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Small flake production and lithic recycling at Late Acheulian Revadim, Israel

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ABSTRACT

The multi-layered Lower Paleolithic Acheulian site of Revadim Quarry provides a rare opportunity to study patterns of continuity and change within the lithic assemblages of the Late Lower Paleolithic period in the Levant. This open-air site was excavated to a large extent (~250 m²) and yielded a wealth of lithic and faunal remains. The rich lithic assemblages are typical of the Late Acheulian in the Levant, including handaxes, but mostly dominated by flake production and flake tools. In this paper, we present the results of a technological study recently conducted in order to establish the character and scale of lithic recycling directed towards the production of small flakes (<2 cm). Our results shed new light on the character and extent of Lower Paleolithic production of small flakes by means of lithic recycling, providing an opportunity for comparison with similar phenomena during contemporaneous as well as later cultural complexes in the Levant and beyond.

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1. Introduction

The multi-layered site of Revadim Quarry (henceforth Revadim) was discovered in 1996 and was ascribed to the late phase of the Acheulian cultural-complex of the Lower Paleolithic period in the Levant (Marder et al., 2011), earlier than 400,000 years ago (Gopher et al., 2010; Bar-Yosef and Belmaker, 2011; Barkai and Gopher, 2013; Mercier et al., 2013). The Acheulian lithic industries of the Levant are mostly characterized by flake production and the manufacture of bifaces, known as handaxes or large cutting tools (e.g., Bar-Yosef et al., 1993; Lycett and Gowlett, 2008; Barkai, 2009; Machin, 2009; Sharon, 2009, 2010). The Acheulian is frequently referred to as a cultural and technological complex reflecting minor behavioral and technological changes compared to later periods (Bar-Yosef, 1994, 2006; Nowell and White, 2010; Somel et al., 2013), attributed by some to the rather limited cognitive and linguistic skills of the hominins involved (Nowell and White, 2010; but see a different view in; Belfer-Cohen and Goren-Inbar, 1994; Goren-Inbar and Belfer-Cohen, 1998). However, we see such assessments as judgmental and unjustified. Significant change in human behavior and the technologies used are more easily observed towards the end of

the Lower Paleolithic period (Nowell and White, 2010; Barkai and Gopher, 2013).

The rich lithic assemblages uncovered so far at Revadim comprise hundreds of thousands of items, some of which are still under study. Assemblages originating in excavation areas B and C have thus far received most scholarly attention: while assemblages of Area B were studied (Solodenko, 2010) and partially published (Rabinovich et al., 2012), the lithics originating from Area C have not yet been fully analyzed with the exception of one section (Malinsky-Buller et al., 2011a). In this paper, we focus our attention on specific aspects of the rich lithic assemblage of Layer C3 West (henceforth: Layer C3, see below for details regarding stratigraphy).

Generally, lithic recycling at Revadim is characterized by two main trajectories. The first trajectory represents the recycling of bifaces into cores for the production of flakes. This practice is manifested at three levels: 1. an opportunistic production of single or few large preferential flakes from an existing biface (e.g., DeBono and Goren-Inbar, 2001); 2. the recycling of bifaces into regular/simple flake cores; and 3. the recycling of bifaces as prepared (Levallois) cores for the production of predetermined blanks (Barkai and Marder, 2010). The second trajectory represents the production of small flakes (<2 cm) from cores-on-flakes (parent flakes), also known as flaked flakes (Ashton et al., 1991; Ashton, 2007). This second trajectory is the focus of our attention in the current work. A third recycling trajectory concerning tools recycled into tools of a different type (e.g., Malinsky-Buller et al., 2011a) is

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not firmly established in our opinion, and should be confirmed by future investigation. It has been suggested (Vaquero, 2011) that lithic recycling plays a significant role in portraying the technological and economic behavior of Paleolithic human groups. Since behavior is partly reflected by settlement and occupational patterns, recycling may also be a significant contribution to interpretations regarding issues such as mobility or site function. Understanding lithic recycling might also be useful for answering questions concerning the formal design and life histories of artefacts. These issues, however, will not be dealt with in this paper, but, rather, will be examined in future study.

In this paper, we present preliminary observations of the wide-scaled lithic recycling practices at Revadim, focusing specifically on the production of small and sharp flakes from existing, previously detached, parent flakes. We term these objects *cores-on-flakes/flaked flakes* (henceforth: COF-FF). COF-FFs at Revadim seem to be mostly similar to the flaked-flakes first described by Ashton et al. (1991) as “a flake that has had one or more smaller flakes removed from any of its edges”, but different from the other, mostly Middle Paleolithic, cores-on-flake presented in the literature (e.g., Solecki and Solecki, 1970; Newcomer and Hivernel-Guerre, 1974; Nishiaki, 1985; Goren-Inbar, 1988; Dibble and McPherron, 2006). The COF-FF category comprises parent flakes that have had further flakes removed from their ventral or dorsal faces (or both), proximal or distal ends (or both) and lateral edges. Removals were most commonly produced in a straight-forward manner, with or without platform preparations. Revadim COF-FFs were mostly not made from truncated-faceted pieces, nor did a truncation serve as a striking platform in their production. Neither were COF-FFs produced using the Nahr Ibrahim technique (see Parush et al., in this volume for details).

The use of flakes as regular (“nodule based”) cores for the production of regular blanks, meaning the exploitation of flakes as cores with single or multiple striking platforms for the recurrent production of relatively large blanks intended to be transformed into tools by subsequent retouch or to be used as is, is seen at many archaeological contexts (for a review on the subject see Parush et al., in this volume). The Revadim COF-FFs, however, represent quite a different phenomenon. These were not intentionally detached flakes produced in order to be transformed into cores within the commonly practiced reduction sequences. Rather, they were by-products of the regular technological system practiced at the site (as blanks, shaped flakes, core trimming elements, and so on), and their current form represents a second life-cycle targeted at the production of small flakes. One group of COF-FFs is fully covered by patina and bearing post-patina flake production scars, indicating a relatively prolonged period of time between the production of the parent flakes and their recycling into COF-FFs.

The transformation of flakes into cores by way of recycling is a well-known and well-attested phenomenon, which was awarded numerous names and varied technical definitions, characteristics and, of course, interpretations. One known example is the Nahr Ibrahim technique, defined by Solecki and Solecki (1970:137) as “consisting of truncating and faceting of one or more ends or sides of a flint flake or tool, and the utilization of the facet thus created as a platform for flake removal.” Another example is that of the Kombewa technique, originally defined by Owen (1938). The Kombewa technique, the production of a double-ventral flake from the ventral face of a larger flake, in fact comprises two separate trajectories. One represents regular production, namely the production of very large Kombewa flakes to be shaped as bifaces (Inizan et al., 1992:57; Tixier and Turq, 1999) while the other represents recycling production in which were produced very small double-ventral flakes from existing flakes (Newcomer and Hivernel-Guerre, 1974; Dibble and McPherron, 2006; Casini,

2010). Other definitions and examples of lithic recycling mostly originate in Middle Paleolithic contexts (e.g., Nishiaki, 1985; Goren-Inbar, 1988; Dibble and McPherron, 2007; Schroeder, 2007; Vaquero, 2011; Vaquero et al., 2012).

Small flakes can be removed from a parent flake in several different manners: from the dorsal or ventral face of the parent, from the thickness or the lateral edge of the parent flake (parallel to the flaking axis) or from the proximal or distal ends (perpendicular to the flaking axis). Flakes produced from the ventral face of a parent flake are recognizable by their two ventral faces whereas flakes produced from the dorsal face of a parent flake are not easily identified as products due to their similarity to regular flakes (e.g., Dibble and McPherron, 2006; and see Amick, 2007 for a recent summary of different methods of recognizing, measuring and interpreting lithic recycling). While some scholars (e.g., Crew, 1976) suggest that flakes produced from COF-FFs are too small to be used, other authors present results indicating that such small flakes should be conceived as workable tools (e.g., Goren-Inbar, 1988; Dibble and McPherron, 2006; Barkai and Marder, 2010; Key and Lycett, 2014). Recently published use-wear studies strongly support such suggestions, demonstrating the effective use of recycled small flakes (Dibble and McPherron, 2007; Barkai and Marder, 2010; Claud et al., 2012; Lemorini et al., in this volume).

The analysis of the lithic recycling phenomenon oriented at the production of small flakes at the Acheulian site of Revadim provides a rare opportunity to present evidence of technological and functional transformations within a cultural complex that is sometimes referred to as “static”, “monotonous” and “stagnant” (Nowell and White, 2010). Evidence for the purposeful production of very small flakes from earlier Lower Paleolithic contexts such as Ubeydia (Shea and Bar-Yosef, 1999), Fuente Nueva 3 (Barsky et al., in this volume), and Bizat Ruhama (Zaidner, 2013) appears to indicate continuous production of desired small flakes throughout the Lower Paleolithic period. Data presented in this paper, however, suggests an intensification in the production of such small flakes in the Late Acheulian in the Levant, a trend that may have further continued into the Acheulo-Yabrudian cultural complex (Assaf et al., in this volume; Barkai and Gopher, 2013; Lemorini et al., in this volume; Parush et al., in this volume). This intensification of recycling technology may also reflect a unique mode of resource exploitation, decision making and adaptation, within the Late Acheulian and Acheulo-Yabrudian cultural complexes.

2. Regional setting

Revadim is an open-air site located on the southern Coastal Plain of Israel, 40 km southeast of Tel Aviv, within the Mediterranean vegetation belt, at an elevation of 71–73 m above sea level (Fig. 1; Marder et al., 1999). Four seasons of excavations were conducted during the years 1996–2004 on behalf of the Israel Antiquities Authority and the Hebrew University of Jerusalem (Marder et al., 1999, 2011).

Dating of the Revadim sequence is yet incomplete. Paleomagnetic analyses of the geological sequence show normal polarity, indicating that the entire sequence is younger than 780 ka (Gvirtzman et al., 1999; Marder et al., 2011). Preliminary dating of carbonate coating of flint artifacts yielded dates between 300 and 500 ka (Malinsky-Buller et al., 2011b), providing a minimum age for these items. Given the characteristics of the lithic and the faunal assemblages, the entire anthropogenic assemblage is assigned to the Late Acheulian cultural-complex of the Levant (Marder et al., 2006, 2011; Solodenko, 2010; Malinsky-Buller et al., 2011a,b; Rabinovich et al., 2012). Revadim's faunal assemblage comprises thousands of animal bones, dominated by *Palaeoloxodon antiquus*, *Bos primigenius*, and *Dama cf. mesopotamica* in addition to other

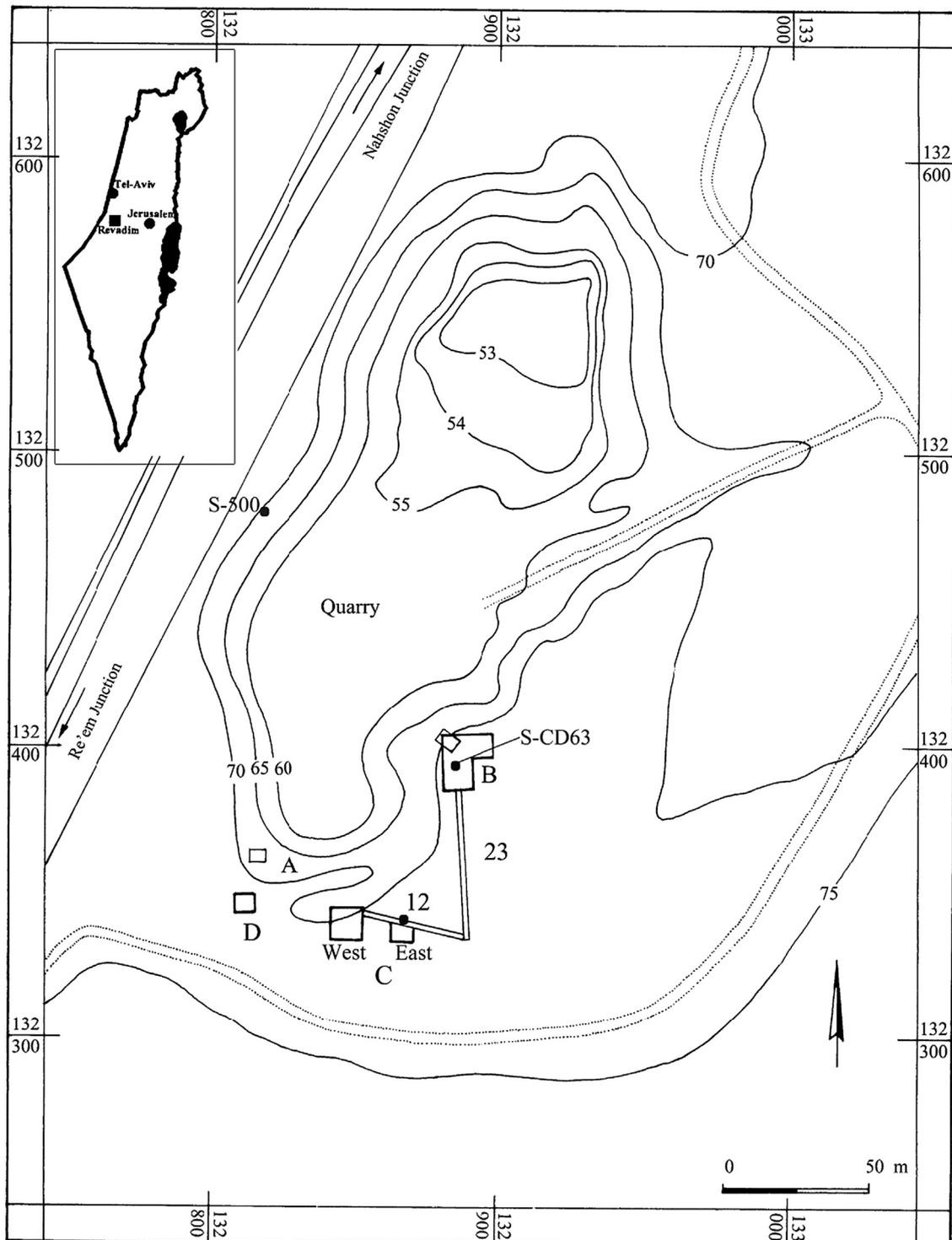


Fig. 1. The location of the Acheulian quarry of Revadim and the site's excavation areas (after Malinsky-Buller et al., 2011a,b).

mammalian species as well as microvertebrates (for more details see Rabinovich et al., 2012).

Excavations at the site focused mainly on Areas B and C, exposing seven archaeological layers (Malinsky-Buller et al., 2011a). While the geological stratigraphy and archaeological sequences, as well as spatial correlations between the excavated areas, are detailed elsewhere (Marder et al., 2006, 2011), here we offer only those data that are directly pertinent to the subject at hand. Area C is the most complete stratigraphic sequence of Revadim (Marder

et al., 2006). It is divided into sub-areas C East and C West, located 8 m apart (Malinsky-Buller et al., 2011a). Extending over 33 m², Area C West revealed five superimposed archaeological layers, labeled from top to bottom as C1 to C5 (Malinsky-Buller et al., 2011a). Layer C3 in Area C West, the focus of this study, is characterized by the highest density of flint artifacts as well as bones both in this area and in the site as a whole (Marder et al., 2006). Stratigraphic correlations between Areas C and B indicate that Layer C5 and B2 are probably contemporaneous, while the

stratigraphic relation between Layer C3 and B1 is unclear (Marder et al., 2006, 2011).

3. Materials and methods

The definitions of lithic recycling at Revadim used in this study follow those offered for lithic recycling at Achelu-Yabrudian Qesem Cave (Parush et al., in this volume; Parush, 2014), adjusted to accommodate uniqueness of the Revadim lithic industry. While lithic recycling was practiced differently at the two sites, significant similarities can be pointed out as well that suffice to serve the current analyses. Additional analyses of lithic recycling at Revadim are forthcoming.

Lithic analyses of Layer C3 assemblage include the examination and classification of all 26,601 lithic items that originated in this layer. Assemblages of Layers B1, B2 (originating from Area B) and C5, which were analyzed previously, are compared to Layer C3. Comparisons include general assemblage composition as well as specific characteristics of recycled COF-FFs and products of the recycling procedure. Layers C1, C2, and C4 have not been studied.

Approximately 25% of all COF-FFs identified in Layer C3 were arbitrarily selected for detailed analysis, yielding a random sample of 200 items, representing each sub-category of the assemblage. Each sampled item was studied in terms of metrics (length, width, thickness, and mass) and type of blank, while information regarding patina was recorded (see below, Figs. 7–12). A similar method was applied to blanks, with a random selection of 100 items (over 13% representing every seventh item in each sub-category; see below, Figs. 13–16).

In this study, we consider a single removal as being sufficient to classify an item as a core-on-flake (Schroeder, 1969, 2007; Goren-Inbar, 1988; Ashton, 2007; Dibble and McPherron, 2007; but see Malinsky-Buller et al., 2011a for a different view). The phenomenon at Revadim clearly reveals intentional removals of single flakes from the ventral or dorsal face of the parent flake alongside parent flakes bearing multiple removals. Both COF-FFs and their resulting blanks are defined in detail from the technological perspective further below.

4. Revadim's lithic assemblage

Layer C3 is by far the richest and densest archaeological layer of the site, yielding 26,601 lithic items at an average density of 4972 items per 1 m³ (Table 1). Artifact density of Layer C3 is extraordinary not only compared to other assemblages at Revadim, but also on a much broader scale, in comparison to other Lower Paleolithic sites (e.g., Goren-Inbar, 1985; Barzilai et al., 2006; Chazan and Horwitz, 2007).

Table 1
Lithic assemblage of Revadim, an overview.

Layer	Lithic assemblage (total number of items)	Excavated area (m ²)	Excavated volume (m ³)	Average artifact density per m ³
B1	5707	72	9.32	612.3
B2	14,400	73	15.3	941.2
C3	26,601	33	5.35	4972.1
C5	1735	8	0.98	1770.4

Present at all layers and accounting for up to 6% of each assemblage (or approximately 5–14% of *débitage* in each), lithic recycling is undoubtedly a significant phenomenon at Revadim. Assemblages originating in Area C show higher proportions of recycled items compared with those originating in Area B. The lithic

assemblage of Layer C3, our subject of interest here, yielded over ten times more items than other areas ($n = 1600$ items; Table 2). Although this represents the highest frequency of recycled items per assemblage (6%), Layer C3 is only second runner in frequency of recycled items among *débitage* alone (13.6%; Table 3). Variability, scale, and intensity displayed by these lithic assemblages correlates well with other observations noted at the site of Revadim. For example, bifaces are abundant in Area B ($n = 86$) yet scarce in Area C, represented only by a few isolated items (Marder et al., 2006; Solodenko, 2010). Similarly, elephant bones are more abundant in Area B (NISP = 67) in comparison to Area C (NISP = 33) (Rabinovich et al., 2012). It is, however, possible that differences in elephant remains are the result of the relatively poor preservation of bones in Area C.

Table 2

General breakdown of Revadim's lithic assemblages *Restricted *débitage* includes flakes, cortical flakes, cores, core trimming elements, special spalls, blades, and primary element blades, and does not include recycled items and tools.

Category	Restricted <i>débitage</i> *	Debris	Recycled items	Tools	Raw material (manuports)	Total	
B1	Quantity	191	5199	24	280	13	5707
	Frequency	3%	91%	<0.1%	5%	<0.1%	100%
B2	Quantity	874	12,031	108	1321	66	14,400
	Frequency	6%	84%	1%	9%	0%	100%
C3	Quantity	7531	14,631	1600	2642	197	26,601
	Frequency	28%	55%	6%	10%	1%	100%
C5	Quantity	208	1235	73	209	10	1735
	Frequency	13%	70%	4%	12%	1%	100%

Table 3

Frequency of recycled items.

	% recycled items from assemblage	% recycled items from total <i>débitage</i>
B1	0.4%	4.8%
B2	0.8%	4.7%
C3	6.0%	13.6%
C5	4.2%	14.3%

The lithic variability characterizing Revadim also conforms to findings reported at other Acheulian sites (e.g., Sharon et al., 2011), where spatial and chronological variability characterizes technological procedures at large. These patterns seem to reflect some spatial division among activities of varied intensity during the human use of Acheulian sites. While reflecting shared cultural and technological perceptions, this variability might also be a testimony to the flexibility of Acheulian hominins in applying their technologies to specific needs and tasks. At Revadim, Area B, characterized by a relatively extended spatial distribution and lower artifact density, appears to have been dedicated to activities involving the relatively intense use of bifaces and manipulating mainly elephant and bovid carcasses taking place in a relatively short yet spatially dispersed area of activity. In contrast, Area C, characterized by a thick deposit spread over a limited extent of excavation area, displays a relatively prolonged intensive yet condensed occupation, focusing on flake production as the primary lithic technology and with a significant component of lithic recycling as a means of producing small flakes.

Three main flake production trajectories were detected at Revadim (Table 4). One trajectory is represented by the mass production of regular flakes from regular flake cores characterized by cores with a single or multiple platforms, indicating rather expedient flake production. A second trajectory manifests in the small-scale production of predetermined flakes from prepared cores,

while the third trajectory comprises the production of small flakes from COF-FFs. Altogether, 1125 regular flake cores were found at Layer C3, classified mostly into single platform cores ($n = 264$, 23.5%), double platform cores ($n = 343$, 30.5%), or cores with more than two platforms ($n = 170$, 15%). Albeit their scarcity, the presence of prepared cores in Layer C3 ($n = 54$) is nevertheless of special significance, being an Acheulian appearance of a technology commonly referred to the Middle Paleolithic Mousterian. The production of small flakes from COF-FFs in Layer C3 is relatively intense. As can be inferred from Table 4, all three flake production trajectories were practiced in all examined assemblages from both Areas B and C; however, flake production in Layer C3 seems to have practiced more intensely. This is particularly true of the production of small flakes from COF-FFs.

Table 4
Cores at Revadim and percentage out of total *débitage*.

	Simple flake cores	Prepared cores	Core-on-flakes/flaked flakes (COF-FF)	Total
B1	17 3.4%	4 0.8%	9 1.8%	30 6.1%
B2	140 6.1%	11 0.5%	49 2.1%	200 8.7%
C3	1125 9.6%	54 0.5%	818 6.9%	1997 17.0%
C5	32 4.9%	8 1.6%	31 6.1%	63 12.3%

5. Small flake production from the perspective of recycling

The production of small flakes from COF-FFs is wide-scaled at Revadim, manifested in all areas and all studied layers, albeit in different intensities. Both parties to the recycling process trajectory are recognized at Revadim. Items used for recycling are the COF-FFs, that is, flakes which were recycled into cores for the production of small flakes. The products of this process are blanks produced from such COF-FFs. A total of 1600 items represents the lithic recycling category in Layer C3. This category comprises 818 COF-FFs and 782 blanks produced from COF-FFs (see Tables 5 and 6 respectively). These items were defined in this study as follows.

Table 5
Quantity and frequency of COF-FF categories.

COF-FF	Total	% of total
Ventral removals	449	55%
Dorsal removals	141	17%
Combined	129	16%
Varia	99	12%
Total	818	100%

Table 6
Quantity and frequency of recycled blank categories.

Blanks produced from COF-FFs	Total	% of total
Regular double ventral flakes	54	7%
Double ventral flakes – varia	241	31%
Double-bulb double ventral “Kombewa” flakes	29	4%
“Tabun snap” items	22	3%
Double-bulb double ventral flakes – Varia	436	56%
Total	782	100%

5.1. Technological definitions

5.1.1. COF-FFs

A COF-FF is a flake from which one or more small flakes were removed. The removal was conducted from one or both faces of the parent flake. A parent flake is a flake that was produced during a previous reduction stage for a purpose other than its transformation into a core. Such parent flakes could have produced either on- or off-site, e.g., a flake collected from an earlier occupation within the site or brought from elsewhere to the site probably in order to be recycled. Removals from the parent flake were conducted with or without platform preparations. This category is further divided into four sub-categories: COF-FFs with ventral removals, dorsal removals, combined removals, and varia.

5.1.1.1. COF-FFs with ventral removals (Figs. 2–3). The removal of one or more small flakes from the ventral surface of the parent flake, i.e., the removal was executed from the dorsal surface towards the ventral face. At the current stage of the analysis we did not separate between ventral and ventral-lateral COF-FFs, that is, removals which carried part of the lateral edge of the COF-FF in addition to parts of its original ventral face.

5.1.1.2. COF-FFs with dorsal removals (Figs. 4–5). The removal of one or more small flakes from the dorsal surface of a parent flake, i.e., the removal was executed from the ventral surface towards the dorsal surface. Dorsal removals at Revadim were usually applied without platform preparations resulting in items that are clearly distinguished from Nahr Ibrahim artefacts (Solecki and Solecki, 1970) and truncated-faceted items (Schroeder, 1969, 2007; Nishiaki, 1985). Similar Paleolithic items sometimes classified as “Clactonian notches” (Ashton, 2007), also boast a single dorsal removal, would be more adequately classified as cores-on-flake and regarded as part of the recycling trajectory. Some of these items, however, might as well represent tools shaped by the removal of items from the dorsal surface of the blank. Further studies, especially regarding traces of use-wear, are needed to clarify this issue.

5.1.1.3. COF-FFs with combined removals (Fig. 6). These involve removal of two or more small flakes from both ventral and dorsal surfaces of the parent flake. In some cases, the ventral and dorsal removals are related to each other, that is, one served as the striking platform for the other, while in other cases the two removals are isolated and unrelated.

5.1.1.4. Varia (Fig. 7). The varia category comprises items from which were removed one or more small flakes and which do not correspond to any of the above categories. A more thorough classification of these items is yet to be performed.

5.1.2. Blanks produced from COF-FFs

Blanks produced from COF-FFs are items that were removed from a parent flake and are identifiable as such. It is clear that a significant portion of this category, and especially blanks removed from the dorsal surface, are not discernible from ordinary flakes and, indeed, such items were not included in this category. This group is further divided into two sub-categories: double ventral flakes and double-bulb double ventral flakes.

5.1.2.1. Double ventral flakes (Fig. 8). These are flakes displaying two ventral surfaces that were removed from the ventral surface of the larger parent flake. The bulb of percussion is observed only on the last ventral surface – the actual ventral surface of the item – while the other ventral surface represents part of the ventral

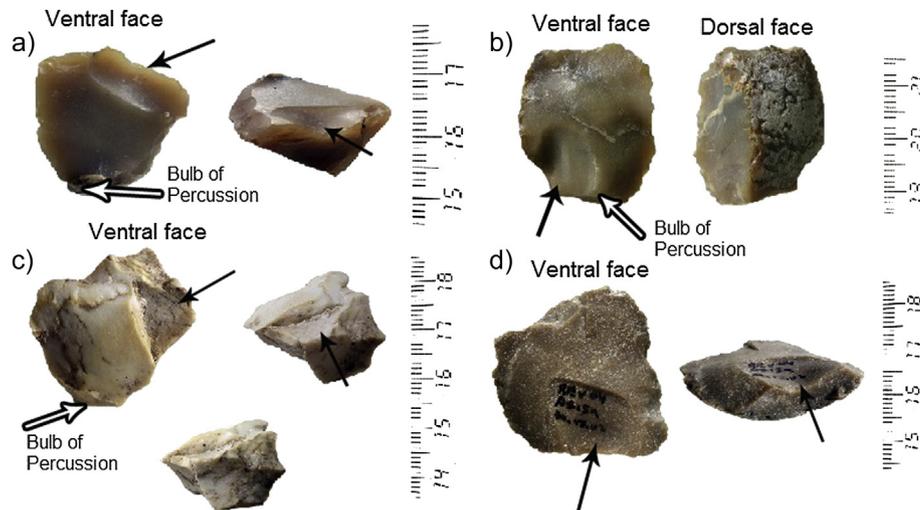


Fig. 2. COF-FFs displaying single ventral removals; Black arrows point at scars resulting from the removal of small flakes while white arrows point at bulbs of percussion.

surface of the parent flake without the original bulb of percussion. This category can be further divided into two subcategories: regular double ventral flakes and varia.

5.1.2.2. Double-bulb double ventral flakes (Fig. 9). These are flakes displaying two ventral surfaces and two bulbs of percussion, one on each of the two ventral surfaces (as opposed to “double impact” or “double cone” items that have two bulbs on the same ventral surface, one next to the other). These items were removed from the ventral surface of the parent flake, taking with them the original bulb of percussion of that flake. This category is further subdivided into three groups: double bulb double ventral Kombewa items, Tabun snap items, and varia.

Double ventral Kombewa items were removed from the ventral surface of the COF-FF, taking with them the original bulb of

percussion of the parent flake. These are usually double-convex in profile and rather sharp and thin at the edges. Tabun snap items resemble items from Tabun Cave, defined as “flakes with two bulbs of percussion, often characterized by thicker butts. The Tabun snap consists of removing the proximal end of a blank by a blow invariably given from the dorsal face” (Shifroni and Ronen, 2000). The varia category includes items with two ventral surfaces and two bulbs of percussion, which do not correspond any of these definitions.

5.2. Attribute analysis

We studied in detail the attributes of a sample of 200 COF-FFs and 100 blanks produced from COF-FFs (see above) in order to characterize these items and tackle the question whether flakes

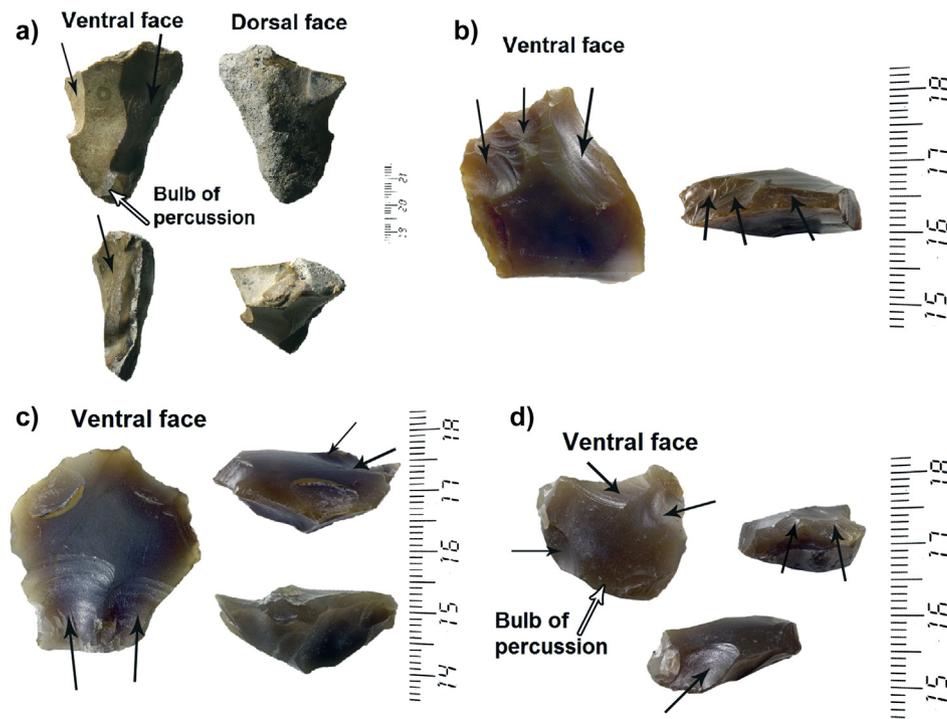


Fig. 3. COF-FFs displaying multiple ventral removals; Black arrows point at scars resulting from the removal of small flakes while white arrows point at bulbs of percussion.

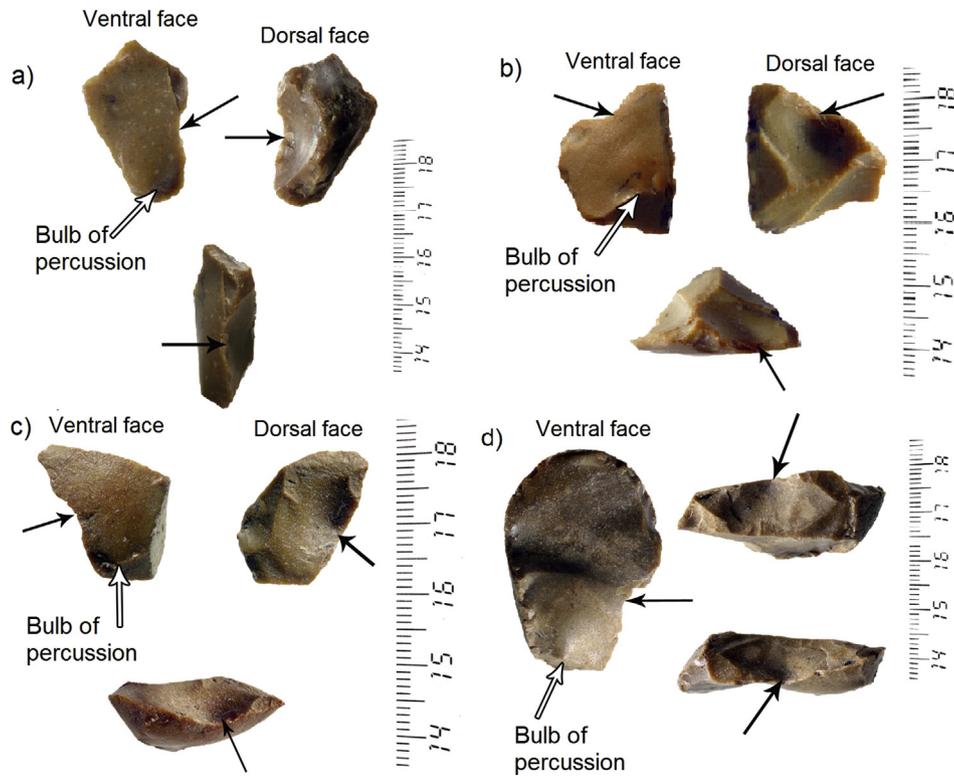


Fig. 4. COF-FFs displaying a single dorsal removal; black arrows point at scars resulting from the removal of small flakes while white arrows point at bulbs of percussion.

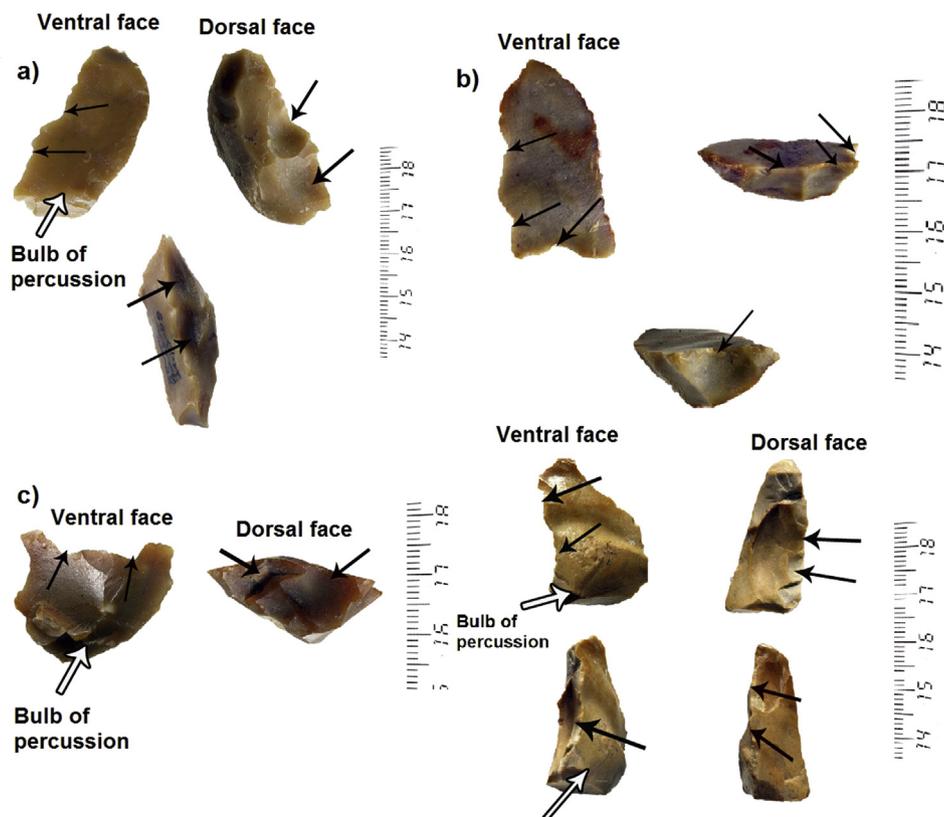


Fig. 5. COF-FFs displaying multiple dorsal removals; Black arrows point at scars resulting from the removal of small flakes while white arrows point at bulbs of percussion.

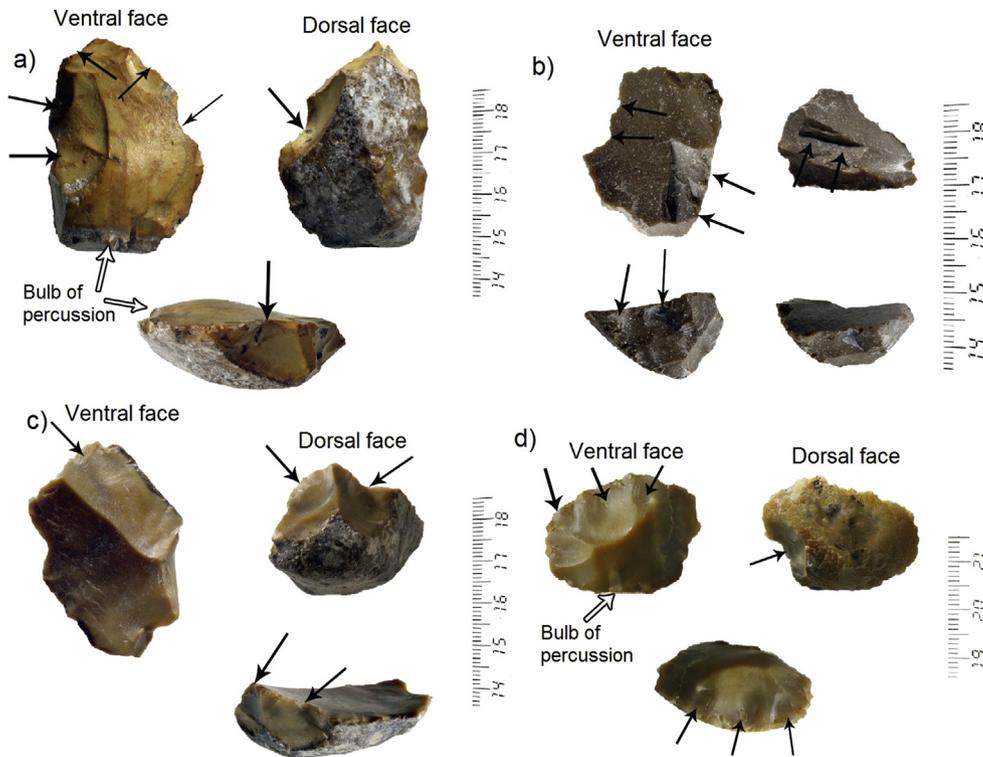


Fig. 6. COF-displaying combined removals from both the ventral and dorsal faces; Black arrows point at scars resulting from the removal of small flakes while white arrows point at bulbs of percussion; Item (d) reflects differences in patination between the original blank and the later removals of the small flakes.

were purposefully produced in order to be transformed into COF-FFs or alternatively were collected from the readily available blanks on or off site. Parameters studied included length, width, mass, and thickness for both COF-FFs and blanks produced from COF-FFs. We also studied type of blank and patina for COF-FFs. The results of this attribute analysis are presented below.

5.2.1. COF-FF general overview

The average length of sampled COF-FFs is 3.2 cm (median value – 3.0 cm). The average width is 2.9 cm (median – 2.8 cm), and the average thickness is 1.4 cm (median – 1.3 cm). Average mass of sampled COF-FFs is 15.3 g (median – 11.0 g).

5.2.2. COF-FF blanks (Fig. 10)

The large majority of blanks among the sampled COF-FFs were made of cortical flakes (43.5%, $n = 87$) and flakes (31.5%, $n = 63$). Other blanks comprised core trimming elements (8.5%, $n = 17$),

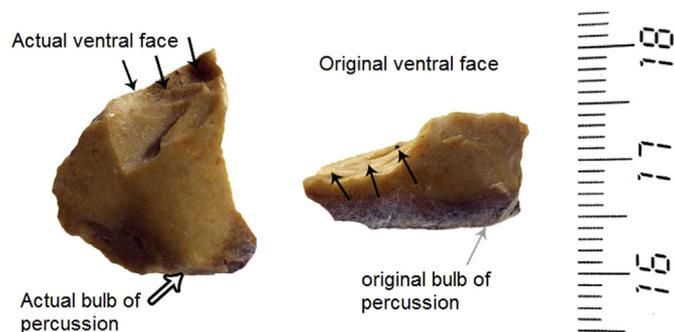


Fig. 7. COF-FF of the varia category made on a double bulb double ventral flake blank, representing double recycling or the recycling of a recycled item aimed to produce small flakes; Full-line arrows point at scars resulting from the removal of small flakes while dotted arrows point at actual bulbs of percussion and dashed lines point at original bulbs of percussion.

shaped tools (5.5%, $n = 11$), and items removed from such shaped tools (7%, $n = 14$) by way of resharpener, reworking, and recycling (special waste, such as biface spalls and burin spalls). The blanks of eight items (4%) could not be determined. The results clearly indicate that while primary and regular flakes were clearly preferred for the production of COF-FFs, in fact, this preference is accentuated when considering that flakes ($n = 3210$) and cortical flakes ($n = 1981$) constitute only 43% out of the entire assemblage of Layer C3 (excluding debris). Nevertheless, items produced in other production trajectories (tools, CTEs, special spalls) made a significant contribution to COF-FF blanks, together amounting to about a quarter of input items. The proportions of CTEs and special spalls are closer to their proportion among the general assemblage, excluding debris, (CTEs – 8% ($n = 1013$); special spalls – 6.6% ($n = 788$)). Tools, on the other hand, are less frequent in the sample, while constituting 22% ($n = 2642$) of the general *débitage*. The variety of blanks indicates that blanks subsequently used as COF-FFs were not manufactured specifically towards this end but rather were selected from blanks available at the site.

5.2.3. COF-FF length (Fig. 11)

COF-FFs range in length from very small (shorter than 2 cm) to very long (5–8 cm long), most aggregating between 2 and 3 cm long (38.5%, $n = 77$) and 3–4 cm long (35.5%, $n = 71$). Only few COF-FFs are particularly short (under 2 cm: 6%, $n = 12$) or particularly long (4–5 cm: 14.5%, $n = 29$; 5–8 cm: 5.5%, $n = 11$). Blanks exhibit a similar preference with 75% ($n = 148$) aggregating at 2–4 cm long. With this wide range of blank lengths selected for the purpose of producing small flakes, no length standard is apparent.

5.2.4. COF-FF width (Fig. 12)

Preferred width for COF-FFs, appears to range at 2–3 cm (50.5%, $n = 101$) or 3–4 cm (30.5%, $n = 61$). A fifth of all COF-FFs are either

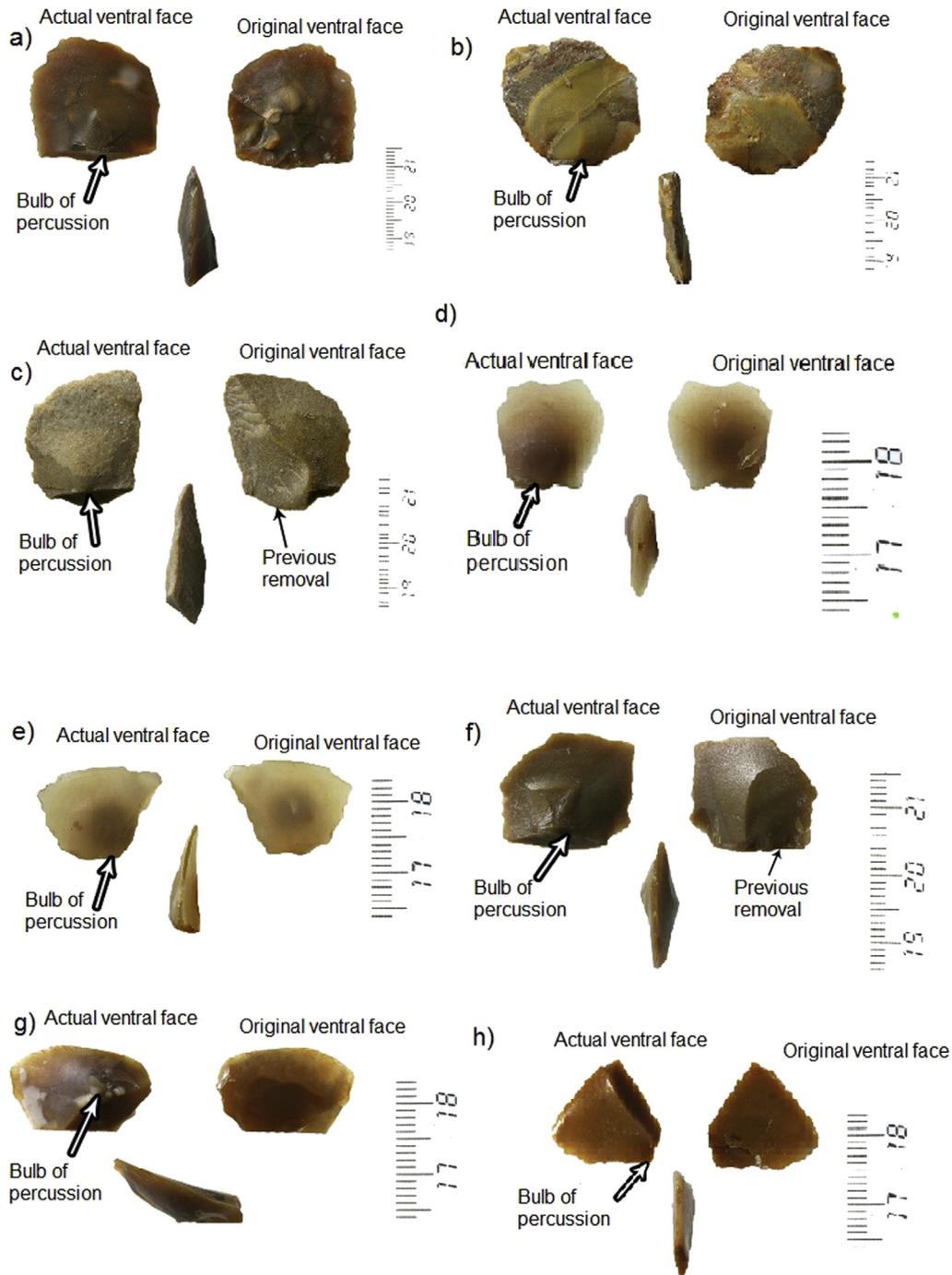


Fig. 8. Double ventral flake blanks produced from COF-FFs: (a–f) regular double ventral flakes; (g–h) double ventral flakes from the varia category; White arrows point at the bulbs of percussion and black arrows point at scars of previous removals.

very narrow (less than 2 cm: 11.5%, $n = 23$) or relatively wide (4–5 cm: 5%, $n = 10$; 5–8 cm: 2.5%, $n = 5$). Blanks exhibit a similar preference ranging 2–4 cm wide ($n = 162$, 81%). The rest show a wide variation in width indicating flexible selection of blanks to be transformed into COF-FFs.

5.2.5. COF-FF mass (Fig. 13)

The mass of sampled COF-FFs varies significantly. Over a third are 5–9 g (37%, $n = 74$) and about a quarter are 10–14 g (28%, $n = 55$) while the remainder span numerous mass groups, mostly heavier than 15 g with a few items that are lighter than 4 g.

5.2.6. COF-FF thickness (Fig. 14)

COF-FFs are also widely distributed among thickness category. One third of the sampled COF-FFs are 1.3–1.6 cm thick (32%, $n = 64$), just under a third are 1–1.3 cm thick (30%, $n = 60$), while the remainder are either considerably thicker (1.6–3 cm: 26.5%, $n = 53$), or very thin (0.5–1 cm (11.5%, $n = 23$).

5.2.7. COF-FF patina (Fig. 15)

The presence of patina and post-patina removals display interesting trends among the sampled COF-FFs. A quarter of the COF-FFs (24%, $n = 48$) show differences in patina between the COF-FF itself

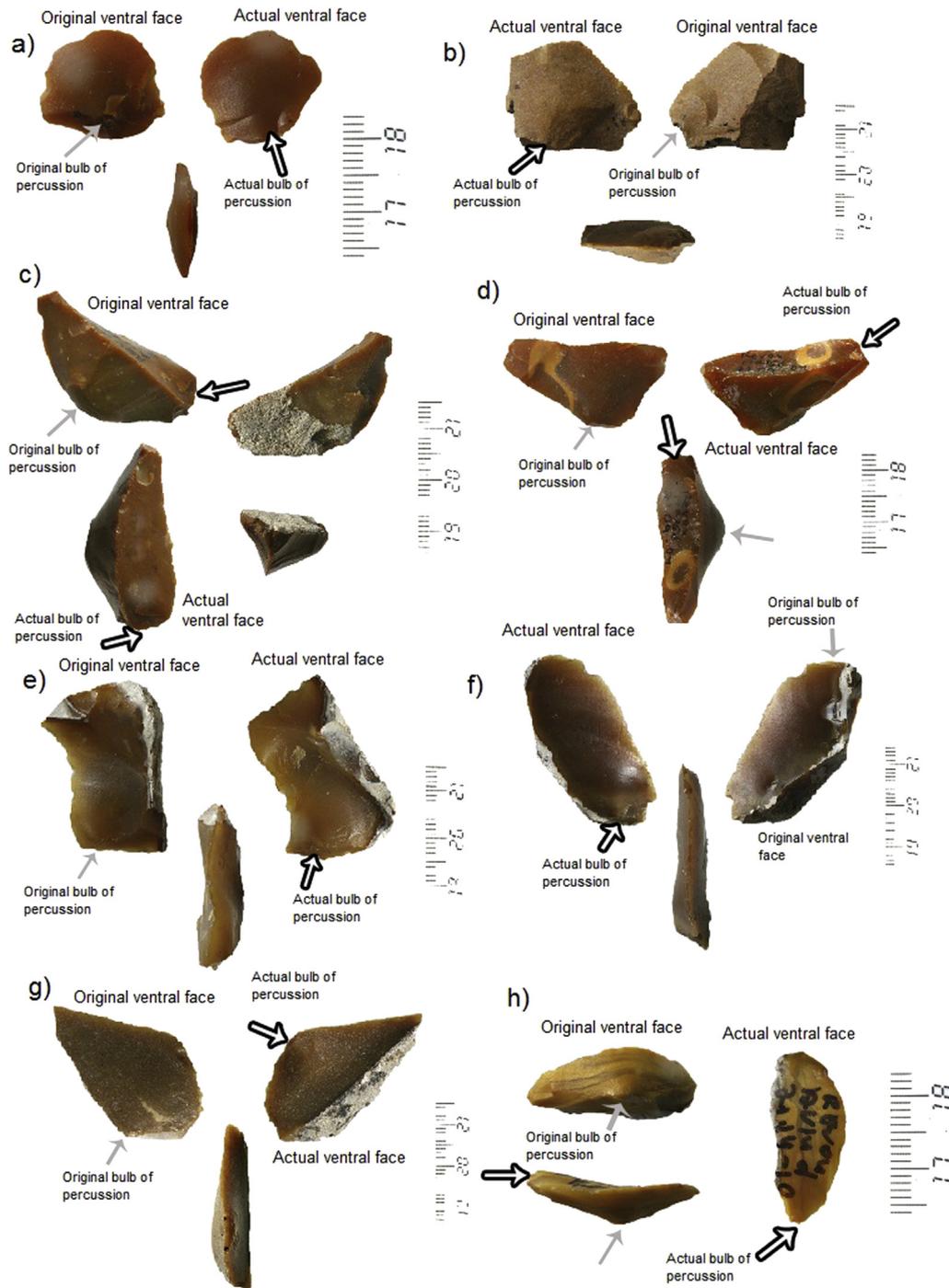


Fig. 9. Double bulb double ventral flake blanks produced from COF-FFs: (a–b) double ventral Kombewa; (c–d) Tabun snap items; (e–h) varia; White arrows mark the actual bulb of percussion, while grey arrows point at actual bulbs of percussion.

and the scars left from the removal of the small flake(s) from it, indicating that these old blanks that were produced and used some time before their new role as COF-FFs. Most of the COF-FFs (76%, $n = 152$), however, show no patina differences to the naked eye between the COF-FFs and later scars of removals, attesting to a choice of fairly fresh blanks as COF-FFs, originating from knapping episodes rather close in time between the moment of their selection and their transformation into COF-FFs. More details, however, are to be expected while these items will be analyzed under the microscope.

5.2.8. COF-FF analysis summary

No specific blank types appear to have been purposely produced for their role as COF-FFs. In our view, the accumulated data presented above indicate that blanks selected to become COF-FFs were mostly chosen among blanks that were already available (and likely produced) at Revadim. This view is further supported by the fact that a significant portion of the sampled COF-FFs indicate the use of old, patinated flakes, enabling the characterization of this small flake production trajectory from COF-FFs as a process of recycling. Selection preferences were rather flexible, including a wide variety

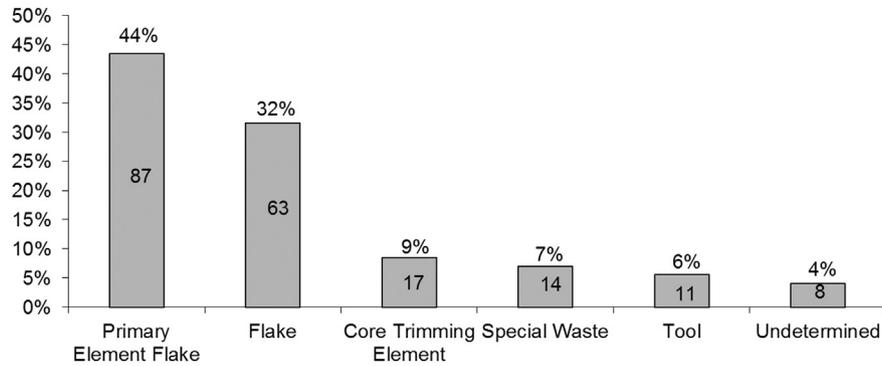


Fig. 10. Quantity and frequency distribution among COF-FF blank types.

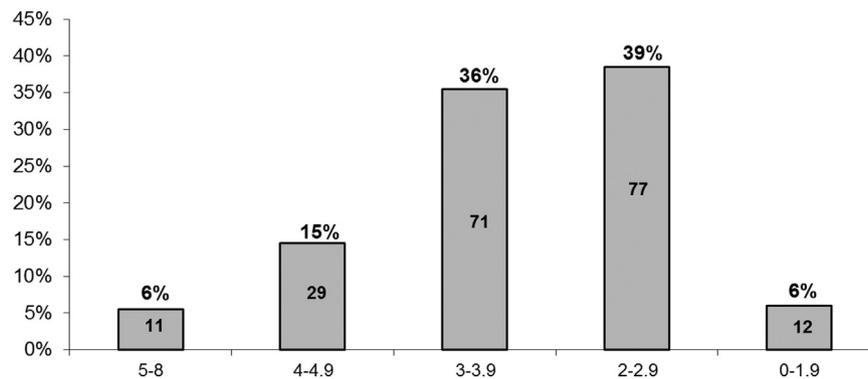


Fig. 11. Quantity and frequency of COF-FF length classes (in cm).

of blank types, sizes, and masses. Notwithstanding, the preferred blanks were flakes and cortical flakes that were 2–4 cm long and 1–1.6 cm thick.

Since 100 products (blanks) manufactured from COF-FFs were sampled for the purpose of attribute analysis, frequency and distribution are identical in numbers and are not repeated.

5.2.9. Blanks general overview

The average length of sampled blanks produced from COF-FFs is 2.2 cm (median value – 2.2 cm). The average width is 2.9 cm (median – 2.8 cm), the average thickness is 0.8 cm (median – 0.8 cm), and the average mass of sampled COF-FFs is 5.2 g (median – 3.0 g).

5.2.10. Blank length (Fig. 16)

A large majority of sampled blanks range between 1 and 3 cm in length (73%), while the remainder are either very short (under 1 cm: 7%) or rather long (3–4 cm: 13%; 4–5 cm: 7%).

5.2.11. Blank width (Fig. 17)

Blanks produced from COF-FFs are mostly 1–2 cm wide (58%) and 2–3 cm wide (23%). Remaining items are either very thin (under 1 cm: 8%) or relatively wide (3–4 cm: 9%; 4–5 cm: 2%).

5.2.12. Blank mass (Fig. 18)

Less than half of the blanks produced from COF-FFs are under 3 g (42%) while just over a quarter are 3–6 g (28%), and another

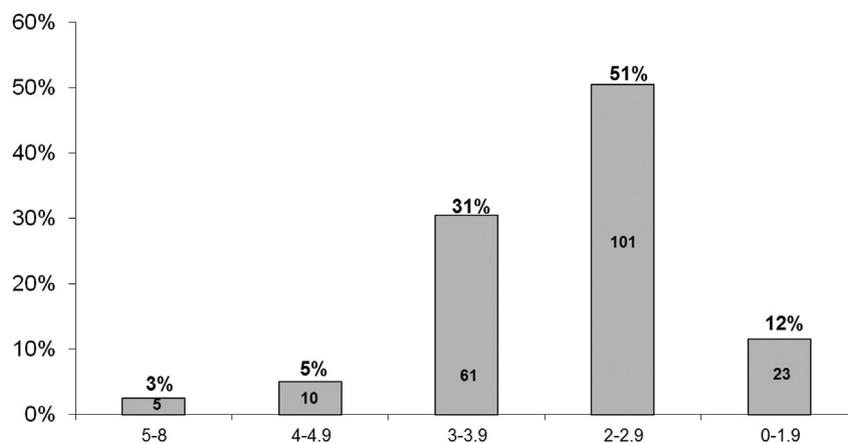


Fig. 12. Quantity and frequency of COF-FF width classes (in cm).

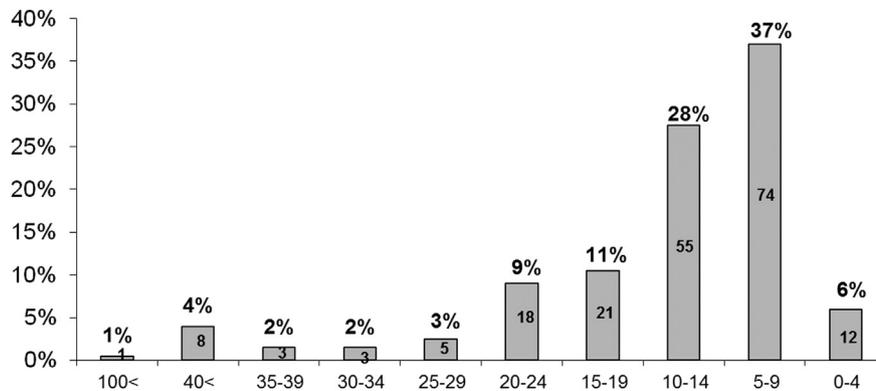


Fig. 13. Quantity and frequency of COF-FF mass classes (in g).

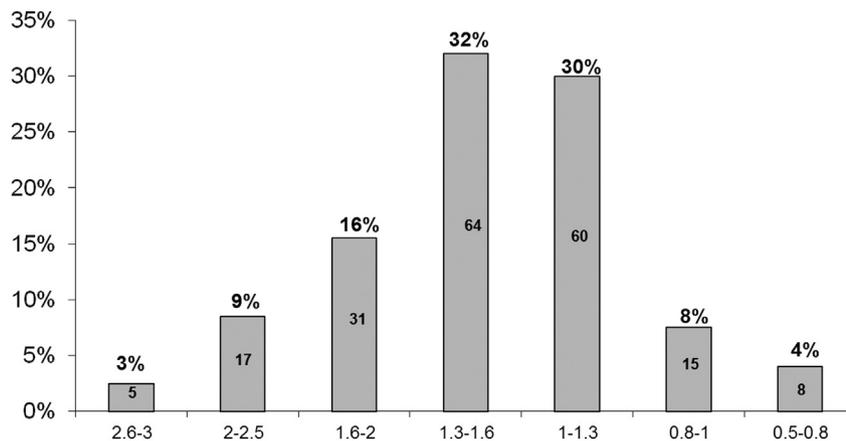


Fig. 14. Quantity and frequency of COF-FF thickness classes (in cm).

noticeable group are 6–9 g (13%). The rest are divided almost equally between mass classes of 9–12 g (6%), 12–18 g (5%), and over 18 g (6%).

5.2.13. Blank thickness (Fig. 19)

Blanks produced from COF-FFs are typically very thin ranging from under 0.5 cm (27%) to 0.5–0.8 cm (23%) while the rest decrease in rate among heavier mass classes: 0.8–1 cm (16%), 1–1.3 cm (17%), 1.3–1.6 cm (11%), 1.6–2 cm (6%).

5.2.14. Blank summary

Generally speaking, most of the blanks produced from COF-FFs are relatively small (~1–3 cm in length and width) and thin (<1 cm thick) resulting in a majority of blanks less than 6 g.

Evidently, there is some miscorrelation between the dimensions of sampled COF-FFs and the dimensions of sampled blanks produced from COF-FFs. It seems that some of the sampled blanks are larger than the scars present on the COF-FFs. This issue will be thoroughly analyzed in future study, by means of detailed analysis of all COF-FFs and blanks produced from COF-FFs from layer C3.

6. Discussion

The COF-FF production trajectory at Revadim is a distinct and profound phenomenon. Preliminary use-wear analysis of a selection of blanks produced from COF-FFs at Revadim identified edge removals suggesting the processing of medium to soft materials (Lemorini, personal communication). The COF-FF technological

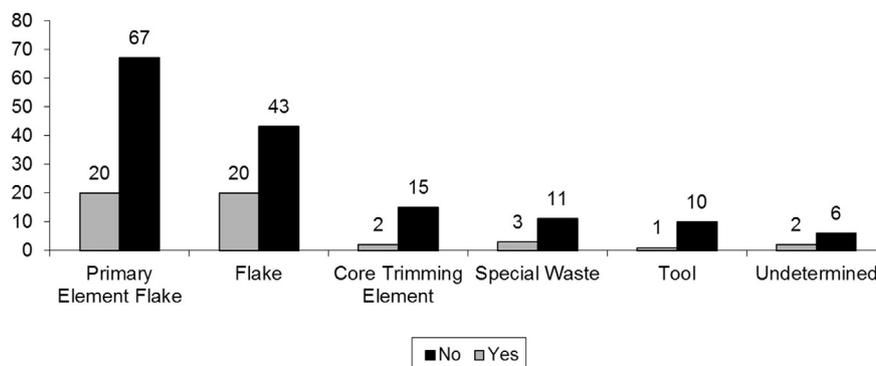


Fig. 15. Distribution of sampled COF-FFs according to blank and presence of post-patina removals.

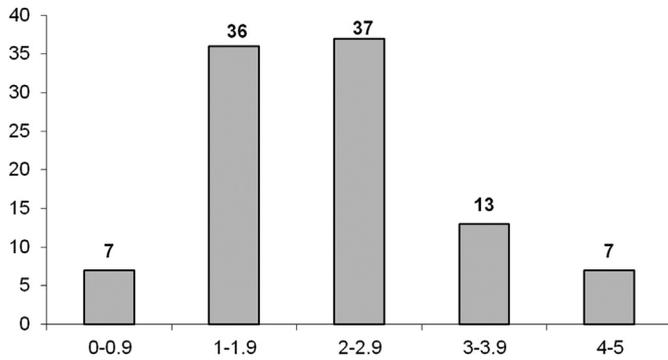


Fig. 16. Quantity and frequency distribution of length classes (in cm) among blanks produced from COF-FFs.

system, however, is yet to be studied in detail including a thorough use-wear analysis before possible interpretations of the Revadim findings may be put forth. The following discussion, therefore, will present other evidence for the production and use of small flakes at Lower Paleolithic sites, and through these we shall suggest our view of this phenomenon at large.

The production of small flakes from parent flakes is well documented in Lower Paleolithic contexts. At Qesem Cave, an Acheulo-Yabrudian (Late Lower Paleolithic) site in Israel, tiny flakes produced from COF-FFs were identified and studied for use-wear analysis, indicating their use mostly in butchery activity (Barkai et al., 2010). The manufacture of very small flakes (<2 cm) in a systematic secondary knapping process was also detected in the Lower Paleolithic site of Bizat Ruhama (Zaidner et al., 2010; Zaidner, 2013). Secondary knapped flakes were further documented in the Western European Mode 1 sites of Happisburgh 3 (Great Britain), Gran Dolina Level TD6 (Spain), and Vallparadís (Spain) as well as Western European Mode 2 sites of Isernia la Pineta (Italy), Notarchirico (Italy), la Niora (Loire river basin, France), and the “P” levels of Caune de l’Arago (France) (see details in Barsky et al., 2013).

In our view, small flakes produced from parent flakes in the archaeological record may be explained in one of two manners: either the flaked-flake itself can be conceived as a core for the production of small flakes, or, alternatively, the COF-FF could be seen as an actual tool by itself, while the small flakes produced from it represent by-products of the process (Ashton et al., 1991). Small, sharp flakes appear to be easily produced from parent flakes requiring little if any preparation. Based on use-wear traces on COF-FFs produced at Qesem Cave and the wide range of activities they attest to in processing soft to medium materials, most likely involving butchery activity (Barkai et al., 2010; Lemorini et al., in

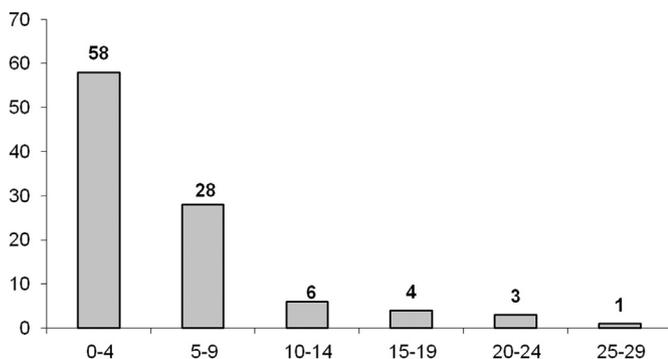


Fig. 17. Quantity and frequency distribution of mass classes (in g) among blanks produced from COF-FFs.

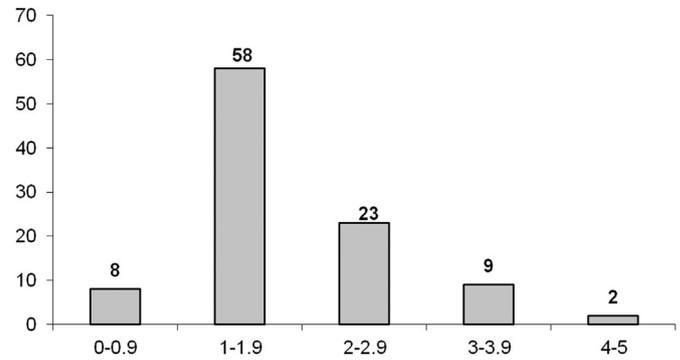


Fig. 18. Quantity and frequency distribution of width classes (in cm) among blanks produced from COF-FFs.

this volume), coupled with the preliminary observations of the Revadim material, we regard blanks produced from COF-FFs as a desired end-product.

The association of elephant bones with the systematic manufacture and use of small sharp flakes in Acheulian sites, clearly manifested at Revadim, should also be mentioned and emphasized. Cut marks were identified at Revadim on two ribs and the scapula of an elephant, indicating that elephants were butchered at the site. Elephants are the most dominant animal taxa within the faunal assemblage of the site, represented by 155 NISP (Rabinovich et al., 2012). The possible association between elephant butchery and small flakes produced at Revadim, therefore, should not be overlooked. Similarly, these small flakes may have been involved in the manipulation of other taxa at the site and under the umbrella of activities other than meat cutting.

Aside from Revadim, elephants' remains were associated with a small flake production industry in numerous Acheulian sites. The site of Evron, an Acheulian site in Northern Israel, produced a rich faunal assemblage, including the remains of two types of elephants (*Elephas* and *Stegodon*). The lithic assemblage of the site is characterized by an industry of tools produced on small flakes, which were related to heavy duty activities, possibly including butchery (Chazan, 2013). Excavations at La Ficoncella (Northern Latium, Central Italy), a Middle Pleistocene site, have yielded remains of straight-tusked elephants, along with a scanty lithic assemblage, indicating human presence at the site. It should be emphasized that three out of the four lithic items at this site are less than 20 mm in length (Aureli et al., 2012). La Polledrara di Ceganibbio is another Middle Pleistocene site in Central Italy whose faunal assemblage is dominated by large mammals, especially *P. antiquus*. The lithic assemblage of this site seems to represent all the phases of the

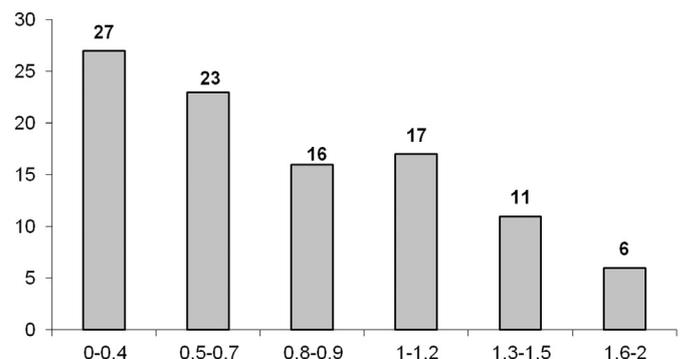


Fig. 19. Quantity and frequency distribution of thickness classes (in cm) among blanks produced from COF-FFs.

reduction sequence directed at the manufacture of small sized (~4–5 cm) flakes with sharp edges. Use-wear analysis showed traces related to butchering activities (Anzidei et al., 2012).

The simultaneous appearance of elephant remains (as well as other taxa) and small flakes production trajectories is repeated in the Lower Paleolithic archaeological record. In some cases, these small flakes have been shown to be related to butchery. While preliminary use-wear analysis of products removed from COF-FFs at Revadim indicates the probable processing of soft to medium materials, further analysis is required to better define the use of these small flakes. Notwithstanding, the dominant presence of elephant bones, alongside other taxa, and their association with the repetitive production of small flakes from parent flakes, suggest that these two phenomena might have been related. These small flakes would have been used not only for the exploitation of elephant carcasses but also that of other prey. It is, however, clear that these small flakes could have also been used for a large variety of non-butchery tasks such as the utilization of vegetal material and plants, an important part of hominin diet and subsistence strategies evident through both ethnoarchaeological and archaeological data (Sept, 1986, 1992; Alpersen-Afil et al., 2009; Hardy et al., 2012, 2013).

7. Conclusions

Lithic recycling at Revadim appears throughout all areas and in all layers and in significant proportions in some of the examined assemblages. Lithic recycling is regarded as a routine procedure at Revadim performed throughout time and space at the site. Although different flakes production techniques appear in all areas and layers, their scales and intensities vary widely. The fact that recycling was practiced at different intensities between the different layers and areas may suggest variation in the scale and intensity of human activities at each of these layers.

The variation in metric attributes detected among studied samples implies that the blanks which were used as COF-FFs were not intentionally produced for that purpose but rather were collected in a separate process, at a stage considerably subsequent to their production, from the array of blanks available on-site or even off site. This proposition is based, among others, on the fact that about one quarter (24%) of the sampled COF-FFs presents different degrees of patina between the original blank and subsequent removals of small flakes from these blanks. This suggests the existence of a clear practice of lithic recycling rather than a single *chaîne opératoire* originating with the intentional production of the parent flake and directed towards the production of small flakes.

The significant use of cortical flakes as COF-FFs (87 sampled items, representing 44% of all sampled items) merits some attention. The presence of cortex on a flake can be perceived as an indicator of core reduction, or primary exploitation and transportation of raw material (Dibble et al., 2005). Therefore, the repeated use of cortical flakes as COF-FFs may be interpreted as the maximization of the available lithic material, exploiting flint items that otherwise would have not been used.

The manufacture of small flakes at Revadim involved a wide variety of parent blanks in terms of both types and size. Patinated blanks indicate the existence of a unique lithic recycling process within the site of Revadim, performed in a rather flexible procedure. This process appears to have been based on available material within the site and aimed at the production of small flakes, typically 1–3 cm long, 1–2 cm wide, and lighter than 3 g. These small flakes may have been used in butchery activities, as implied by similar items from other Lower Paleolithic sites (e.g., Barkai et al., 2010).

It is our opinion that lithic recycling was a basic and common practice at Revadim and that it should be regarded as an integral

component of Acheulian lithic technology at large. Furthermore, the appearance of lithic recycling in both Late Acheulian and Acheulo-Yabrudian assemblages, as is clearly demonstrated by assemblages recovered at both Revadim and Qesem Cave (Assaf et al., in this volume; Parush et al., in this volume), suggests that lithic recycling was a fundamental and common Lower Paleolithic technology serving specific activities in the Levant and beyond.

Acknowledgments

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