

WHEN DISCARDED BONES BECAME IMPORTANT: NEW BONE RETOUCHERS FROM THE LOWER SEQUENCE OF QESEM CAVE, ISRAEL (CA. 300-420 KA)

Abstract

Pleistocene archaeological sites contain a high diversity of bone fragments resulting from activities related to anthropogenic processing of animal carcasses and other biostratigraphic and fossil diagenetic phenomena. Specifically, intentional bone breakage to access marrow generates a high number of small- and large-sized bone fragments, which are eventually discarded. Yet, some of these bones are morphologically suitable for human use and are introduced into the lithic tool manufacturing processes. Here, we present some new early cases of bone retouchers from the Middle Pleistocene site of Qesem Cave, Israel. This site shows a long stratigraphic sequence of over 11 m of sediments, dated between 420 and 200 ka by U-series, TL and ESR, all assigned to the late Lower Palaeolithic Acheulo-Yabrudian Cultural Complex (AYCC). Among the many technological and socio-economic innovations of this post-Acheulian/pre-Mousterian entity is the use of bone retouchers. In previous studies we reported nine bone retouchers from the hearth area at the top part of the lower sequence of Qesem Cave (dated to ca. ~300 ka). Here, we present 15 new items from a deeper sedimentary deposit located under the rock shelf (> 300 ka, closer to 400 ka). These objects are fragments of long bone shafts with a slight pattern of selection towards specific ungulate size categories. Nine retouchers belong to small ungulates, four to medium-sized animals, and two to large ungulates. We suggest that some of these implements may have played a role in the shaping and/or re-sharpening of Quina and demi-Quina scrapers, as well as in the shaping of other tools. Bone retouchers became a significant part of knapping toolkits in the subsequent cultural complexes and served a specific role within lithic reduction sequences.

Keywords

Middle Pleistocene; Levant; Bone retouchers; Acheulo-Yabrudian Cultural Complex (AYCC); Qesem Cave

Introduction

Bones used for shaping stone tools are prevalent in late Lower Palaeolithic Europe and in the Levant as early as MIS 13 (Roberts and Parfitt, 1999; Smith, 2013; Stout et al., 2014). These bone tools vary in

typology (retouchers, compressors, hammers) and function, and it has become clear that using discarded bone for shaping stone tools is rooted deep in humanity's prehistory as a tool maker and hunter.

The need to incorporate this group of bone tools within studies of Palaeolithic lithic technology and subsistence economy has advanced rapidly among Palaeolithic archaeologists, while the need to provide a cultural context and consider the significance of this phenomenon clearly demands more thought and discussion. This paper details an assemblage of bone retouchers from the Middle Pleistocene Qesem Cave, Israel, and attempts to view these tools used for shaping stone tools in their wider cultural context. We will first present the Qesem Cave archaeological context, and then present the bone retouchers, and finally make suggestions on the context and role of bone retouchers at Qesem Cave that may be relevant to other sites in the region with bone retouchers, including future discoveries, and hopefully to an even wider scale.

As an introduction to the topic, we stress that we are not exploring the old Palaeolithic tradition of using bone as raw material for making tools, mainly handaxe-like tools shaped on bones of large animals. Such tools appear in Acheulian sites both in Europe (e.g., Castel di Guido; Boschian and Saccà, 2014) and in the Levant (e.g., Revadim Quarry; Rabinovich et al., 2012). This tradition of modifying and shaping tools on bone predates the use of discarded bone fragments as retouchers; both are part of a long history of non-dietary uses of bones by hominins, representing primordial undercurrents of the complex bone-stone relationship (see Zutovski and Barkai, 2016).

Qesem Cave in context

Qesem Cave is a large karstic chamber cave located 12 km east of Tel Aviv (**Figure 1**) in a presently Mediterranean climatic zone, with 500–600 mm of annual rain, very similar to the environment reconstructed for the area during the late Lower Palaeolithic based on microfauna, fauna, sediments and stable isotopes (e.g., Gopher et al., 2010; Stiner et al., 2011; Smith et al., 2013; Maul et al., 2016). The sedimentary sequence is dated by Uranium-series, TL and ESR, with over one hundred dates spanning

MIS 11 to MIS 7, between 420 and 200 ka (Barkai et al., 2003; Gopher et al., 2010; Mercier et al., 2013; Falguères et al., 2016), and with good accordance between the different methods.

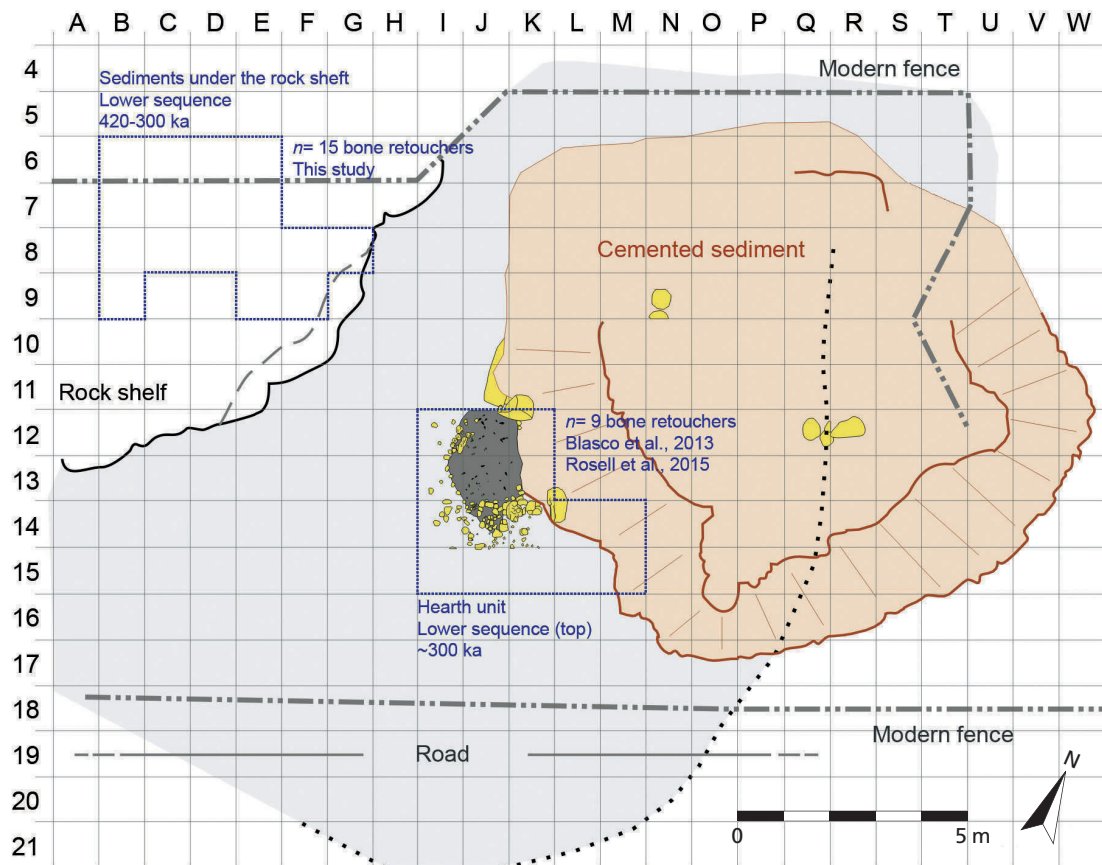
Qesem Cave is a Middle Pleistocene site assigned to the Acheulo-Yabrudian Cultural Complex (AYCC) of the late Lower Paleolithic, postdating the Acheulian but predating the Mousterian in the Levant. Qesem is a well-preserved cave rich in lithics (e.g., Assaf et al., 2015; Parush et al., 2015) and faunal remains (e.g., Stiner et al., 2009, 2011; Blasco et al., 2014), and it also yielded human dental remains (Hershkovitz et al., 2011, 2016). The ongoing field and laboratory work at the cave has provided a major source of information on the AYCC. The AYCC has matured in recent years into a surprisingly dynamic, innovative local entity, quite distinctly divorced from the preceding Lower Palaeolithic Acheulian. We have suggested that the AYCC, as a whole, and Qesem Cave in particular, displays a unique cultural transformation from the Acheulian, possibly related to local hominin evolutionary processes and the appearance of a new hominin lineage in the Levant (Ben-Dor et al. 2011; Barkai and Gopher 2013; Gopher and Barkai, 2016; and see discussion below).

The introduction of bone retouchers is a well established phenomenon from the very beginning of the Middle Pleistocene AYCC at Qesem Cave (somewhat before 400 ka); yet, it is but one of the many innovations of this post-Acheulian era. It is reasonable to examine the background and nature of these changes in the Levant that brought about, amongst other things, the emergence of bone retouchers as a distinctive cultural element. We believe that our intensive studies of these changes in hominin behaviour and adaptation at Qesem Cave in recent years provide a reasonable arena in which the new bone retouchers can be contextualized (Barkai and Gopher, 2013; Blasco et al., 2013; Rosell et al., 2015). Below, we briefly mention selected aspects from long list of innovations offered by the Qesem Cave data that may be relevant to the overall site context.

Most conspicuous is the habitual use of fire (Karkanas et al., 2007). A constructed central hearth



Figure 1 Location of Qesem Cave in the Levant and position of the studied faunal samples in relation to the grid system of the excavation.



dated to ca. 300 ka was exposed (Shahack-Gross et al., 2014) and hearth-centred activities were identified, showing functionally differentiated and distinct activity areas around it – one dominated by blade-cutting tools and one by Quina scrapers. A spatial distribution analysis of the faunal remains around this hearth indicates further spatial patterning, including a possible tossing zone (Blasco et al., 2016a).

Another aspect is the economy. The taxonomic profile at Qesem consists of Palearctic species only, with fallow deer (*Dama cf. mesopotamica*) as main species. This differs from earlier and later faunal assemblages of the southern Levant, which show more African influences. It is worth mentioning there are no elephants at Qesem Cave or any other AYCC site (see Ben Dor et al., 2011; Barkai and Gopher, 2013). We have indications of cooperative / social hunting targeted mainly at prime-aged fallow deer (Stiner et al., 2009; Blasco et al., 2014). On-site butchering involved a designated tool kit comprising blades and small, sharp flakes produced by means of lithic recycling (Lemorini et al. 2015, Parush et al. 2015), and Quina and demi-Quina scrapers. Unique patterns of cut marks on bones were interpreted as an indication of meat sharing habits, an important point concerning hunters-gatherer behaviour (Stiner et al., 2009, 2011).

Innovative lithic aspects include: 1) raw material acquisition from near-by and farther afield sources, including flint quarrying from deep underground sources as well as a high correlation between raw materials and tool types; 2) intensive and systematic blade production employing an efficient and straightforward technology, with naturally backed knives and a clear component of Upper Paleolithic-like tools, including end scrapers, burins and some Chatelperron-like points; 3) intensive flint recycling activities indicative of a few well established trajectories (Barkai et al., 2009; Barkai and Gopher, 2013; Assaf et al., 2015; Parush et al., 2015); 4) a noticeable, fully fledged presence of “ahead-of-their-time” Quina scrapers (ca. 420 ka), in addition to Quina debitage, Quina retouch and re-sharpening. We should mention the fact that Quina is not very

well known in the Levant before or after the AYCC (Lemorini et al., 2016; Zupancich et al., 2016a).

As for human remains, 13 teeth have been found throughout the sequence to date, none of which show affinities to *Homo erectus* (Hershkovitz et al. 2011, 2016). Although they resemble to some extent the anatomically modern human Skhul-Qafzeh samples of the Middle Palaeolithic Levant, they bear Neanderthal traits, too. So, they may belong to an as yet unknown and new, local hominin lineage.

Material and methods

The faunal remains at Qesem Cave are studied according to the conventional standards published for zooarchaeology and taphonomy (Binford, 1978; Lyman, 1994; Stiner, 1994; Blasco et al., 2013; and references there in). Given the high degree of fragmentation, most of the remains have not been identified at the anatomical and taxonomic level. These specimens have been classified as long bones (appendicular skeleton), flat bones (cranial, axial skeleton) and articular bones (patellae, carpal, tarsal, sesamoid bones). To include these specimens with those identified to the genus/species level, we established five size categories related to the estimated body weight of taxa identified in the assemblage following Africanist methodologies (Bunn et al., 1988; Sahnouni et al., 2013; see details for Qesem in Blasco et al., 2014), as follows: size class 1, very small size including 1a and 1b (< 20 kg); size class 2, small size (20-120 kg); size class 3, medium size including 3a and 3b (120-300 kg); size class 4, large size (300-1000 kg); and, size classes 5 and 6, very large size (> 1000 kg). Quantification of skeletal parts is based on number of specimens (NSP) and number of identified specimens (NISP).

The damage observed on the bone surface has been treated both macroscopically and microscopically using a stereo light microscope (up to 120x magnification, oblique cold light source) and a KH-8700 3D Digital Microscope. The analysis was completed with an analytical FEI QUANTA 600 Environmental Scanning Electron Microscope (ESEM)



Figure 2 Examples of recycled blades and flakes (A-B) and scrapers (C) from the hearth unit and the lower sediments under the rock shelf from Qesem Cave.

operated in low vacuum mode (LV). In the case of bone retouchers, the identified damage has been described following the criteria and the terminology related to the orientation, type, distribution and morphology, established in previous works (Armand and Delagnes, 1998; Malerba and Giacobini, 1998; Patou-Mathis, 2002; Mozota, 2009; Mallye et al., 2012). This damage consists of pits, defined as depressions with triangular or ovoid forms on the bone surface, and striations, which refer to deep incisions with rectilinear, sinuous, concave or convex delineation. In the same way, the striation texture surface has been classified as smooth or rough. The

distribution of the striations is noted in terms of isolated, dispersed, concentrated or superposed. In cases of concentrated and superposed distributions, we ascribe the term “use areas”, the locations of which are described according to width axis (apical, central, covering and lateral).

Data presentation

The bone retouchers presented here come from two stratigraphically and spatially distinct assemblages. The first assemblage originates from an area char-

acterized by a superimposed central hearth, dated to about 300 ka, and the zone around it (Shahack-Gross et al., 2014). The second assemblage originates from sediments under the rock shelf at the northern part of the cave (Figure 1). The bone retouchers from the hearth unit were already presented in previous works (Blasco et al., 2013; Rosell et al., 2015); however, the objectives of this paper, based on a comparison between the two assemblages, require the description of all items and their archaeological context.

Hearth Unit

The hearth unit is dated around 300 ka (Falguères et al., 2016) and it mainly occupies parts of the central and southern areas of the site, including the areas associated with the hearth (squares I-J-K-

L/12-13-14-15, ~15m²; Blasco et al., 2016a) (Figure 1). This combustion feature displays specific characteristics that point to a certain diachrony in its formation, as at least two major cycles of intensive fire use can be recognised (Shahack-Gross et al., 2014). This succession of cycles at the same location in the cave suggests that the hearth, as a central beacon in the interior landscape of the cave, has repeatedly played a role as a focus of hominin activities (Blasco et al., 2016a). The lithic assemblage of the hearth area consists of 18,837 items and shows the highest density of all the assemblages of the cave (6144 per m³ for the hearth itself; see Gopher et al., 2016), indeed indicating intensive lithic production, use and discard in this area. The lithic industry of the hearth is attributed to the Amudian industry and shows a conspicuous presence of cutting implements, including blades, naturally backed knives and small

	Hearth unit		Lower sequence	
	NSP	NISP	NSP	NISP
Carnivora	1	1	1	1
<i>Stephanorhinus hemitoechus</i>	12	12	8	8
<i>Equus ferus</i>	103	103	21	21
<i>Equus hydruntinus</i>	18	18	-	-
<i>Sus scrofa</i>	38	38	18	18
Cervidae	28	28	2	2
<i>Dama cf. mesopotamica</i>	2370	2370	1655	1655
<i>Cervus cf. elaphus</i>	213	213	163	163
<i>Bos primigenius</i>	123	123	97	97
<i>Capra aegagrus</i>	1	1	7	7
<i>cf. Capreolus capreolus</i>	25	25	11	11
<i>Hystrix</i>	-	-	1	1
<i>Testudo sp.</i>	57	57	104	104
<i>Cygnus sp.</i>	-	-	1	1
<i>Columba sp.</i>	1	1	-	-
<i>Corvus ruficollis</i>	3	3	-	-
Large bird	2	2	-	-
Aves, indeterminate	-	-	2	2
Very large size	4	-	-	-
Large size	1988	-	1324	-
Medium size	6510	-	2776	-
Small size	24,484	-	14,436	-
Unidentified	1323	-	1646	-
Total	37,304	2995	22,273	2091

Table 1 Number of specimens (NSP) and number of identified specimens (NISP) from the hearth unit and the lower sequence under the rock shelf.

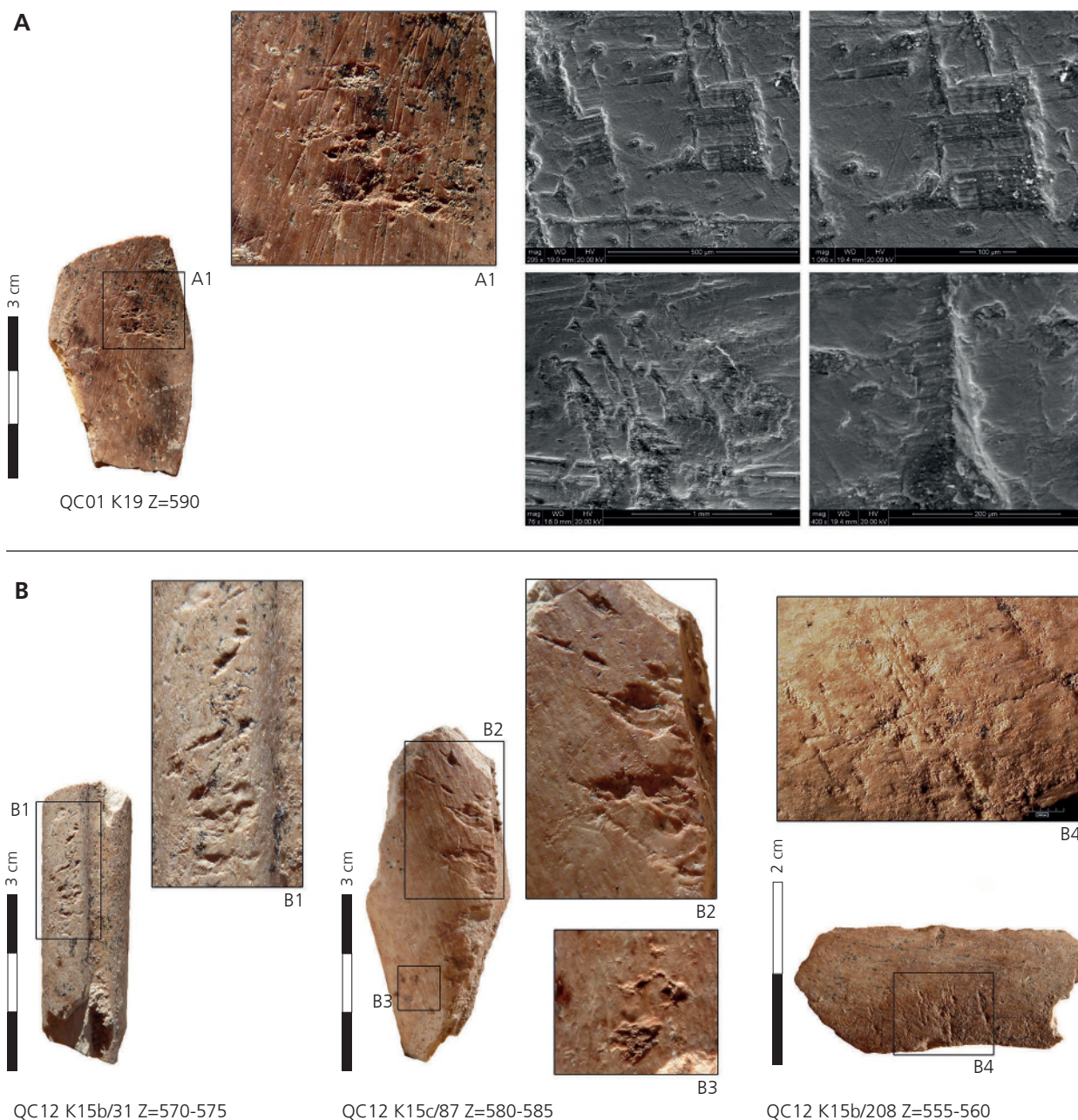


Figure 3 Examples of bone retouchers from the hearth unit (including the associated southern area) of Qesem Cave: (A) long bone shaft of a medium-sized ungulate and details of the percussion striations under ESEM (modified from Blasco et al., 2013); (B) (from left to right) fallow deer metatarsal, red deer humerus and long bone shaft of a medium-sized ungulate (B1-B3 modified from Rosell et al., 2015).

sharp items produced by means of lithic recycling (Figure 2), indicating a set of cutlery densely concentrated in the likely meat roasting area.

The number of faunal remains studied in this sector is 37,304 teeth and bone fragments (Table 1). The fauna shows a high degree of fragmentation, most apparent in the area directly associated with

the overlapping combustion features. In this specific point, the bone fragments rarely exceed 2 cm in length, increasing slightly in the adjacent areas (Blasco et al., 2014). Generally speaking, the assemblage consists long bone diaphysis fragments of small-sized ungulates, mostly belonging to *Dama* cf. *mesopotamica*. Remains of other medium-sized un-

Table 2 Inventory and interpretative results for the bone retouchers at Qesem Cave.

ID Item	Skeletal element	Taxa	Length (mm)	Thickness (mm)	Use area		Damage			Freshness	Use intensity	Reference
					No.	Location	Distribution	Pits	Striations / Scores			
QC01 K19 Z=590	Long bone shaft	Medium size	43	6	1	Cent	Conc	Ov	Rect, Sin/Sm	Scal, Hat	M-Int	Blasco et al., 2013
QC06 I13d Z=590-595/376	Long bone shaft	Medium size	31	6	1	Cent+Apic	Disp	Ov	Rect, Sin/Sm, Ro	-	F-Interm	Rosell et al., 2015
QC08 J12a Z=560-565/1	Long bone shaft	Large size	58	8	1	Cent	Conc	-	Rect/Sm	-	F-Interm	Rosell et al., 2015
QC08 J12a Z=555-560/5	Long bone shaft	Large size	26	8	1	Cent+Apic	Disp	Ov	Rect /Sm, Ro	-	F-Interm	Rosell et al., 2015
QC12 K15c Z=580-585/87	Humerus	<i>Cervus cf. elaphus</i>	52	7	2	Lat/Cent	Conc/Conc	Tr	Rect, Sin/Sm	Scal	M-Int	Rosell et al., 2015
QC12 J15b Z=585-590/113	Tibia	Medium size	32	6	1	Cent	Disp	Ov	Rect/Sm	-	F-Interm	Rosell et al., 2015
QC12 K15a Z=555-560/196	Long bone shaft	Small size	26	4	1	Lat	Disp	Tr	Rect/Sm, Ro	-	Interm	Rosell et al., 2015
QC12 K15b Z=555-560/208	Long bone shaft	Medium size	33	6	1	Lat	Conc	Tr	Rect/Sm	Hat	F	Rosell et al., 2015
QC12 K15b Z=570-575/31	Metatarsus	<i>Dama cf. mesopotamica</i>	48	5	1	Cent	Disp	Ov	Rect/Sm	Pit	Interm	Rosell et al., 2015
QC13 F9c Z=725-730/25	Metacarpus	<i>Dama cf. mesopotamica</i>	54	6	1	Api	Conc	Ov	-	Scal	Interm	This study
QC13 F9b+d Z=660-665/16	Long bone	Medium size	37	7	1	Lat+Cent	Disp	-	Rect/Sm	-	F	This study
QC13 F09b+d Z=665-670/33	Long bone	Medium size	35	6	1	Api+Cent	Conc	Ov	Rect/Ro	Hat	Dry	This study
QC13 E8b Z=890-985/2	Long bone	Large size	43	9	1	Lat	Conc	Ov	Rect/Sm	Pit	Interm	This study
QC13 E8b Z=875-880/10	Metacarpus	<i>Cervus cf. elaphus</i>	62	8	2	Api/Api	Conc/Isol	-	Rect/Sm	Pit/-	Dry	This study
QC13 E8b Z=835-840/10	Metacarpus	<i>Dama cf. mesopotamica</i>	39	7	1	Cov	Disp	Ov/Tr	Rect, Covx/Sm	-	F-Interm	This study
QC13 E8b Z=945-950/4	Long bone	Small size	33	4	1	Lat+Cent	Dist	-	Rect/Sm	-	F	This study
QC13 E8b Z=915-920/5	Tibia	<i>Dama cf. mesopotamica</i>	52	5	1	Cent	Isol	-	Rect/Sm	-	F	This study
QC13 E8d Z=845-850/1	Humerus	<i>Dama cf. mesopotamica</i>	48	6	2	Api/Lat	Isol	-	Rect/Ro	-/Scal	Interm	This study
QC13 E8d Z=835-840/3	Long bone	Large size	43	8	1	Apic	Conc	-	Sin/Sm	-	F	This study
QC13 D6b+d Z=900-940/481	Femur	<i>Cervus cf. elaphus</i>	73	6	1	Cent	Conc	Ov	Rect/Ro	Scal	F	This study
QC13 D6b+d Z=900-940/492	Long bone	Small size	38	4	1	Apic	Conc	-	Sin/Sm	Scal	F-Interm	This study
QC13 B8b Z=940-945/1	Long bone	Small size	21	4	1	Apic+Lat	Isol	Ov	Rect+Sin/Ro	-	Dry	This study
QC13 D7c Z=1040-1045/2	Long bone	Small size	40	5	2	Lat/Lat+Api	Conc/Disp	Ov/-	-/Rect/Ro	Pit/Scal	Interm	This study
QC13 D7b+d Z=990-995/17	Long bone	Small size	30	5	1	Lat	Disp	-	Rect/Sm	-	Fr	This study

Cent= Central; Apical=Apic; Lat= Lat; Cov= Covering; Conc=Concentrated; Disp=Dispersed; Iso=Isolated; Tr=Triangular; Ov=Ovoid; Rect=Rectilinear; Sin=Sinuous; Cov=Concave; Cvx=Convexa; Sm=Smooth; Ro=Rough; Hat=Hatched area; Scal=Scaled area; Pit=Pitted area; F=Fresh; Interm=Intermediate freshness; L=Low-used; M=Medium-used; S= Slightly used; Int= Intensively used.

gulates have also been recognised, such as red deer (*Cervus cf. elaphus*) and other large-sized ungulates, including horses (*Equus ferus*), rhinos (*Stephanorhinus hemitoechus*) and aurochs (*Bos primigenius*). The presence of flat bones and/or bone fragments belonging to the axial and cranial skeleton of these ungulates is proportionally very low. Bones belonging to other very small-sized animals have also been documented, such as tortoises (*Testudo* sp.) and some birds (Blasco et al., 2014, 2016b; Sánchez Marco et al., 2016).

Cut marks, as well as intentional anthropogenic fractures and burning alterations, are abundant throughout the assemblage. This indicates a clear association of ungulates and very small-sized animals (e.g., tortoises) with subsistence activities of the human groups (Stiner et al., 2009, 2011; Blasco et al., 2014, 2016a, 2016b). On the other hand, carnivore-induced damage is virtually nonexistent, indicating few visits of these animals to the cave, if at all.

The studied assemblage from the hearth unit yielded nine bone retouchers, constituting 0.02% of the assemblage (**Figure 3; Table 2**): two limb bone shafts of large-sized animals, four limb bone shafts of medium sizes, one red deer humerus, one fallow deer tibia and one limb bone shaft of a small-sized animal. All these items are broken; up to now no complete bones were used as bone retouchers at Qesem. Their lengths range from 58 mm, for a diaphysis fragment of a large-sized animal, to 31 mm, for a diaphysis fragment of a small-sized animal. The modifications observed are mainly pits, mostly ovoid morphology and in two cases triangular, striations and grooves. The striations and the grooves are rectilinear in nearly all cases. Slightly sinuous striations are present in two diaphyses of medium-sized animals and one deer humerus. Rough incisions are observed only in the case of one large-sized diaphysis and one medium-sized diaphysis. In all cases, it is possible to define a single use area, characterised by hatched areas in two medium-sized diaphyses and scaled areas in two medium-sized diaphyses. Almost all use areas are located in the centre of the fragments. Only in one medium and one small-sized diaphysis do we see use areas in a lateral position;

one large and one medium-sized diaphysis have use areas located in the apical position. Only in the case of the deer humerus can we mention two use areas, one located in the centre of the diaphyseal fragment and another more to the side. In any case, they are discrete use areas, formed by a relatively low number of percussion marks, indicating a slight to moderate use of these blanks.

The absence of chips and significant loss of cortical tissue suggests that the bone blanks were mostly used fresh or in an intermediate stage of freshness. This could be related to the scraping-marks observed in the use areas of three items, likely associated with removing the periosteum.

Sediments from the Lower Sequence under the Rock Shelf

The second assemblage comes from a new chamber discovered under the rock shelf in the northern part of the cave (**Figure 1**). According to Gopher et al. (2010), Mercier et al. (2013) and Falguères et al. (2016), all the sediments of the stratigraphic sequence under the rock shelf are older than 300 ka. The sedimentary sequence under the shelf is composed of at least six metres of sediments, as bedrock has not been reached yet. The uppermost levels of the sequence under the shelf contain a Yabrudian lithic assemblage; the sediments directly underneath that are characterized by an Amudian lithic assemblage (see Parush et al. 2016; **Figure 2**). Most of the new bone retouchers presented here originate from a deep sounding under the rock shelf, some three to four metres below the abovementioned Amudian layer. Three retouchers originate from the middle part of the sedimentary sequence under the rock shelf and one was found two metres below the upper Amudian level. All in all, the bone retouchers presented here originate from the deepest and medial sectors of the sedimentary column below the shelf and are older than 300 ka, most probably closer to 400 ka for the deepest sample. The lithic assemblages from these contexts are currently under study and seem to belong to an Amudian industry.



Figure 4 Examples of bone retouchers from the lower sequence of Qesem Cave located under the rock shelf: (A) red deer femur; (B) long bone shaft of small-sized ungulate; (C) fallow deer metacarpal; (D) long bone shaft of small-sized ungulate; (E) fallow deer metacarpal; (F) long bone shaft of large-sized ungulate.

So far, a total of 22,273 faunal remains have been studied from this sector (Table 1). The faunal composition does not differ to any significant extent from the fauna in the central hearth unit. The fragments of small-sized ungulates, including *Dama* cf. *mesopotamica*, remain the most abundant, followed by medium and large-sized ungulates, particularly deer (*Cervus elaphus*), aurochs (*Bos primi-*

genius) and horses (*Equus ferus*). Very large-sized ungulates, such as rhino (*Stephanorhinus hemitoechus*), have also been recovered, although they are present in significantly lower numbers than other ungulates. As in the hearth unit, tortoise (*Testudo* sp.) and bird remains have also been recovered. Following the general dynamics of the stratigraphic sequence of Qesem, the unit under the rock shelf is

dominated by limb bone fragments, mostly under 30 mm in length.

From a taphonomic point of view, the assemblage does not differ greatly from the hearth unit. Cut marks remain relatively abundant (NSP = 368), as do the signs of intentional fracturing (NSP = 280). Although no combustion structures have been recognised, the number of bones with signs of thermal alteration is still abundant (NSP = 6,644), indicating that the use of fire is already included in the behavioural pattern of the hominids that inhabited Qesem Cave from its oldest formation phase. Carnivore modifications are again very scarce.

The total number of bone retouchers identified so far is 15 (**Figure 4; Table 2**), amounting to 0.07% of the assemblage, which is only slightly higher than in the hearth unit. Regarding the bone blanks selected, we observe greater diversity than in the hearth area. In this particular case, there seems to be no preference for animals according to body size. Percussion marks have been observed on two limb bone shafts of large-sized animals, two limb bone shafts of medium-sized animals, one shaft of red deer femur, one mid-shaft of red deer metacarpal, five limb bone shafts of small-sized animals, two mid-shaft fragments of fallow deer metacarpal, one shaft fragment of fallow deer humerus and one shaft fragment of fallow deer tibia. The longest blank measures 73 mm, represented by a fragment of a deer femur, and the shortest is 21 mm, a long bone diaphysis fragment of a small-sized animal. However, most are within a range of 35-45 mm. As in the hearth unit, the smooth-textured percussion striations are the most abundant modification, although some pits of ovoid morphology are also seen, as well as one case of triangular pit morphology. Rough incisions also appear in five cases. In general, most striations are rectilinear, although one large and one small-sized diaphysis show smooth sinuous striations, and one fallow deer metacarpal fragment exhibits smooth, convex striations. In seven of the retouchers, the striations are concentrated in well-defined use areas. However, there are five bone blanks where the striations are scattered over the entire surface and three with

single, isolated striations. There is no clear trend in the position of these striations, or in the use areas, on the bone surface. In seven cases the striations or use areas trend towards the lateral position, while six show damage in the apical position. Two cases have modifications located in the centre of the fragment. Only one of the bone blanks, a red deer metacarpal, bears two well-defined use areas, which are situated toward both apical ends of the fragment.

The low intensity with which these objects appear to have been used means that there are very few overlapping marks. Only one long bone diaphysis shows a hatched area. One large-sized diaphysis, one red deer metacarpal bone and one small-sized diaphysis each show pitted areas. Scaled areas are shown on one red deer femur, one fallow deer humerus and one small-sized diaphysis.

As in the hearth unit assemblage, most blanks appear to have been used in a fresh or semi-fresh state. However, one red deer metacarpal bone, one medium-sized diaphysis and one small-sized diaphysis include some striations associated with chipped, or exfoliated, surfaces as a result of rapid drying of the bone from subaerial exposure or fire. As a result, these blanks appear to have been used in a dry state, indicating a lack of preference in selection regarding the freshness of the bone blanks.

Discussion

We open the discussion with a general statement about a bio-energetic model Ben Dor et al. (2011) proposed for the demise of *Homo erectus* and the appearance of a new hominin lineage some 400,000 years ago in the Levant. Explaining this model is especially useful here since the proposed biological replacement took place in tandem with significant innovative cultural changes, among which we find the bone retouchers. This bio-energetic model suggests that the disappearance of elephants from the human diet in the Levant around this time triggered a selection process in favour of those who were better adapted to the hunting of larger numbers of

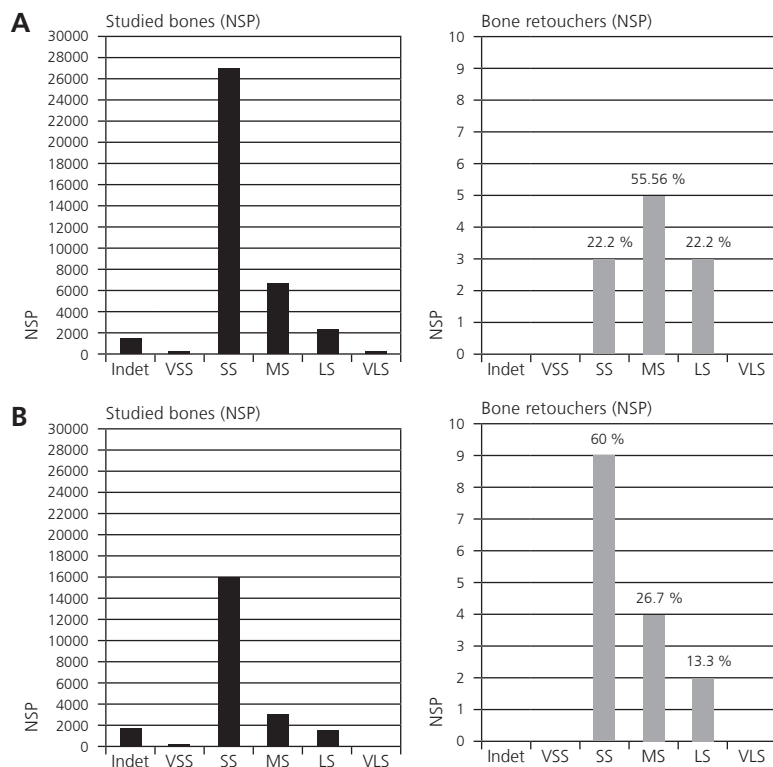


Figure 5 Number of specimens (NSP) and bone retouchers from Qesem Cave grouped into body-size classes: (A) specimens from the hearth area (and associated southern area); (B) specimens from the lower sequence located under the rock shelf. VSS: very small size or size class 1, including 1a and 1b (< 20 kg); SS: small size or size class 2 (~20-120 kg); MS: medium size or size class 3, including 3a and 3b (~120-300 kg); LS: large size or size class 4 (~300-1000 kg); VLS: very large size or size classes 5 and 6 (> 1000 kg); Indet: indeterminate (following Bunn et al., 1988).

smaller, faster animals. The absence of elephants at Qesem Cave and the dominance of fallow deer, conjoined with the plethora of recorded cultural change at Qesem Cave, are the basic ingredients of the model. We emphasize the cultural and behavioural aspects since many of them shows a clear departure from the preceding Acheulian (e.g., Barkai and Gopher 2013; Gopher and Barkai, 2016) – a complete change in lifeways compared to the Acheulian Cultural Complex. So, something specific and special has happened in the Levant some 400 ka, post-Acheulian and pre-Mousterian. The finds of Qesem Cave show, on the one hand, a suite of "ahead-of-their-time" transformative innovations in human behaviour and culture, and, on the other hand, the possible appearance of a new lineage of hominins (Barkai and Gopher, 2013). It is in this innovative cultural landscape that bone retouchers are contextualized.

From a technological point of view, the AYCC consists of innovative industries. Among the most significant is the systematic production and retouching of over a thousand Quina and demi-Quina scrapers. The elements related to retouching in AYCC assem-

blages seem to be relevant; therefore, bone retouchers should be studied in detail. From this point of view, the presence of bone retouchers in the hearth unit and under the rock shelf suggests that these items represented a common technological solution for the human groups who occupied Qesem Cave. It should be stressed, however, that only faunal remains related to Amudian assemblages are presented here. These assemblages include Quina and demi-Quina scrapers, though in lesser proportions compared to Yabrudian assemblages (e.g., Parush et al., 2016). We have just started to study faunal assemblages originating from Yabrudian layers, and it would be interesting to quantify the ratio of scrapers to bone retouchers in these assemblages and compare the results to the data presented here. Our first impression is that there are quite a number of bone retouchers in the Yabrudian too.

Broadly speaking, the two Amudian units studied do not show significant differences. Both assemblages maintain similar technology and the composition of the faunal record is similar. Perhaps the most important difference is the presence of a preserved fireplace in the hearth unit as the central

element of the activities (Blasco et al., 2016a), but this does not mean that in the lower unit (unit under the rock shelf) hearth related activities were less significant. The large number of bones with signs of thermal alteration precisely indicates the existence of similar behaviour regarding fire as in the upper sedimentary units.

Although some bone retouchers from Qesem show use areas that could be linked to intensive use, most of these items show isolated and scattered marks, forming discrete areas that could be related to low use intensity. These characteristics may be connected to immediate activities, in which bone blanks are selected for very specific tasks, re-sharpening an edge, for example, and then discarded again among the rest of the waste. The bone blanks seem to be selected following a preference for medium-sized animals, taking into account the ratio between body size categories and bone retouchers recovered in both units (Figure 5). Selection is also observed regarding length of the blanks. In both areas, the dominant bone fragments do not exceed 3 cm in length, but the bone blanks used are all between 3 cm and 7 cm (Figure 6). Therefore, there appears to be a preference for larger/longer bone elements, perhaps depending on the physical characteristics of the knapped items or other specific needs. A selection of blanks by bone characteristics, such as length

and/or thickness, has also been suggested in some European sites of later periods, including Payre (MIS 9-5) (Daujeard et al., 2014) and Noisetier (MIS 3) (Mallye et al., 2012) in France. Other localities, however, do not show the same preferences, such as the case of Biache-Saint-Vaast (MIS 7) (Auguste, 2002), Artenac (MIS 6) (Armand and Delagnes, 1998), and Chez-Pinaud/Jonzac (MIS 3) (Beauval, 2004, Jaubert et al., 2008), all in France.

Bone retouchers being used as soft hammers (of sorts) have practical purposes, and possibly structural advantages. Suffice is to say that for the AYCC in the Levant, we may relate the possible use of soft retouchers to a quite restricted range of flint tools. We find the bone retouchers at Qesem to be insufficiently large and heavy for shaping handaxes, which we note are rare at Qesem Cave (Barkai and Gopher, 2009). Thus, we suggest that these bone tools may be related mainly to shaping tools, such as blades and flakes, as well as Quina and demi-Quina scrapers. Quina scrapers exhibit a very special and unique shaping technology, characterized by a scalar retouch on their working edges. These scrapers are at present the topic of large-scale, detailed use wear and residue analyses, accompanied by an intensive experimental programme. Preliminary results indicate three major functions: hide working, bone working and butchering (Lemorini et al., 2016;

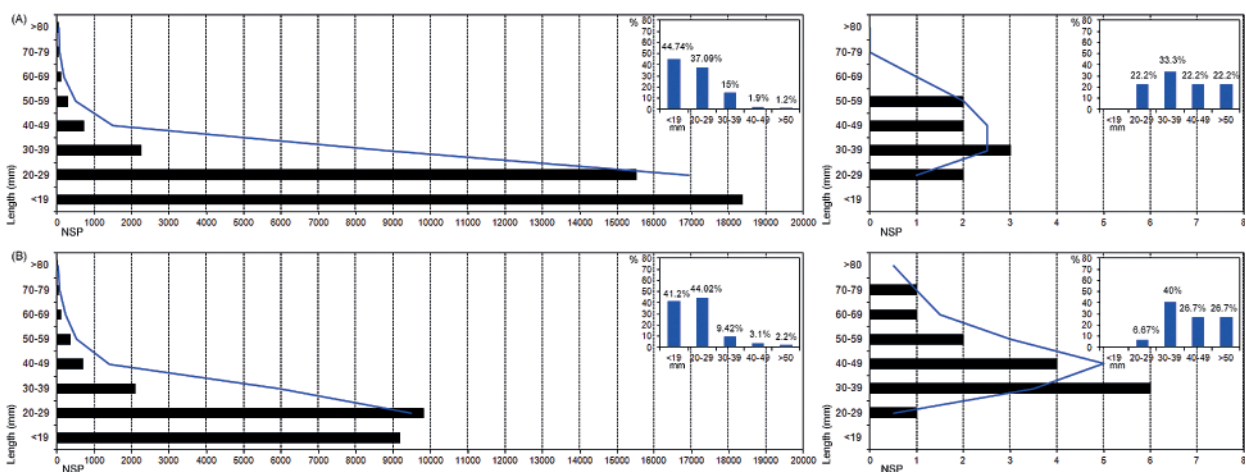


Figure 6 Lengths of all bone specimens (left) and bone retouchers (right), grouped in 10 mm intervals (excepting for the first and last range): (A) specimens from the hearth area (and surrounding area); (B) specimens from the lower sequence of Qesem Cave located under the rock shelf.

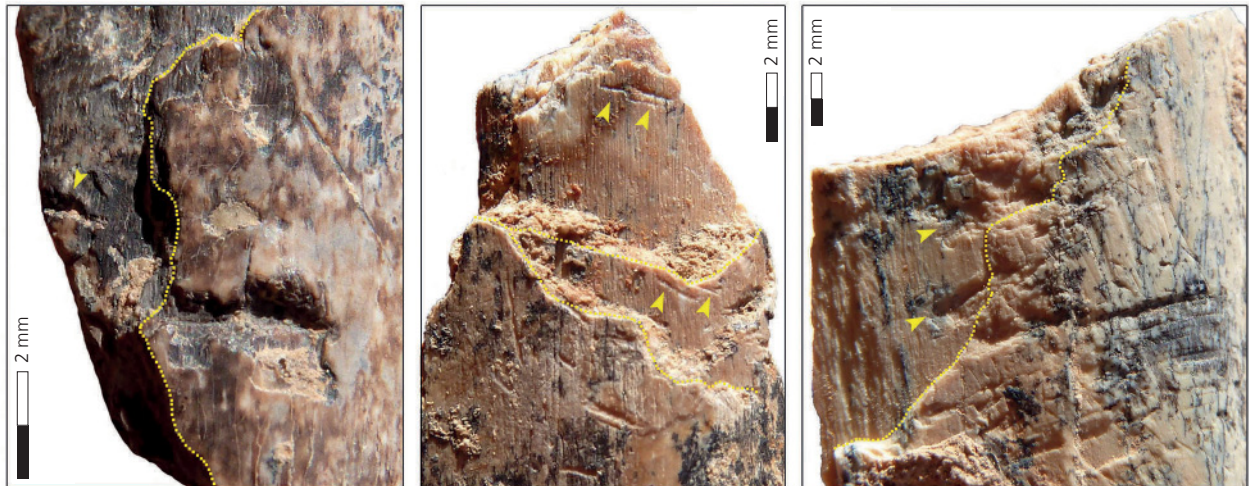


Figure 7 Bone retouchers probably used in a dry or semi-dry state from the area under the rock shelf. Note that percussion striations and chips are located on previous detachment of bone plaques, likely as a result of the bone's lack of natural elasticity when used.

Zupancich et al., 2016a, 2016b). These results encourage us to see the innovative Quina scrapers at Qesem Cave and other sites as part of a new behaviour in the AYCC where bone retouchers appear for the first time and in large quantities. Quina scrapers, together with blades and small cutting tools made of recycled items, may have been part of a local strategy aimed at processing the carcasses of medium-sized game (see Claud et al. 2012 for a case in France) – a particular combination of technologies that reflects a specific adaptation with no known counterparts in Africa or Europe at present.

It should be borne in mind that both Quina scrapers and bone retouchers, to the best of our knowledge, appear in the Levant no later than the AYCC and cease to appear within the Middle Palaeolithic Mousterian. However, the quantity of bone retouchers is exceptionally low to account for the number of shaped tools and Quina or demi-Quina type scrapers found at the site. The hearth unit contained a total of 462 tools, while 1412 tools have been documented in the portion of the lower sequence under the rock shelf analysed thus far (B-C-D-E/6-7-8 and B/9, Z=700-1050). There is still a great deal of material to be analysed and it will be critical to study the faunal remains from scraper-rich Yabrudian contexts. This is currently under way and additional

bone retouchers have been found. More significantly, the number of marks on the use areas is too low for what is required to transform a flake into a Quina or demi-Quina scraper with the characteristic multi-staged, overlapping retouches, assuming that each mark corresponds to one contact between retoucher and the flint item being retouched. In this sense, most bone retouchers from Qesem are substantially different from those recovered in later sites and perhaps more associated with the entire process of scraper shaping. At La Quina, in France, the bone retouchers show a large number of overlapping percussion marks that are mostly pitted areas configured into large use areas, which sometimes preserve use areas at both apical ends of limb bone blanks (Verna and d'Errico, 2011). From this perspective, it is conceivable that most of the Qesem retouchers are more likely to be linked to short use episodes within the configuration of the retouched tools, like occasional re-sharpening or curving.

On the other hand, according to several experiments (Mozota, 2009; Rosell et al., 2011; Verna and d'Errico, 2011; Daujeard et al., 2014), bone retouchers are usually used fresh or in an intermediary state of freshness. In these cases, the most common features are deep to shallow marks, usually clustered in well-defined use areas. Most of the bone retouchers

from Qesem show these characteristics, indicating a relatively short period of time between bone discard and re-selection for use as a retoucher. However, two bone blanks from the unit under the rock shelf and one from the hearth unit show different characteristics. These bone fragments show chips associated with a loss of cortical tissue, and percussion striations on previous detachment of bone plaques as a result of the bone's loss of natural elasticity (Figure 7). So, these bone blanks could have been used in dry state, suggesting an occasional indifference for the state of the bones.

All these elements allow us to place the Qesem bone retouchers within a framework of recycling. That is, they are previously discarded objects, which, after fulfilling their initial nutritional function are taken from the waste and given a different function from the original. This second life cycle plays an important part in the lithic industry *chaîne opératoire*. However, these objects require no more preparation than possible scraping of the periosteum to improve percussion. In this case, they differ from some of the objects recovered at level XVIIIa of the Spanish site of Bolomor Cave (MIS 9), where one of the bone fragments used as a retoucher was shaped before use, presumably to make it more ergonomic (Blasco et al., 2013; Rosell et al., 2015).

From this perspective, Qesem Cave, and by extension the AYCC, represents a new stage in which the recycling of previously discarded objects appears to play an important role. Considering the age of this new approach (ca. 400 ka), Qesem could be considered one of the places where the previous Acheulian techno-complexes were supplanted for the first time during the second half of the Middle Pleistocene. Therefore, the use of bones to retouch lithic artefacts should be viewed in the same light as other sophisticated and diversified technologies, including laminar items, Quina and demi-Quina scrapers and backed knives, and the habitual use of fire as a central element of hominin occupations and recycling. This additional technological innovation appears to have different expressions in other world regions, but they all indicate the inclusion of bone in the lithic *chaîne opératoire*.

To date, the AYCC does not have any other large faunal assemblages similar to Qesem Cave; thus, no comparative studies validating the importance of these objects in the AYCC in the Levant can be made. However, other evidence is available in the European Middle Pleistocene that reinforces the idea of a diversified use of bone for purposes beyond nutrition. At the French site of Caune de l'Arago (MIS 12) teeth and jaws of large animals have been recovered with very long marks that have been interpreted as *billots*, or large bone fragments on the surface of which meat or other soft materials were cut (Moigne et al., 2016). There is also clear evidence for introducing bone and antler into the lithic *chaîne opératoire* during MIS 13 at the site of Boxgrove (UK). At this site, a collection of deer antlers with deep striations has been interpreted as a result of their use as hammers to make large tools, e.g., bifaces (Roberts, 1997; Roberts and Parfitt, 1999; Bello et al., 2013). Along with these hammers were found some bone retouchers for more delicate activities, some of which preserve small fragments of embedded flint (Smith, 2010, 2013). A single bone retoucher on a deer femur has been mentioned at the site of Terra Amata, France (MIS 11) (Moigne et al., 2016).

Although sporadic evidence of bone retouchers can be detected in the preceding Acheulian period (e.g., Boxgrove), this technological behaviour seems to have become widespread during the post-Acheulian contexts and especially after MIS 9 in Europe. Some relevant cases are Schöningen in Germany (Julien et al., 2015; van Kolfschoten et al., 2015), Orgnac 3 (Moncel et al., 2012), La Micoque (Langlois, 2004) and Cagny-l'Épinette (Lamotte and Tuffreau, 2001) in France, and Bolomor Cave and Gran Dolina in Spain (Rosell et al., 2011, 2015; Blasco et al., 2013; Rodríguez-Hidalgo et al., 2013). From this point of view, bone retouchers may be considered an element that was deeply assimilated during post-Acheulian times and widely adopted in subsequent periods and cultural complexes. This does not mean that soft retouchers were not used in previous periods, but rather that the spectrum of uses for recycled bone expanded significantly during

MIS 9 in western Europe, and previous to that in the AYCC of the Levant, to include bone retouchers aimed at rather delicate flint working.

Conclusions

Qesem Cave, and by extension the AYCC, shows a series of innovative technological behaviours, amongst which retouching acquired a growing importance. This may be part of an increasing diversity of human needs and newly introduced activities. At Qesem Cave we observe a broadening in the spectrum of activities, ranging from the most highly planned and complex, like the emergence of food sharing and social hunting (Stiner et al., 2009; 2011; Blasco et al., 2014), to what may be considered immediate and improvised, but equally successful. This duality of more immediate activities that do not require prior planning, like lithic recycling, and highly planned activities emphasizes the highly flexible and creative nature of these hominin groups in developing innovative solutions to novel tasks.

In this sense, some of the Qesem retouchers, and the immediacy with which they appear to have been used, fit with the improvised part of the activity spectrum. They are simple objects with little or no prior preparation and recycled from waste previously discarded by the same or previous hominin groups. Their use appears to have been short and limited to a few retouch motions, perhaps related to the curving and/or re-sharpening of lithic tools, including Quina scrapers. This sense of improvisation increases by the detection of the use of fresh, intermediate, and even dry bone blanks for these purposes.

Finally, this paper also delves into the role of these tools within the changing cultural landscape and the changing discourse between humanity and the world – culture and nature. Deciphering the relationships between hominins, animals, bone and stone may be significant to understanding Palaeolithic hunter-gatherers. In this context, bone retouchers are, in our view, a qualitative change, and their appearance is clearly not random or coinciden-

tal. These bones were used in what may basically be viewed as a recycling context: they were used to shape stone tools for use in meat processing or in hunting of animals whose bones were then used as bone retouchers to shape stone tools. This falls way beyond a partnership in shaping tools; it is rather an amalgamation of the two materials, of two basic existential dispositions. These tools then should not be looked at in isolation but rather as a component of a wide-ranging cultural transformation (e.g., Barkai and Gopher 2013; Gopher and Barkai, 2016).

We see this technology-related innovation as a two-faceted story. On the one hand, we are dealing with a new concept originating from interactions with the natural world, between hominins and animals. This involves a distancing of immediate and direct consumption, introducing another use for hunted animals – in a way, a deep concept of recycling. The second facet of bone retouchers is the union of bone, gained through hunting and food consumption, and stone technology, represented by tools for hunting. In our view, this is an important integration of two primordial elements of Palaeolithic existence – a polarity yet to be studied in depth.

Acknowledgments

The Qesem Cave excavation project has been supported by the Israel Science Foundation, the CARE Archaeological Foundation, the Leakey Foundation, the Wenner-Gren Foundation, the Dan David foundation and the Thyssen Foundation. This work has been developed within the framework of the Spanish MINECO/FEDER projects CGL2015-65387-C3-1-P and CGL2015-68604-P, CGL2016-80000-P, the Generalitat de Catalunya-AGAUR projects 2014 SGR 900 and 2014/100573, and the SENECA Foundation project 19434/PI/14. We thank Marie-Anne Julien, Jarod Hutson and an anonymous reviewer for providing helpful comments on an earlier draft of the manuscript.

References

- Armand, D., Delagnes, A., 1998. Les retouchoirs en os d'Artenac (couche 6c): perspectives archéozoologiques, taphonomiques et expérimentales. In: Brugal, J.-P., Meignen, L., Patou-Mathis, M. (Eds.), *Économie Préhistorique: Les Comportements de Subsistance au Paléolithique*. XVIII^e Rencontre Internationale d'Archéologie et d'Histoire d'Antibes. Éditions APDCA, Sophia Antipolis, pp. 205-214.
- Assaf, E., Parush, Y., Gopher, A., Barkai, R., 2015. Intra-site variability in lithic recycling at Qesem Cave, Israel. *Quatern. Int.* 361, 88-102.
- Auguste, P., 2002. Fiche éclats diaphysaires du Paléolithique moyen: Biache-Saint-Vaast (Pas-de-Calais) et Kulna (Moravie, République Tchèque). In: Patou-Mathis, M. (Ed.), *Retouchoirs, Compresseurs, Percuteurs...Os à Impressions et à Éraillures. Fiches Typologiques de l'Industrie Osseuse Préhistorique, Cahier X*. Éditions Société Préhistorique Française, Paris, pp. 39-57.
- Barkai, R., Gopher, A., Lauritzen, S.E., Frumkin, A., 2003. Uranium series dates from Qesem Cave, Israel, and the end of the Lower Palaeolithic. *Nature* 423, 977-979.
- Barkai, R., Lemorini, C., Shimelmitz, R., Lev, Z., Stiner, M.C., Gopher, A., 2009. A blade for all seasons? Making and using Amudian blades at Qesem Cave, Israel. *Hum. Evol.* 24, 57-75.
- Barkai, R., Gopher, A., 2013. Cultural and biological transformations in the Middle Pleistocene Levant: a view from Qesem Cave, Israel. In: Akazawa, T., Nishiaki, Y., Aoki, K. (Eds.), *Dynamics of Learning in Neanderthals and Modern Humans Volume 1: Cultural Perspectives*. Springer, Tokyo, pp. 115-137.
- Beauval, C., 2004. La faune des niveaux moustériens de "Chez-Pinaud" (Jonzac, Charente-Maritime, France. Première analyse. In: Airvaux, J. (Ed.), *Le Site Paléolithique de Chez-Pinaud à Jonzac, Charente-Maritime. Préhistoire du Sud-Ouest Supplément 8, Cressensac*, pp. 125-156.
- Bello, S.M., Parfitt, S.A., De Groote, I., Kennaway, G., 2013. Investigating experimental knapping damage on an antler hammer: a pilot-study using high-resolution imaging and analytical techniques. *J. Archaeol. Sci.* 40, 4528-4537.
- Ben-Dor, M., Gopher, A., Hershkovitz, I., Barkai, R., 2011. Man the fat hunter: the demise of *Homo erectus* and the emergence of a new hominin lineage in the Middle Pleistocene (ca. 400 kyr) Levant. *PLOS ONE* 6, e28689.
- Binford, L.R., 1978. *Nunamiut Ethnoarchaeology*. New York, Academic Press.
- Blasco, R., Rosell, J., Cuartero, F., Fernández Peris, J., Gopher, A., Barkai, R., 2013. Using bones to shape stones: MIS 9 bone retouchers at both edges of the Mediterranean Sea. *PLOS ONE* 8, e76780.
- Blasco, R., Rosell, J., Gopher, A., Barkai, R., 2014. Subsistence economy and social life: a zooarchaeological view from the 300 kya central hearth at Qesem Cave, Israel. *J. Anthropol. Archaeol.* 35, 248-268.
- Blasco, R., Rosell, J., Sañudo, P., Gopher, A., Barkai, R., 2016a. What happens around a fire: faunal processing sequences and spatial distribution at Qesem Cave (300 ka), Israel. *Quatern. Int.* 398, 190-209.
- Blasco, R., Rosell, J., Smith, K.T., Maul, L.C., Sañudo, P., Barkai, R., Gopher, A., 2016b. Tortoises as a dietary supplement: a view from the Middle Pleistocene site of Qesem Cave, Israel. *Quatern. Sci. Rev.* 133, 165-182.
- Boschian, G., Saccà, D., 2014. In the elephant, everything is good: carcass use and re-use at Castel di Guido (Italy). *Quatern. Int.* 361, 288-296.
- Bunn, H.T., Bartram, L.E., Kroll, E.M., 1988. Variability in bone assemblage formation from Hadza hunting, scavenging, and carcass processing. *J. Anthropol. Archaeol.* 7, 412-457.
- Claud, E., Soressi, M., Jaubert, J., Hublin, J.-J., 2012. Étude tracéologique de l'outillage moustérien de type Quina du bonebed de Chez-Pinaud à Jonzac (Charente-Maritime). *Nouveaux éléments en faveur d'un site de boucherie et de traitement des peaux. Gallia Préhist.* 54, 3-32.
- Daujeard, C., Moncel, M.-H., Fiore, I., Tagliacozzo, A., Bindon, P., Raynal, J.-P., 2014. Middle Paleolithic bone retouchers in South-eastern France: variability and functionality. *Quatern. Int.* 326-327, 492-518.
- Falguères, C., Richard, M., Tombret, O., Shao, Q., Bahain, J.J., Gopher, A., Barkai, R., 2016. New ESR/U-series dates in Yabrudian and Amudian layers at Qesem Cave, Israel. *Quatern. Int.* 398, 6-12.
- Gopher, A., Ayalon, A., Bar-Matthews, M., Barkai, R., Frumkin, A., Karkanas, P., Shahack-Gross, R., 2010. The chronology of the late Lower Paleolithic in the Levant based on U-Th ages of speleothems from Qesem Cave, Israel. *Quatern. Geochronol.* 5, 644-656.
- Gopher, A., Barkai, R., 2016. State of the art of the multidisciplinary research at Middle Pleistocene Qesem Cave, Israel, 2015 – an introduction. *Quatern. Int.* 398, 1-5.
- Hershkovitz, I., Smith, P., Sarig, R., Quam, R., Rodríguez, L., García, R., Arsuaga, J.L., Barkai, R., Gopher, A., 2011. Middle Pleistocene dental remains from Qesem Cave (Israel). *Am. J. Phys. Anthropol.* 144, 575-592.
- Hershkovitz, I., Weber, G.W., Fornai, C., Gopher, A., Barkai, R., Slon, V., Quam, R., Gabet, Y., Sarig, R., 2016. New Middle Pleistocene dental remains from Qesem Cave (Israel). *Quatern. Int.* 398, 148-158.
- Jaubert, J., Hublin, J.-J., McPherron, S.P., Soressi, M., Bordes, J.-G., Claud, É., Cochard, D., Delagnes, A., Mallye, J.-B., Michel, A., Niclot, M., Niven, L., Park, S.-J., Rendu, W., Richards, M., Richter, D., Roussel, M., Steele, T.E., Texier, J.-P., Thiébaud, C., 2008. Paléolithique moyen récent et Paléolithique supérieur ancien à Jonzac (Charente-Maritime): premiers résultats des campagnes 2004-2006. In: Jaubert, J., Bordes, J.-G., Ortega, I. (Eds.), *Les Sociétés du Paléolithique dans un Grand Sud-Ouest de la France: Nouveaux Gisements, Nouveaux Résultats, Nouvelles Methods. Journées SPF, Université Bordeaux 1, Talence, 24-25 Novembre 2006. Mémoire 47. Société Préhistorique Française, Paris*, pp. 203-243.
- Julien, M.-A., Hardy, B., Stahlschmidt, M.C., Urban, B., Serangeli, J., Conard, N.J., 2015. Characterizing the Lower Paleolithic bone industry from Schöningen 12 II: a multi-proxy study. *J. Hum. Evol.* 89, 264-286.
- Karkanas, P., Shahack-Gross, R., Ayalon, A., Bar-Matthews, M., Barkai, R., Frumkin, A., Gopher, A., Stiner, M.C., 2007. Evidence for habitual use of fire at the end of the Lower Paleolithic: site-formation processes at Qesem Cave, Israel. *J. Hum. Evol.* 53, 197-212.

- Lamotte, A., Tuffreau, A., 2001. Les industries lithiques de la séquence fluviatile finiede Cagny-Epinette (Somme). In: Tuffreau, A. (Ed.), *L'Acheuléen dans la Vallée de la Somme et Paléolithique Moyen dans le Nord de la France: Données Récentes*. Centre d'Études et de Recherches Préhistoriques, Université de Lille, pp. 113-135.
- Langlois, A., 2004. Au sujet du Cheval de La Micoque (Dordogne) et des comportements humains de subsistance au Pléistocène moyen dans le Nord-Est de l'Aquitaine. Ph.D. Dissertation, Université de Bordeaux 1.
- Lemorini, C., Venditti, F., Assaf, E., Parush, Y., Barkai, R., Gopher, A., 2015. The function of recycled lithic items at late Lower Paleolithic Qesem Cave, Israel: an overview of the use-wear data. *Quatern. Int.* 361, 103-112.
- Lemorini, C., Bourguignon, L., Zupancich, A., Gopher, A., Barkai, R., 2016. A scraper's life history: morpho-techno-functional and use-wear analysis of Quina and demi-Quina scrapers from Qesem Cave, Israel. *Quatern. Int.* 398, 86-93.
- Lyman, R.L., 1994. *Vertebrate Taphonomy*. Cambridge University Press, Cambridge.
- Malerba, G., Giacobini, G., 1998. Les retouchoirs sur éclats diaphysaires du Paléolithique moyen et supérieur de trois sites de l'Italie nord orientale (Grotte de San Bernardino, Abri de Fumane et Abri Tagliente). Proceedings of the XIII International Congress of the Union of Prehistoric and Protohistoric Sciences (Forlì, Italia, 8-14 September 1996), Volume 6. ABACO Edizioni, Forlì, pp. 167-171.
- Mallye, J.-B., Thiébaud, C., Murre, V., Costamagno, S., Claud, E., Weisbecker, P., 2012. The Mousterian bone retouchers of Noisetier Cave: experimentation and identification of marks. *J. Archaeol. Sci.* 39, 1131-1142.
- Maul, L.C., Bruch, A.A., Smith, K.T., Shenbrot, G., Barkai, R., Gopher, A., 2016. Palaeoecological and biostratigraphical implications of the microvertebrates of Qesem Cave in Israel. *Quatern. Int.* 398, 219-232.
- Mercier, N., Valladas, H., Falguères, C., Shao, Q., Gopher, A., Barkai, R., Bahain, J.J., Vialettes, L., Joron, J.L., Reyss, J.L., 2013. New datings of Amudian layers at Qesem Cave (Israel): results of TL applied to burnt flints and ESR/U-series to teeth. *J. Archaeol. Sci.* 40, 3011-3020.
- Moigne, A.-M., Valensi, P., Auguste, P., García-Solano, J., Tuffreau, A., Lamotte, A., Barroso, C., Moncel, M.-H., 2016. Bone retouchers from Lower Palaeolithic sites: Terra Amata, Orgnac 3, Cagny-l'Épinette and Cueva del Angel. *Quatern. Int.* 409, 195-212.
- Moncel, M.-H., Moigne, A.-M., Combier, J., 2012. Towards the Middle Palaeolithic in Western Europe: the case of Orgnac 3 (southeastern France). *J. Hum. Evol.* 63, 653-666.
- Mozota, M., 2009. El utillaje óseo musteriense del nivel "D" de Axlor (Dima, Vizcaya): análisis de la cadena operativa. *Trab. Prehist.* 66, 27-46.
- Parush, Y., Assaf, E., Slon, V., Gopher, A., Barkai, R., 2015. Looking for sharp edges: modes of flint recycling at Middle Pleistocene Qesem Cave, Israel. *Quatern. Int.* 361, 61-87.
- Parush, Y., Gopher, A., Barkai, R., 2016. Amudian versus Yabrudian under the rock shelf: a study of two lithic assemblages from Qesem Cave, Israel. *Quatern. Int.* 398, 13-36.
- Patou-Mathis, M. (Ed.), 2002. *Retouchoirs, Compresseurs, Percuteurs...Os à Impressions et à Éraillures. Fiches Typologiques de l'Industrie Osseuse Préhistorique, Cahier X. Éditions Société Préhistorique Française, Paris.*
- Rabinovich, R., Ackermann, O., Aladjem, E., Barkai, R., Biton, R., Milevski, I., Solodenko, N., Marder, O., 2012. Elephants at the Middle Pleistocene Acheulian open-air site of Revadim Quarry, Israel. *Quatern. Int.* 276-277, 183-197.
- Roberts, M., 1997. Boxgrove: Palaeolithic hunters by the seashore. *Archaeol. Int.* 1, 8-13.
- Roberts, M., Parfitt, S., 1999. *A Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex*. English Heritage, London.
- Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., Cáceres, I., Huguet, R., Lombra-Hermida, A., Mosquera, M., Morales, J.I., Pederagnana, A., Rodríguez, X.P., Carbonell, E., 2013. Ancient bone retouchers at Gran Dolina site: a recurrent technical behaviour during the Middle Pleistocene. *Proceedings of the European Society for the Study of Human Evolution* 2, 187.
- Rosell, J., Blasco, R., Campeny, G., Díez, J.C., Alcalde, R.A., Menéndez, L., Arsuaga, J.L., Bermúdez de Castro, J.M., Carbonell, E., 2011. Bone as a technological raw material at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). *J. Hum. Evol.* 61, 125-131.
- Rosell, J., Blasco, R., Fernández Peris, J., Carbonell, E., Barkai, R., Gopher, A., 2015. Recycling bones in the Middle Pleistocene: some reflections from Gran Dolina TD10-1 (Spain), Bolomor Cave (Spain) and Qesem Cave (Israel). *Quatern. Int.* 361, 297-312.
- Sahnouni, M., Rosell, J., van der Made, J., Vergès, J.M., Ollé, A., Kandi, N., Harichane, Z., Derradji, A., Medig, M., 2013. The first evidence of cut marks and usewear traces from the Plio-Pleistocene locality of El-Kherba (Ain Hanech), Algeria: implications for early hominin subsistence activities circa 1.8 Ma. *J. Hum. Evol.* 64, 137-150.
- Sánchez Marco, A., Blasco, R., Rosell, J., Gopher, A., Barkai, R., 2016. Birds as indicators of high biodiversity zones around the Middle Pleistocene Qesem Cave, Israel. *Quatern. Int.* 421, 23-31.
- Shahack-Gross, R., Berna, F., Karkanas, P., Lemorini, C., Gopher, A., Barkai, R., 2014. Evidence for the repeated use of a central hearth at Middle Pleistocene (300 ky ago) Qesem Cave, Israel. *J. Archaeol. Sci.* 44, 12-21.
- Smith, G.M., 2010. A contextual approach to the study of faunal assemblages from Lower and Middle Palaeolithic sites in the UK. Ph.D. Dissertation, University College London.
- Smith, G.M., 2013. Taphonomic resolution and hominin subsistence behaviour in the Lower Palaeolithic: differing data scales and interpretive frameworks at Boxgrove and Swanscombe (UK). *J. Archaeol. Sci.* 40, 3754-3767.
- Smith, K.T., Maul, L.C., Barkai, R., Gopher, A., 2013. To catch a chameleon, or actualism vs. natural history in the taphonomy of the microvertebrate fraction at Qesem Cave, Israel. *J. Archaeol. Sci.* 40, 3326-3339.
- Stiner, M.C., 1994. *Honor among Thieves: A Zooarchaeological Study of Neandertal Ecology*. Princeton University Press, Princeton.
- Stiner, M.C., Barkai, R., Gopher, A., 2009. Cooperative hunting and meat sharing 400-200 kya at Qesem Cave, Israel. *Proc. Natl. Acad. Sci. USA* 106, 13207-13212.
- Stiner, M.C., Gopher, A., Barkai, R., 2011. Hearth-side socioeconomics, hunting and paleoecology during the late Lower Paleolithic at Qesem Cave, Israel. *J. Hum. Evol.* 60, 213-233.

- Stout, D., Apel, J., Commander, J., Roberts, M., 2014. Late Acheulean technology and cognition at Boxgrove, UK. *J. Archaeol. Sci.* 41, 576-590.
- van Kolfschoten, T., Parfitt, S.A., Serangeli, J., Bello, S.M., 2015. Lower Paleolithic bone tools from the 'Spear Horizon' at Schöningen (Germany). *J. Hum. Evol.* 89, 226-263.
- Verna, C., d'Errico, F., 2011. The earliest evidence for the use of human bone as a tool. *J. Hum. Evol.* 60, 145-157.
- Zupancich, A., Lemorini, C., Gopher, A., Barkai, R., 2016a. On Quina and demi-Quina scraper handling: preliminary results from the late Lower Paleolithic site of Qesem Cave, Israel. *Quatern. Int.* 398, 94-102.
- Zupancich, A., Nunziante-Cesaro, S., Blasco, R., Rosell, J., Cristiani, E., Venditti, F., Lemorini, C., Barkai, R., Gopher, A., 2016b. Early evidence of stone tool use in bone working activities at Qesem Cave, Israel. *Sci. Rep.* 6, 37686. DOI: 10.1038/srep37686.
- Zutovski, K., Barkai, R., 2016. The use of elephant bones for making Acheulian handaxes: a fresh look at old bones. *Quatern. Int.* 406, 227-238.

Jordi Rosell ^{a,b,*}, Ruth Blasco ^{c,d}, Ignacio Martín-Lerma ^e, Ran Barkai ^d, Avi Gopher ^d

^a Àrea de Prehistòria, Universitat Rovira i Virgili (URV), Avinguda de Catalunya 35, 43002 Tarragona, Spain

^b IPHES, Institut Català de Paleoecologia Humana i Evolució Social, Campus Sescelades URV (Edifici W3), 43007 Tarragona, Spain

^c Centro Nacional de Investigación sobre la Evolución Humana (CENIEH), Paseo Sierra de Atapuerca 3, 09002 Burgos, Spain

^d Department of Archaeology, Tel-Aviv University, Institute of Archaeology, POB 39040, 69978 Tel Aviv, Israel

^e Departamento de Prehistoria, Arqueología, Historia Antigua, Historia Medieval y Ciencias y Técnicas Historiográficas, Universidad de Murcia, Facultad de Letras, C/ Santo Cristo 1, Campus de la Merced, 30001 Murcia, Spain

* Corresponding author. Email: jordi.rosellardevol@gmail.com