Core reduction refers to the process of flake removal for the acquisition of detached pieces and is central to an understanding of lithic technological organization (Andrefsky 2009). A detailed reconstruction of core reduction processes requires introducing the notion of time and deconstructing the core reduction in a set of operational phases and technical actions (Leroi-Gourhan 1964, 1971; Pelegrin 1985; Geneste 1989, 1991; Perlés 1991; Inizan *et al.* 1999). In the absence of large series of refits as is our case, diacritical reading is the most reliable procedure to understand and reconstruct reduction sequences (e.g. Dauvois 1976; Forestier 1999; Inizan *et al.* 1995; Boëda 2001; Slimak & Lucas 2005; Tiffagon 2006; Baena *et al.* 2010, in press; Diez-Martín *et al.* 2012). Nonetheless, refits have sometimes contradicted previous assertions made by 'diacritic readings' based on scar-pattern superposition (e.g. Bar-Yosef & Van Peer 2009).

It is important to make clear that diacritical reading is a complex procedure aimed at macroscopically interpreting the last reduction phases of a core through the identification of the scar chronology and scar directionality (Callahan 1988; Baena & Cuartero 2006). One of the methodological deficiencies noted in the technological analysis applied to early African industries is that they do not usually include a detailed inspection of reduction sequences (Braun 2012: p. 235; for an excellent reconstruction and description of core reduction sequences see Delagnes & Roche 2005). The results have generally been quite limited when it was attempted, as the diacritical analysis applied often omits scar chronology. Additionally, there is a tendency to associate flaking method with core morphology, which has generated what we call the 'core morphology fallacy' that could be added to the list of 'major fallacies surrounding stone artifacts' (Dibble *et al.* in press). This could explain the interpretative discrepancies arising around the 'bifacial centripetal hierarchical' flaking method (Diez-Martín *et al.* 2012 vs. de la Torre *et al.* 2003). Diacritical reading has proved extremely useful in this case for assessing knapping concepts such as 'hierarchization' and 'preparation' (Diez-Martín *et al.* 2012). Several authors who have applied exhaustive experimental diacritical studies have stated that recurrent orthogonal crossing series of removals on both surfaces generate cores that morphologically look like bifacial centripetal hierarchical cores, but technically they do not show a centripetal scar pattern and, most importantly, are not hierarchized (Baena *et al.* 2010; Diez-Martín *et al.* 2012; this paper). This highlights the importance of a complete diacritical reading and emphasizes technology rather than morphology. The criteria followed here for decoding the chronology and trajectory of scars are: stigma on the negative scar edge (striae and grooves), flake morphology and topography between negative scars.

The studied cores have been classified in six reduction models (RMs) defined according to faciality (the number of faces or flaking surfaces that have been the subject of exploitation) and the type of core rotation (the way in which the knapper rotates the surfaces that have been the subject of exploitation in order to manage core reduction) (Fig. 2). It is necessary to note that the type of core rotation (defined here only in bifacial cores) was established through a previous diacritical analysis. Our emphasis on core rotation is based on the fact that it informs about technical breaks in the progress of the production sequence and thus the aim of each reduction phase, which is essential to identify if two surfaces are hierarchically related. The six RMs defined are: (i) Multifacial (MF), characterized by the flaking of more than two surfaces; (ii) Unifacial (UF), characterized by the flaking of one surface; (iii) Bifacial Alternating (BFG), characterized by two flaking surfaces managed by a continuous alternation (rotation) of the surfaces by which the next removal employs the negative of the previous one as a striking platform; (iv) Bifacial Alternate (BFA), characterized by two flaking surfaces managed by a discontinuous alternation (rotation) of the flaking surfaces and the removals of one surface very often are used as the striking platform of the opposite surface; (v) Bifacial Continuous (BFC), characterized by continuity in its production, the core is rotated once, there is no alternation of surfaces and the removals of one surface are always used as the striking platform of the opposite surface; (vi) Bifacial Hierarchized (BFH), characterized by two flaking surfaces managed according to the following technical and geometric principles that are shared with the Levallois method defined by Boëda (1994, 1995): (A) the core volume is conceived as two surfaces hierarchically related (striking platform surface and flaking surface characterized by continuity in their production); (B) the fracture plane of the flaking surface is parallel or subparallel to the plane of intersection (parallel percussion), removing flakes from a surface rather than a volume and following the longitudinal axis; (C) the line created by the intersection of the striking platform surface is perpendicular or subperpendicular to the flaking axis (Fig. 3).

The technological analysis was complemented with the observation of other technical variables (see Fig. 2) that have been applied in other ESA assemblages to the study of flaking cores (e.g. de la Torre *et al.* 2003; de la Torre & Mora 2005; Diez-Martín *et al.* 2009, 2010, 2014a, b; Stout *et al.* 2010; de la Torre 2011; Gallotti 2013; Sánchez-Yustos *et al.* 2016), namely: (i) type of reduction: isolated reduction, series of single

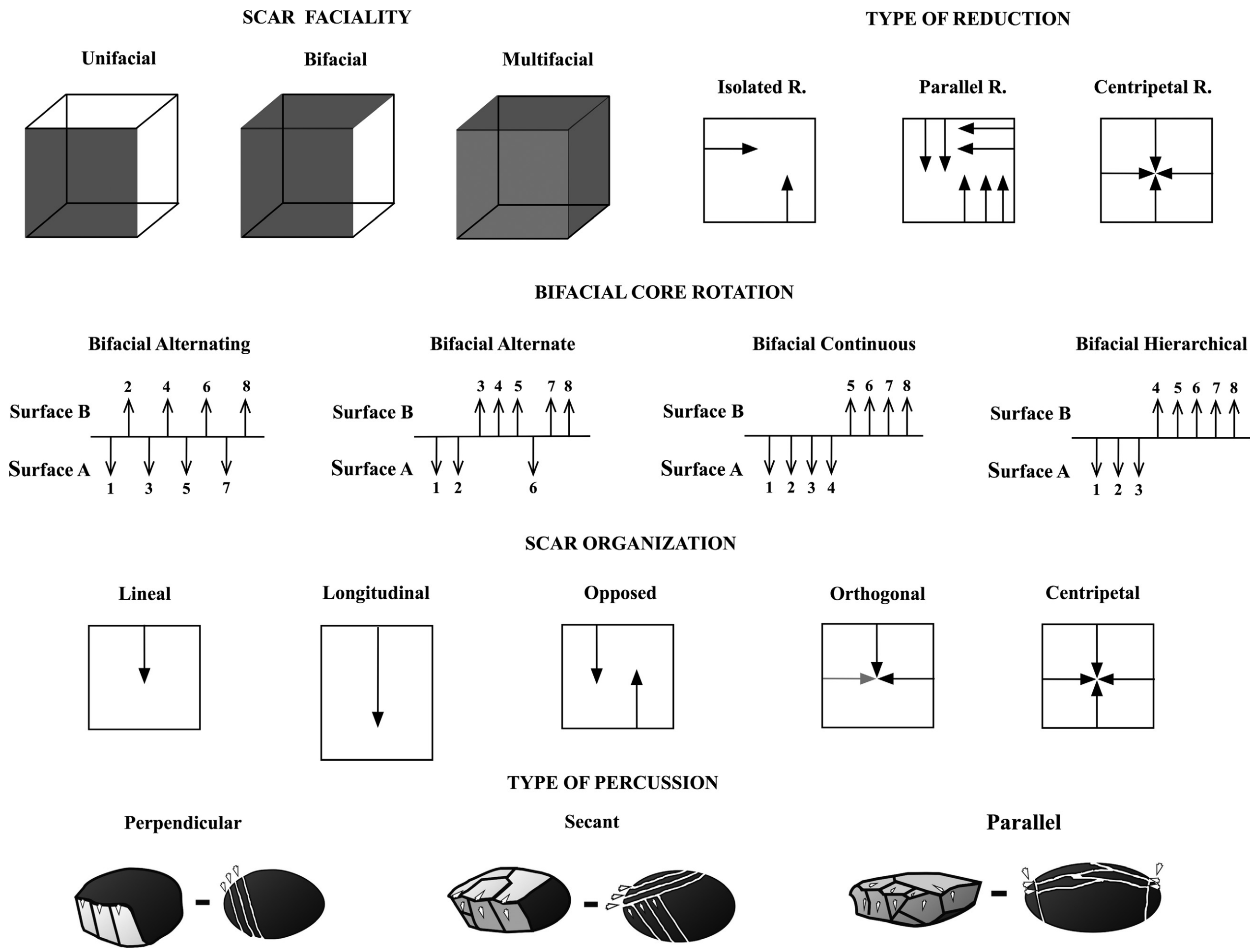

Fig. 2. Technical variables employed for core analysis (R = removal).

and isolated removals; parallel reduction, series of two or more removals in parallel or subparallel arrangement; centripetal reduction, series of single removals in centripetal arrangement; (ii) scar organization, the arrangement of the removals on the flaking surface namely: linear, longitudinal (follows the longitudinal axis), opposed, orthogonal and centripetal; (iii) type of percussion, the angle that forms the fracture plane of the flaking surface with the plane of intersection (perpendicular, secant and parallel); (iv) flake size production, the length of the scars (micro: ≤20 mm; small: 21–50 mm; medium: 51–100 mm; large: >100 mm); (v) type of blank: spherical or rounded (cobbles and pebbles), angular (blocks or fragments of blocks), hemispherical (split cobbles) and flake.

Results

Reduction models

Multifacial (MF). – The MF RM is the most common in both SHK and BK (25.4% or n = 27, and 36.2% or n = 42, respectively). Quartz is the raw material most often used (SHK: 77.7% or n = 21; BK: 61.9% or n = 26), while basalt has a secondary representation, albeit with major importance in BK (35.7% or n = 15), and other raw materials such as gneiss and quartzite are employed marginally (Table 1). A statistical significance exists in BK between raw material and weight (Fisher transformation test, *p*-value: 0.001), and between raw material and flake size production (Fisher transformation test, *p*-value: 0.023). In this regard we noted that the MF cores in quartz tend to show low weight values (mean = 233.2 g), while basalt ones show high values (mean = 653.9 g). Accordingly, quartz cores produce more flakes of lower dimensional values than those generated by the basalt ones (Table 1). In contrast, there is not a statistical correlation in SHK between raw material and weight (Chi-square test, *p*-value: 0.415). In any case, flake production is aimed to small flake detaching at both sites (SHK: 68.5% or n = 24; BK: 74% or n = 40), and the production of micro flakes is only represented in BK (Table 1).

Despite the differences mentioned, the MF RM is strongly homogeneous in terms of technical actions. The reduction sequence is generally conducted through

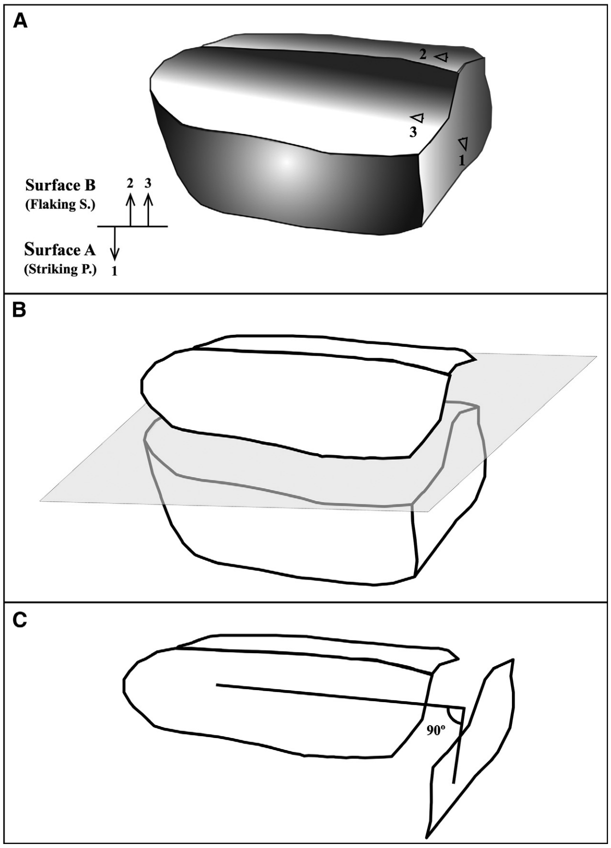

Fig. 3. Technical and geometric principles of the Bifacial Hierarchized Model. A. The core volume is conceived as two surfaces hierarchically related (striking platform preparation or hierarchization surfaces). B. The fracture plane of the flaking surface is parallel or subparallel to the plane of intersection (parallel percussion), removing flakes from a surface rather than a volume and following the longitudinal axis. C. The line created by the intersection of the striking platform surface is perpendicular or subperpendicular to the flaking axis.

isolated and disorganized removals obtained through perpendicular percussion (Table 1). This casual reduction scheme, which shows the highest mean of scars per core (SHK: 9.1; BK: 8.3), consists of detaching the most flakes possible using any available flaking angle (generally a right angle) and striking platform. The maintenance of production is carried out by uninterrupted core rotation, flaking new planes or scars that are repeatedly used as striking platforms (Fig. 4). The way to extend the perimeter of the flaked surface is by using multiple platforms, generating multiple flaking surfaces often consisting of a single removal. Short series of parallel scars and/or secant percussion have been recorded in some MF cores, but these technical features never prevail over isolated removals obtained through perpendicular percussion (Table 1).

Unifacial (UF). – The UF cores exhibit a similar representation in both sites (SHK: 15% or n = 16; BK 15.5% or n = 18). Quartz is the raw material most employed (SHK: 75% or n = 12; BK: 50% or n = 9), basalt shows a secondary use and other materials such as phonolite and flint are employed marginally (Table 1). There is a low statistical significance between assemblages and blank types (Student′s *t*-test, *p*-value: 0.066). Nevertheless, this is the only RM in which hemispheric blanks are used (n = 4). These blanks are split cobbles where flaking is carried out using the plane created (break surface) as a striking platform, which suggests that cobble splitting could have been intended to prepare a suitable striking platform. These blanks are reduced through a series of parallel scars detached by perpendicular percussion (Fig. 5B). This method of volume reduction is also found in the rest of the unifacial cores (Table 1), except for three cores documented in BK whose flaking axis follows the length axis (parallel percussion). The UF cores show the lowest mean of scars per core (SHK: 4.9; BK: 4.2) and their reduction is principally focused on the production of small flakes (SHK: 77.7% or n = 14; BK: 89.4% or n = 17), but medium and large flakes are also produced (Table 1). The weight of the cores from SHK is unevenly distributed, while in BK they tend to be concentrated in the lower values (Table 2).

Bifacial Alternating (BFG). – This RM is represented on a secondary level in both SHK and BK (13.2% or n = 14, and 9.4% or n = 11, respectively). Quartz is the raw material most often used (SHK: 64.2% or n = 9; BK 81.8% or n = 9), while basalt and other raw materials such as phonolite, gneiss or quartzite present a marginal use (Table 1). Although the cores employed for this RM show the same types of blanks in both assemblages, the most notable difference between the assemblages is documented in the case of cobbles (SHK: 14.2% or n = 2; BK 36.3% or n = 4). It is interesting to note the use of flakes as blanks in both sites, uncommon in many of the other reduction schemes (Table 1).

The BFG RM is characterized by the production of alternating isolated flakes generally detached through secant percussion. This continuous alternation of knapped surfaces implies that the next removal employs the negative of the previous one as a striking platform. This type of reduction is sometimes carried out through perpendicular percussion, and in rare occasions presents short series of parallel scars (two removals) that in any case do not break the alternating pattern of reduction (Fig. 6A).

The scars are mostly arranged in a linear or orthogonal manner, while opposed or centripetal (discoid) scar patterns are very rare (Table 1). This type of reduction is aimed to producing small-sized flakes in both sites (SHK: 78.5% or n = 11; BK: 63.6% or n = 7). A few BFG cores produce medium and large flakes in SHK (21.4% or n = 3), while this RM is one of the most

Table 1. Technical variables employed for the analysis of cores sorted by reduction model (RM) and raw material. Type of blank: cobble (1), block/fragment (2), hemispheric (3) and flake (4). Flake size: micro (1), small (2), medium (3) and large (4). Type of reduction: isolated removals (1), parallel removals (2) and centripetal removals (3). Type of percussion: perpendicular (1), secant (2) and parallel (3). Scar pattern: linear (1), longitudinal (2); opposed (3), orthogonal (4) and centripetal (5). M = mean.

Site	RM	Material	No.	Scars (M)	Blank				Flake size				Reduction			Percussion			Scar pattern				
					1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	4	5
SHK	MF		27	9.3	6	21	–	–	–	24	9	2	27	5	–	26	3	–	–	–	–	–	–
		Quartz	21	9.2	3	18	–	–	–	18	6	2	21	4	–	20	3	–	–	–	–	–	–
		Basalt	5	8.8	3	2	–	–	–	5	3	–	5	1	–	5	–	–	–	–	–	–	–
		Others	1	10	–	1	–	–	–	1	–	–	1	–	–	1	–	–	–	–	–	–	–
	UF		16	5	4	9	3	–	–	14	2	2	1	16	–	11	5	1	14	–	1	1	–
		Quartz	12	4.8	3	8	1	–	–	10	2	2	1	12	–	9	3	1	10	–	1	1	–
		Basalt	4	5.2	1	1	2	–	–	4	–	–	–	4	–	2	2	–	4	–	1	1	–
	BFG		14	6.1	1	6	–	6	1	11	2	1	14	–	–	1	14	–	7	–	–	5	1
		Quartz	9	5.8	–	4	–	5	1	7	1	1	9	–	–	1	9	–	5	–	–	3	1
		Basalt	1	6.5	1	–	–	–	–	2	–	–	2	–	–	–	2	–	–	–	–	1	–
		Others	3	6	–	2	–	1	–	2	1	–	3	–	–	–	3	–	2	–	–	1	–
	BFA		29	8.2	10	15	–	4	1	27	13	1	20	26	–	6	20	8	5	–	2	18	4
		Quartz	19	8.5	4	11	–	4	1	17	7	1	12	18	–	5	13	5	2	–	2	13	2
		Basalt	8	8.6	4	4	–	–	–	8	4	–	7	7	–	1	5	3	2	–	–	4	2
		Others	2	7.5	2	–	–	–	–	2	2	–	1	1	–	–	2	–	1	–	–	–	1
	BFC		16	7.1	9	7	–	–	–	15	5	–	5	16	–	6	10	2	11	–	–	4	1
		Quartz	7	7.4	3	4	–	–	–	7	2	–	2	7	–	3	4	–	5	–	–	2	–
		Basalt	7	6.1	5	2	–	–	–	6	3	–	2	7	–	2	5	2	5	–	–	1	1
		Others	2	8	1	1	–	–	–	2	–	–	1	2	–	1	1	–	1	–	–	1	–
	BFH		4	6.1	4	–	–	–	–	4	3	–	2	3	1	–	–	4	–	3	–	–	1
		Quartz	3	6	3	–	–	–	–	3	2	–	1	3	–	–	–	3	–	3	–	–	–
		Basalt	1	6.3	1	–	–	–	–	1	1	–	1	–	1	–	–	1	–	–	–	–	1
	Total		106	6.9	35	58	3	10	2	95	34	6	64	65	1	50	52	15	37	3	3	29	8
BK	MF		42	8.9	5	37	–	–	3	40	10	1	41	11	–	36	11	–	–	–	–	–	–
		Quartz	26	8.2	3	23	–	–	3	24	3	–	25	7	–	21	9	–	–	–	–	–	–
		Basalt	15	8.6	2	13	–	–	–	15	7	1	15	4	–	14	2	–	–	–	–	–	–
		Others	1	10	–	1	–	–	–	1	–	–	1	–	–	1	–	–	–	–	–	–	–
	UF		18	4.1	9	8	1	–	–	17	2	–	3	15	–	11	4	3	15	–	1	2	–
		Quartz	9	4.6	2	7	–	–	–	9	–	–	1	8	–	6	2	1	7	–	–	2	–
		Basalt	7	3.8	6	–	1	–	–	7	1	–	2	5	–	4	2	1	6	–	1	–	–
		Others	2	4	1	1	–	–	–	1	1	–	–	2	–	1	–	1	2	–	–	–	–
	BFG		11	5	4	3	–	4	6	7	–	–	11	1	–	1	11	–	6	–	2	3	–
		Quartz	9	6.2	2	3	–	4	6	5	–	–	9	1	–	1	9	–	4	–	2	3	–
		Basalt	1	6	1	–	–	–	–	1	–	–	1	–	–	–	1	–	1	–	–	–	–
		Others	1	3	1	–	–	–	–	1	–	–	1	–	–	–	1	–	1	–	–	–	–
	BFA		30	7.2	8	14	–	8	2	28	4	–	21	19	–	7	26	3	7	–	5	10	7
		Quartz	16	7.4	1	10	–	5	1	15	–	–	11	8	–	3	16	–	3	–	2	7	4
		Basalt	12	7.7	5	4	–	3	1	12	3	–	8	10	–	4	8	3	4	–	2	3	2
		Others	2	6.5	2	–	–	–	–	1	1	–	2	1	–	–	2	–	–	–	1	–	1
	BFC		7	5.5	3	4	–	–	1	5	1	–	1	7	–	–	6	1	5	1	–	1	–
		Quartz	6	7	3	3	–	–	1	5	–	–	1	6	–	–	5	1	4	1	–	1	–
		Basalt	1	4	–	1	–	–	–	1	–	–	–	1	–	–	1	–	1	–	–	–	–
	BFH		8	7	3	3	–	2	1	7	2	1	4	4	1	–	–	8	–	3		2	3
		Quartz	4	7.5	–	2	–	2	–	4	–	–	2	1	1	–	–	8	–	1		1	2
		Basalt	4	6.5	3	1	–	–	1	3	2	1	2	3	–	–	–	8	–	2		1	1
	Total		116	6.6	32	69	1	14	12	105	19	2	81	57	1	55	58	15	33	4	8	18	10

often employed for producing micro-sized flakes in BK (36.3% or n = 6). The BFG cores from BK tend to be lighter (n = 10) than those from SHK (Table 2).

Bifacial Alternate (BFA). – This is one of the most widespread RMs in both sites (SHK: 27.3% or n = 29; BK: 25.8% or n = 30). Many of the BFA cores are made from quartz (SHK: 65.5% or n = 19; BK: 53.3% or n = 16), some of them from basalt and a few from phonolite or gneiss (Table 1). The main difference between assemblages is that basalt represents 40% (n = 12) of the cores in BK and in SHK it represents 27.5% (n = 8).

Angular blocks, rounded cobbles and flakes are used as blanks and represented by this order in both assemblages (Table 1). Cobble type blank reaches its highest value in this RM (SHK: 34.4% or n = 10; BK: 26.6% or n = 8). Flake type blanks, documented in both sites, are more important in BK (26.6% or n = 8). It is likely that the three basalt flakes reduced by this RM at BK

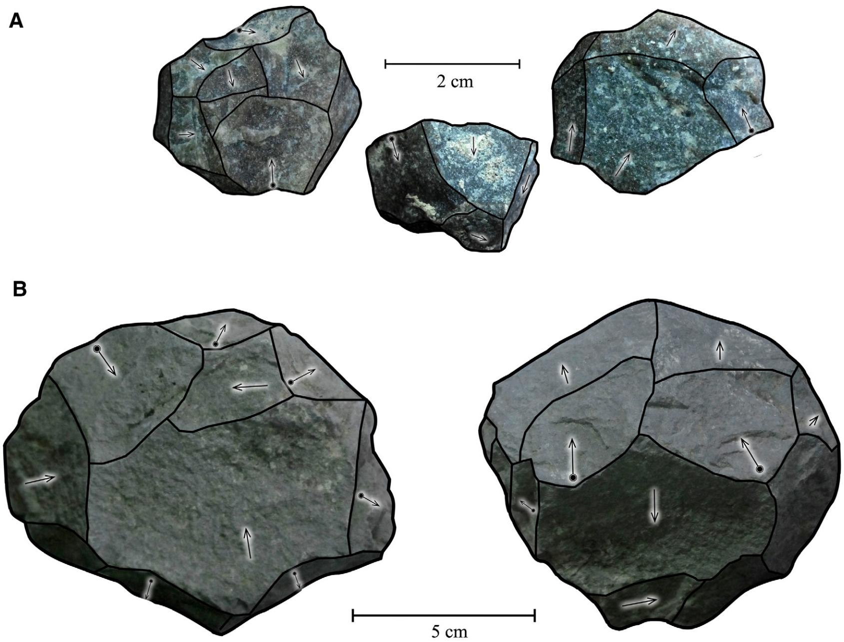

Fig. 4. Multifacial (MF) cores made from quartzite (A) and basalt cobbles (B). Note how the reduction sequence is conducted through isolated and disorganized removals obtained through perpendicular percussion.

were initially blanks for LCTs that at a given point in their shaping are transformed into flaking cores.

This RM is focused on the production of small flakes in both assemblages (SHK: 64.2% or n = 27; BK: 82.3% or n = 28), and the production of both micro and large flakes is absent or rare (Table 1). However, both variables, the assemblage and flake size production, show a medium statistical significance level (Chi-square test, *p*-value: 0.029). In this regard we observe that the production of medium-sized flakes is more abundant in SHK (Table 1). According to the results of a robust MANOVA test, the assemblages are not statically significant when they are compared by length (*p*-value: 0.182), breadth (*p*-value: 0.703), thickness (*p*-value: 0.284) and weight (*p*-value: 0.357).

The BFA RM is the most difficult to characterize due to its lack of homogeneity in its operational phases and technical actions. The most recognizable traits of these cores are: the high mean of scars per core; reduction is carried out by the articulation of different types of knapping sequences (isolated flakes and series of parallel removals); the discontinuous alternation of knapped surfaces; and the use of previous scars as striking platforms (Fig. 6B). Core reduction is conducted through different types of percussion (Table 1), of which secant percussion is the most recurrent (SHK: 58.8% or n = 20; BK: 72.2% or n = 26). The maintenance of production is carried out by discontinuous core rotation and extending the perimeter of the flaked surface through successive crossing series of parallel and isolated removals (Table 1). For this reason the orthogonal and, at a certain distance, the centripetal scar patterns show their highest values in this RM (Table 1). The centripetal scar pattern is not necessarily the result of a series of centripetal removals, as several series of parallel removals on the same surface could also produce a centripetal scar pattern.

Bifacial Continuous (BFC). – The bifacial continuous RM exhibits a secondary presence in SHK and a marginal presence in BK (SHK: 15% or n = 16; BK: 6% or n = 7). Quartz and basalt are represented equally in SHK (43.7% or n = 7), whereas quartz is clearly dominant in BK (85.7% or n = 6). Both blank types, cobbles and blocks (whole or fragmented), have a quite similar representation in both assemblages (Table 1).

The BFC RM is characterized by continuity in its production. The core is rotated once, hence there are one technical break and two reduction phases, and the scar or scars of one surface are used as the striking platform for the removals detached on the other surface (Fig. 7). The production is in all cases and in both assemblages, carried out by series of parallel removals (Table 1). However, these parallel removals are sometimes found together with isolated flakes. For instance: there are four cores (three from SHK and one from BK) with a series of parallel removals that employed a wide and isolated removal as a striking platform. This suggests that such isolated removals could have been intended to prepare a suitable striking platform (Fig. 7B). The exploitation of the BFC cores is conducted by different types of percussion, amongst which secant percussion is the most widespread (SHK: 62.5% or n = 10; BK: 85.7% or n = 6). A large part of these

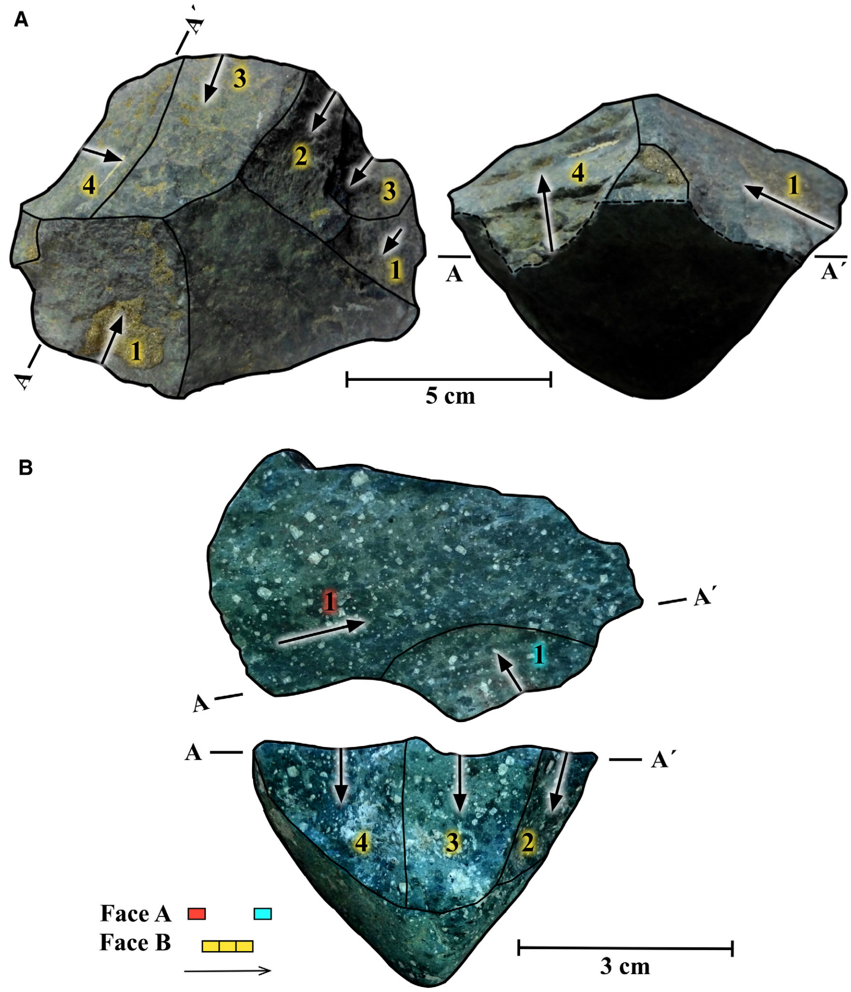

Fig. 5. Diacritical analysis. A. Unifacial core in basalt: the reduction sequence is conducted through isolated and parallel scars obtained through secant percussion. B. Unifacial core in phonolite: Phase 1, split cobble (red); Phase 2, full production (yellow): parallel removals produced through perpendicular percussion; Phase 3, later production (blue): isolated removal produced through parallel percussion.

cores are focused on the production of small flakes (SHK: 93.7% or n = 15; BK: 85.7% or n = 6) and the linear scar pattern is the most recurrent RM in both assemblages (SHK: 68.7% or n = 11; BK: 71.4% or n = 5) (Table 1). The cores from BK tend to be lighter than those documented in SHK (Table 2).

Bifacial Hierarchical (BFH). – This RM is represented the least in both samples. A robust MANOVA test shows no statistical significant differences in raw material (*p*-value: 0.374) or blanks (p-value: 0.167) when the BFH cores of both assemblages are compared. The reduction sequences are quite diversified, and include parallel removals with longitudinal forms, isolated orthogonal removals and recurrent centripetal removals (Table 1). The latter reduction phase often consisted of smaller removals that break core hierarchization (Figs 8, 9). Parallel and centripetal removals respectively generate a lateral and peripheral convexity that favours the maintenance of production. There are two cores that seem to exhibit a preparation of latero-distal convexities on the flaking surface (Figs 9A, 10A); however, we prefer to be cautious as geometric constraints of fracture mechanics can give rise to what appears to be highly predetermined flakes. The BFH cores are largely devoted to producing small–medium flakes (Table 1), but large flake production was documented in one core (Fig. 10A). Once again, the cores from BK tend to be lighter than those documented in SHK (Table 2).

Reduction methods and rules

In order to assess whether the RMs are really reduction methods because they evidence 'an orderly sequence of actions following an elaborate plan' (Roche 2000: p. 101), or conversely respond to an arbitrary and *ad hoc* core classification employed in this work, we conducted four robust MANOVA tests that investigated the following traits of the RMs (dependent

Table 2. Typometric values of the cores, sorted by site, reduction model (RM) and raw material. Min. = minimum; Max. = maximum; M = mean; SD = standard deviation.

Site	RM	Material	No.	Length (mm)				Width (mm)				Thickness (mm)				Weight (g)			
				Min.	Max.	M	SD	Min.	Max.	M	SD	Min.	Max.	M	SD	Min.	Max.	M	SD
SHK	MF	Quartz	21	47	111	76.22	17.37	44	107	69.04	1804	35	101	58.47	17.2	104	3376	801.71	893.74
		Basalt	5	62	111	77.4	18	50	100	70.5	18.58	44	79	57.4	12.24	201	1347	679.4	436.4
	UF	Quartz	12	57	132	90.12	23.85	45	99	68.45	21.11	33	85	55	15.72	155	1954	718.41	612.68
		Basalt	4	60	94	79.25	13.62	43	87	61.25	19	32	64	47.5	12.09	161	696	413.25	240.95
	BFG	Quartz	9	41	81	56.62	13.39	33	75	51.5	12.13	22	52	34.5	8.47	34	399	152.37	111.55
		Basalt	2	94	110	102	8	85	92	88.5	3.5	63	67	65	2	654	731	692.5	38.5
	BFA	Quartz	19	42	180	76.44	32.83	30	119	62.27	23.6	18	81	47.5	15.47	27	2586	430.88	586.06
		Basalt	8	70	140	93.75	19.62	47	108	75.12	18.81	52	484	114.8	139.9	380	2884	945	875.14
	BFC	Quartz	7	47	139	83.14	29.96	38	83	60.42	15.64	34	71	52.85	13.97	65	1053	508.57	327.38
		Basalt	7	71	105	87.14	10.7	67	92	75.42	8.74	47	70	57	7.76	291	731	482.71	161.27
	BFH	Quartz	3	69	88	79.66	7.93	65	71	68	2.44	52	58	55	2.44	389	543	453.33	65.37
		Basalt	1	71	–	–	–	60	–	–	–	46	–	–	–	277	–	–	–
BK	MF	Quartz	24	32	95	56.7	18.86	27	86	52	17.81	24	75	45.04	15.43	10	739	233.2	208.7
		Basalt	15	36	114	85.4	18.47	35	107	74.53	17.98	35	84	62.53	12.76	64	1519	653.93	355.41
	UF	Quartz	8	43	84	58.25	12.46	38	69	56.75	8.43	28	44	34.75	5.88	34	384	157.5	94.54
		Basalt	6	58	98	72.5	12.63	51	86	63.16	12.53	38	68	48.33	9.53	162	896	365	249.83
	BFG	Quartz	9	24	61	42.22	10.78	21	45	35.44	7.79	14	45	26.88	10.19	14	142	60	45.29
		Basalt	1	49	–	–	–	43	–	–	–	42	–	–	–	148	–	–	–
	BFA	Quartz	16	27	84	53.5	12.31	26	66	45.25	11.1	15	65	35.68	13	12	419	128.31	105.54
		Basalt	12	58	121	81.25	16.02	51	101	68.41	14.46	35	75	53.75	12.03	143	1409	484.58	207.31
	BFC	Quartz	6	40	103	66	21.4	37	87	86.16	15.81	31	54	38.66	7.52	56	927	289.16	294.21
		Basalt	1	81	–	–	–	55				53	–	–	–	358	–	–	–
	BFH	Quartz	4	40	59	51.25	6.94	38	53	48.25	6.01	17	50	35.5	13.27	29	198	117.75	62.25
		Basalt	4	71	117	84.75	18.43	54	116	72.75	25.31	36	76	51.25	15.25	254	1190	493	402.48

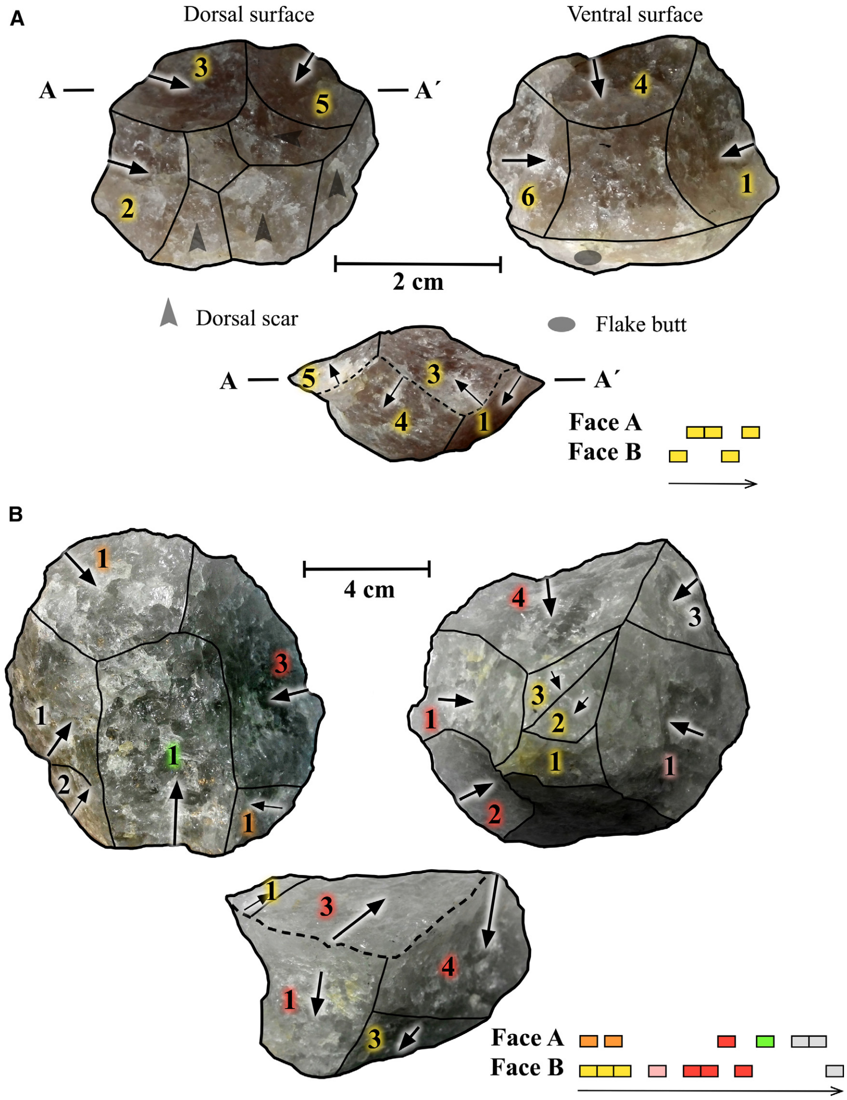

Fig. 6. Diacritical analysis. A. Bifacial Alternating core made from a quartz flake: the reduction sequence is characterized by the production of alternating isolated flakes detached through secant percussion. The red arrows are the negatives of the dorsal face, and the blue dot marks the impact point. B. Bifacial Alternate core in quartz: Phase 1, early production (orange and yellow): bifacial removals with undetermined type of production and, probably, obtained through secant percussion; Phase 2, full production (pink, red and green): bifacial removals whose production varies between isolated and alternating removals obtained through secant percussion.

variable): (i) technical homogeneity, analysed independent variables: type of reduction, type of percussion and scar pattern (MANOVA test 1, MT1); (ii) typometrical homogeneity, analysed independent variables: length, width and thickness (MANOVA test 2, MT2); (iii) blank selection, analysed independent variables: type of raw material and blank (MANOVA test 3, MT3); (iv) reduction intensity and production aim (i.e. flake size production), analysed independent variables: weight, number of scars, and flake size production (MANOVA test 4, MT4). The variables employed here to analyse core reduction intensity (i.e. weight and number of scars) have been previously used by other authors to measure reduction intensity in handaxes (Shipton & Clarkson 2015).

According to the results of MT1, the RMs are very homogenous in technical terms, as there is a high statistical significance between the RMs and the type of percussion (p-value: <0.001) and the scar patterns (p-value: <0.001), and a low statistical significance between the RMs and the type of reduction (p-value: 0.079). The MT2 indicates that the RMs are also quite homogenous in typo-metric terms, having a statistical correlation when the RMs are compared by length (p-value: 0.035) and width (p-value: 0.038). However, MT3 shows that the RMs are not statically correlated with raw material (p-value: 0.387) and blank types (p-value: 0.622). Finally, MT4 evidences that different levels of statistical significance exist between the RMs and the dependent variables related to reduction

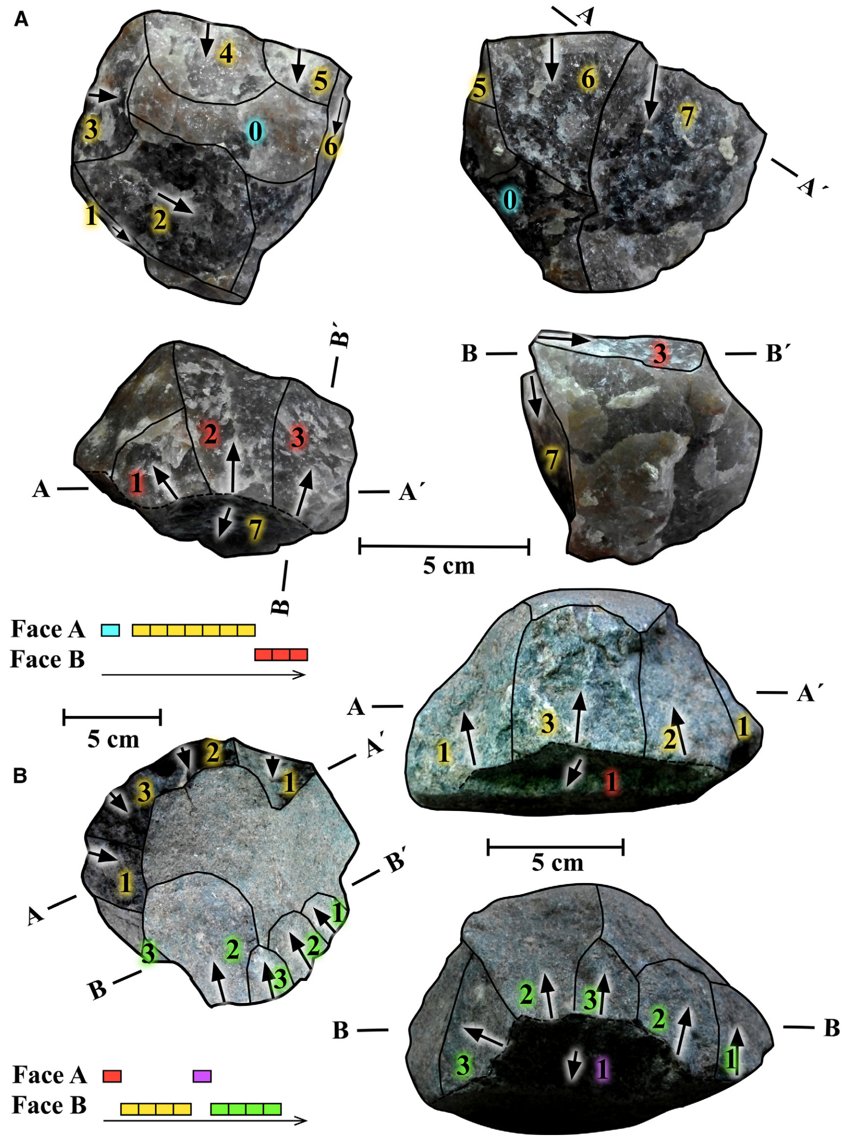

Fig. 7. Diacritical analysis. A. Bifacial Continuous core in quartz: Phase 1, early-full production (yellow): parallel removals produced through secant percussion; Phase 2, later production (red): parallel removals produced through secant percussion. B. Bifacial Continuous core in basalt: Phase 1, striking platform preparation (red): isolated removal obtained through secant percussion; Phase 2, early production (yellow): parallel removals produced through secant percussion; Phase 3, striking platform preparation (pink): isolated removal obtained through secant percussion; Phase 4, later production (green): parallel removals produced through secant percussion.

intensity (number of scars, p-value: <0.001; weight, p-value: 0.092), but there is no correlation between the RMs flake size production (p-value: 0.743).

In sum, the RMs are consistent in technical and typo-metric terms and are probably connected with core reduction intensity, and can thus be regarded as reduction methods (sequence of planned actions) rather than arbitrary core categories. Core reduction was very often geared to obtain a high production of flakes, as the most frequent RMs (MF and BFA) are those that produce the largest amount of flakes (Table 1). High reduction intensity produced long reduction sequences and sometime branching operative sequences through the use of core-flakes. The technical actions implemented to manage core reduction intensity are core rotation and elongation of the perimeter of the flaked surface (scar pattern). By contrast, the fact that the RMs do not show statistical correlation with specific raw materials or blanks and the production of flakes of particular size may suggest flexible technological behaviour, inasmuch as to produce flakes with similar or different sizes the knappers employed diverse RMs, raw materials and blanks.

Such technological versatility is complemented with complex technical actions such as CP. It suggests that the DO knappers had already understood the regularity that exists between platform constraints (exterior

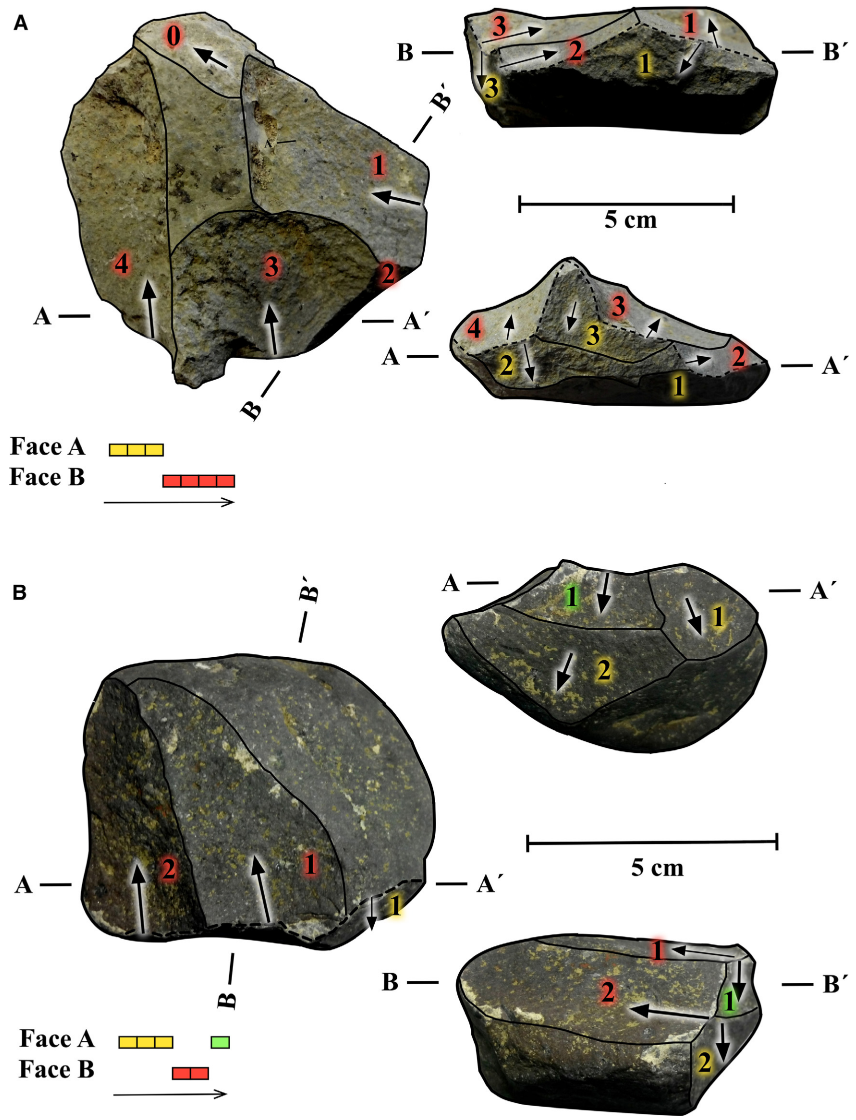

Fig. 8. Diacritical analysis. A. Bifacial Hierarchical core in basalt: Phase 1, platform preparation (yellow): parallel removal obtained through perpendicular percussion; Phase 2, full production (red): isolated removals produced through parallel percussion. B. Bifacial Hierarchical core in basalt: Phase 1, striking platform preparation (yellow): parallel removals obtained through secant percussion; Phase 2, full production (red): parallel removals produced through parallel percussion.

platform angle and platform depth) and the control and prediction of the outcome of flaking (Nonaka *et al.* 2010; Rezek *et al***.** 2011), and therefore they were not constrained by attributes of the raw materials or blanks. The knowledge of this core reduction rule would allow knappers to discriminate the geometric features of the blank that affect the flake morphology and apply different gestural actions (e.g. platform preparation) for detachment success and core reduction effectiveness.

An analysis of variance (ANOVA) test does not show statically significant differences when the assemblages are compared by RMs (p-value: 0.294). However, a MANOVA test shows different levels of statistical significance when the assemblages are compared by length (p-value: <0.001), weight (p-value: 0.096) and flake production (p-value: 0.017). In other words, the cores from BK tend to be smaller and lighter due to the importance that the production of micro and small size flakes had in this site, whereas in SHK that reduction type is much moderate and the production of medium and large-sized flakes is numerically more significant (Tables 1 and 2). Therefore, the most remarkable difference between the cores of the two assemblages seems to be related to quantitative differences in the production of flakes of particular size, resulting in statistically significant differences in the size of the blanks selected.

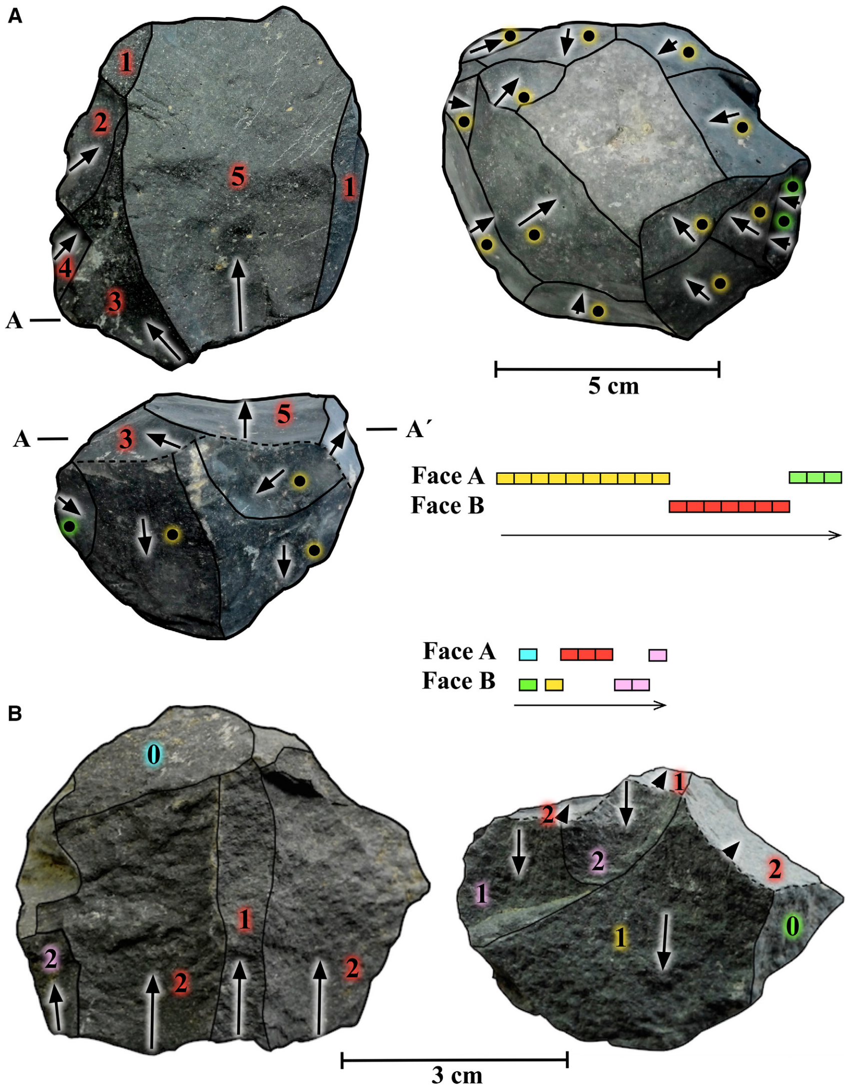

Fig. 9. Diacritical analysis. A. Bifacial Hierarchical core in basalt: Phase 1, early production and/or platform preparation (yellow): parallel and isolated removals probably produced through perpendicular percussion; Phase 2, full production (red): centripetal removals produced through parallel percussion, removal number six could be a preferential flake and thus the other removals of this surface may have been intended to configure the flaking surface; Phase 3, later production (green): isolated and parallel removals produced through perpendicular percussion). B. Bifacial Hierarchical core in basalt: Phase 0, early reduction (blue and green scars); Phase 1, striking platform preparation (yellow): isolated removal obtained through secant percussion; Phase 2, full production (red): parallel removals produced through parallel percussion; Phase 3, later production (purple): parallel and isolated removals produced through perpendicular and parallel percussion.

Discussion

Regarding CP, it is important to distinguish between striking platform preparation and flaking surface preparation. The evidence of the former is limited but diverse in the studied sample (n = 20 or 16.3%). It has been documented in three different RMs (UF, n = 4; BFC, n = 4; and BFH, n = 12) and each one has its own volume management (Fig. 11). The evidence of flaking surface preparation is rare and uncertain, and a larger sample would be required to assess its occurrence and significance. The reconstruction of the flaking processes carried out in the studied assemblages allows us to claim that CP was not carried out through rigid technical and geometric principles, and the products obtained lack a strong component of predetermination. In any case, at this early stage of CP, the creation of serviceable striking angles (<90°) in the absence of natural ones would be very useful in core reduction terms for two reasons: a wider range of shapes could be knapped, as the toolmakers were not constrained by the original shape of the blanks; and it enabled more effective management of the reduction of some blanks. The latter improvement is more evident in the case of the BFH cores, because their technical and geometric architecture provides an optimal control over the flaking process, facilitating the standardization of products.

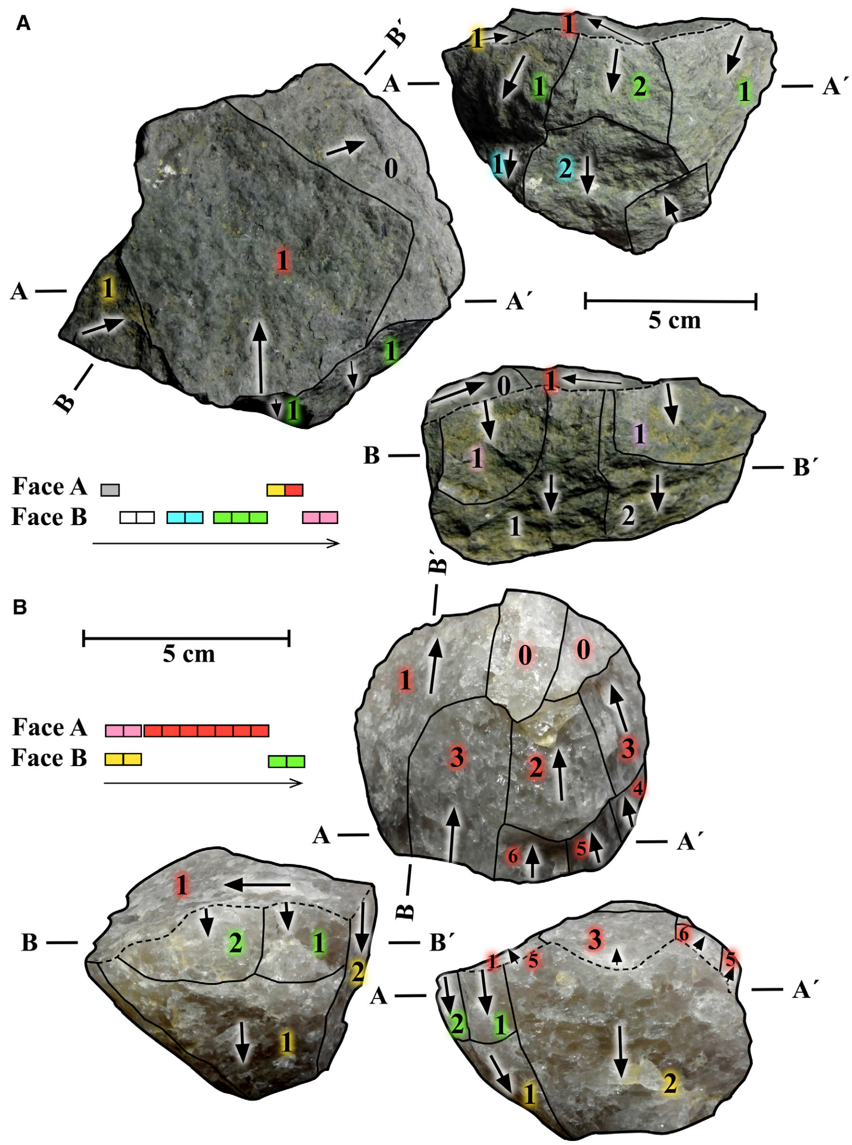

Fig. 10. Diacritical analysis. A Bifacial Hierarchical core in basalt: Phase 1, split boulder (grey); Phase 2, early reduction (purple and blue): parallel removals produced through perpendicular percussion; Phase 3, platform preparation (green): parallel removals produced through perpendicular percussion; Phase 4, flaking surface preparation (yellow): isolated removal produced through secant percussion; Phase 5, large flake-blank production (red): isolated predetermined removal produced through parallel percussion; Phase 6, later production (pink): parallel removals produced through perpendicular percussion. B. Bifacial Hierarchical core in quartz: Phase 1, early production and/or platform preparation (blue and yellow): parallel removals produced through perpendicular percussion: Phase 2, full production (red): two consecutive series of parallel removals produced through parallel percussion; Phase 3, later production (green): parallel removals produced through perpendicular percussion.

Although the technical and geometric features of the BFH cores could be perceived as proof of conceptual and operational complexity, this RM should not be subsumed within the Levallois method *sensu* Boëda (1994, 1995), as hardly any of those cores fulfil the principle of flaking surface preparation. The requisite technological attributes of what can be considered Levallois is a matter of debate (see various contributions in Dibble & Bar-Yosef 1995 and Peresani 2003), but in recent years a growing consensus has emerged around Boëda's Levallois principles (Boëda 1994, 1995). Less rigid is the concept of Prepared Core Technology (PCT), which is characterized by two phases of working, whatever method is used: (i) a preparation phase in which the knapper organized the volume according to the technological and geometric principles illustrated in Fig. 3 in order to manage more effectively the removals, whose shape and size are both controlled and anticipated; (ii) an exploitation phase in which standardized and/or predetermined end-products are obtained (White *et al.* 2011: p. 54). Therefore, the two concepts 'hierarchization' and

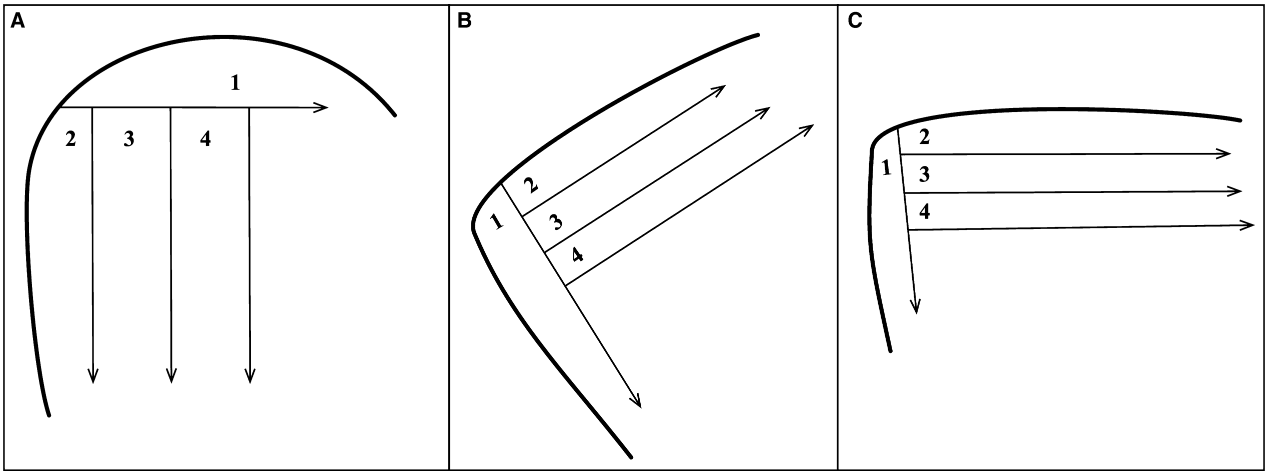

Fig. 11. Representation of the different models of striking platform preparation according to their technical and volumetric conception (the first scar is in all cases for platform preparation). A. Perpendicular percussion. B. Secant percussion. C. Parallel percussion.

'predetermination' are not necessary interconnected. The degree of predetermination of those methods that could be subsumed within PCT has long been a contentious issue (Dibble 1989; Van Peer 1992a, b; Davidson & Noble 1993; Boëda 1995; Schlanger 1996; Bar-Yosef & Van Peer 2009). In view of that, it would be appropriate to differentiate between 'Complex Prepared Core Technology' (CPCT, high degree of predetermination) and 'Simple Prepared Core Technology' (SPCT, low degree of predetermination). At this point, it is important to differentiate between 'core preparation' (technical action by which two knapped surfaces are hierarchically related) and 'prepared core technology' (orderly sequence of technical actions following a precise volume design aimed at obtaining standardized and/or predetermined end-products).

On another front, the present paper can shed light on the long-standing DO/EA debate from the perspective of core reduction. The studied DO assemblages share with some Oldowan assemblages an important number of traits, such as flaking control, high reduction intensity and convergence of different RMs, while at the same time they exhibit a set of traits, such as CP, prepared core technology and production of flake-blanks, that have not been recorded in Oldowan assemblages (e.g. Delagnes & Roche 2005; de la Torre & Mora 2005; Braun *et al.* 2009; Diez-Martín *et al.* 2010; Stout *et al.* 2010). As far as the archaeological record suggests, the Oldowan knappers were constrained by the original shape of the blank because, in the absence of naturally occurring striking angles, they did not create new ones of the studied DO assemblages present an interesting association of primitive and derived traits.

These derived traits, particularly CP, can be tracked in other ESA assemblages. The earliest evidence of CP is seen just before the Acheulean emergence (*c.* 1.77 Ma), in a late Oldowan assemblage at Kokiselei 5 (Kenya), where knappers first display the ability to modify the original geometric features of the core by preparing a new striking platform. This technical action, according to Texier *et al.* (2006), suggests that the knappers possessed both the conceptual and technical background necessary to evolve towards the Acheulean. According to some authors, the earliest evidence of SPCT is seen in a group of DO *sensu lato* assemblages dated between 1.5–1.3 Ma (Texier 1995; de la Torre *et al.* 2003; de la Torre 2009; Gallotti 2013). SHK and BK should be included within this group, but conversely to the observations of these authors, CP is in these assemblages an infrequent technical action, documented in different RMs, carried out through varied technical actions and generating diverse volumetric constructions. Additionally, the evidence of flaking surface preparation in SHK and BK is rare and uncertain and, therefore, we have to assume a low or null degree of predetermination in flake production. This does not imply that the knappers did not possess the ability to discriminate and create the geometric features of the blank that affect the flake morphology, but at least they did not do so for the production of regular flakes (non-large flakes). In fact, prepared core technologies with different degrees of predetermination and associated with the production of large flake-blanks for LCTs have been recorded in EA sites dated between 1.5–1.3 Ma (de la Torre *et al.* 2008; Diez-Martín *et al.* 2014a, b; Leader *et al.* in press). Furthermore, the production of cleavers, already recorded in the earliest Acheulean assemblages (Beyene *et al.* 2013; Diez-Martín *et al.* 2015), implies some degree of predetermination through flaking surface preparation (Texier & Roche 1995). This body of evidence emphasizes Borde's idea that Levallois is inherent in the Acheulean (Bordes 1971), a hypothesis recently supported by Adler *et al.* (2014). In sum, CP and the resulting PCT can definitely be accepted as derived traits within the Oldowan-Acheulean gradient. Its presence within DO assemblages confirms their innovative nature, while also suggesting a very close relationship between the DO and EA assemblages.

Conclusions

The flake production processes identified in SHK and BK exhibit great technological homogeneity. The most remarkable difference between the cores of the two assemblages is probably linked to differences in productive requirements (i.e. flake size). The technical and metric coherence of the RMs into which the studied cores were sorted support their consideration as reduction methods. The employment of different RMs, raw materials and blanks to produce flakes with similar or different sizes highlights the flexible and versatile character of the technological behaviour. The most frequently implemented technical actions employed to manage core reduction were core rotation and elongation of the perimeter of the flaked surfaces, and they seem to be related to high reduction intensity. Another technical action documented is CP, particularly flaking surface preparation, which allowed on the one hand a wider range of shapes to be knapped, and on the other more effective management over the flaking process. Although the presence of flaking surface preparation in the studied sample is ambiguous, the mere presence of striking platform preparation implies that the DO knappers had already fully mastered the technical parameters of stone production, and possessed the perceptual-motor skills needed for controlled and predictable flake detachment and the cognitive control required to create serviceable striking angles in the absence of natural ones. This contrasts with the cognitive control demands attributed to Oldowan knappers, while it is consistent with the demands attributed to Acheulean knappers (i.e. Wynn 1981, 1993; Stout *et al.* 2008, 2015).

To sum up, we would like to conclude by highlighting the main contributions of this paper to the study of early human technological behaviour. We have analysed the DO/EA debate, traditionally focused on different aspects of handaxes, from the perspective of core reduction for the first time. Secondly, we have provided tested evidence enabling CP to be definitively accepted as a derived trait within the Oldowan–Acheulean gradient, confirming a strong relationship between the DO and EA assemblages. Finally, we have provided an original methodological approach to assess one of the most remarkable and crucial technical competences acquired by the ESA knappers (i.e. CP). Our approach is based on the study and classification of flaking cores through detailed diacritical and technological studies regardless of aprioristic morphological considerations.

Acknowledgements. – We wish to thank Tanzanian COSTECH and the Antiquities Unit for permits to conduct research in Olduvai Gorge. We also thank the Spanish Ministry of Economy and Competitiveness for funding this research through program HAR2010-18952-C02- 02. Dr Sánchez-Yustos is the beneficiary of a postdoc position from University of Valladolid. We are grateful to two anonymous reviewers and Prof. J. A. Piotrowski for reading over an early draft of this manuscript and providing comments that strengthened it.

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