Quaternary Science Reviews 190 (2018) 123–136

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Life history of a large flake biface

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ARTICLE INFO

Article history:
Received 31 October 2017
Received in revised form
5 April 2018
Accepted 20 April 2018

Keywords:
Large flake Acheulian
Biface
Handaxe
Cleaver
Lithic technology
Levant
Iberia
Quarry to discard

ABSTRACT

Bifaces, primarily handaxes and cleavers, are the hallmark of the Acheulian techno-complex lithic industry. They spread across Africa and Eurasia during the Early to Middle Pleistocene. While many attempts have been made to define and describe the typology and technology of these tools, most focus on a single stage in their manufacture and usage, from quarry to discard. These attempts are fragmented, primarily due to the fact that at no single site are all stages of biface manufacture and use represented. An additional factor that appears to impede attempts to present the full "life cycle" of bifaces is the view of all Acheulian assemblages as belonging to a single cultural entity. While all assemblages belong to the same techno-complex, distinct stages and phases should be recognized, each different in typology, technology, and probably also in chronology. This research focuses on the large flake stage of the Acheulian. Data accumulated over many years of research from different regions are analyzed together in an attempt to present a holistic view of the life cycle of a biface. The study of particular Acheulian sites from the Levant and Western Europe enables us to reconstruct all stages of the biface, from raw material exploitation to final discard. The result is a model more comprehensive and precise than those suggested previously for understanding the Large Flake Acheulian.

1. Introduction

Acheulian bifaces have been studied by prehistorians since their discovery in Europe where handaxes were first identified as prehistoric stone tools. The earliest identification of such tools from Hoxne, Suffolk by John Frere in 1797 and later by Boucher-de-Perthes (Boucher-de-Perthes, 1864) from Somme River terraces, were supported by finds from the Manzanares River (Madrid) in San Isidro (De Prado, 1864; Wernert and Pérez de Barradas, 1925) and from the Thames Valley (Evans, 1872, 1897). Over the years, researchers have defined, described, and attempted to understand the 'biface enigma' (after Wynn, 1995). Some researchers focused on the manufacturing technology of bifaces and others on the typological definition of the tools and their significance. Many described different assemblages or collections; others suggested a regional or a holistic view of the Acheulian techno-complex. However, the full "life cycle" of a bifacial tool, from the selection and extraction of raw material at the outcrop to final discard, has been less frequently discussed (Bárez del Cueto et al., 2016; Goren-Inbar and Sharon, 2006a; Méndez-Quintas et al., 2018; Paddayya et al., 2006; Petraglia et al., 1999).

This is particularly true for the later stages in the "life" of a tool, primarily because such stages are harder to observe and identify in ancient Acheulian sites. Raw material selection strategies and acquisition have been identified and studied (e.g. Barkai and Gopher, 2009; McPherron, 2006; Sharon, 2008). The technology of biface production can be reconstructed by the tools and waste excavated at sites, with substantial support from experimental studies. However, the later stages in the life of a biface, its storage, usage, and discard are harder to reconstruct. After decades of study, we cannot even confirm the purpose for which bifaces were used. Common knowledge suggests their use in the consumption of large game (e.g. Kleindienst and Keller, 1976; Machin et al., 2007; Viallet, 2016), hence the term "Large Cutting Tools" (see discussion and references in Sharon, 2007). Beyond their actual use, bifaces are poorly understood in other aspects as well. The understanding and interpretation of the "extremely rich assemblages" are highly debatable (Wynn, 1995), as is the role of re-sharpening in biface final usage and shape (e.g. Goren-Inbar and Sharon, 2006a; McPherron, 1999, 2006). The discard of these tools is enigmatic, as most tools show almost no visible evidence of use. They seem to have been left behind when still fully usable and for no obvious reason (to our modern eyes).

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https://doi.org/10.1016/j.quascirev.2018.04.015
0277-3791/

An additional issue hampering the discussion of the life cycle of bifacial tools is the tendency to look at the Acheulian techno-complex as a single entity. While all bifacial dominated early assemblages are defined as Acheulian, much variability can be identified within them. The variability is expressed in typology and technology that bear chronological and even climatic significance (e.g. Bordes, 1961; Leakey and Roe, 1994; Malinsky-Buller, 2016; Moncel et al., 2015; Roe, 1981, 2001; Sharon, 2007). The Acheulian reduction sequence can, and should, be divided into different stages or phases. The study of each stage separately will, we believe, enable a better understanding of the life history of bifacial tools and the socio-spatial organization of the human activities in each stage. In this paper we focus on the large flake phase of the Acheulian techno-complex (Sharon, 2009, 2010; Sharon and Barsky, 2015). The existence of large flake based biface assemblages signifies the presence in this Acheulian stage of complex and structured reduction processes including sophisticated raw material catchment strategies, primary production of flakes (initial *débitage*), and the application of particular shaping methods later adapted to large flake manufacture (*façonage*) processes. In order to understand the complexity of one of the most representative Acheulian expressions, we will limit and focus our analysis to these techno-cultural strategies. Such focus will allow us to propose a reconstruction of the entire life cycle of a large flake handaxe or cleaver from raw material outcrop to discard.

The definition and identification of large flake assemblages also enables us to compare sites from different regions and of different natures (quarry, workshop, home base etc.), each contributing details to a holistic view of the biface "life cycle." In this paper we compare and discuss Large Flake Acheulian (LFA) sites from two regions remote from each other, the Levant and the Iberian Peninsula. To date, the only LFA in the Levant is the assemblage from Gesher Benot Ya'aqov (GBY). The GBY assemblage comprises a long sequence of intensive occupations at the shore of the Paleo-Hula Lake in the Early Middle Pleistocene (Goren-Inbar, 2011; Goren-Inbar et al., 2000, 2018; Sharon et al., 2011). In contrast, the Iberian Peninsula has numerous LFA assemblages; unfortunately, many of them originated in disturbed contexts such as river terraces (e.g. Blain et al., 2014; Santonja and Pérez-González, 2010; Santonja et al., 2016; Santonja and Villa, 2006; Sharon and Barsky, 2015). In recent years, new excavations and studies at the Madrid Basin exposed a series of undisturbed LFA sites, many of which have been reconstructed as quarries or workshops. The comparison of data from the Levantine and Iberian LFA sites can complete the puzzle of the biface life cycle.

2. Characterizations of the Iberian and Levantine Acheulian

2.1. The Acheulian of the Iberian Peninsula

The Acheulian of the Iberian Peninsula seems to represent different lithic traditions that overlap and coexist over long periods (Bárez del Cueto et al., 2016; Falguères et al., 2006; Méndez-Quintas et al., 2018; Santonja et al., 2016; Santonja and Villa, 2006). Non-Acheulian Lower Paleolithic flake industries are found in sites like Cuesta de la Bajada (Santonja et al., 2016) and Bolomor (Blasco et al., 2008; Fernández Peris, 2007). Such assemblages are considered by some scholars as "pre-Acheulian", but the dating is debatable and the presence of non-biface assemblages in Acheulian sites such as in Notarchirico, Italy (Cassoli et al., 1999; Pereira et al., 2015; Piperno et al., 1998; Piperno and Tagliacozzo, 2001) suggests a more complex scenario. Early Acheulian sites, potentially similar to Early Acheulian sites in other regions such as 'Ubeiydia (Bar-Yosef and Goren-Inbar, 1993) or even the Early Acheulian African sites (Asfaw et al., 1992; Beyene et al., 2013), can be identified at Bois-de-Riquet in France (Bourguignon et al., 2016) and La Boella in Spain (Mosquera et al., 2016). A local evolution of pre-Acheulian industries into the Western European Early Acheulian indicated by factors such as the presence or absence of large flakes, the absence of cleavers, and the presence of larger-sized tools has been suggested (Mosquera et al., 2016; Sharon and Barsky, 2015).

Subsequent to these early stages, the Iberian Acheulian contains abundant assemblages with numerous bifacial tools. Many of these assemblages are from the fluvial contexts of river terraces, which limits the integrity of the data retrieved both in techno-typological and chronological aspects (Santonja et al., 2016; Santonja and Villa, 2006). Nevertheless, the recent excavation of several sites in primary context makes it possible to draw a general picture of the Iberian Acheulian (Santonja and Pérez-González, 2010; Santonja et al., 2016, 2017; Sharon and Barsky, 2015). The Iberian Acheulian presents variability of tool production strategies and typological expressions. It varies from classic biface assemblages with symmetric handaxes, cleavers, and organized core flaking to assemblages showing the simplest bifacial types such as pics, trifacials, and chopping tools accompanied by polyhedric core reduction (Dennell et al., 2011; Martínez and Garcia Garriga, 2016; Ollé et al., 2016; Santonja et al., 2016). Examples include Ambrona (Santonja et al., 2017), Galería y Gran Dolina (Ollé et al., 2016), La Solana (Jiménez-Arenas et al., 2011), Transfesa-Tafesa (Baena et al., 2010), Pinedo and Las Cien Fanegas (López Recio et al., 2015), Cerro (Monteiro-Rodrigues and Cunha-Ribeiro, 2014), and many others (Lhomme et al., 1998). Generally, the following observations can be suggested for the Iberian Acheulian: (1) frequent use of non-flint, coarse-grained raw material for the production of bifacial tools; (2) good representation of cleavers; and (3) presence of the LFA in the majority of its assemblages (e.g. Moloney et al., 1996; Santonja, 1996; Santonja and Villa, 2006; Sharon and Barsky, 2015).

2.1.1. The lower paleolithic of the Madrid Basin

The Acheulian of central Iberia is traditionally defined by assemblages characterized by the presence or absence of bifacial tools and Levallois technology. However, the use of typological elements to assign techno-cultural tradition must be done cautiously. Many of the assemblages come from quarrying and alluvial contexts and indicate a high degree of variability. Among other reasons, this is best explained due to raw material constraints (Baena et al., 2000).

In recent years, new Acheulian sites were discovered and excavated between the Manzanares and Jarama Rivers in the regions of El Cañaveral, Los Berrocales, and Los Ahijones (Bárez and Pérez-González, 2006). In these regions different chrono-cultural traditions can be recognized. Some sites have been reconstructed as representing short occupation occurrences, while others comprised of palimpsests and re-occupation are indicative of a more intensive occupation history. All sites in this region share a great abundance of knapping waste in a context of rich flint outcrops of Tertiary age. This richness of lithic resources is related to the wide range of knapping strategies observed at the sites. (For details on the sites' stratigraphy and chronology see the supplementary material.)

2.2. The Large Flake Acheulian of the Levant

The large flake stage of the Acheulian techno-complex was suggested by one of us (Sharon, 2007, 2010) with GBY defined as the type site of this stage. The criteria defining a site as LFA were published elsewhere (Sharon, 2007). Here we focus on other aspects of the GBY lithic assemblage, in particular those indicating the use, reuse, and discard patterns of LFA bifaces. The numerous occupation events represented within the documented 34 meter stratigraphy of GBY, which accumulated over tens of thousands of

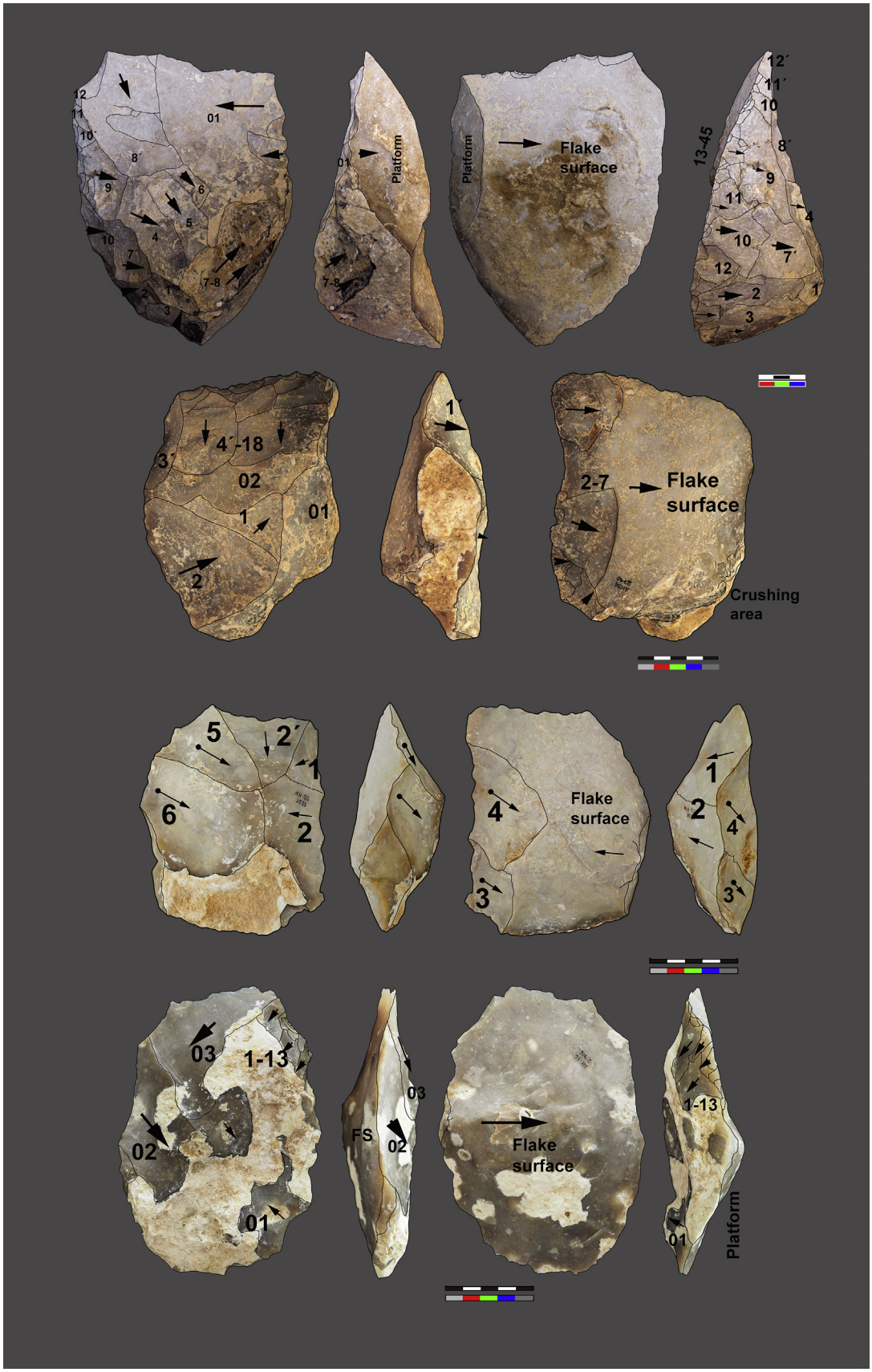

Fig. 1. Cleavers and tested flakes from Charco Hondo 2.

years, demonstrate a variety of different technological behaviors and activities (Goren-Inbar et al., 2000, 2018). One of the GBY layers, Layer II-6/L1, has been interpreted as a butchering locality (Goren-Inbar et al., 1994a,b) where a straight-tusk elephant was processed. Other layers, such as Layer II-6/L2, have been interpreted as "home-bases" (Alperson-Afil, 2008; Alperson-Afil et al., 2009; Goren-Inbar et al., 2004) in the sense presented by Leakey and Isaac (e.g. Isaac, 1969; Isaac, 1971; Isaac et al., 1981; Leakey, 1975), while the biface pavement of Layer II-6/L4 is an example of biface rich layers (Goren-Inbar et al., 2018; Saragusti, 1996) typical of many African sites (Sharon, 2007, for references). Additional layers at GBY tell a different story with evidence for the use and re-shaping of bifaces, but with very few bifacial tools found, indicating complex mobility patterns and discard behavior (Goren-Inbar and Sharon, 2006a; Sharon and Goren-Inbar, 1999). These diverse activities were all carried out within LFA contexts (Sharon et al., 2011). Hence, GBY is an ideal site to shed light on the different stages of the life cycle of a large flake biface considered here.

3. The life cycle of a biface

The entire process of biface production, use, and discard, from

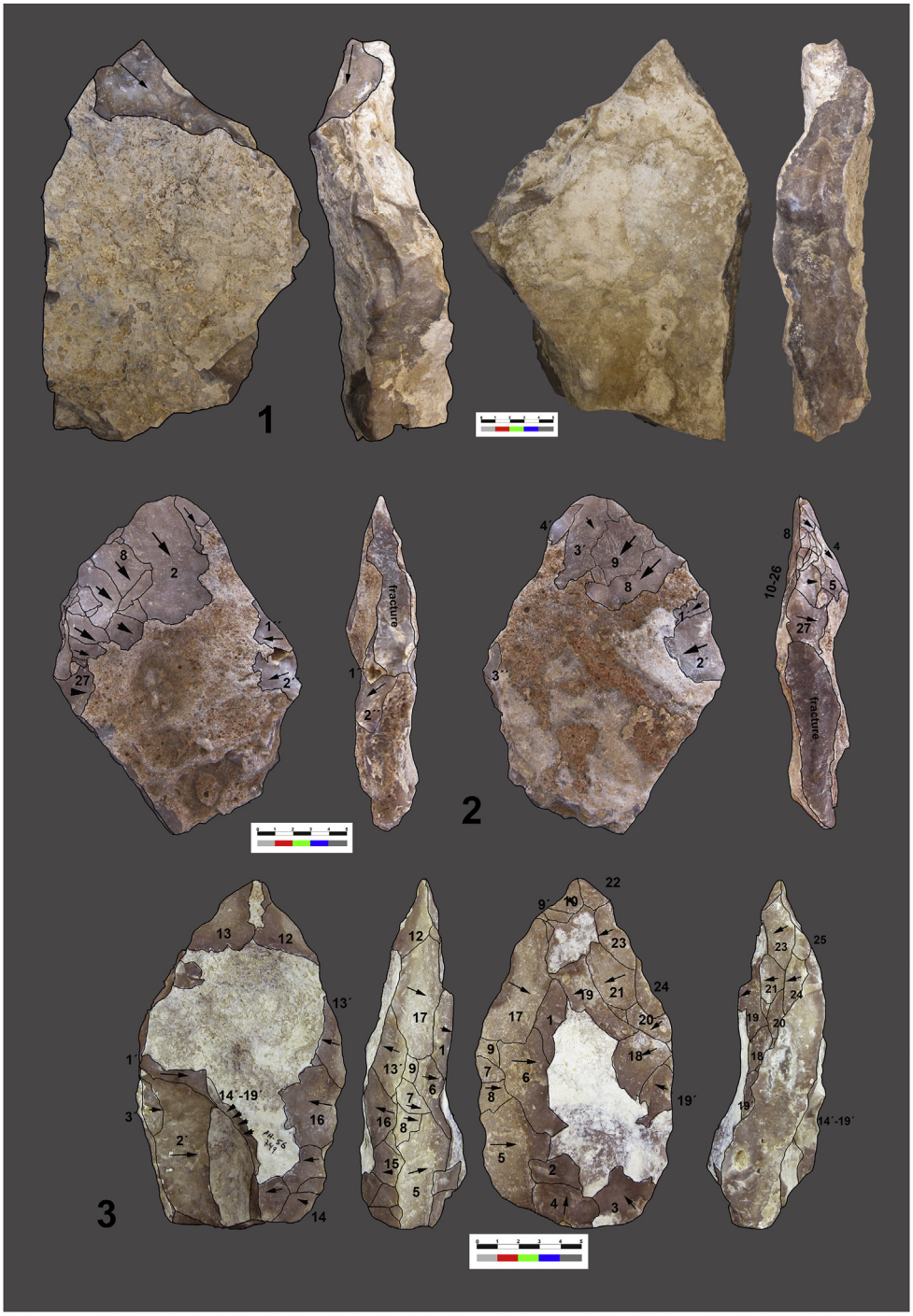

Fig. 2. Handaxes from Charco Hondo 2 G-2.

locating suitable raw material at a quarry to tool disposal has never been documented at a single archaeological site. Additionally, the "life" of a biface unearthed at a site cannot be described without the post-depositional processes the biface underwent between the time of discard and discovery. Acheulian sites are among the oldest sites; hence, they are often the subject of intensive transportation, rolling and in situ weathering (e.g. Grosman et al., 2011; Schick, 1986; Schick et al., 1999). The life cycle of an LFA biface can be described as follows: raw material is acquired at the outcrop or quarry; large flakes are produced and shaped into bifaces at the workshop (located at the quarrying place, adjacent to it or at a distance from it); bifaces are then transported along the landscape and used in a variety of ways for different activities; some are re-sharpened and reused; and finally they are discarded. Of course, the tools can be discarded during any of the above stages. No single locality documents all these activities; rather they seem to be dispersed over a longer period and a wider landscape (for discussion see Turq et al., 2013). Hence, here we combine the data from two distinct regions with the goal of obtaining a more complete picture. As noted, we will limit the discussion to the LFA bifaces. Bifaces attributed to other phases of the Acheulian may present a different (and sometimes very different) "life cycle."

An additional remark is needed before presenting the life of the biface. We use the term biface as a general term, including, in the case of the LFA, both handaxes and cleavers. Researchers have suggested many definitions for these tool types and we follow the handaxe definitions of Roe (1981) and Kleindienst (1962) and the cleaver definition of Tixier (1956). In the LFA, both handaxes and

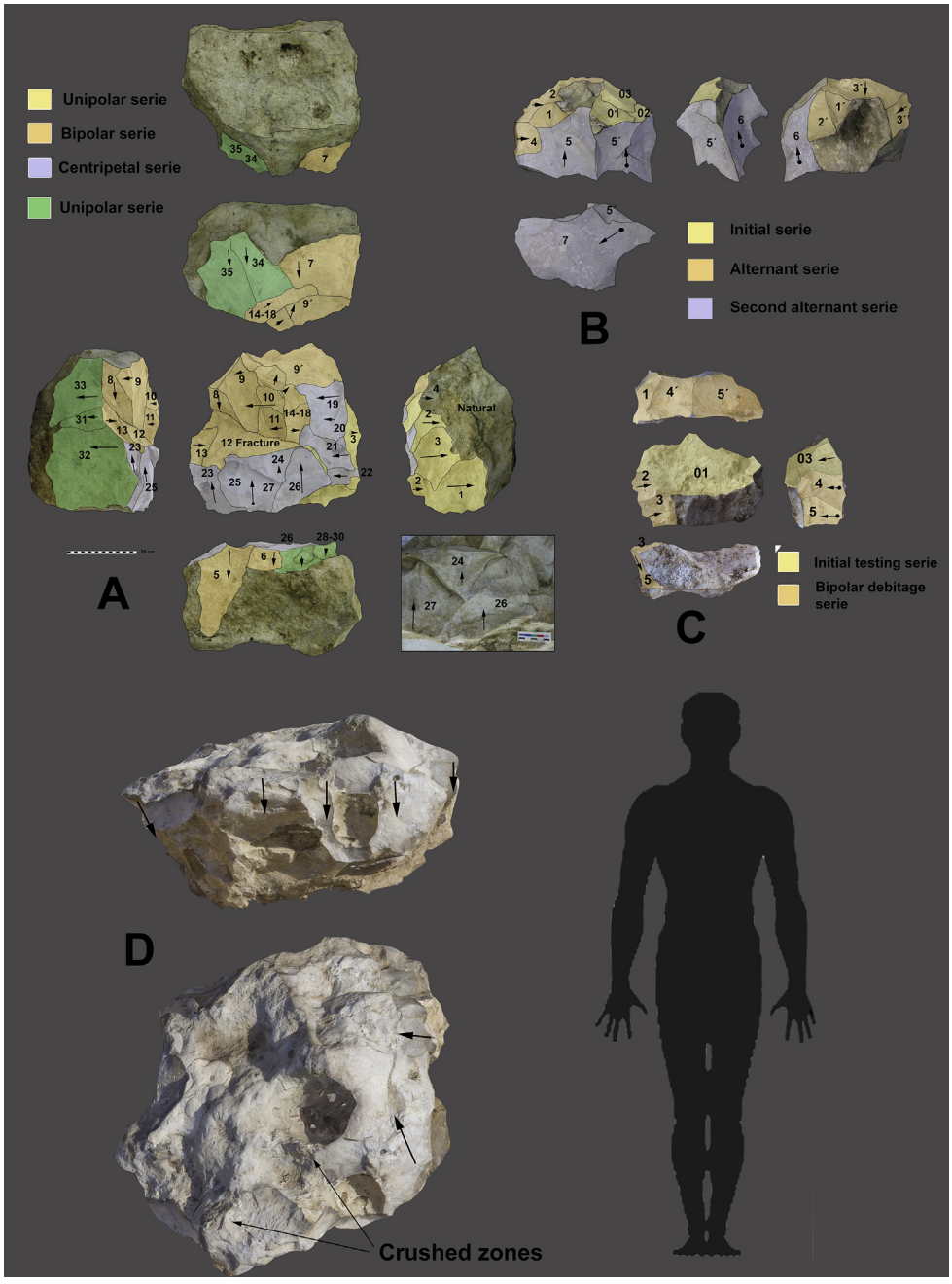

Fig. 3. Giant cores of Charco Hondo 2.

cleavers were generally produced and shaped on large flake blanks (>10 cm, definition by Kleindienst, 1962) and seem to have been treated and maintained in somewhat similar ways by the Acheulian knappers and users. Newcomer (1971) defined three different stages of handaxe production, based on the non-large flake reduction sequence of the British Acheulian. The first stage or *roughing-out* consists of the initial configuration of the nodule by removals "around its edges by direct percussion with the large hammerstone", applying alternate sequences with no thinning. Attributes of the original large flake remain visible in this stage. During the second stage, called *thinning and shaping*, thinner pieces are produced using a soft hammer. The removals cover the entire piece and flakes present typical morphology of soft hammer technique (Sharon and Goren-Inbar, 1999). The third stage, *finishing*, consists of final shaping to produce a sharp edge and straight edges and to give a final symmetry to the piece. Newcomer's terminology will be used here to illustrate the different stages observed at the sites.

We suggest the following stages for the life cycle of a large flake biface, from raw material acquisition to post-deposition. While the final stage is obviously post-reduction sequence and post-discard, it is essential to the discussion of the significance of the spatial tool distribution as unearthed in prehistoric sites. By combining data from the Levant and the Iberian Peninsula we were able to fill in stages missing from any single region and provide examples for all stages suggested.

3.1. At the quarry

The first stage in all reduction sequences is the acquisition of raw material. Producers of LFA bifaces naturally based their production sequence on boulder-sized rocks suitable for the extraction of large flakes. This may be the reason for the observed preference by the LFA knappers for coarse-grained rock types as raw material (Sharon, 2008). In regions where suitably sized raw material was unavailable, innovative skills and creativity were required to produce suitable large flakes from the available rock, as in the use of large rounded quartzite cobbles for the production of Entame and Kombewa flakes in North Africa (Sharon, 2007, 2011). Nevertheless, most LFA assemblages were produced on boulder-sized rocks collected either at riverbeds or quarried directly from outcrops (e.g. Paddayya et al., 2006; Roche et al., 1988). The Acheulian sites near Madrid provide good examples of such quarries:

Recent excavation at the site of Charco Hondo 2 G-1 exposed an assemblage interpreted as resulting from intensive quarrying activity and exploitation of large flint blocks. The flint boulders (or nodules) did not require being unearthed; rather the knappers selected them from natural exposures at the outcrop. These blocks were then exploited as giant prepared cores for the production of large flakes. The next stage in the large flake biface reduction sequence, the rough-out of the flake into a primary tool, is also observed at the site. The lithic assemblage from the site is accordingly rich in giant core and typical waste products but is poor in

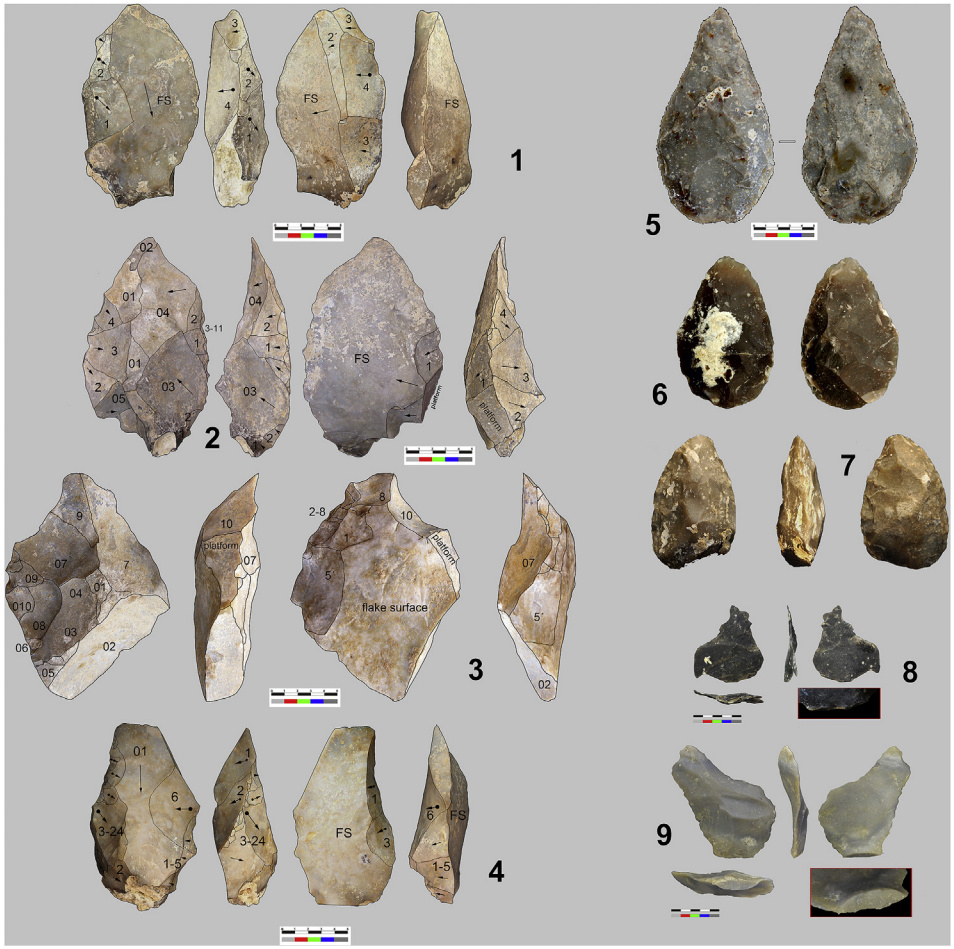

Fig. 4. Charco Hondo 2 and 1 preforms (1–4) shaped bifaces (5–7) and biface shaping flakes (8–9).

shaped "finished" bifaces. The assemblage contains almost no retouched tools and small *débitage* products (Kombewa flakes and orthogonal/discoid reduction flakes) are rare. Only two cleavers and not a single handaxe were exposed (see Fig. 1). The characteristics of this lithic assemblage denote a quarry context in which large flakes were produced, and all the suitable bifacial tool blanks were exported to another location. The advanced stages of biface production, namely shaping and finishing (Newcomer, 1971), were clearly not practiced at this locality.

At Charco Hondo 2 G-1, the reduction sequence began with the extraction of giant flint blocks from the outcrop. Flint block dimensions at this locality ranged in size from 1 to 2 meters in length. Once a suitable block was extracted, it was split into smaller, manageable pieces that were then shaped into giant cores for the production of large flakes. Natural fissures and cracking within the blocks may have facilitated their downsizing.

Two subsequent sub-stages are also evident at the quarry. The first consisted of testing the flint quality of the large flake blank and initiation of bifacial *façonage*. Unsuitable blanks (low quality of raw material, fissures, small dimensions, etc.) were discarded immediately. The final sub-stage was the recycling of smaller flakes and fragments usable for the production of non-bifacial tools (e.g. Goren-Inbar et al., 2008) and the selection of *misse en forme* such as large flakes, which may explain the presence of "Kombewa" *débitage*. This reduction sequence indicates a complex, multi-step quarrying process (Stout, 2011) efficiently exploiting the nature of the outcrop.

The site of Charco Hondo 2 Level G-2 revealed a different picture. In this level, the primary blanks used for the production of handaxes were not large flakes but smaller flint slabs (Moncel et al., 2013). Nevertheless, this is also a quarry or workshop context, as not a single, complete, fully shaped biface was found in the layer. Bifacial tools are present in the assemblage only in the form of broken fragments. Preforms or initial stages of biface production were probably exported from the site to another location as deduced from the total absence of shaping flakes (in the sense of Newcomer, 1971; see above) from more advanced stages (Fig. 2).

Additional examples of Acheulian quarrying for extraction of giant cores for large flake production are rare in the Lower Palaeolithic archaeological record. A good example is the limestone quarry at Isampur, India (Paddayya et al., 1999, 2006; Petraglia et al., 1999), where large limestone slabs were exploited for the production of large flakes, primarily using the "slab slicing" method (Sharon, 2007). The Vaal River Acheulian in South Africa provides an additional example of an excavated quarry (Kuman, 2001).

3.2. Giant core reduction

The evidence presented above, together with observations from other quarry sites, suggests that the detachment of large flake blanks from giant cores was executed near the outcrop. This is, of course, not surprising when considering the size and weight of the slabs extracted and the cores produced from them. Archaeological and experimental evidence indicate that the total weight reached tens or even hundreds of kilograms (Madsen and Goren-Inbar, 2004). As many as nine different core methods applied by large flake producers have been identified in LFA contexts throughout the Old World (Sharon, 2007, 2009), indicating a high level of technological adaptivity, innovation, skill, dexterity, and productivity. Experimental work demonstrated that an experienced knapper can produce 10 to 20 blanks suitable for bifaces from a single core in relatively short time (Madsen and Goren-Inbar, 2004; Sharon, 2009). When properly executed, the large flakes produced from a pre-planned giant core are highly suitable in morphology to be shaped into bifaces. The blanks of many of the large flake-based bifaces display only few scars from shaping, which are primarily from thinning the bulb of percussion, the thickest part of the flake blank (Goren-Inbar and Saragusti, 1996; Madsen and Goren-Inbar, 2004; Sharon, 2007). This observation is supported by meticulous experimental work by Jones (1994), who demonstrated the minimal effort involved in the production of a large flake biface. Such observation can contribute to our understanding of two stages in the life cycle of the biface: the absence of shaping flakes from quarry sites and the wealth of bifacial tools in "rich sites" (see below).

The reconstruction presented here suggests that the large flakes were detached and then knapped into pre-forms at the quarry (see Fig. 3). The final stage of biface production, the shaping and finish stage (Newcomer, 1971), was executed at a different location, as illustrated by ethnographic observation in Papua New Guinea. There, pre-form blanks were brought to the home-base and finished by an expert knapper at the village (Pétrequin and Pétrequin, 1993). An alternative explanation for the low number of biface shaping and finishing flakes at giant core quarry sites is that each large flake biface produced only a small number of such flakes. However, experimental knapping demonstrated that even a minimal number of removals per biface results in hundreds of such flakes at the workshop (Madsen and Goren-Inbar, 2004). We suggest, therefore, that the second stage of the life of a biface, the shaping, was done outside the quarry. GBY data clearly indicate that

Fig. 5. GBY Layer II-6/L4 biface "pavement".

shaping and finishing of the large flake bifaces was not executed at cache sites or at home-base sites. Layer II-6/L4 at GBY is a "pavement" of bifacial tools with over 14 basalt handaxes and cleavers per square meter. If these bifaces had been shaped by knapping on site, the expected number of flakes would be in the tens of thousands. However, the actual number of small basalt flakes in this layer is in the range of a few hundred only (Goren-Inbar et al., 2018).

3.3. Shaping the large flake into a biface

The quarry site of Charco Hondo 2 exposed the following stages: production of large flake blanks, their testing by primary retouch, and their shaping into pre-forms. The medium-sized quartzite hammer-stones found at the site were most probably used in this reduction stage. Not a single biface shaped beyond pre-form stage was found. Only two hundred meters away is the site of Charco Hondo 1 (without secured geological correlation to Charco Hondo 2) where different quarrying and knapping activities are documented. At Charco Hondo 1 giant core production is absent. Instead, bifaces were extracted from medium-sized flint blocks. Only the final reduction stages were carried out at Charco Hondo 1 (thinning and shaping and finishing) evidenced by the low frequency of biface rough-out flakes and the presence of broken, yet well-shaped bifaces, indicating brakeage during advanced stages of the reduction sequence (Fig. 4).

3.4. Caching and storage

Caching and storage is possibly the least understood stage in the life cycle of a large flake biface. LFA sites in the Levant and Africa are sometimes so extremely rich in bifaces that the tools created a "pavement of bifaces". A rich biface assemblage was reported recently from Spain (Méndez-Quintas et al., 2018). In some of these sites, such high concentrations of tools may have resulted from fluvial activity. In others, the tremendous number of tools can be explained by the lengthy time period represented by the exposed layer. The production of only two bifaces a year over a ten thousand

Fig. 6. El Sotillo site (Ciudad Real, Spain). A. Giant and micro-bifaces from the same horizon of El Sotillo. B. Fieldwork of 2017 and find distribution.

year timespan would result in a layer of 20,000 bifaces. However, sites like GBY refute such explanations. At Layer II-6/L4 the archaeological horizon is only a single artifact thick and contains, in the c. 10 square meters exposed, over 200 handaxes and cleavers. The observed density is of 14 bifaces per square meter. The tools were embedded in silty sediment deposited at low energy. Sedimentation processes at GBY Layer II-6 L4 would not have provided the energy required to transport or deposit the numerous large flake bifaces where they were found (Goren-Inbar et al., 2000, 2018; Goren-Inbar and Saragusti, 1996).

A model suggested to explain the extremely rich biface horizons at some Acheulian sites is the stone cache model (Potts, 1988, 1993), the storage of modified tools and raw material in various locations for more efficient, future productivity. For example, caching tools at a large game hunting site remote from a raw material source enabled immediate meat processing following a successful hunt. It is suggested that such caches were spread throughout the landscape by Acheulian foragers, although not always used. Layer II-6/L4 at GBY may represent such a "forgotten" cache (Fig. 5).

The stone cache model is applicable to Iberian sites as well. Guijoso (Cuenca-Spain), O Cabron and Portomaior–Pontevedra (Méndez Méndez Quintas et al., 2006; Quinteiro, 2011), Pinedo and Puente Pino in Toledo (De Tembleque Moreno, 2007; López Recio et al., 2015) and the recently excavated site of El Sotillo in Ciudad Real (Ciudad Serrano, 1986; Vallespí Pérez et al., 1979) show high concentrations of bifacial tools with low numbers of small flakes (see Figs. 6 and 7). Most of these sites are located within fluvial and river terrace contexts and the role of water transport cannot be ruled out. Nevertheless, the deposition of high quantities of bifacial tools in specific places suggests that some of them may have resulted from intentional human activity rather than from (post) depositional processes (Méndez-Quintas et al., 2018).

3.5. Use of bifaces

After nearly 200 years of research, the actual use of bifacial tools is not fully understood; however, it is generally accepted that large flake bifaces were used primarily for the slaughter of large game (Isaac, 1986; Jones, 1980, 1994; Machin et al., 2016; Potts et al., 2000). Some scholars have suggested that handaxes (most explanations seem to ignore cleavers) were multipurpose tools used for cutting, digging, scraping, and other tasks (Isaac, 1977; Wymer, 1968). Others have conjectured that they were woodworking tools (Dominguez-Rodrigo et al., 2001; Ollé Cañellas, 2005; Viallet, 2016), used as missiles in hunting (see discussion, references, and refutation in whittaker and McCall, 2001), or cores for the production of flakes (Davidson, 2002).

The "handaxe enigma" (Wynn, 1995) presented by assemblages of thousands of large, symmetrical objects of indeterminate function has led some researchers to suggest non-functional explanations. Some have argued that handaxes were employed in sexual selection (Kohn and Mithen, 1999), emphasizing that the considerable time it takes to produce a well-made handaxe could be rationalized if the handaxe is viewed as analogous to a peacock's tail to impress and advertise, as explained by Zahavi's handicap principle (Zahavi, 1977). This debate is ongoing as seen by the claim for a potential genetic basis for the shape of a handaxe similar to bird songs (Corbey et al., 2016).

At GBY, Layer II-6/L1 provides a good example for the use of handaxes and cleavers for the butchering of a straight-tusk elephant (Goren-Inbar et al., 1994a,b). An elephant skull – surrounded by bifaces and other tools – was exposed displaying evidence of attempts to penetrate the massive skull to reach the brain. In comparison to Layer II-6/L4 ("the pavement"), the bifaces in Layer II-6/L1 are fewer, yet still significant in number, and were most probably used for butchering. The successful processing of an elephant at the site supports the stone cache model, demonstrating that GBY was, indeed, viewed as a suitable location for a potential later use that necessitated large numbers of cutting tools. The knappers who cached the L4 bifaces did not use them; however, many years later a different group used their bifaces at the same location.

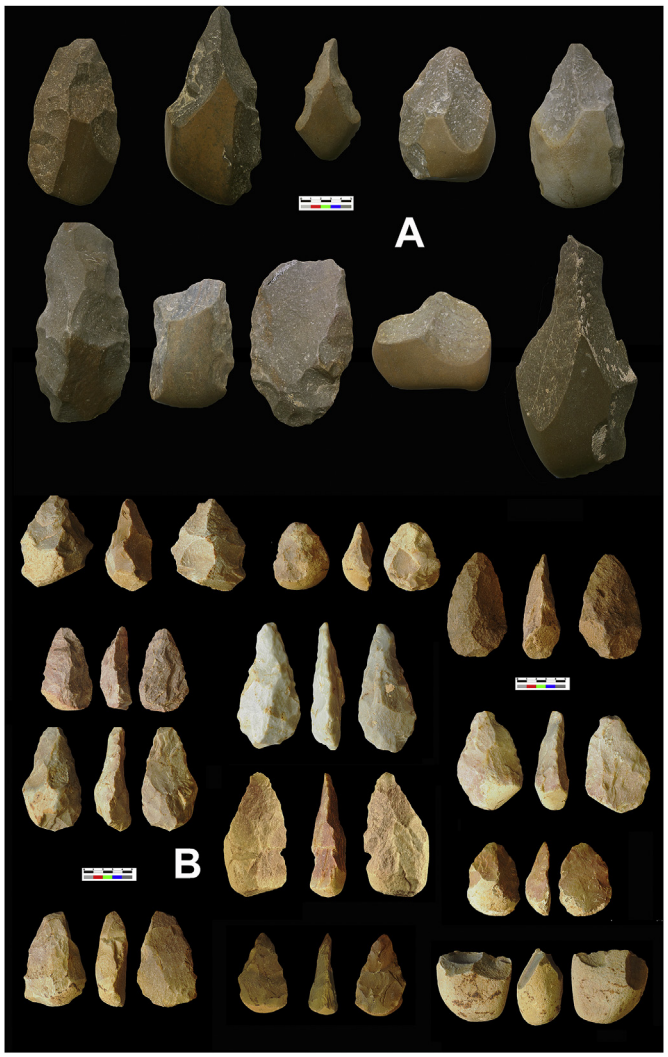

Fig. 7. Two examples of Iberian Acheulian sites with high frequencies of bifaces. a. Bifaces, cleavers and thriedral pieces from Pinedo (Toledo). b. Bifaces from El Guijoso (Cuenca).

Most other Acheulian butchering sites have yielded small numbers of bifacial tools, if any. In the Iberian Peninsula sites rich in faunal remains typically have low densities of bifacial tools. Examples are the sites of Áridos, Transfesa/Tafesa, Valdocarros and Ambrona (Santonja et al., 2017). Sites like Boxgrove, Hoxne, and South Woodford in England, Atapuerca- Galeria and Dolina or Aridos 2 in Spain or Soucy1, 3 and Orgnac, levels 6, 5b, 5a and 4a, in France show a preferential use of bifaces in butchery (Lhomme et al., 1998). Some experimental approaches in use wear and functional morphology have suggested the possible use of bifacial tools in processing animal carcasses (Machin et al., 2007). Fat residues on edges of bifaces and scrapers indicate the direct processing of animal carcasses (Claud et al., 2009; Yravedra et al., 2010; but see Agam et al., 2015; Wenban-Smith et al., 2006) (Fig. 8).

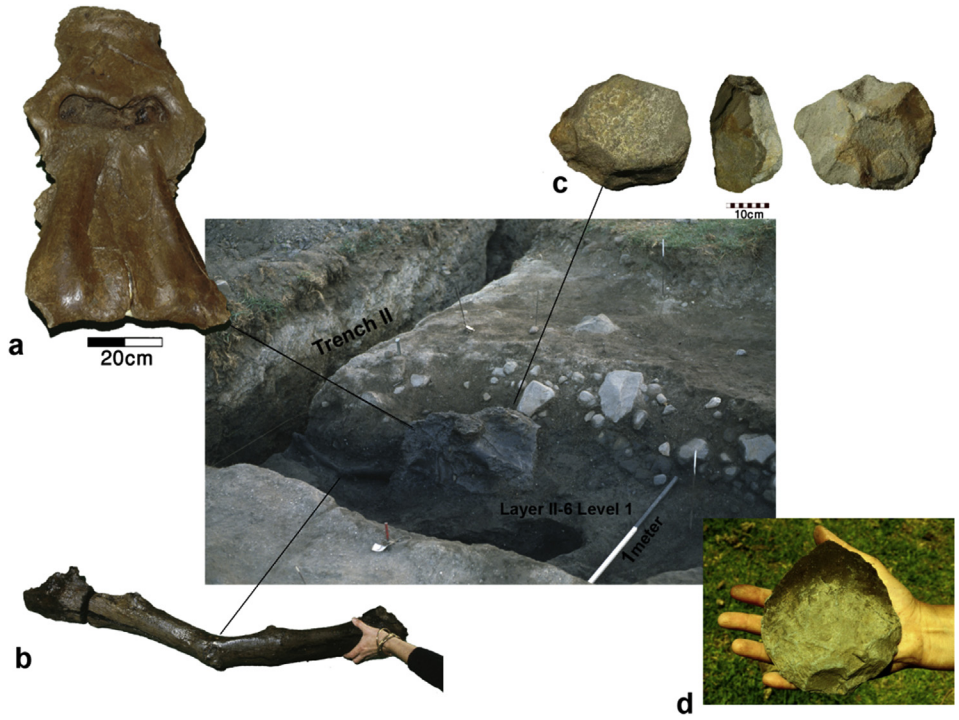

Fig. 8. GBY layer II-6/L1 the elephant.

3.6. Re-sharpening and reuse

After the initial use of a biface, a subsequent stage in its life cycle can be identified, the re-sharpening and reuse of the tool. In contrast, some have argued that the reshaping and sharpening of handaxes is the primary factor dictating their shape (McPherron, 2006). It should be noted that we are unaware of any case in which cleavers show evidence of sharpening or reuse. The re-sharpening and reuse stage in biface use can be seen in some layers of GBY. GBY Layer V-5/V-6 is rich in evidence for sharpening of handaxes in the context of an exceptionally rich faunal assemblage (Gaudzinski-Windheuser et al., 2010; Rabinovich et al., 2008). The layer exposed a wealth of biface production and re-sharpening flakes but not a single handaxe was found (Goren-Inbar and Sharon, 2006b). This pattern indicates that handaxes were probably used for butchering activity, were re-sharpened when becoming blunt from intensive use and then taken from the site by the hominids for future use at different localities. The Levantine Acheulian also provides evidence for biface recycling, as documented in the use of flint handaxes as cores for flake production at the site of Ma'ayan Baruch (Debono and Goren-Inbar, 2001) (Fig. 9).

3.7. Discard

Discard is possibly the most enigmatic stage in the life of a biface. It is challenging to identify a discarded biface as opposed to a biface forgotten, cached, or left behind for some unknown reason. What defines the final stage in the life of the tool? As demonstrated above and mentioned by many scholars (e.g. Dibble et al., 2017), the fact that a biface is found in an archaeological horizon does not mean that it was deserted by its maker or user. Many (if not most) of the bifaces excavated from good preservation contexts show no evidence of intensive use or breakage that would have motivated their users to discard them. We are still far from fully understanding the reasons for the discard of complete and still usable (at least in our modern eyes) bifaces.

3.8. Post-depositional processes

Most bifaces found originate from disturbed contexts. From the first handaxes identified from the terraces of the Thames River in the UK to the Vall River sites in South Africa, bifacial tools were moved and re-deposited by water and other gravitational forces before found by archaeologists. In recent years, new analytical tools have been developed that can quantify the intensity of the post-depositional processes in dictating biface morphology and typology. Analysis demonstrated that handaxes collected at the river banks near GBY show a typical breakage pattern that can be used to distinguish them from other, in-situ bifaces (Grosman et al., 2011, 2013).

4. Discussion and conclusions

Bifacial tools are the hallmark of the Acheulian. Yet, after nearly 200 years of study, the handaxe enigma (Wynn, 1995), or better, the biface enigma, remains a barrier in our understanding of the Acheulian techno-complex. After excavation of hundreds of sites from South Africa to China and the UK, and the study of tens of thousands of bifaces, we have reasonably good understanding of the manufacturing technology behind biface production. Yet, the lack of evidence beyond the tools themselves in the great majority of sites and assemblages hinders our ability to look beyond technology into other aspects of the Acheulian bifaces. The life cycle of a biface beyond its actual knapping is hard to grasp from the archaeological record. Raw material acquisition, function and use of the tools, tool handling strategies (or economy), tool mobility within and between sites and discard patterns leave very vague evidence in the archaeological record if any at all.

Nevertheless, in light of recent excavations and research in remote parts of the Old World, we can now suggest a

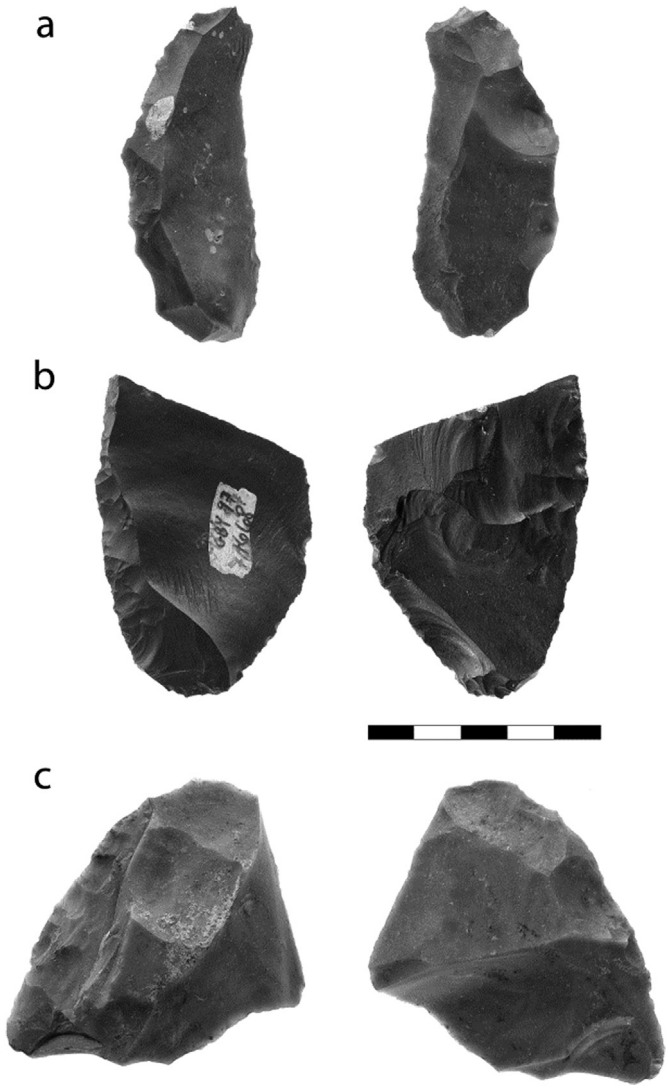

Fig. 9. Biface re-sharpening flakes. GBY Layer V.

comprehensive reconstruction of the stages in the life cycle of the Acheulian biface. As noted above, we restrict our discussion to the LFA stage (Sharon, 2010). This is a reasonably defined stage, both geographically and chronologically, within the lengthy Acheulian techno-complex. While additional examples exist in other regions of the world where LFA assemblages are recognized, we base our reconstruction of the life history of a biface on sites in the Levant and the Iberian Peninsula, which, in our view, are complimentary as they expose different stages in the long process leading from raw material acquisition to discard.

The different stages presented here for the life cycle of a bifacial tool are hypothetical, aiming to describe in an understandable way a long and complex process. The biface reduction sequence required pre-planning and decision making during implementation. It was executed by different people in different parts of the world on a variety of raw materials over a very long period of time (possibly hundreds of thousands of years). The order of some of the suggested stages in the biface life cycle may have differed between sites and not all tools and assemblages went through all stages. For example, it seems obvious that bifaces that were left in caches and "forgotten" by their makers were never actually used, re-sharpened, and discarded. Otherwise we would not have found them in caches. The hypothesis presented here is not one of a rigid chain of events, but rather a framework illustrating what we currently know about the different stages most LFA bifaces went through from raw material acquisition to their discovery by the archaeologist.

The life cycle of a bifacial tool begins with the need for a tool to execute particular tasks necessary for survival. Apparently, the Acheulian tool makers possessed a concept of the tool required. This (sometimes debatable) "mental template" defines the reduction sequence that suited the acquisition of the desired implement. Knowledge of the environment and of the different properties of the rocks in the vicinity enabled identification of suitable outcrops and to obtain raw material by collecting or quarrying. As many as eight stages were identified in the life history of a biface:

1. Raw material selection and acquisition: the quarrying or selecting of large rocks.
2. Shaping of giant cores from the acquired rocks, and the detachment of large flakes to be used as blanks for shaping of bifacial tools.
3. Selection of suitable blanks and the shaping of the selected large flakes into handaxes and cleavers.
4. Accumulation of large numbers of bifacial tools in "pavements" or "caches."
5. Use of the bifacial tools for different tasks such as butchering.
6. Re-sharpening and reuse of bifacial tools.
7. Discard of the tool.
8. Post-depositional processes.

The early stages in the biface life history (stages 1–3) encompass the reduction sequence of the tool. They resulted in a "finished" biface. This reduction sequence leads from the block of raw material to a "usable" handaxe or cleaver, requiring additional technological know-how and understanding beyond knowledge relating to raw material and its acquisition. The varied core methods applied for the production of large flakes from giant cores were perfectly suited to the shape and size of the available rocks in the different localities. Detachment of large flakes is probably the most efficient (fast and energy saving) method to produce handaxes and cleavers (Jones, 1994; Madsen and Goren-Inbar, 2004). High dexterity and efficiency are also evident from the shaping of these large flakes into tools.

The subsequent stages 4–6 describe the different courses that a large flake biface might have undergone depending upon the needs of the Acheulian tool users. With regard to these stages, no real difference can be observed between LFA tools and non-large flake handaxes (cleavers, by definition, are produced on large flakes; Tixier, 1956). Use, re-sharpen, discard, and post-depositional processes are common to all Acheulian bifaces while being use strategy and site condition dependent. Our knowledge of biface use strategies is less solid than that of their production. However, if the stone cache model can explain the tremendous number of bifaces in some archaeological horizons, then the implications for planning and knowledge of the environment are obvious. The use of bifacial tools for butchering large game has been acknowledged by many scholars and is exemplified by the butchered elephant of GBY Layer II-6/L1 (Goren-Inbar et al., 1994a,b). Bifaces were surely used for other tasks and had additional functions that will be better understood with time.

The final two stages in the life cycle of a biface aim to evaluate what happened to a biface from the point of discard to its being unearthed by the archaeologist. The reasons for discard of the bifaces are far from being fully understood, although their intended discard is undisputable. Better understood are some of the post-depositional processes, which vary between sites and sometimes

between assemblages within the same site.

The stages suggested here for the life history of the LFA bifaces are not real stages fully defining the behavior of Acheulian knappers and tool users. Rather, dividing the history of the tool into these stages helps us, as paleoanthropologists, to better understand the processes that resulted in the cleaver or handaxe unearthed. Further research will surely help refine the stages suggested here. Yet, they indicate a complex and sophisticated behavior of the Acheulian tool makers and users. Moreover, it should be remembered that bifaces represent only one, probably limited, element in the Acheulian tool-kit and range of behaviors. The large number of bifacial tools available for study and the accumulating new data from different localities and regions can now help us present a comprehensive picture of at least one aspect of Acheulian ways of life in this very remote period.

Acknowledgments

We thank Rob Hosfield and James Cole for inviting us to the "Coping with climate: the legacy of Homo heidelbergensis" workshop meeting in Brighton. We also thank the Junta de compensación de Los Ahijones y El Cañaveral (Vicálvaro –Coslada), Jorge Vega (AUDEMA) and Sergio Bárez and the Dirección General de Patrimonio de la Comunidad de Madrid. This work is financed by the MINECO projects HAR2016-76760-C3-2-P, the Project HUM-F039 from UAM and the Master of Prehistory and Archaeology of the UAM department. We also want to thank the Los Ahijones archaeological team. We would also like to thank both reviewers for their insightful comments on the paper.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.quascirev.2018.04.015.

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