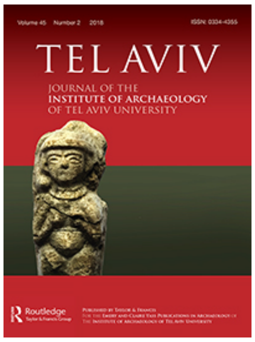

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Small Flake Acheulian: Further Insights into Lithic Recycling at Late Acheulian Revadim, Israel

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The multi-layered Lower Paleolithic Late Acheulian site of Revadim has yielded rich lithic assemblages, including dozens of handaxes. These lithic assemblages are for the most part dominated by flake-production technologies and flake tools, as is the rule of thumb at many other Acheulian localities. This study presents the results of an analysis of Layer C3 at Revadim, focusing on several newly-explored aspects of the production of small, sharp flakes by means of lithic recycling. We present definitions of new typo-technological categories of cores-on-flakes and the small flakes produced from cores-on-flakes. We also present a typo-technological analysis of the tool types detected in the Layer C3 assemblage and provide an analysis of the degree of homogeneity of the flint types used for the manufacture of these small, sharp flakes. Our results demonstrate that the technological repertoire of Late Acheulian hominins was more complex than is commonly acknowledged, and that production of small flakes was an integral component within Lower Paleolithic technologies and activities.

Keywords Late Acheulian, Revadim, Lower Paleolithic, Lithic recycling, Cores-on-flake, Flake production

The Acheulian cultural complex is characterized by significant transformations in human behaviour (the use of fire, colonization of new landscapes, big-game hunting and more) as well as diversity and variability in lithic technology (the adoption of the Levallois method, the use of soft hammers, etc.). Several of these transformations seem to have accelerated particularly towards the end of the Lower Paleolithic (e.g., Barkai and Gopher 2013). The present study demonstrates new aspects of one of the expressions of Acheulian lithic and behavioural diversity—the manufacture of small flakes by means of lithic recycling, as demonstrated in the lithic assemblage of Layer C3 at the Late Acheulian site of Revadim, Israel.

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The efficiency of small flakes was advocated in the past (e.g., Key and Lycett 2014a, 2014b), and their actual use was detected at several Lower Paleolithic archaeological sites (e.g., Barkai, Lemorini and Gopher 2010; Zaidner, Yeshurun and Mallol 2010; Lemorini *et al.* 2015).

As described by Vaquero (2011), and highlighted during a workshop in 2013 (Barkai, Lemorini and Vaquero 2015), the recycling of previously-discarded lithic artefacts to produce small flakes was a common practice during the Paleolithic. While some scholars define similar phenomena differently (e.g., Bourguignon *et al.* 2004; Mathias 2016), lithic recycling has been defined and described at several archaeological sites.[1]

Previous studies demonstrated a recurrent presence of small flakes produced from larger cores-on-flakes (also described as 'parent flakes') at Lower Paleolithic Revadim (Malinsky-Buller, Grosman and Marder 2011). In a study published recently (Agam, Marder and Barkai 2015) we presented preliminary results of a lithic analysis revealing the mechanisms of small flake production by means of lithic recycling at the site, a trajectory we termed *cores-on-flakes/flaked flakes* (henceforth: COF-FFs), following the description of Ashton, Dean and McNabb (1991). The Blanks produced from these COF-FFs (henceforth termed BPFCs), were classified following the definitions applied in the study of lithic recycling at the Acheulo-Yabrudian site of Qesem Cave (Parush *et al.* 2015). In the work presented here we deepen our examination, providing new results in three aspects:

- A detailed classification of the BPFCs, including the description of new types, presented here for the first time.
- Preliminary results of a flint type classification for the COF-FFs and the BPFCs, focusing on the degree of homogeneity.
- A detailed analysis of tool types identified in the Layer C3 assemblage, with an emphasis on aspects of lithic recycling.

Lithic recycling—towards a definition

Until recently, lithic recycling received little attention, mostly because it is difficult to detect in the archaeological record (Vaquero 2011). The growing interest in the subject has led to the publication of studies defining this phenomenon, and an international workshop dealing with Paleolithic recycling took place in Tel Aviv in 2013 (Barkai *et al.* 2015). While Odell (1996: 59) claims that "recycling is a concept that is too difficult to characterize adequately in interpreting the archaeological record", many authors have been successful in studying lithic recycling in recent years.

Schiffer (1972) defines recycling as the exploitation of an old item whose use has ended in order to manufacture a new item, either of the same type, or a different one. Parush *et al.* (2015: 61) define recycling as "a behavior that implies successive stages of modification and use of an artefact", but with an emphasis on the purpose as being "different than the

1 The early Lower Paleolithic: e.g., Zaidner 2013; Barsky *et al.* 2015; the Late Lower Paleolithic: e.g., Agam, Marder and Barkai 2015; Parush *et al*. 2015; Shimelmitz 2015; the Middle Paleolithic: e.g., Nishiaki 1985; Goren-Inbar 1988; Schroeder 2007; Vaquero 2011; Vaquero *et al*. 2015; Wojtczak 2015; the Upper Paleolithic: e.g., Vaquero *et al*. 2015; Belfer-Cohen and Bar-Yosef 2015.

original one". The significance of change in function for the definition of recycling is also stressed by Camilli and Ebert (1992). Parush *et al.* (2015) mention the importance of a phase of discard between the two stages of exploitation, as do Preysler *et al.* (2015), or as stated by Vaquero (2011: 115): "Recycling is not an extension of the use-life of the artefact, but the beginning of a secondary use-life after the first one has ended".[2]

Amick (2007) emphasizes the significance of a modification process in the definition of recycling. He mentions two trajectories of lithic recycling: (1) the use of existing tools (often worn or discarded) for the manufacture of usable flakes or a different type of tool; (2) the 'scavenging' of lithic artefacts from the archaeological record, to be reused, reworked or transformed into cores. According to Amick (2007: 223), "lithic recycling is recognized as the key mechanism for reversing the flow of the lithic reduction process as waste materials can again become usable resources".

Amick further claims that Paleolithic recycling is not motivated by ecological perceptions of past hominins, but, rather, mostly by the need to maximize sources and optimize efficiency (2015).

Bamforth (1986) considers recycling as one aspect of curation practices, along with maintenance. He argues that both aspects are closely related to lithic material availability and questions why there would be a need to transport tools when raw materials were ubiquitously available (1986: 40). Several other scholars also suggest a link between lithic recycling and a situation of scarcity of lithic materials (e.g., Vaquero *et al.* 2015). However, since lithic recycling might involve a stage of discard (Wojtczak 2015), and as lithic recycling was detected at sites located in environments which have a profusion of lithic materials (e.g., Parush *et al.* 2015; Preysler *et al.* 2015; Shimelmitz 2015), perhaps it would be more suitable to relate lithic recycling to practical, social or cultural aspects (Preysler *et al.* 2015), or possibly to see it as another strategy of lithic material provisioning, which reduces the dependency on primary lithic material sources (Vaquero *et al.* 2015), rather than an outcome of scarcity.

As for Revadim, in our view the lithic recycling phenomenon should include only items that were manufactured, discarded (used or unused), and then selected to be used *in a manner different from the original*. In other words, a time gap (short, long and anything in between), as well as a change in functionality, are necessary to define lithic recycling. Differences in patina can attest for a time gap (a lack of such differences can indeed make this identification difficult), while the type of the original blank and/or the removal of old ridges/retouches can assist in identifying a change in function. The data presented below regarding the lithic assemblage of Layer C3 in Revadim follows this view.

As Vaquero *et al.* (2015) correctly stress, core-on-flakes should not be automatically associated with lithic recycling, as flakes might have been purposefully produced to serve as cores (in the framework of the concept of Ramification [see Bourguignon, Faivre and Turq 2004]). We will argue that in the case of Revadim, lithic recycling is indeed the case. As elaborated below, a significant number of the COF-FFs found at the site are covered by patina and bear post-patina removals as the result of the subsequent removal of small

[2] While Vaquero *et al*. (2015) also define lithic recycling by the presence of a discard phase, in their view, a change in function between the two use cycles is not essential.

flakes. Also, a wide variety of blank types were selected to be used as COF-FFs, implying that those items were not manufactured to be used as COF-FFs but rather selected within the large variety of existing items produced in the framework of different lithic production trajectories practiced on-site. Indeed, not all blanks used as COF-FFs bear double-patina, or, alternatively, were produced on a blank indicating a different old function. However, it should be stressed that the lack of double-patina does not necessarily indicate the absence of a time gap between the technological stages identified. Furthermore, the patinated artefacts, as well as those artefacts with a change in function, present a manufacture procedure like the one detected on pieces without either of these two characteristics. Thus, we suggest that most, if not all, COF-FFs and BPFCs have been recycled.

Revadim

Revadim is an open-air site located on the southern Coastal Plain of Israel, 40 km southeast of Tel Aviv (Fig. 1). Four seasons of excavations were conducted during the years 1996–2004 (Marder *et al.* 2011).

The site was preliminarily dated by both Paleomagnetic analyses of the geological sequence, showing normal polarity, indicating that the entire sequence is younger than 780 kyr (Marder *et al.* 2011), and Uranium series dating of carbonates covering flint artefacts, which yielded dates between 300–500 kyr (Malinsky-Buller, Grosman and Marder 2011), providing a minimum age for these artefacts. Based on the lithic and faunal assemblages, the entire anthropogenic assemblage was assigned to the Late Acheulian cultural-complex of the Levant (Marder *et al.* 2011; Rabinovich *et al.* 2012). Revadim's faunal assemblage is dominated by *Palaeoloxodon antiquus,* in addition to other mammalian species (Rabinovich *et al.* 2012.

In Area C West, which covers an area of 33 m^2, five superimposed archaeological layers were exposed, labelled C1 to C5, from top to bottom (Malinsky-Buller, Grosman and Marder *et al.* 2011). Layer C3 in Area C West, the focus of this study, is the densest layer at the site, both in terms of flint artefacts and bones (Marder, Milevski and Matskevich *et al.* 2006).

Residue and use-wear analyses of items from Area B at the site detected use-signs as well as fat residues on a handaxe and a scraper, found in association with butchered elephant remains (Solodenko *et al.* 2015, and for a review concerning elephant procurement during the Paleolithic, see Agam and Barkai 2018). These results provide one of the earliest direct evidence for meat and hide processing and consumption by early humans in the Levant.

Materials and methods

The definition of lithic recycling at Revadim presented in this study originally stemmed from the definitions suggested for the lithic recycling present at the Acheulo-Yabrudian site of Qesem Cave (Parush *et al.* 2015). However, while many similarities between the two phenomena do exist, there are also significant differences. As a result, several adjustments, along with the establishment of some new definitions, were made to fit the distinctiveness of the Revadim lithic industry.

We published a preliminarily report of our study of the lithic assemblage of Layer C3 in Agam, Marder and Barkai 2015. However, we discovered a few additional boxes of unsorted material from this layer at the Tel Aviv University storage facility These boxes

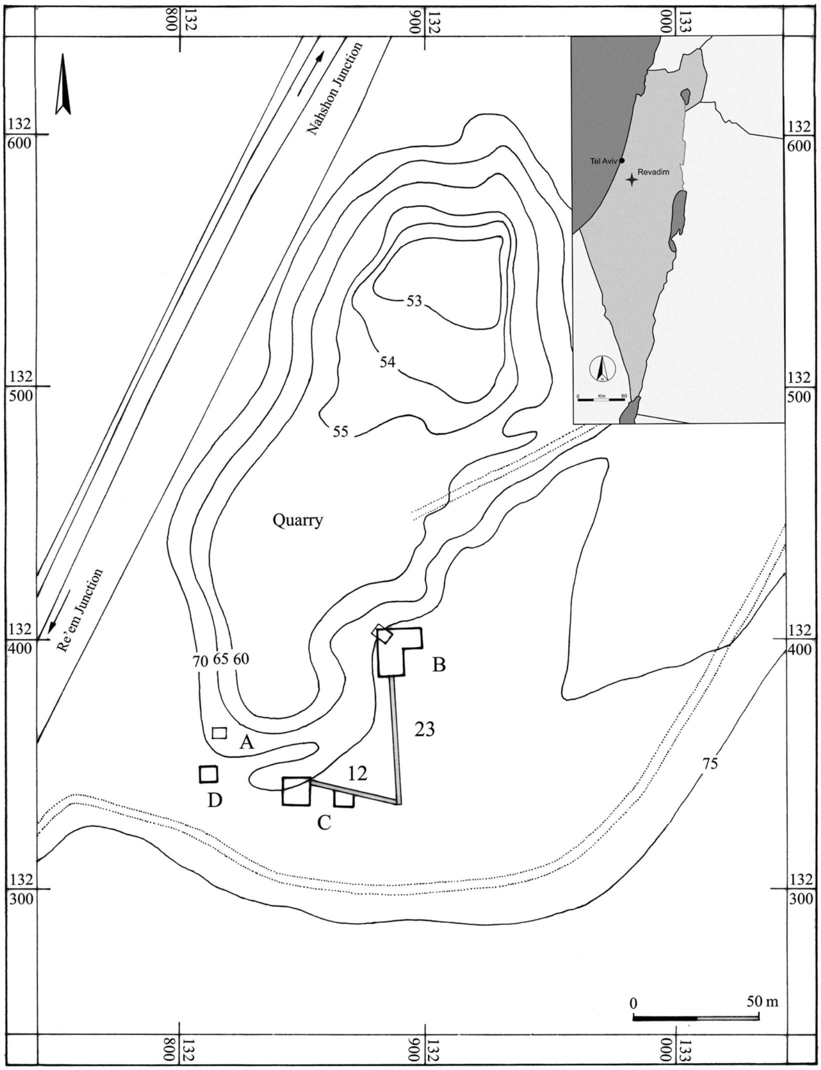

FIGURE 1 The location of the Late Acheulian site of Revadim and the site's excavation areas (after Malinsky-Buller, Grosman and Marder 2011a).

were typo-technologically classified, and integrated into the previous results. In addition, we further analysed the shaped items identified within the assemblage into sub-categories, and we present them here for the first time. For each shaped item we define the type of blank on which it was produced, and indicate whether it bears post-patina removals or retouch.

All the COF-FF trajectories (i.e., COF-FFs and BPFCs) were typologically and technologically classified and the presence of patinated surfaces was noted as well. In addition, COF-FFs were also classified for type of original blank. We reexamined the items previously classified as products of lithic recycling and introduced a new, more rigorous system of definitions. This process resulted in the establishment of new categories and the re-classification of some of the originally categorized recycled items to other typo-technological groups.

In addition, 150 items of all 944 COF-FFs identified in Layer C3 (~16% of the COF-FFs), and 100 items of all the 708 BPFCs (~15% of the BPFCs) were arbitrarily selected for detailed analysis in the following procedure: In order to establish these samples, each sub-category was lined up and every fourth COF-FF and every seventh BPFC was selected, In that way, we achieved a random sample of 250 items representing both sub-categories of the recycled items. Each sampled piece was documented in terms of metrics (length, width, thickness and weight).

Some scholars define as cores-on-flakes only items with a minimum number of three scars of later removals (e.g., Malinsky-Buller, Grosman and Marder 2011). In our view, however, a single removal is sufficient to classify an item as a COF-FF (see also Schroeder 2007; Goren-Inbar 1988; Ashton 2007; Shimelmitz 2015). The study of small flake production at the site of Qesem Cave, which is supported by an extensive array of usewear results (Barkai, Lemorini and Gopher 2010; Leomrini *et al.* 2015; Parush *et al.* 2015) is in favour of such an approach and demonstrates that in many cases only a single small flake was purposely removed from an existing flake to be used. BPFCs are termed and described in detail below. In addition, all COF-FFs and BPFCs were classified according to a degree of homogeneity, and patterns of preference and selection were looked for and analysed.

Results

Layer C3 lithic assemblage

The entire lithic assemblage of Layer C3 at Revadim comprises a total of 28,439 items, including *débitage* (cores and tools included) and debris (see Online Supplementary Material 1– Table 1). The average density is 5,316 items per 1 cu m (Agam, Marder and Barkai 2015) and of comparable density to some of the densest Paleolithic cave sites in Israel (e.g., Gopher *et al.* 2016). This high density is unique not only compared to other archaeological contexts at Revadim, but also on a broader scale, compared to other Lower Paleolithic sites (e.g., Barzilai, Malinsky-Buller and Ackermann 2006). The *débitage* constitutes 63.5% of the assemblage.

Cores (excluding COF-FFs) constitute 7.3% of the débitage (n=1,323). Most dominant are flake cores with two striking platforms (29.3% of the cores, n=388), followed by flake cores with one striking platform (22.6%, n=299), core fragments (20.7%, n=274), and flake cores with multiple striking platforms (14.6%, n=193). Cores with isolated removals (4.2%, n=55) and tested nodules (3.6%, n=48) are present as well. Cores bearing blade scars are extremely rare (0.2%, n=2). Of special note are the prepared cores (n=64, 4.8% of the cores) demonstrating a possible early appearance of the Levallois method (Barkai and Marder 2010).

Tools analysis

In total, 2541 shaped tools were detected in Layer C3 (see Online Supplementary Material 2 – Tool Analysis, Additional Data). Retouched flakes are most dominant (n=1084 pieces; 42.7% of the tools). These are followed by retouched broken flakes (n=581, 22.9%), notches (n=400, 15.7%), and denticulates (n=145, 5.7%). Of special note are 51 choppers

(2.0%; Fig. 2: 3–4), 33 side scrapers (1.3%), 21 retouched BPFCs (0.8%), and 12 bifaces (0.5%; Fig. 2: 1–2).

Of the 2,541 tools, 504 present post-patina flaking (19.8%). This indicates that at least one-fifth of the tools were produced on blanks produced in a separate, previous procedure. The exploitation of previously produced blanks is especially pronounced within the retouched BPFCs (10 patinated blanks, out of 21, 47.6%).

The exploitation of previously-used blanks is also stressed by the wide range of types of blanks that were used for the manufacture of Layer C3 tools. The most prominent blank used in tool production is regular flakes (n=1,330, 52.3% of the tools), followed by cortical flakes (n=834, 32.8%). The use of artefacts which certainly had a previous life cycle is worth noting, although in these cases ramification is not out of the question and this is not necessarily evidence for recycling. Core trimming elements, for example, served as blanks for the production of 125 tools (4.9%). Cores were fashioned into tools in 13 cases (0.5%), while tool spalls were turned back into tools in eight other cases (0.3%). The use of BPFCs for the production of tools deserves special attention, as it indicates further use of products of lithic recycling not only as sharp items, but as shaped tools. A total of 87 such blanks were retouched and shaped into tools (3.4% of the entire tool assemblage). Moreover, one third out of these 87 BPFCs bear post-patina removals, emphasizing further recycling of products of recycling.

The production of small sharp flakes by means of lithic recycling in Layer C3

The focus of this study is the trajectory of small flake production from existing flakes by means of lithic recycling. In total, 944 COF-FFs were detected within the lithic assemblage of Layer C3 (5.2% of the débitage and tools), and 708 BPFCs (3.9%). The number of BPFCs is somewhat reduced in comparison to our previous study (782 BPFCs back then, Agam, Marder and Barkai 2015) due to a more rigorous re-evaluation. In any case, the number of items produced is smaller than the number of cores-on-flakes, and this is due to the fact that it is much simpler to identify the cores than to identify the small blanks produced from the cores. Moreover, small flakes removed from the dorsal face of the parent flake are indistinguishable from regular flakes produced from regular cores, and were thus not included in the BPFCs category. The seeming mismatch between the cores and the blanks can be understood in light of the above statement.

COF-FFs

Since elaborated definitions of COF-FFs were presented in our previous publication (Agam, Marder and Barkai 2015), we will repeat only the relevant points here. A COF-FF (or a parent flake) is a flake or a tool produced in the course of a previous reduction stage for a purpose other than its transformation into a COF-FF, and from which one or more small flakes were subsequently removed. This category is further divided into four sub-categories: COF-FFs with ventral removals (Fig. 3), dorsal removals (Fig. 4), combined removals (Fig. 5), and varia.

FIGURE 2 Handaxes and choppers from the Layer C3 assemblage: (1–2) handaxes; (3–4) choppers.

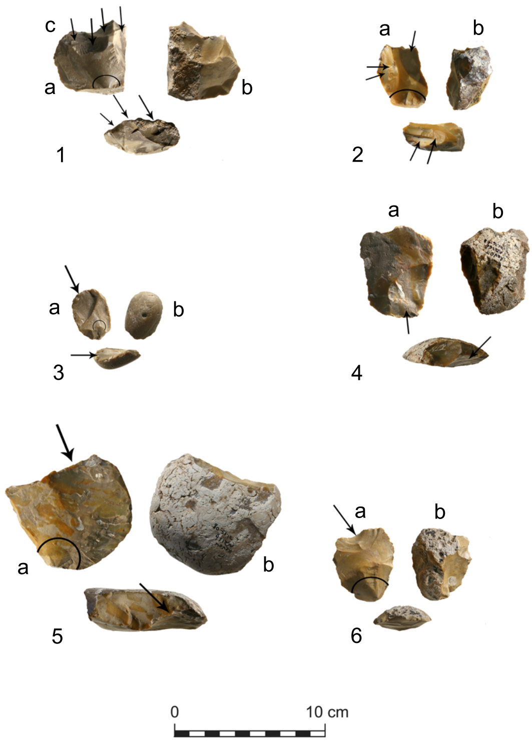

FIGURE 3 COF-FFs with ventral removals: (1–2) multi-ventral removals; (3–6) single ventral removals. Note the differences in patina on Item 2. *(a) ventral face; (b) dorsal face; (c) ventral removals.*

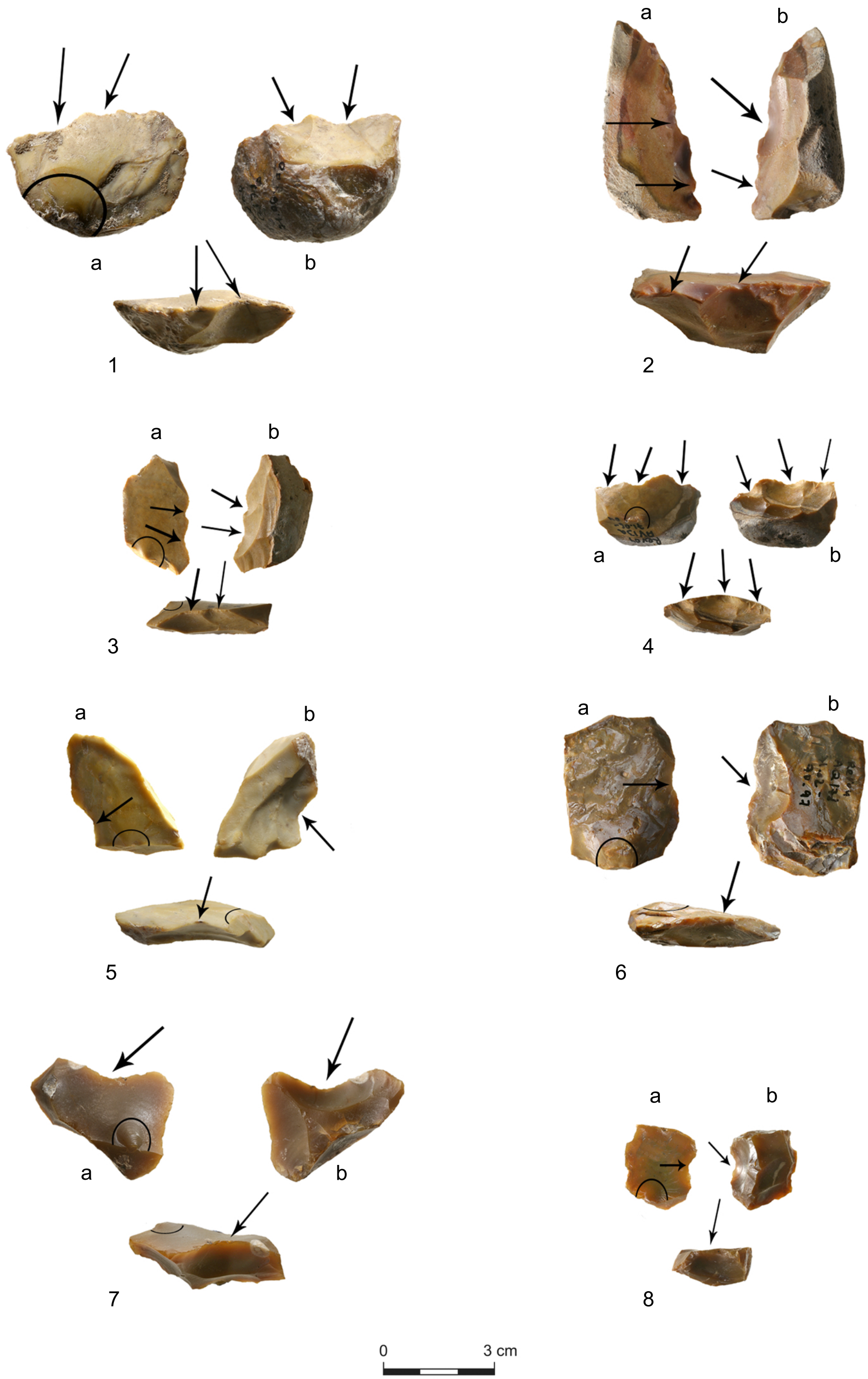

FIGURE 4 COF-FFs with dorsal removals: (1–4) multi dorsal removals; (5–8) single dorsal removals. Note the differences in patina on Item 6. *(a) ventral face; (b) dorsal face.*

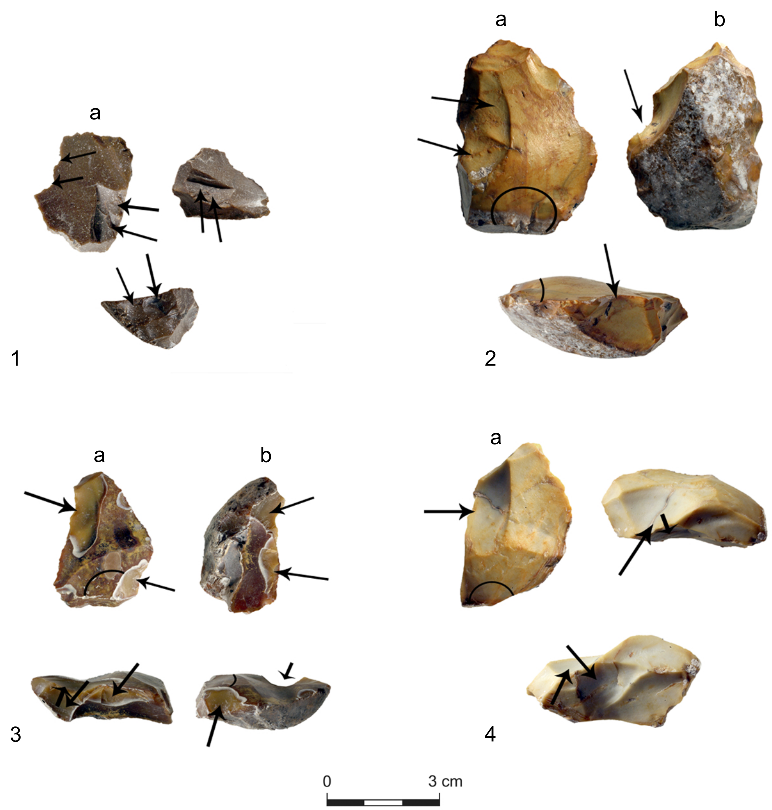

FIGURE 5 COF-FFs with combined removals: (1–2) combined unrelated removals; (3–4) combined related removals. Note the differences in patina on Item 3. *(a) ventral face; (b) dorsal face.*

Blanks produced from COF-FFs (BPFCs)

BPFCs are items that were removed from COF-FFs and are identifiable as such.[3] This category includes only clear products of this recycling procedure, meaning items with two ventral faces. It should be further stated that the small size of many of these items might have led to some issues in their field recovery and some problems in identification during lithic analysis, and hence the number of items in this category should be conceived as a minimum number of a much larger group of items. This category is further divided as follows:

Regular double ventral items (Fig. 6: 1–4, Fig. 10: 1–3)

Items that were removed from the ventral face of the parent flake, removing a part of the original ventral face of the parent flake, without removing the original bulb of percussion. These items are usually plano-convex in profile and rather sharp and thin at the edges.

[3] The actual ventral face of an artefact is the last ventral face created by the last strike, while the original ventral face is the remains of the ventral face associated with the original old artefact.

Double-bulb Kombewa items (Fig. 8: 1–3; Fig. 10: 4-5)

Originally termed by Owen (1938), these are items removed from the ventral face of the parent flake, removing the original bulb of percussion of the parent flake as well as parts of the original ventral face. These items are typically double-convex in profile and rather sharp and thin at the edges.

Lateral double ventral items (Fig. 6: 5–6; Fig. 8: 5–6; Fig. 11: 1–2)

Items which removed, in addition to part of the ventral face, one of the lateral edges of the parent flake, creating an acute angle between the actual ventral face of the item and the original ventral face of the parent flake. The sharp edge of the item is located between the two ventral faces while the opposite edge is abrupt, thus resembling a naturally backed knife. Some of these items include the removal of the original bulb of percussion.

Reversed lateral double ventral items (Fig. 7: 1–3; Fig. 11: 3–7)

Items that removed one of the lateral edges of the original parent flake, creating an obtuse angle between the two ventral faces. Unlike the lateral double ventral items, the sharp edge of these items is located at the intersection between the actual ventral face and the dorsal face of the parent flake. Some of these items include the removal of the original bulb of percussion (Fig. 9: 1–2).

Double ventral overshot items (Fig. 7: 4–7)

Items that remove a part of the distal end and/or lateral edge of the parent flake. These items resemble overshot items in appearance and may represent knapping errors.

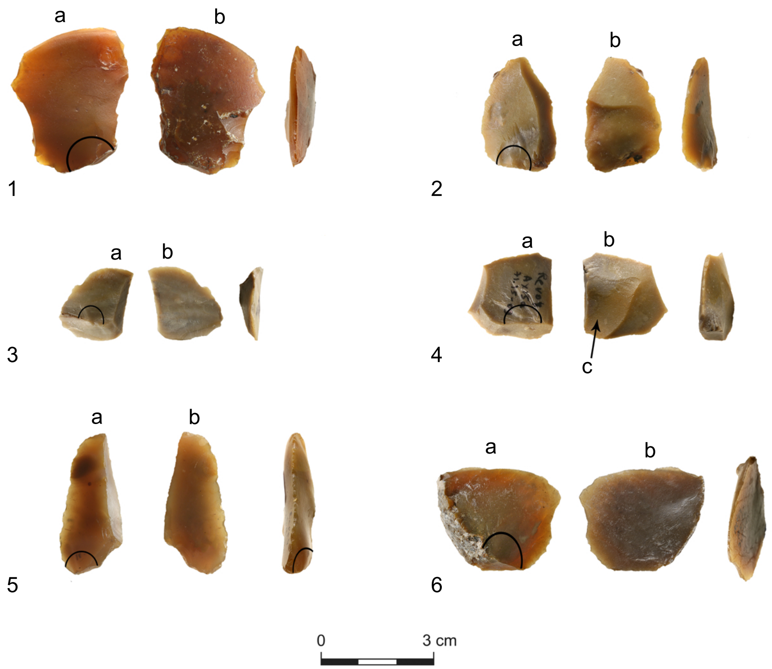

FIGURE 6 (1–4) Regular double ventral items; (5–6) lateral double ventral items. Note the differences in patina on Item 1. *(a) actual ventral face; (b) original ventral face; (c) previous removal.*

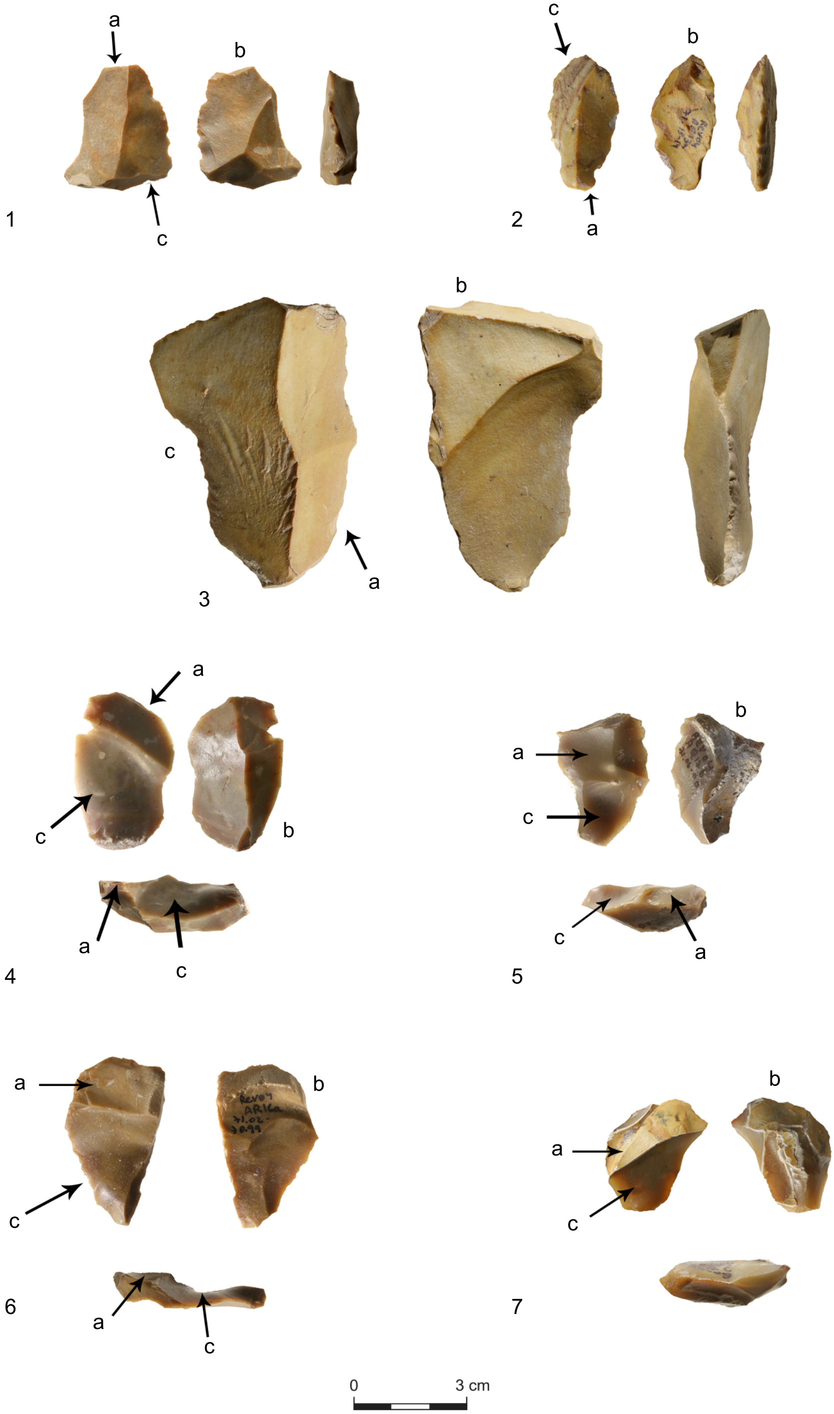

FIGURE 7 (1–3) Reversed lateral double ventral items; (4–7) double ventral overshot items. Note the differences in patina on Item 7. (a) *original ventral face; (b) dorsal face; (c) actual ventral face.*

Proximal end removal items

Items that removed the proximal end of the original parent flake, together with the original bulb of percussion, and thus have two bulbs of percussion—the original one, and the actual one. This category is further sub-divided as follows:

Tabun Snap items (Fig. 9: 3–4; Fig. 12: 1–2)

These resemble items from Tabun Cave known by that name, which were defined as "removing the proximal end of a blank by a blow invariably given from the dorsal face" (Shifroni and Ronen 2000). In the case of Revadim, these items are removed by force applied at the lateral edge of the parent flake in a 30–90 degree angle to the flaking axis of the original parent flake.

Proximal end striking items (Fig. 9: 5–6; Fig. 12: 6–7)

In these items the proximal end of the original ventral face of the parent flake serves as a striking platform for the removal of a small flake. The removal is aimed towards the original ventral face, resulting in an obtuse angle between the original ventral face and the actual ventral face. The sharp edge in those cases is created at the intersection between the actual ventral face and the dorsal face of the parent flake, at the distal end of the item.

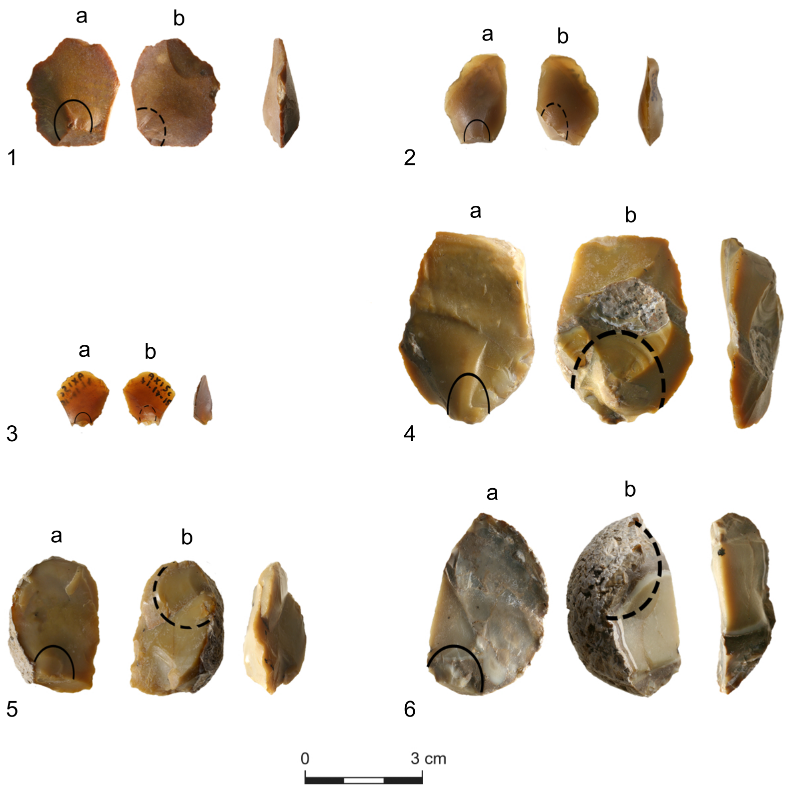

FIGURE 8 (1–4) Double-bulb Kombewa items; (5–6) lateral double ventral items, with two bulbs of percussion .Semi-circles mark actual blubs of percussion, while dotted semi-circles mark original bulb of percussion. *(a) actual ventral face; (b) original ventral face.*

Bulb removal items (Fig. 9: 7–8; Fig. 12: 3–5)

Items that remove the original bulb of percussion, with a very small portion of the proximal end of the original ventral face of the parent flake. The bulb is removed by applying force from the dorsal face and/or the lateral edge towards the ventral face of the parent flake and the bulb. The bulb itself is removed, usually without taking the entire proximal end of the parent flake. An acute angle is created between the two ventral faces, resulting in a sharp edge.

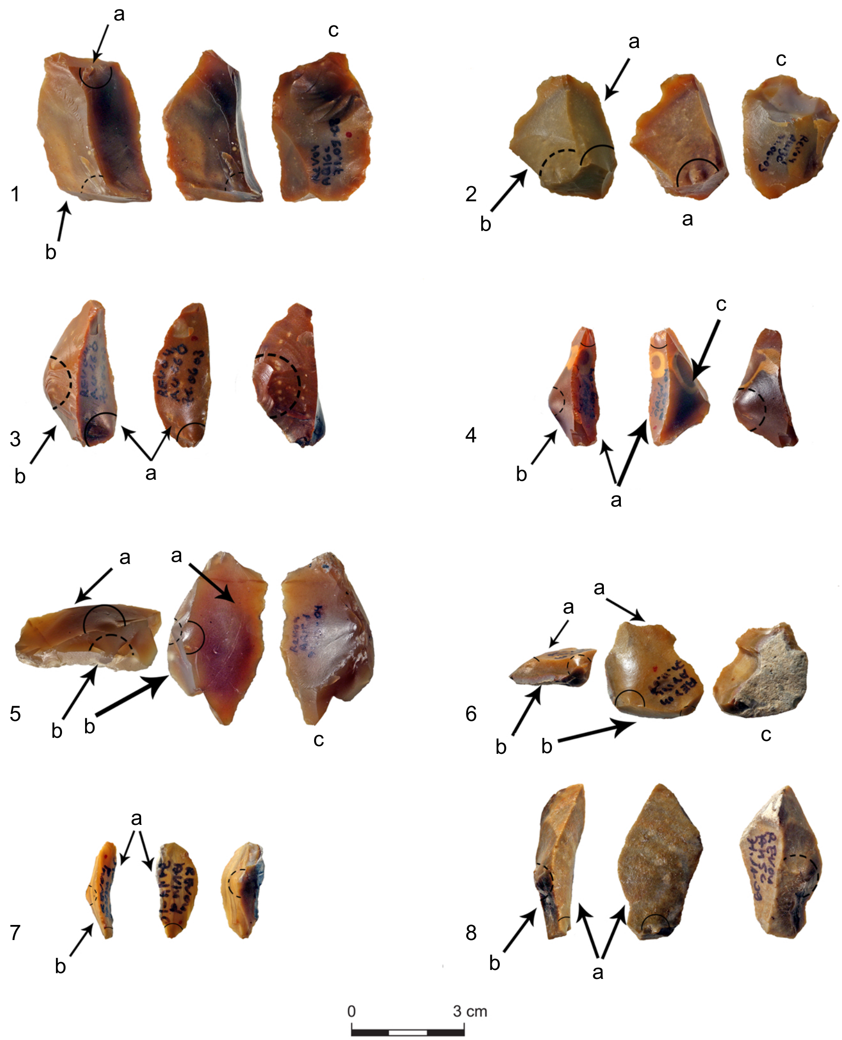

Figure 9 (1–2) Reversed lateral double ventral items with two bulbs of percussion; (3–4) *Tabun* snap items; (5–6) proximal end removal from the bulb area items; (7–8) bulb removal items. Semi-circles mark actual bulbs of percussion, while dotted semi-circles mark original bulb of percussion. *(a) actual ventral face; (b) original ventral face; (c) dorsal face.*

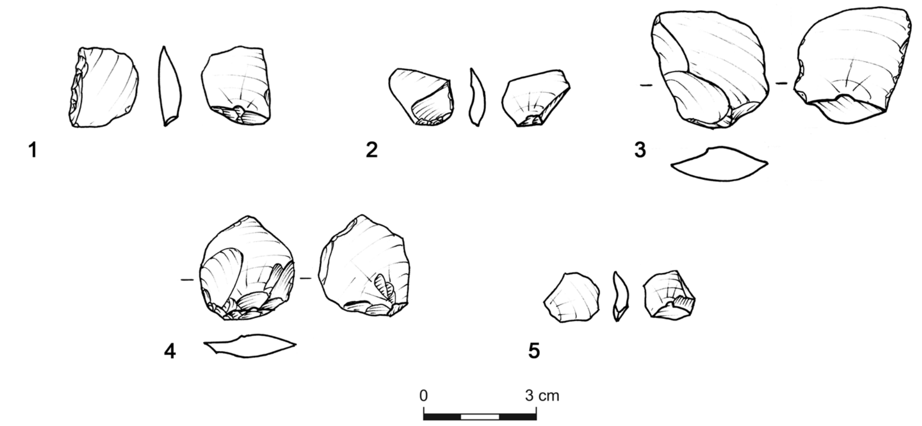

FIGURE 10 (1–3) Regular items; (4–5) Kombewa items.

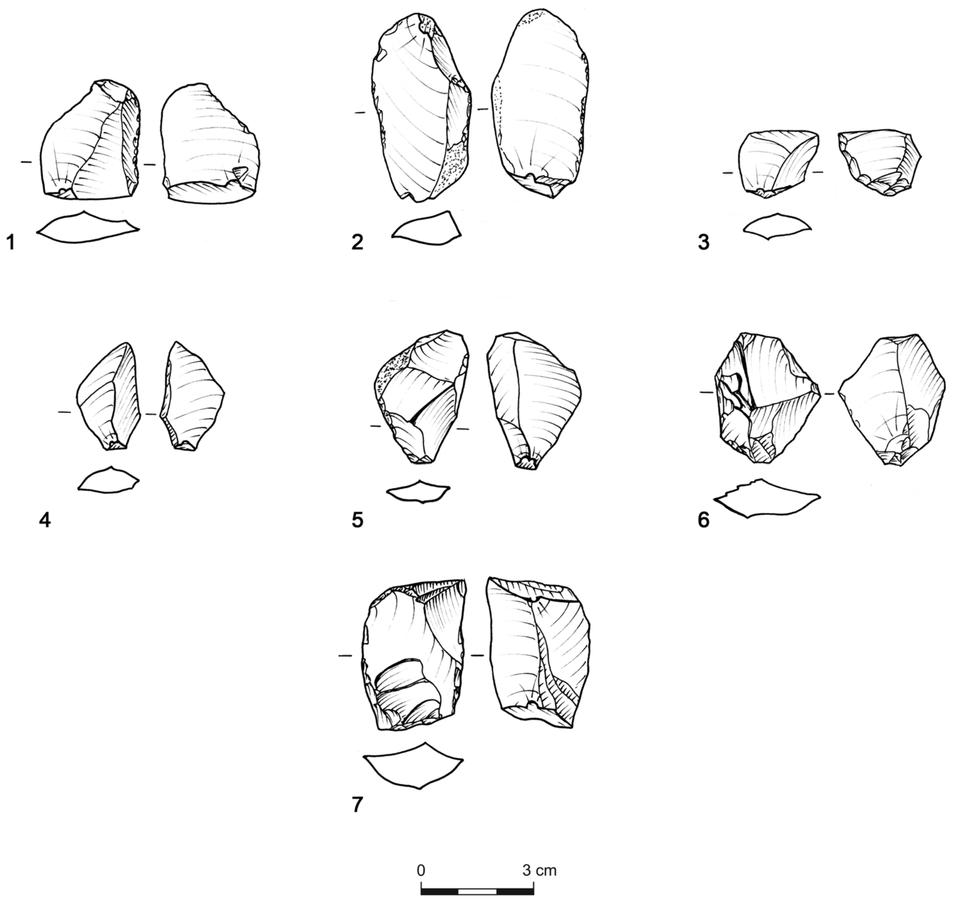

FIGURE 11 (1–2) Lateral double ventral items; (3–7) reversed lateral double-ventral items.

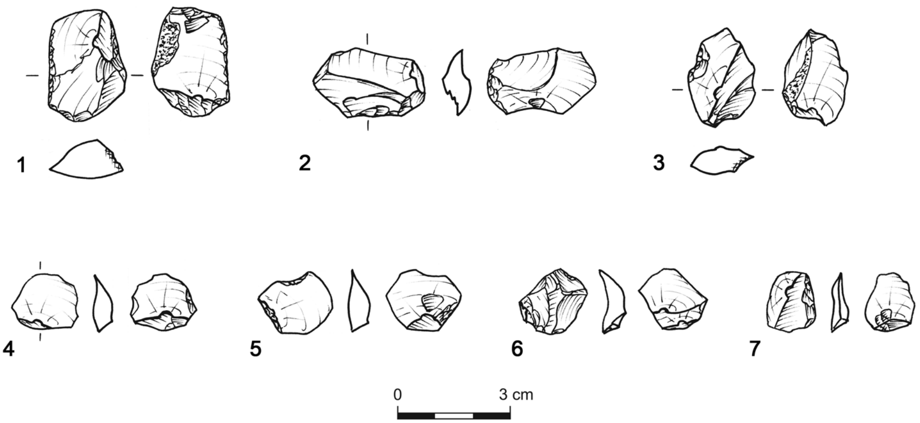

FIGURE 12 Proximal end removal items: (1–2) *Tabun* snap items; (3–5) bulb removal items; (6–7) proximal end striking items.

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items with two ventral faces and one bulb of percussion that do not correspond to any of the above-mentioned definitions. Some of these items include the original bulb of percussion of the parent flake.

Data analysis

Most of the COF-FFs are characterized by the production of small flakes from the ventral face of the parent flake (Table 1). COF-FFs with a single ventral removal constitute 29.0% of the COF-FFs (n=274), while COF-FFs with multiple removals from the ventral face constitute 26.0% (n=246). These are followed by COF-FFs with combined removals from both ventral and dorsal faces (n=179, 19.0%; divided into two sub-types: COF-FFs with removals unrelated to each other—n=108, and COF-FFs with removals some of which were used as a striking platform for others, n=71); and COF-FFs with a single dorsal removal (n=162, 17.2%). Only two items (0.2%) to some extent resemble, products of the Nahr Ibrahim (Solecki and Solecki 1970) or truncated-faceted (Nishiaki 1985; Schroeder 1969, 2007) techniques.

The BPFCs (Table 2) present a wide variety of types of the product. Double ventral flakes that cannot be assigned to a specific category ('varia') are the most common in this category, with 183 items (25.9%), followed by double ventral regular flakes (n=163, 23.0%), double ventral reversed lateral flakes (n=119, 16.8%), and double ventral lateral flakes (n=118, 16.7%). Other sub-categories appear in lower proportions, however still in worth-noting quantities, demonstrating the different modes of production of small flakes from parent flakes.

Most of the BPFCs (79.1%, n=560) do not show patina differences between the original ventral face and the actual ventral face, and thus do not provide an indication regarding the time interval between the production of the parent flake and the removal of the BPFC. However, the remaining 20.9% (n=148) do present differences in patina, thus indicating

TABLE 1
Quantity and frequency of COF-FF sub-categories

Sub-category	Number?	% of Total
Single ventral	274	29.0
Multi ventral	246	26.0
Combined	179	19.0
Single dorsal	162	17.2
Multi dorsal	45	4.8
Lateral single ventral	20	2.1
COF-varia	16	1.7
Truncated faceted	2	0.2
Grand Total	*944*	*100.0*

TABLE 2
Quantities and frequencies of recycled blank sub-categories

Sub-category	Total	% of Total
Double ventral varia	183	25.9
Double ventral regular	163	23.0
Double ventral reversed lateral	119	16.8
Double ventral lateral	118	16.7
Proximal end removal flakes	71	10.0
Double bulb Kombewa	30	4.2
Double ventral overshot	24	3.4
Grand Total	*708*	*100.0*

a time gap between the two stages of manufacture. Such patinated items are present in all sub-categories. The presence of patina and of post-patina removals indicate a time gap between the two events of use (Vaquero *et al.* 2015), thus testifying, in these cases, for separate procedures of manufacture and recycling, rather than the existence of a single *chaîne opératoire* (as in the case of ramification [e.g., Bourguignon *et al.* 2004; Mathias 2016]).

Among the COF-FFs, the presence of patina-bearing pieces is even more emphasized. Almost a third of the COF-FFs (28.1%, n=265) present patina differences between the original blank and the scars of the small flakes removed from them, demonstrating a time gap between the two production cycles and strengthening our view of this phenomenon as recycling.

There is a wide variation in the blanks used as COF-FFs (see Online Supplementary Material 1- Table 2). About one-half of the COF-FFs (48.0%, n=453) were made on cortical flakes, followed by 32.4%, n=306 on regular flakes. Cortical flakes, which are mostly associated with early stages of core reduction, are not generally characterized by sharp edges due to the intersection between the ventral face and the cortex. Thus, it is possible that the significant quantity of cortical flakes in this category is related to the maximization of by-products of core reduction that otherwise would have not been used. Core trimming elements (CTE) (7.8%, n=74), flakes produced from COF-FFs (6.6%, n=62), tools (1.6%, n=15), blades (1%, n=9), and bifacial spalls (0.1%, n=1) were also used as blanks for the production of small flakes from COF-FFs. As CTEs and bifacial spalls originate from specific technological processes related to maintenance of cores and tools, while tools also had a different original previous function, it seems that these items were not intentionally produced to be further used for the production of small flakes. It is most conceivable that these items were collected and recycled after being discarded and used as COF-FFs. Moreover, the subsequent use of 62 flakes which were produced from cores-on-flakes as COF-FFs for the production of more, smaller flakes, is overwhelming and is viewed by us as the recycling of items that had been previously recycled.

A random sample of 150 COF-FFs and 100 BPFCs was selected for metric measurements (see charts in Online Supplementary Material 1: Figs. 1–8). The average length of the sampled COF-FFs is 3.1 cm (median–3 cm; standard deviation–0.97), with most (n=111; 74%) between 2 and 4 cm long. Average width is 2.8 cm (median–2.6 cm), thickness–1.3 cm (median–1.3 cm), average weight, 13.3 g (median–10 g).

The average length of the 100 sampled BPFCs is 2.5 cm (median–2.4 cm; standard deviation–1.08), most of which (67%) are between 1 and 3 cm long. Average width is 2.1 cm (median–2.0 cm), average thickness 0.9 cm (median–0.8 cm), and average weight–7.2 g (median–5.0 g).

It seems that items between 2 and 4 cm in length were preferred as blanks for the procedure of small flakes production, though a certain variation in blank size is depicted. As indicated, the broad variety of blanks used as COF-FFs suggests that these blanks were not intentionally produced to be further used for the manufacture of these small flakes. The sample of BPFCs exemplifies the probable end-product—a small flake usually between 1 and 3 cm long.

The functionality of the different types of BPFCs is yet to be studied. A preliminary use-wear examination of several BPFCs suggested the use of BPFCs for processing of soft to medium materials (Agam, Marder and Barkai 2015), results which accord well with use-wear results known from Acheulo-Yabrudian Qesem Cave (Israel), implying the processing soft to medium materials, most likely involving butchery and plant processing activities (Barkai, Lemorini and Gopher 2010; Lemorini *et al.* 2015). Variation in angle between the two ventral faces is a factor deserving special attention. While the regular, lateral'and Kombewa sub-types present an acute angle between the original ventral face and the actual ventral face, forming a sharp edge, several of the new sub-types defined in this study (i.e., double ventral reversed laterals, proximal end removal items) present a different pattern. In these types, the angle 'trapped' between the original ventral face and the actual one is right or obtuse. Key and Lycett's experimental study (2014b) demonstrated that the cutting efficiency of small flakes is significantly affected by the angle of the working edge, with more acute angles being more effective, while more obtuse angles demanded the application of greater force by users. It is thus possible that the variation in the location of the sharp edge and the angle 'trapped' between the two ventral faces reflect differences in function and motion performed with the different sub-types. These differences may be related to the gripping of the different sub-types, or, alternatively, to the hafting of certain of them, as was already attributed to other Lower Paleolithic artefacts (e.g., Wilkins *et al.* 2012; Lemorini *et al.* 2015). Detailed use-wear analysis, which is required in order to establish this issue, is currently underway.

Homogeneity analysis

The homogeneity of flint, in terms of both colour and texture, is the result of the absence of impurities. Here it is divided into three sub-groups: homogenous, fairly homogenous and heterogeneous. The homogeneity analysis demonstrates that there is a tendency for using flint types which are homogenous or fairly homogenous for the production of small flakes by means of recycling (see Online Supplementary Material 1- Tables 3 and 4; Fig. 9): 63.9% of the COF-FFs (n=603) and 74.4% of the BPFCs (n=527) are either homogenous or fairly homogenous. Interestingly, within a general sample taken from the entire assemblage of Layer C3 (n=613), in terms of technological characteristics and form, or in terms of flint qualities, only 50.1% (n=307) were made of homogeneous flint, suggesting a certain preference toward homogeneous flints in the production of small flakes by means of recycling. It is likely that these pieces presented features that were suitable for the task at hand—the further production of small flakes—and were thus selected to be recycled as COF-FFs.

Discussion

It is our view that rather than lack of available lithic resources, technological, functional and/or cultural motivations were the reason for the extensive lithic recycling and small flake production in the Levant during Paleolithic times. Furthermore, the trajectory of small flake production existed alongside (and not instead of) the common use of 'regular' cores and flakes and 'giant' cores used for the production of very large flakes. Thus, it seems that this procedure of small flake production served a different purpose than the 'regular' cores trajectory. Hence, lithic recycling is an additional reduction strategy aimed specifically at the manufacture of small flakes, rather than a result of flint scarcity.

Small flakes, including those produced by lithic recycling, are a major component in Layer C3 at Revadim. Other Acheulian hallmarks, on the other hand, such as handaxes and choppers, are represented in very small numbers. It is thus our contention that this specific lithic composition represents a technological variant within the Late Acheulian cultural complex of the Levant, rather than an independent cultural entity. It is therefore likely that Layer C3 reflects a task specific assemblage, possibly such with a special emphasis on the processing of soft to medium materials (Agam, Marder and Barkai 2015) via the use of small and sharp cutting implements.

The exploitation of old blanks for the production of tools, as reflected by the variety of blanks used and by the significant presence of patina and post-patina removals on these blanks, demonstrates that lithic recycling was a common behaviour in the Revadim inhabitants' life cycle.

We do not know where the blanks used as COF-FFs came from. It is possible that these blanks originated from the site itself, a remnant from a past usage. Ethnographic data show that items with the potential of being recycled are often discarded in areas from which they can be easily retrieved when the need arises (e.g., Chang 1991), a scenario also plausible in the case of Revadim's lithic recycling. On the other hand, these items could also be a remnant from the work of previous visits to the site, maybe even by previous groups of inhabitants, and thus are not necessarily the by-products of the group that eventually used them as cores-on-flakes. However, it is also possible that the potential COF-FFs were found elsewhere in the landscape, outside the site, and were brought to the site to be recycled as COF-FFs due to their suitability to the task at hand (for such cases, see Amick 2007 and Lemorini *et al.* 2015). Earlier Acheulian occupations at nearby sites could have been a source for such collections. This suggestion could be supported by the presence of items bearing post-patina flaking that might have been left on the surface and collected by the site inhabitants at the site or in the landscape. Such a scenario may imply the realization of future needs (Vaquero *et al.* 2015).

Another possible scenario is that flint was recycled in a more expedient manner, without a stage of planning in advance (Vaquero *et al.* 2015). However, we believe that lithic recycling as appears at Revadim and other Lower Paleolithic sites exemplify the understanding of the potential that lies within an old flake to be suited for the manufacture of double ventral sharp small flakes. Thus, we see this process as implying the existence of an ability to plan in advance and to acknowledge that technological potential beforehand.

The blanks chosen to be used as COF-FFs most probably presented the characteristics required from a potential COF-FF, meaning: the right angles, the right shape and size, and the old ventral face, which most likely played a main role in this procedure. In most of the analysed COF-FFs the original ventral face was used as a production platform for the removal of new small sharp flakes.

In any case, as demonstrated by the homogeneity analysis, a preference towards homogeneous pieces can be suggested. This implies that the choice of which flint type to use for the production of small flakes from COF-FFs has taken this feature into consideration.

While Amick (2015: 14–15) claims that “humans generally seek to maximize the sustainable yield of their resources and efficiency seems to be the most important variable determining resource procurement and consumption rates”, we cannot rule out the possibility that other considerations, possibly related to technological, and/or to social and cultural aspects, also encouraged the inhabitants of Revadim to recycle flint. Furthermore, though Amick (2015) firmly doubts the existence of ecological concernss in the process of lithic recycling by prehistoric groups, we can only bring to discussion the option that prehistoric societies were highly familiar with their environment, and might indeed have been influenced by their relationships and interactions with the world around them.

Concluding remarks

Small flake production by means of lithic recycling from COF-FFs, or parent flakes, was commonly practiced in all archaeological contexts at Late Acheulian Revadim, but it is particularly prevalent in Layer C3. It was one of two main trajectories aimed at producing flakes, alongside the exploitation of ‘regular’ cores. Preliminary data collected from various Lower Paleolithic sites strongly associate these small flakes with the processing of animal remains, however plant processing and hide working were also indicated. The function of the small flakes of Layer C3 at Revadim is currently under study.

Bamforth wonders “why would anyone transport tools from place to place if raw material could be obtained everywhere?” (1986: 40). We consider such a notion as strongly influenced by modern thought. As natural lithic materials were most likely abundantly available during the Paleolithic of the Levant, we suggest a different explanation to the question of why recycle flint. It is our view that, alongside the technological and practical advantages that these small flakes probably have had in comparison to regular flakes in certain tasks (Key and Lycett 2014a), Acheulian hominins were highly sensitive to the environment they inhabited and might have repeatedly recycled flint because of practical reasons and also as a part of a cultural/cosmological perception of living in the world, communicating and interacting with the non-human agents surrounding them, rocks included.

The repetitive production of small flakes by means of recycling is evident, in the light of recent research, during significant parts of the Lower Paleolithic period in the Levant. In the case of Revadim, the notable proportions of small flakes produced by lithic recycling in Layer C3, alongside the exploitation of 'regular' cores (and not instead of), suggest that these tiny flakes should be viewed as an additional integral component of the Acheulian tool kit. This observation further stresses the variability and creativity that characterizes Acheulian lifeways, especially towards the end of the Acheulian, rather than the stagnation often attributed to it (e.g., Elias 2012; Renfrew and Morley 2009, Finkel and Barkai 2018).

The dominance of small flakes, produced by the exploitation of both 'regular' cores and COF-FFs, in addition to the meagre presence of bifaces, suggests that Layer C3 represents a task-specific assemblage, oriented towards activities related to the processing of soft to medium materials. It is most conceivable that the production of small flakes, alongside other common traits of the Acheulian (e.g., Bifacial tools, large flake production, the exploitation of mega fauna, etc.) enabled flexibility in human adaptation and enhanced the persistence of this specific mode of existence throughout hundreds of thousands of years in the Old World.

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