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Techno-functional analysis of small recycled flakes from Late Acheulian Revadim (Israel) demonstrates a link between morphology and function

Flavia Venditti[a,b,*], Aviad Agam[a], Ran Barkai[a]

[a] Institute of Archaeology, Tel Aviv University, Tel Aviv 69978, Israel
[b] Department of Classics, LTFAPA Laboratory, Sapienza University of Rome, Italy

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ABSTRACT

Revadim is a multi-layered Late Acheulian site in the Levant which has yielded rich lithic assemblages comprising dozens of handaxes, as well as many thousands of other items, mostly flakes. The techno-functional study presented here focuses on Layer C3, the densest layer at the site in terms of flint artefacts and animal bones. The lithic assemblage is characterized by an intense production of flakes, including a specific lithic recycling trajectory oriented towards the production of small flakes from existing flakes (Cores-On-Flakes). In this study, two categories of artefacts are sampled: the flakes used as cores for the production of new blanks (termed here COF-FFs) and the small flakes produced from them (termed BPFCs or products of recycling). Use-wear analysis conducted mainly at a low magnification, combined with residue analysis and a typo-technological characterization of the artefacts demonstrated that the small flakes produced from these COF-FFs were the desired end-products of this lithic trajectory, with a rather high percentage of used items while the COFs were rarely used, confirming their role as cores. The characterization of the used edges suggests a correlation between the activities performed and the different types of small flakes produced. Our results demonstrate the existence of a well-defined link between small flakes form and functionality, highlighting the capability of the Revadim Lower Paleolithic hominins to produce artifacts with pre-determined size, morphology, and specific utilizable edge features, suitable for the execution of anticipated targeted tasks.

1. Introduction

Since the dawn of human cultural and biological evolution our ancestors have modified natural rocks to produce tools of different sizes and forms (Režek et al., 2018). Variability in tool-shaping and the technological changes occurred during the very long Paleolithic epoch have led archeologists to study the different reasons and rational behind these technological systems and transformations through time (e.g. Bordes and Sonneville-Bordes, 1970; Schiffer and Skibo, 1997; Ambrose, 2001). As stone tools were, first and foremost, the means by which daily activities were performed by prehistoric hominins, archeologists have soon drew a link between form and function in order to explain the morphological variability of prehistoric lithic tools in light of their effectiveness in accomplishing the tasks performed at prehistoric sites (Odell, 1981; Barton, 1990; Yerkes et al., 2012; Wojtczak and Demidenko, 2018; Key, 2016; see Key and Lycett, 2017 for a review of the topic).

An example that comes to mind is the lively debate between F. Bordes and L. Binford during the 1960 s concerning Mousterian lithic variability (known as the Mousterian Debate, see Binford, 1973; Bordes, 1961a,b; Bordes and Sonneville-Bordes, 1970; Dibble, 1987; Mellars, 1970; Rolland and Dibble, 1990; Monnier and Missal, 2014). According to Binford (1973 and Binford and Binford, 1966), the Mousterian variability should be viewed as the expression of functional needs, rather than reflecting different technological or cultural traditions, as argued by Bordes (1961a,b). The heart of the debate concerned the lithic variability viewed as a source of information to reconstruct the cultural behaviors of Pleistocene hominids. Important questions about evolution and adaptation were related in this debate, which is still a current topic among archeologists, fifty years later (Monnier and Missal, 2014; Faivre et al., 2017).

However, the Bordes-Binford debate at that time was more than a clash over the interpretation of chipped stone tools. It epitomized the break between the Old and the New Worlds, representing a significant turning point which definitely influenced the practice of Paleolithic archeology thereafter. It was time for the emergence of a 'New Archeology' that would leverage the scientific method to find general laws of cultural growth to explain early human behavior. In this

* Corresponding author at: LTFAPA Laboratory, Department of Classics, Sapienza University of Rome, P.le Aldo Moro 5, 00185 Rome, Italy.
E-mail address: flavia.venditti@gmail.com (F. Venditti).

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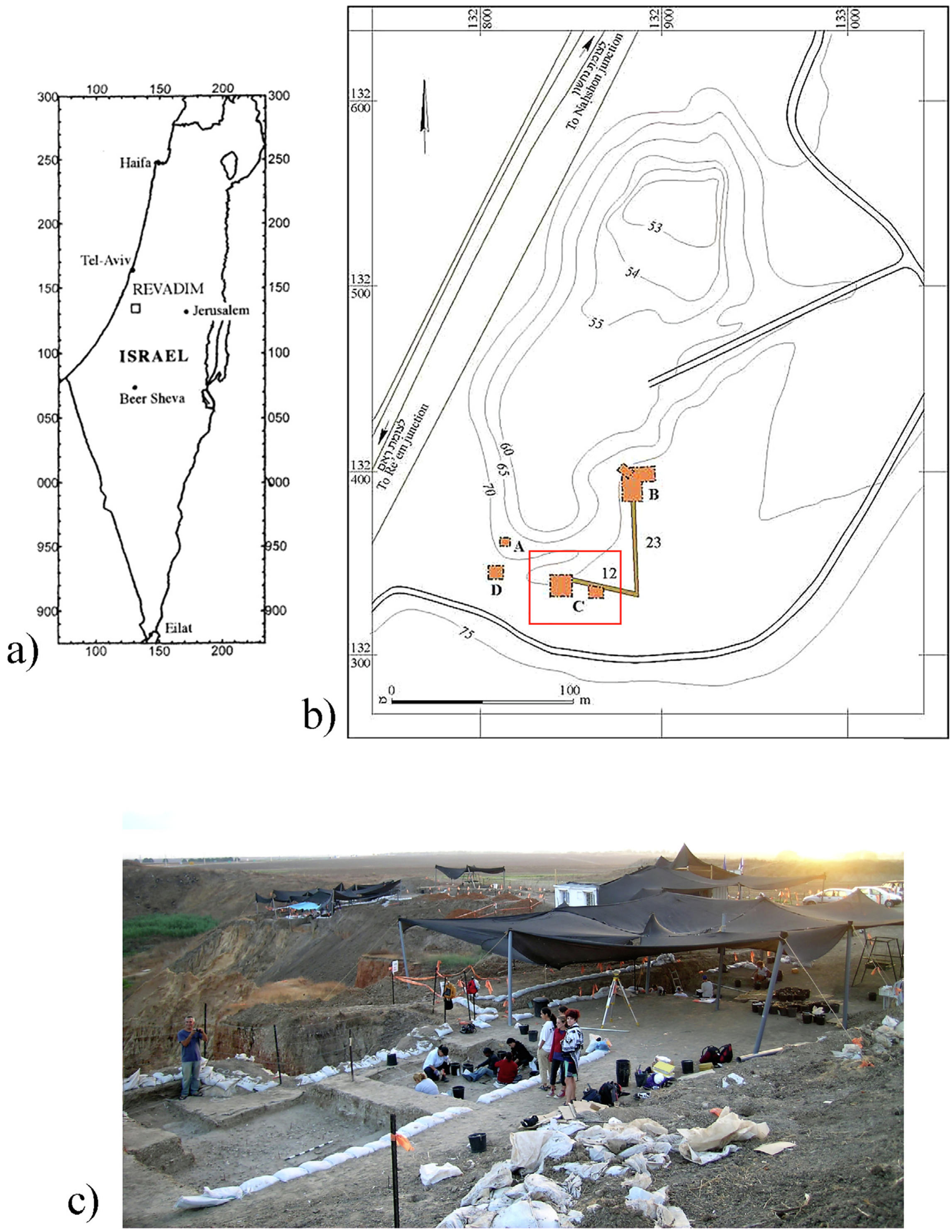


Fig. 1. a) The location of Revadim. b) The site's excavation areas (after Malinsky-Buller et al., 2011a). c) Overview of excavation area C.

scenario, the technological investigation of stone tools started to be flanked by new disciplines such as ethnography, ethnoarchaeology, experimental archeology and lithic microwear and residues analyses, which greatly improved the understanding of tool technologies and functionality (Semenov, 1964; Keeley, 1980; Keeley and Toth, 1981; Vaughan, 1985; Mansur-Franchomme, 1986; van Gijn, 1990, 2010; Rots, 2010; Langejans, 2010; Hayden, 2015). In particular, the use of replicas of stone-tools in controlled experiments as an essential part of the use-wear methodology have provided important evidences concerning the suitability of certain forms and edge morphology for specific functional tasks (Sonnenfeld, 1962; Jones, 1980; Van Gijn, 1990, 2010; Galán and Domínguez-Rodrigo, 2014; Eren et al., 2016).

This work discusses late Acheulian lithic variability by adopting a technological and functional approach for the study of a specific lithic trajectory at the site of Revadim (Israel). We focus our attention on the analysis of a category of items that for many years have been largely overlooked and considered as byproducts of the main *chaîne opératoires* performed at Paleolithic sites: the category of small flakes, and in particularly those produced by means of lithic recycling. At Revadim, small flakes were produced in the course of diverse *chaîne opératoires* (the reduction of single and multi-platform "regular" cores, biface façonage, tool shaping and resharpening etc.), however we focus our attention on a specific lithic trajectory oriented towards the production of flakes smaller than 3–4 cm, produced from the ventral and/or dorsal faces of "old" existing flakes recycled as cores-on-flakes (henceforth, COFs) (Agam et al., 2015; Agam and Barkai, 2018a). Different types of blanks produced from COFs have been typo-technologically characterized, mostly based on the location and angle of the removal coupled with the morphology of the blank (see Agam and Barkai, 2018a for details). Using a dedicated experimental reference collection replicating the archaeological technological procedure we tested the suitability of these different blanks in performing a series of activities on a variety of worked materials. We paid particular attention to the suitability of the certain edge morphology to work different materials of degrees of hardness and to perform specific types of activities. We mainly tested longitudinal and transversal motions to process soft materials such as meat, plants, soft wood, fresh hide; medium materials including wood, dry hide, cartilaginous tissues, tendon and hard materials like bone. In accordance with the archaeological results, we mainly concentrated our trials on the exploitation of animal resources. Following recent advances in understanding the purpose of the intentional production of small flakes by means of lithic recycling during Lower Paleolithic times (Venditti, 2019; Venditti et al., 2019a), our goal was to examine the hypothesis that the Revadim hominins intentionally produced small flakes with specific shapes and edge features in order to respond to targeted anticipated/functional needs and situations. The possibility of a direct connection between form and functionality might explain Acheulian lithic variability in terms of utilitarian objectives, the small flakes of Revadim being a part of a diversified tool-kit including the typical hallmarks of the Acheulian industries (i.e., handaxes, cleavers, bifaces, scrapers, as well as flakes in all dimensions). Moreover, the experimental and functional results may allow to speculate whether the production of small blanks from "old" existing flakes should be considered an opportunistic behavior, since recycling procedures have been sometime associated with expedient context or a reflection of lithic constrains (Vaquero et al., 2012, 2015; Vaquero and Romagnoli, 2017). Alternatively, it may be viewed as a planned and thought-of production trajectory constituting an integral part of the technological repertoire practiced and not a reflection of any constrain. Therefore, Revadim provides an important case-study for the investigation of three topics which have recently gained new interest among researchers, namely: 1) the production and the functional role of small fakes in Acheulian assemblages; 2) Acheulian lithic and behavioral diversity, and 3) the adoption of lithic recycling procedures.

1.1. Revadim and the concept of lithic recycling

Revadim is an open-air site located on the southern Coastal Plain of Israel, some 40 km southeast of Tel Aviv (Fig. 1a; Marder et al., 1999). In total, four seasons of excavation were carried out between 1996 and 2004 on behalf of the Israel Antiquities Authority and the Hebrew University of Jerusalem (Marder et al., 2011).

The site was preliminarily dated using 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 artifacts, which yielded dates between 300 and 500 kyr (Malinsky-Buller et al., 2011b), providing a minimum age for these items. 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). The faunal assemblages include thousands of animal bones, with a dominance of Palaeoloxodon antiquus, Bos primigenius, and Dama cf. mesopotamica (Rabinovich et al., 2012). The presence of Palaeoloxodon antiquus in Revadim may indicate a wide range of possible environments, from wooded to more open areas (Marder et al., 2011).

The excavations at Revadim focused mainly on Areas B and C. In total, seven archaeological layers were exposed. Area C represents the most complete stratigraphic sequence revealed at the site (Fig. 1b,c; Marder et al., 2006). It was divided into two sub-areas: C East and C West, located 8 m apart (Malinsky-Buller et al., 2011a). Area C West covers an area of 33 m^2 in which five superimposed archaeological layers were revealed, labeled C1 to C5, from top to bottom (Malinsky-Buller et al., 2011a). Layer C3 in Area C West, which is the focus of this study, is the densest layer at the site in terms of both flint artefacts and bones (Marder et al., 2006).

Residue and use-wear analyses of items from Area B at the site revealed use-wear in addition to fat residues on a handaxe and a scraper, found in association with the remains of a butchered elephant (Solodenko et al., 2015). These results provide one of the earliest direct evidence of meat and hide processing and consumption by early humans (Zupancich et al., 2018).

Previous studies have demonstrated the recurrent presence of small flakes produced from larger cores-on-flakes (also termed "parent flakes") at Revadim (Malinsky-Buller et al., 2011a; Agam et al., 2015; Agam and Barkai, 2018a). In our last studies (Agam et al., 2015; Agam and Barkai, 2018a) we demonstrated 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 and colleagues (1991). Blanks produced from these COF-FFs were termed BPFCs. Our definitions were derived from those applied in the study of lithic recycling at the Acheulo-Yabrudian site of Qesem Cave (Parush et al., 2015; Venditti et al., 2019a).

While Vaquero et al., (2015) stress that core-on-flakes should not be automatically viewed as the expression of lithic recycling, as flakes might have been intentionally produced to serve as cores in the framework of the concept of Ramification (see Bourguignon et al., 2004; Mathias, 2016), it is our view that the case of Revadim reflects a case of lithic recycling. As demonstrated in Agam and Barkai (2018a), a significant number of the COF-FFs from Revadim are covered by patina and bears post-patina removals due to subsequent removal of small flakes. In addition, a wide variety of blanks were selected to be used as COF-FFs, suggesting that these artifacts were not originally produced in order to be used as COF-FFs, but, rather, were chosen from a large variety of existing items produced within the different lithic production trajectories practiced at the site (and for more information see Agam and Barkai, 2018a). Similar observations and interpretations are reflected in the production and use of small flakes as products of recycling at the terminal Lower Paleolithic Acheulo-Yabrudian site of Qesem Cave, Israel (Parush et al., 2015; Lemorini et al., 2015; Venditti, 2019; Venditti et al., 2019a).

Lithic recycling was performed at Revadim using other trajectories as well, as about a fifth of the shaped items from layer C3 were produced from old patinated blanks (Agam and Barkai, 2018a). Moreover, the C3 shaped items were produced on a wide variety of blanks, including regular flakes, cortical flakes, Core Trimming Elements, cores, tool spalls, and flakes produced from cores-on-flakes. This suggests that at least some of the blanks were not initially manufactured for the anticipated production of these shaped items. Another trajectory of lithic recycling observed in Revadim is the recycling of bifaces into cores for the production of flakes.

2. Materials and methods

The lithic assemblage of Layer C3 at Revadim contains 28,439 items, including *débitage* (flakes, blades, core trimming elements, COF-FFs and blanks produced from COF-FFs, special spalls, flaked pebbles, cores and shaped items) and debris (chunks, chips, micro flakes and manuports, see Table 1). In total, 944 COF-FFs were detected within the lithic assemblage of Layer C3 (5.2% of the débitage and shaped items), and 708 Blanks Produced From COF-FFs (BPFCs; 3.9%).

We define a COF-FF (or a parent flake) as a flake or a shaped flake

Table 1
A general breakdown of the lithic assemblage of Layer C3. Note: Broken flakes are items with a ventral face, which lack a bulb of percussion; Cortical flakes and blades are flakes or blades with at least 30% cortex on their dorsal face; The special waste category includes burin spalls, bifacial spalls, and other shaped items spalls; micro flakes are complete flakes smaller than 2 cm classified under Debris since these items are not usually separated from the chips in many other studies.

Category	Quantity	% of Débitage and tools	% of assemblage
Flakes	3734	20.7%	13.1%
Broken Flakes	4717	26.1%	16.6%
Cortical Flakes	2397	13.3%	8.4%
Lipped Flakes	30	0.2%	0.1%
Blades	87	0.5%	0.3%
Cortical Blades	40	0.2%	0.1%
Cores	1323	7.3%	4.7%
Core Trimming Elements (CTE)	1104	6.1%	3.9%
Cores-on-Flakes (COF-FFs)	944	5.2%	3.3%
Blanks Produced from COF-FFs	708	3.9%	2.5%
Shaped item	2541	14.1%	8.9%
Special Waste	301	1.7%	1.1%
Flaked Pebbles	127	0.7%	0.4%
Sum of Débitage and tools	**18,053**	**100.0%**	**63.5%**
Chips	7252	–	25.5%
Micro Flakes	1721	–	6.1%
Chunks	1211	–	4.3%
Untreated Nodules	202	–	0.7%
Sum of Debris	**10,386**	**–**	**36.5%**
Total	**28,439**	**–**	**100.0%**

which was originally produced in the course of a previous reduction stage, most probably 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, dorsal removals, combined removals, and varia. For the full definitions, see Agam et al. (2015).

BPFCs are items which were removed from a COF-FF. As many items of this category, and especially blanks removed from dorsal faces, are difficult to be distinguished from regular flakes, this category includes only clear products of this recycling procedure. We included in this category only artifacts with two distinct ventral faces. Therefore, the number of items in this category is an underrepresentation of the actual number of BPFCs in Layer C3. This category includes the following sub-categories: regular double ventral items, double-bulb “Kombewa” items, lateral double ventral items, reversed lateral double ventral items, double ventral overshot items, and “proximal end removal” items (see Agam and Barkai, 2018a for details).

Artifacts described here as a part of the recycling phenomenon (i.e., COF-FFs and BPFCs) were typologically and technologically classified. In addition, the presence of patinated surfaces was indicated. Also, COF-FFs were classified for type of the original blank on which they were produced.

While some scholars define cores-on-flakes only as items with a minimum number of three scars of later removals (e.g., Malinsky-Buller et al., 2011a; Malinsky-Buller, 2014), it is our view, as in our previous studies, that a single removal is sufficient to classify an item as a COF-FF (and see Schroeder, 2007; Goren-Inbar, 1988; Ashton, 2007; Dibble and McPherron, 2007; Shimelmitz, 2015; Barkai et al., 2010; Parush et al., 2015). For the full definitions of COF-FFs and BPFCs see Agam et al. (2015) and Agam and Barkai (2018a).

For the functional analysis, we sampled 65 COF-FFs and 283 BPFCs (Table 2).

For the core-on-flakes, however, we randomly selected a relatively small number of items since in light of the results published by Lemorini et al., (2015) a low rate of use was expected. Concerning the BPFCs, we

Table 2
Quantity and frequency of COF-FFs and BPFCs sub-categories recovered in Area C with the related quantity of sampled items and items with use-wear traces.

Sub-category of COFs	Total	% of total	Sampled COF-FF	COF-FFs with use-wear
Single ventral	274	29.0%	15	2
Multi ventral	246	26.1%	15	1
mixed	179	19.0%	10	1
Single dorsal	162	17.2%	15	5
Multi dorsal	45	4.8%	10	2
Lateral single ventral	20	2.1%	/	
COF-varia	16	1.7%	/	
Truncated faceted	2	0.2%	/	
Gran Total	944	100.0%	65	11 (18%)

Sub-category of BPFCs	Total	% of total	Sampled BPFC	BPFC with use-wear
Double ventral varia	183	25.7%	20	6
Double ventral regular	163	23.0%	80	41
Double ventral reversed lateral	119	16.8%	60	12
Double ventral lateral	118	16.7%	60	19
“Proximal end removal” flakes	71	10.0%	35	12
Double bulb Kombewa	30	4.2%	15	12
Double ventral overshot	24	3.4%	12	5
Grand Total	708	100.0%	283	107 (38%)

randomly selected half of the number of the identified items for each category of artefacts.

Although the varia category includes a high number of artifacts, we sampled 20 such items due to the heterogeneity of items in this category. Finally, we analyzed the accumulated data, crossing the typo-technological categories with the use-wear results.

A preliminary evaluation of the degree of preservation of the archeological material was carried out by the naked eye and with a stereomicroscope before the use-wear analysis took place. The investigation of post-depositional alterations is important in order to discriminate between traces due to use and evidence of natural modifications. In that way it is possible to reduce the possibility of considering alterations that can mimic use-wear traces. The recycled small flakes in layer C3 suffered post-depositional alterations, mostly of chemical origin. According to our microscopic observations, the flakes are relatively complete and do not show significant evidence of abrasions or rolling (for an overview see Venditti et al., 2019b). Many flakes bear patinated surfaces with bright appearance, which have limited the identification of micro use-wear traces. Micromorphological analysis suggested long-termed inundation shortly after the deposition of layer C3 and the resulting water activity contributed to activate chemical reactions responsible for the desilification of the flint surfaces and the consequent formation of patina (Malinsky-Buller et al., 2011a; Marder et al., 2011; Venditti et al., 2019b).

Functional analysis of lithic materials was carried out both at the Laboratory of Technological and Functional Analyses of Prehistoric Artefacts (LTFAPA) in the University of Rome and in the Tel Aviv University applying the Low and the High-Power approaches (Lenoir, 1970; Tringham et al., 1974; Odell and Odell-Vereecken, 1980; van Gijn, 1990, 2010; Rots, 2010). Use-wear analysis of the archeological materials was mostly carried out at low magnification and only few cases of micro polish were detected and interpreted (Venditti et al., 2019b).

In order to assess the relation between form and functionality on the archeological artefacts, the used-edge portions bearing diagnostic traces were morphologically described according to their shape and profile, cross-section and edge-angle through four variables: 1) zenithal outline (frontal view), 2) sagittal profile (profile view), 3) section and 4) cross-edge angle (the angle formed by the intersection between the

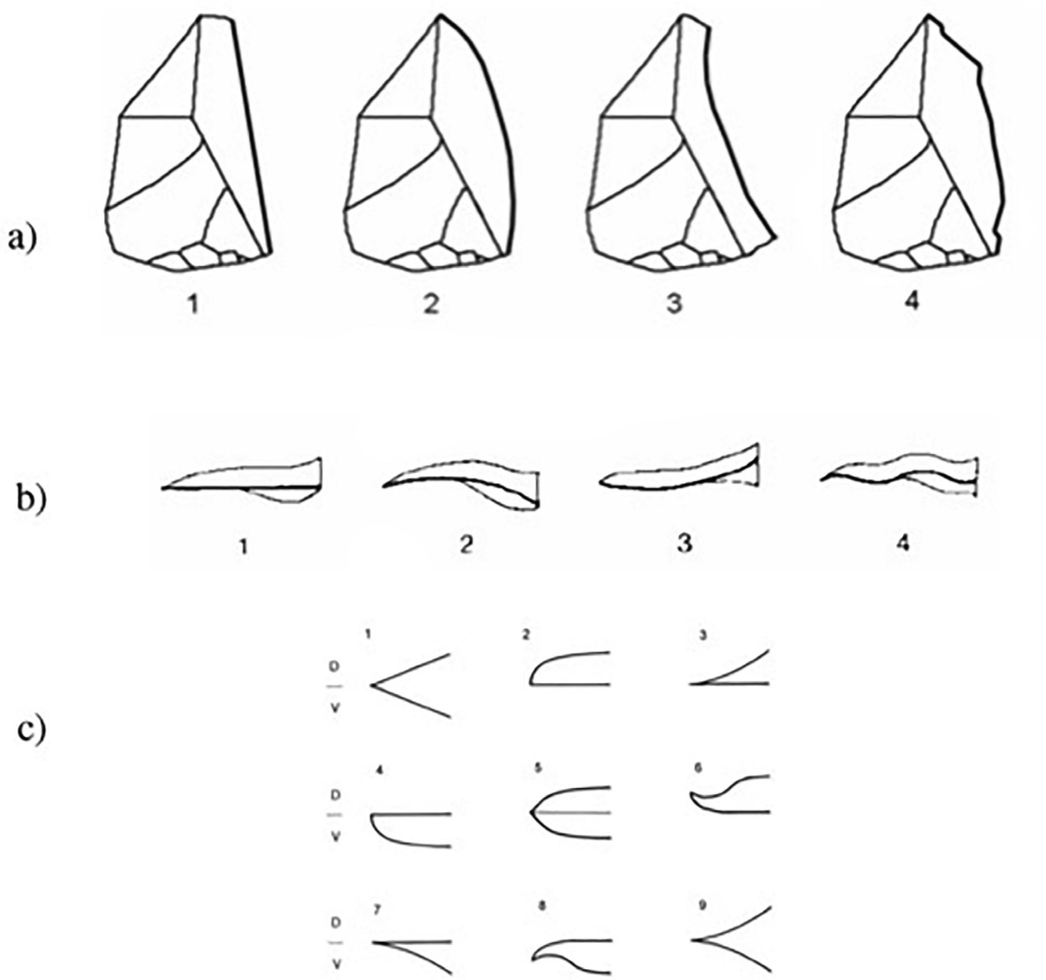


Fig. 2. Illustration of the description of the functional edge. a) zenithal outline: 1. straight, 2. convex, 3. concave, 4. Irregular (after Claud, 2008 modified); b) sagittal profile: 1. straight, 2. convex, 3. concave, 4. Irregular; c) cross-section: 1. straight-straight, 2. straight-convex, 3. straight-concave, 4. convex-straight, 5. convex-convex, 6. convex-concave, 7. concave-straight, 8. concave-convex, 9. concave-concave (after van Gijn, 1989).

dorsal and ventral surface, Fig. 2).

Edge angles were measured with a goniometer, usually in the middle of the used-edge portions or where edge damage was mostly developed, which implies a major contact with the worked material.

The exceptional combination of favorable environmental conditions which occurred soon after the deposition of the archeological materials allowed the preservation of the organic and inorganic micro remains found entrapped inside flint scars and on the zones of prehension of the small recycled flakes.

Ancient residues were detected by using three different and complementary approaches: 1) the morphological characterization, distribution and location of micro residues performed at low and high magnification; 2) the chemical characterization of residues by using the Fourier Transform Infrared Spectroscopy (FTIR); 3) the elemental characterization thought the application of the SEM-EDX analysis (see details in Venditti et al., 2019b).

Wear traces and residues observed on the archeological artefacts have been interpreted by comparison with a comprehensive reference collection, built up through a wide range of experiments (mostly focus on the exploitation of animal materials) performed with small flakes replica produced according to the same technological procedures recognized at the site (see Venditti et al., 2019b).

Along with the active edge, particular attention was paid to the prehensile areas where the small flakes were handled during the execution of the activities tested.

The experimental replicas were microscopically studied by means of the same methodology used for the archeological ones.

2.1. The experimental reference collection

The experimental reference collection used in comparison with the archeological data rely on a rich corpus of experiments produced in the framework of the small recycled flakes investigations (Barkai et al., 2010; Lemorini et al., 2015; Venditti, 2019). Small flakes replica were produced from local flint sources, similar to flint types used at the Paleolithic sites under investigation and following the technological processes identified by the archaeological analysis. Replicas of small flakes were employed in processing a variety of worked materials (different species of wood and vegetal, tubers, roots, fleshy tissues, bones, hide, tendons) in order to test activities such as scraping, cutting, sawing, debarking, peeling, filleting, dismembering, skinning etc…

In addition, according to the Revadim case study, a specific experimental trial was set in order to text the functional potential of small flakes during a whole butchery process. We performed two butchery trials on two medium size animals: a roe deer and a juvenile deer. Three small flakes replica (2 Lateral and a Kombewa flake) were used through all the main stages involved in the butchery sequence, starting from the skinning process through dismembering, disarticulation, filleting of meat, and stripping flesh from bones. We also include in the reference collection the processing of fresh bones (i.e. cow femora) with the aim

Fig. 3. Experimental activities performed with replicas of small recycled flakes. a, b) skinning; c) disarticulation; d) removing periosteum; e) cleaning bone from meat.

of removing the periosteum before bone breakage for marrow extraction (Fig. 3).

Edges were in contact with muscular tissue, tendons, fresh hide and fur, bone and connective tissues.

Related edge damage includes feather, half-moon and step scars terminations along with snap fracturing which may include smaller feather removal inside (Fig. 4a,b,c). Edge rounding is never highly development except for very thin and acute edge which round fast, especially after working hide. Micro polish is characterized by a bright greasy appearance with a rough to smooth texture and a granular towards domed topography (Fig. 4e,f,g). The fresh aspect of the worked materials is reflected in the greasy and bright polish appearance (Fig. 4e). Bone was frequently hit throughout the butchery resulting in the hinge and/or step scars with a discontinuous distribution along the used edge (Fig. 3c). At a microscopic level, a well recognizable bone-polish with a smooth texture and a domed to flat topography is recognizable (Fig. 4d,g). The distribution is spotted along the used edge since bone-contact was mostly accidental during the work.

The activities were carried out with straight, convex and concave edges with edge angle ranging from 20 to 50°. The results show that the edge effectiveness was extremely high towards the processing of soft and medium materials through longitudinal motions thanks to the sharp and regular edges. For these activities, straight or convex edge profile are recommended while concave morphology proved to be suitable to perform transversal motions such as scraping flesh from bone, or scraping off the periosteum tissues on small or medium size bones.

In general, the experimentation pointed out the strong affordance of small flakes to carry out meticulous tasks addressed towards the execution of finishing operations of animal carcass manipulation. On the other hand, it highlighted their non-versatile character, due to the small dimensions and short sharp edge portions which have represented a limitation in processing hard materials over a long duration (e.g., cut in half a bone or a hard branch of wood) or material of significant volume.

3. Result

Overall, 348 artefacts (65 cores-on-flakes and 283 small flakes) were sampled for this use-wear study, with a total of 117 used items (10 cores-on-flakes and 107 small flakes). Two small flakes and one core-on-flake exhibit traces along two different portions of their edge attributable to the same working activity. As a consequence, a total of 120 use-wear areas were recognized. Overall, 226 items provided no evidence of wears and 5 unreliable evidence of utilization.

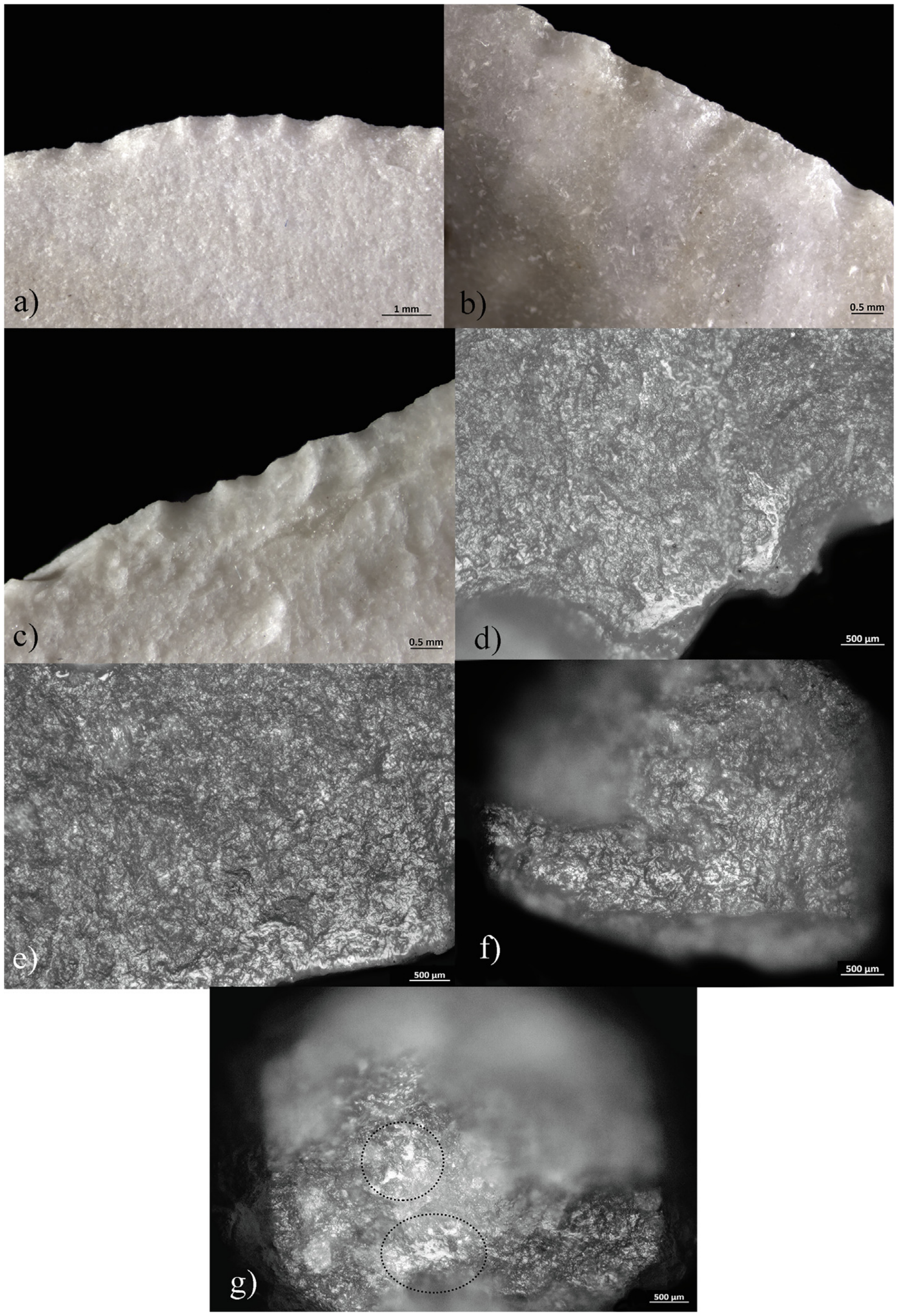


Fig. 4. Experimental use-wear traces after processing animal materials. a) edge damage after removing periosteum; b, c) edge damage after butchery; d) micro polish after butchery showing bone contact; e) micro polish after skinning; f, g) micro polish after removing periosteum.

3.1. Cores-on-flakes

In recording functional traces on COFs, we only took into consideration use-wear observed along the new edges created by the intersection of the negative of the recycled flake and the ventral or dorsal surface of the COF itself. Two COFs exhibited traces not related with the recycling trajectory and were not counted. Overall, 10 COFs out of the 65 sampled exhibited wears related to use (Table 3).

In our sample, COFs generally show concave edge profile with thick edge and wide edge-angle (65°, on average). When used, they exhibit a preference for transversal activities on medium and medium-soft materials (Fig. 5a). Only one COF bear straight edge profile related to cutting soft material (Fig. 5b).

Table 3
Interpreted function on COF-FFs.

Worked material	Cutting	Scraping	Mixed	Total
Soft material	1	4		5
Soft to medium material		1		1
Medium material		3	2	5
Total				10 (11FA)

Experimental activities with COF replicas and concave zenithal edge outlines proved them to be suitable for target tasks using transversal motions, as their edges are limited in length and with no regular profiles (e.g., debarking soft medium branch of different wood species, scraping bone). The COFs bearing straighter and more regular edge

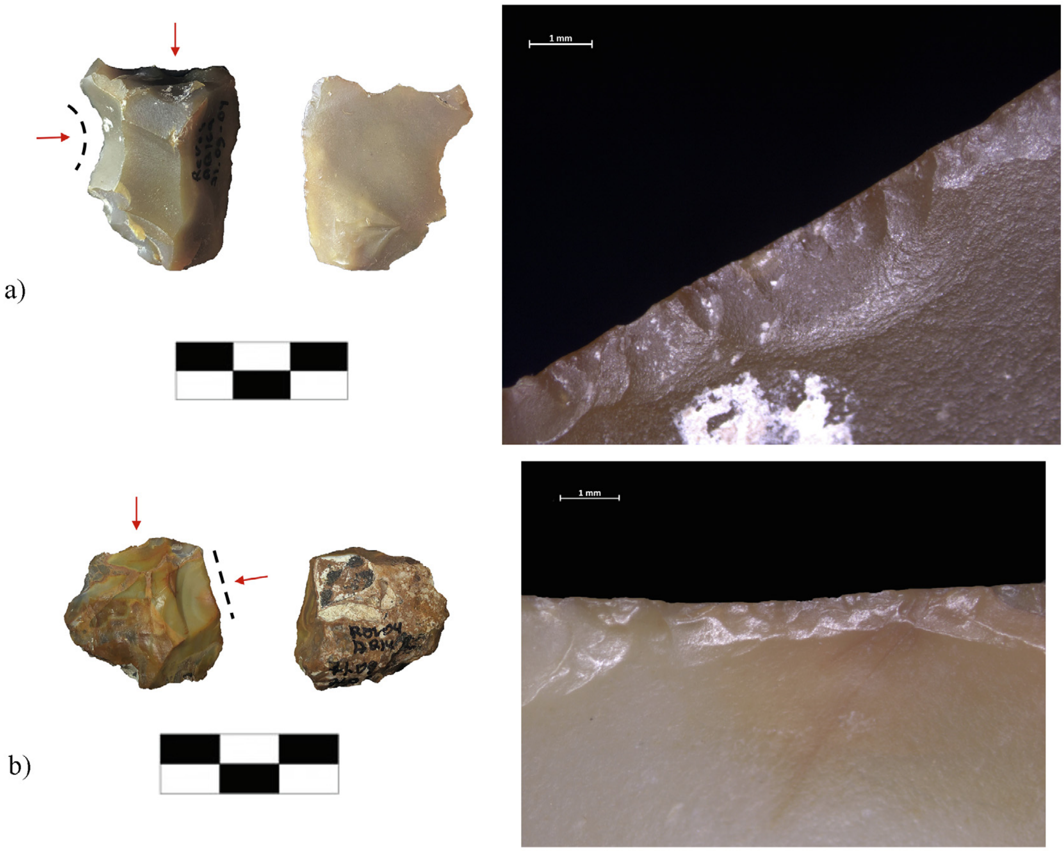


Fig. 5. Example of COFs and related edge damage modification. a) Multi dorsal COF bearing edge damage interpreted as scraping of soft material; b) Multi ventral COF bearing edge damage interpreted as cutting soft material. Red arrows indicate the detachments of the small recycled flakes from the COFs.

profiles are better suitable for longitudinal activities (Lemorini et al., 2015). While experimental activities demonstrated a lack of edge precision during their utilization, they also demonstrated a remarkable grip force due to their large and thick shapes. Moreover, as COFs are frequently made on cortical flakes, the cortex constitutes a less slippery surface, compared to smooth flake scars, thus improving handgrip.

The contribution of the use-wear data corroborated previous technological results showing a rare utilization of COFs for practical activities. Their primary function seems to be limited to serve as cores for the production of new small blanks. However, the few observed cases of utilization reflect the ingenuity and flexibility of the Revadim hominins in using the cores-on-flakes when the grip and the edge morphology were suitable and appropriate for the task at hand.

3.2. Small recycled flakes

The interpretation of the worked materials and the activities carried out by the 107 used small flakes show that they were primarily used to performed longitudinal motions while scraping and mixed activities are less represented in the sample (Table 4).

Cutting activities are characterized by oblique and unidirectional edge damage orientation while edge damage distribution, often developed only on one of the two faces, suggests that the flakes were held with an inclination close to 45° degrees toward the worked material (Fig. 6a,b).

Scraping activities are less common within the sample, counting fourteen small flakes with a preference towards the processing of soft to medium and medium material (Fig. 6c-e).

Mixed actions were observed on five specimens while three flakes provided evidence of use, but without enough information to interpret the worked material and the activity carried out.

Concerning the processed materials, small flakes showed a preference towards the processing of soft and soft to medium materials. The processing of hard materials is scarcely documented (Table 4).

We were able to combine the edge damage identification with the micro polish characterization on five flakes exhibiting sufficient preservation conditions for the analysis at high magnification. The artefacts showed evidence of contact with fresh animal materials such as fleshy tissues, hide, connective tissues and bone (Fig. 7, see details in Venditti et al., 2019b).

Functional interpretations were confirmed by the remarkable presence of organic and inorganic residues related to animal materials (bony tissues, compacted bone powder, collagen fibers, fat and meat structures) morphologically identified on 11 small flakes and also detected through X-ray (scanning electron microscopic analysis coupled with X-ray detector) and IR spectroscopy (Fourier transform infrared spectroscopy) on 41 items. (For details on residues results see Venditti et al., 2019b).

The use wear analysis and the morphological characterization of the used edges allowed us to highlight a certain variation in edge morphology and edge-angle used to process the different materials and carrying out the activities (for the used edge morphological characterization assigned to each BPFCs type see Table 5). The two variables seem to be directly proportional: we noticed that the harder the worked material, the more robust the edge is. According to this, soft materials were mostly exploited with regular flakes where used-edge portions appear straight or convex in profiles characterized by very sharp and thin morphologies (edge-angles have an average of 29° degrees, Table 5). The processing of soft-medium and medium materials was mostly performed with items showing stronger edges as those of Lateral/Reversed lateral, Kombewa and Proximal end removal flakes. Straight and convex edge profile were preferred, but here the flakes

Table 4
Interpreted function on BPFCs.

Worked Material	Cutting	Slicing	Scraping	Mixed	General Working	Indeterminable	Total
Fleshy tissues	1						1
Fleshy tissues + bone	1		1				2
Bone			1				1
Connective tissues + fresh hide	1						1
Soft material	48	1	2	1	1		53
Soft to medium material	14		5	1	2		22
Medium material	13		5	3			21
Medium to hard material	1		2				3
Indeterminable						5	5
Total							107 (109FA)

exhibited a major amplitude of their edges with value around 45°. Although less represented, medium to hard materials were processed with straight profiles with rather thicker edges (50°).

Moreover, we observed another well-defined correlation between the morphology of the edge and the activities performed with the small flakes. Table 5 and chart in Fig. 8 show that Revadim hominins preferred straight or convex edges for their daily working activities, with whom they mainly performed longitudinal activities. Instead, transversal activity was often associated to concave outline of the used edges. We observed the same trend in the use of COFs where the concave edge produced by the detachment of the small flakes bear always transversal edge damage modifications related to scraping activity.

3.3. Prehensile traces

Studies concerning how lithic tools were manipulated by prehistoric hominins during their daily working activities have always interested the scientific community and many studies, both experimental and archeological, have given proof of manipulation and hafting behavior (Rots, 2013; Dinnis et al., 2009; Zupancich et al., 2016; Baena Preysler et al., 2016; Chen et al., 2017; Degano et al., 2019). Studies investigating hafting or prehension traces integrating technological and

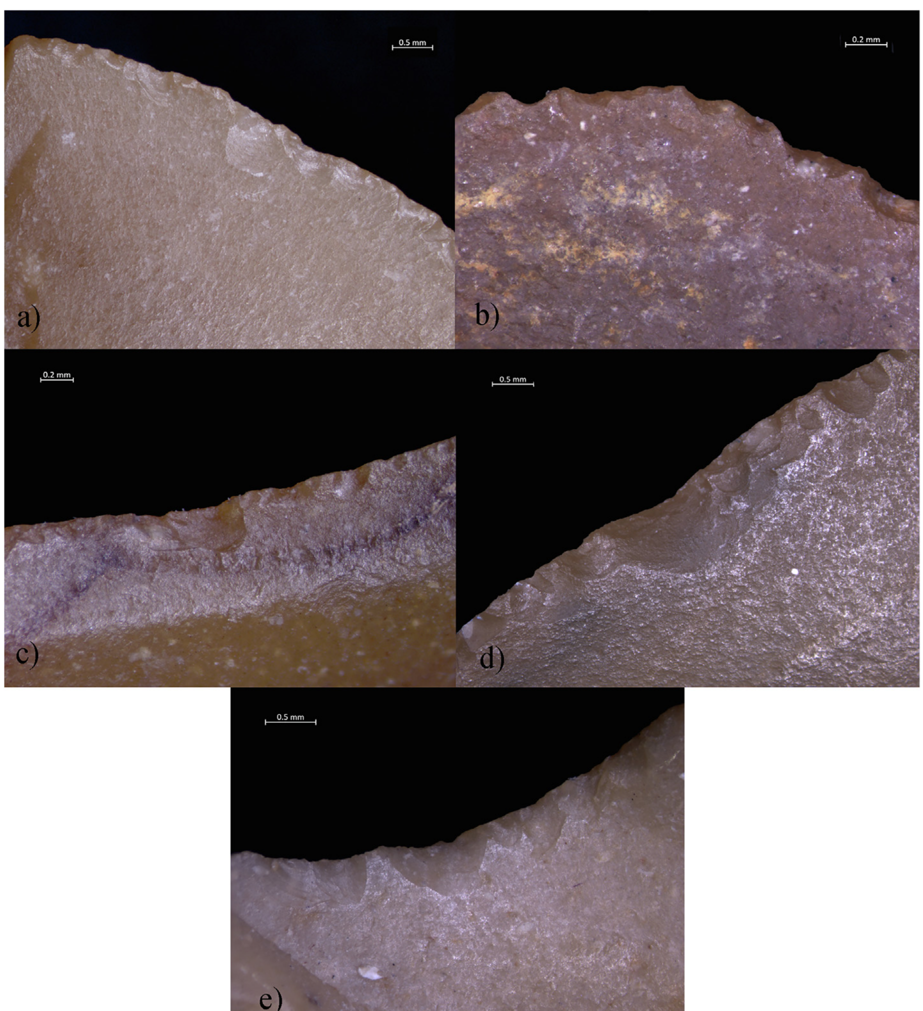


Fig. 6. Edge damage identified on the BPFCs. a) scarring related to cutting soft to medium materials; b) scarring related to cutting soft material; c) scarring related to scraping soft to medium material; d) scarring related to scraping medium to hard material; e) scarring related to scraping medium material.

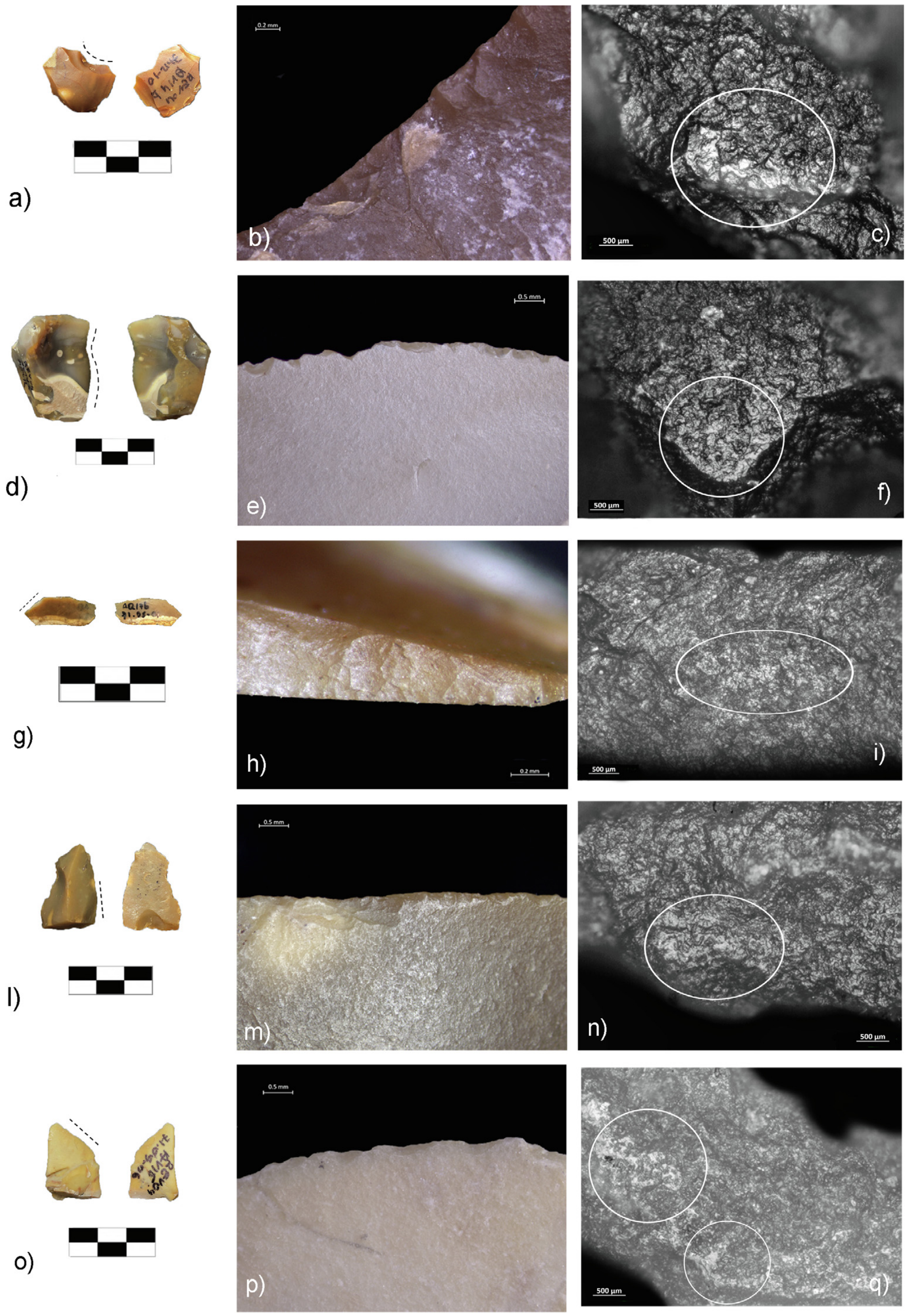


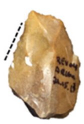
Fig. 7. Archeological small recycled flakes and related use-wear traces. a) Lateral item AV14b 71.12-10; b) hinge and step close-regular scars associated with a transversal activity on medium to hard material; c) smooth and domed polish interpreted as a prolonged contact with bone; d) Varia item AW14c 71.14-12; e) hinge and step termination scars with a close-regular distribution and a semi-oblique orientation associated to a longitudinal activity; f) rough to smooth polish with a domed topography interpreted as a contact with fresh animal material of a medium hardness (e.g., cartilage) and probably hide; g) Regular item AQ17b 71.08-01; h) cone feather features along with the outer edge with a close-regular distribution and a transversal orientation; i) rough and granular polish with a discontinuous distribution interpreted as contact with fresh fleshy tissues during an activity of scraping off the meat from the bone; l) Lateral item AS14a 71.11-08; m) feather scars becoming step with a close-regular and overlapping distribution and transversal orientation; n) rough to smooth texture and a granular to domed topography with a greasy appearance interpreted as contact with animal fleshy tissues including fat and involving contact with bone during the processing of animal carcasses; o) Kombewa item AV15b 71.09-06; p) lightly oblique half-moon sliced scars with a close regular distribution; q) rough granular polish which appears as smooth and domed on specific spots caused by a more prolonged contact with a hard material.

functional analyses on items of small dimension are however rare (Borel et al., 2017). In a paper by Alperson-Afil and Goren-Inbar (2016) the authors showed the possibility that small items from Gesher Benot Ya'aqov were hafted as a consequence of the modification of their proximal ends, but no use-wear analysis was performed to confirm this interpretation.

While no traces of hafting were recognized on the Revadim small flakes, we were able to reconstruct the way small recycled flakes were manipulated during the activities performed at the site. The possibility of identifying prehensile traces on lithic stone tools was considered with suspicion by researchers due to the difficulty in interpreting the light and poorly developed features derived from tool's manipulation (for an overview see Rots, 2010). Despite of that, by now it has been demonstrated by experimental and blind tests that manipulative strength during stone tools use allows the formation of systematic and patterned traces whose interpretation greatly improve our knowledge concerning hominins manipulative behaviors (Rots, 2004, 2010; Rots et al., 2006; Zupancich et al., 2016).

The occurrence of prehension scarring depends on several variables which may act at the same time when the tool is held during the activity. These include the position of fingers on the stone tools, the pressure/strength involved during the activity, the use of wrapping material, the morphological features of the prehensile area, the type of gripping, the activity/the hardness of the worked materials, the

Table 5
Morpho-technological characteristic of the used edge according to the recycling categories.

	n. of used items	Zenithal outline	Sagittal profile	Cross-Section	Cross-edge angle (on average) 	Standard deviation
Regular 	41	Straight and/or convex	Straight and/or convex	Straight-straight and/or straight-convex	33°	8.78°
Kombewa 	12	Convex and/or straight	Straight and/or convex	Straight-straight	36°	6.01°
Lateral 	19	Straight	Straight	Straight-straight and/or Straight-convex	44°	9.79°
Reversed lateral 	12	Straight	Straight	Straight-straight	48°	8.44°
Overshots 	5	Straight	Straight	Straight-straight	48°	10.23°
Proximal end-removals 	12	Straight and/or convex	Straight	Straight-straight and /or straight-convex	54°	6.24°
Varia 	6	Straight	Straight	Straight-straight	45°	5.34°

working time and the human hand/fingers anatomy (Williams-Hatala et al., 2018; Key et al., 2018; Key and Dunmore, 2018).

In general, microscopic evidence for the identification of prehensile wear consists of characterized polish, scarring and rounding or smoothing. Here, we base the interpretation on edge damage identification because lithic surfaces did not allow the investigation of micro-wear at high magnification. As for the active edge of the tools, edge damage on the "non-active" areas were interpreted based on their morphology, distribution and location, while also considering the degree of the edge-rounding.

The interpretation of the archeological prehensile evidence was determined with reference to an experimental collection of small recycled flake replicas used hand-held on several worked materials to perform different activities. On few of them scarring due to manipulation were observed, according to the duration of work, type of activity, tools morphology, tool's user and grip. We mostly recorded lighter rectangular scars with feather or hinge terminations. They are usually small and occur in specific spot of the artefact outline (where the finger pressure acted the most), usually with a continuous close regular distribution (Fig. 9a,b). Snap fractures of the edge may occur during the manipulation (in case of very thin grabbed edges) with the resulting formation of lighter scars running inside the fractures. Scarring and edge rounding are more pronounced when the prehensile part is wrapped in a piece of leather. In this case we observed half-moon scars with snap or step terminations running all along the edge with a close and regular distribution. In this case the degree of rounding is higher than on flakes used without being wrapped (Fig. 9c).

Within the archeological sample, we identified edge damage due to prehension on nine small flakes.

The prehensile areas were mostly observed on the distal end of the artefacts (opposite to the bulb area), rarely along the lateral edge. In one case only, the small portion created by the butt has acted as a supporting surface to better secure the artefact between the fingers.

Prehensile wear appears as small rounded scalar and trapezoidal

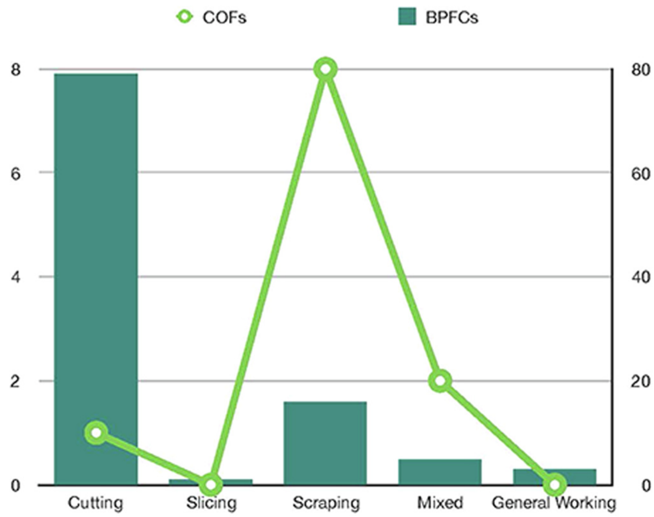


Fig. 8. Comparison of the actions carried out with the core-on-flakes (COFs, light green) and the blanks produced from core-on-flakes (BPFCs, dark green). Notice the high frequency of longitudinal activities carried out with the small recycled flakes in comparison with the preeminence for transversal motions practiced with COFs.

scars with feather and step terminations, sometimes with half-moon in shape (Fig. 10a-c). They occur in distinct, run-together portion of the opposite or adjacent edge to the functional one with a close and regular and sometimes overlapped distribution. In some cases, scars were observed only on one side of the grabbed edge (dorsal or ventral), corresponding to the opposite one on which pressure was exerted by the finger, the same pressure which allowed the formation of the scars. Edge-rounding is usually rather developed, testifying that a great force was exerted on the flake during the activity. Concerning that, we cannot exclude the possibility that wrapping elements (of animal or vegetal origin) may have been used to support the prehension, but in the absence of a microscopic investigation it cannot be claimed for sure.

According to the location and distribution of the prehension damage, we suggest a reconstruction of the hand-held gripping mode where the index finger was arranged along a precise spot of the flake's outline (measuring 5 mm on average). The thinness of the edge, along with a good dose of strength exerted by the finger during the motion, allowed the formation of well-recognizable prehensile scarring (Fig. 10).

This way of manipulating the tool between the thumb, the index and the lateral side of middle finger reflects the three-jaw chuck pad-to-side grip described by Key and colleagues (2018) where the index finger is used in a forceful opposition to the tool's cutting edge.

This kind of grip is categorized between those which allow fine manipulation of objects by the fingers and the thumb (precision grip) in opposition to those called power grips which employ the palm in securing the objects (Napier, 1956; Marzke and Shackley, 1986; Key et al., 2018).

It is important to stress the possibility that other kinds of precision grips may have been used by the Revadim hominins during their daily activities performed with small flakes (include those where pads of index and middle fingers are in opposition to thumb pad in order to stabilize the tool see Key et al., 2018 for detail). These kinds of grips are well-adapted to hold small objects, but they are more difficult to identify on small recycled flakes with patinated surfaces. These latter, in fact, show in general smooth ventral surfaces without the presence of ridge on which scars may have been formed, and, in the absence of detailed microscopic investigation, these grips may leave no evidence of scarring on a macroscopic level.

4. Discussion

The study of the production and use of implements of small dimension (flakes or tools less than 3–4 cm) in prehistoric assemblages is a topic that has recently gained the interest of scholars (Pargeter, 2016; Pargeter and Shea, 2019; Venditti, 2019). Small artifacts represent a part of the lithic production and a significant category of artefacts produced at Lower and Middle Paleolithic sites across Africa and Eurasia. Different lithic trajectories across time and space have been identified for the production of flakes and tools of small dimension (e.g., recycling, ramification, miniaturization, specific local trajectories) resulting in a broad technological variability which makes sometimes difficult comparisons between the different archeological contexts (Burdukiewicz and Ronen, 2003; Bourguignon et al., 2004;

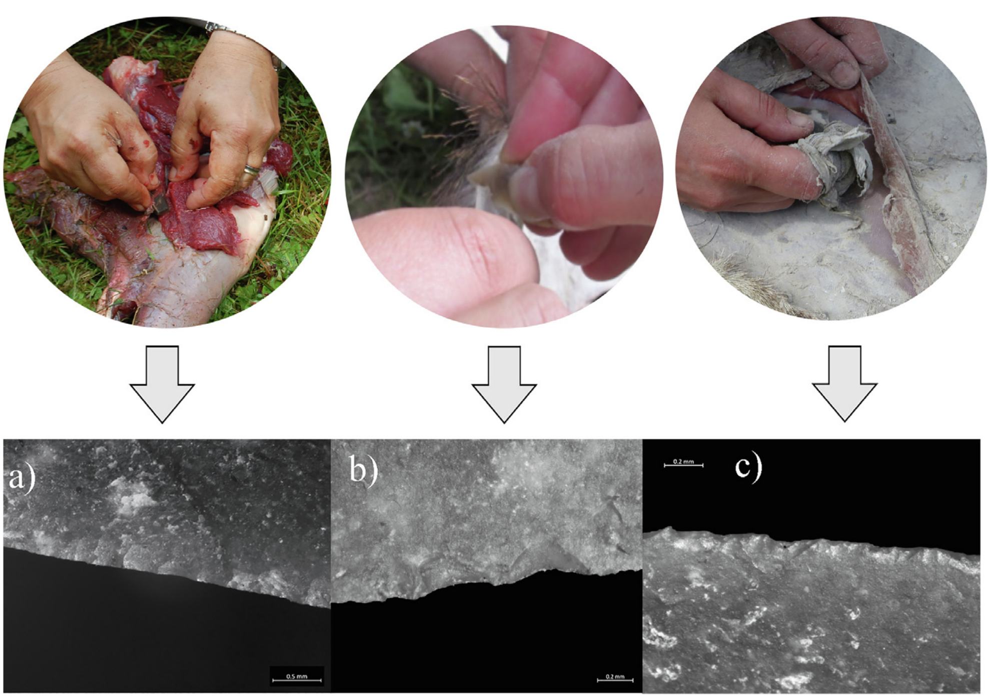


Fig. 9. Prehensile scars on experimental small flakes tools used for processing animal material. a) edge damage related to free-hand manipulation after filleting meat; b) edge damage related to free-hand manipulation after cutting dry hide; c) edge damage related to free-hand manipulation wrapped with hide after removing the subcutis from the hide.

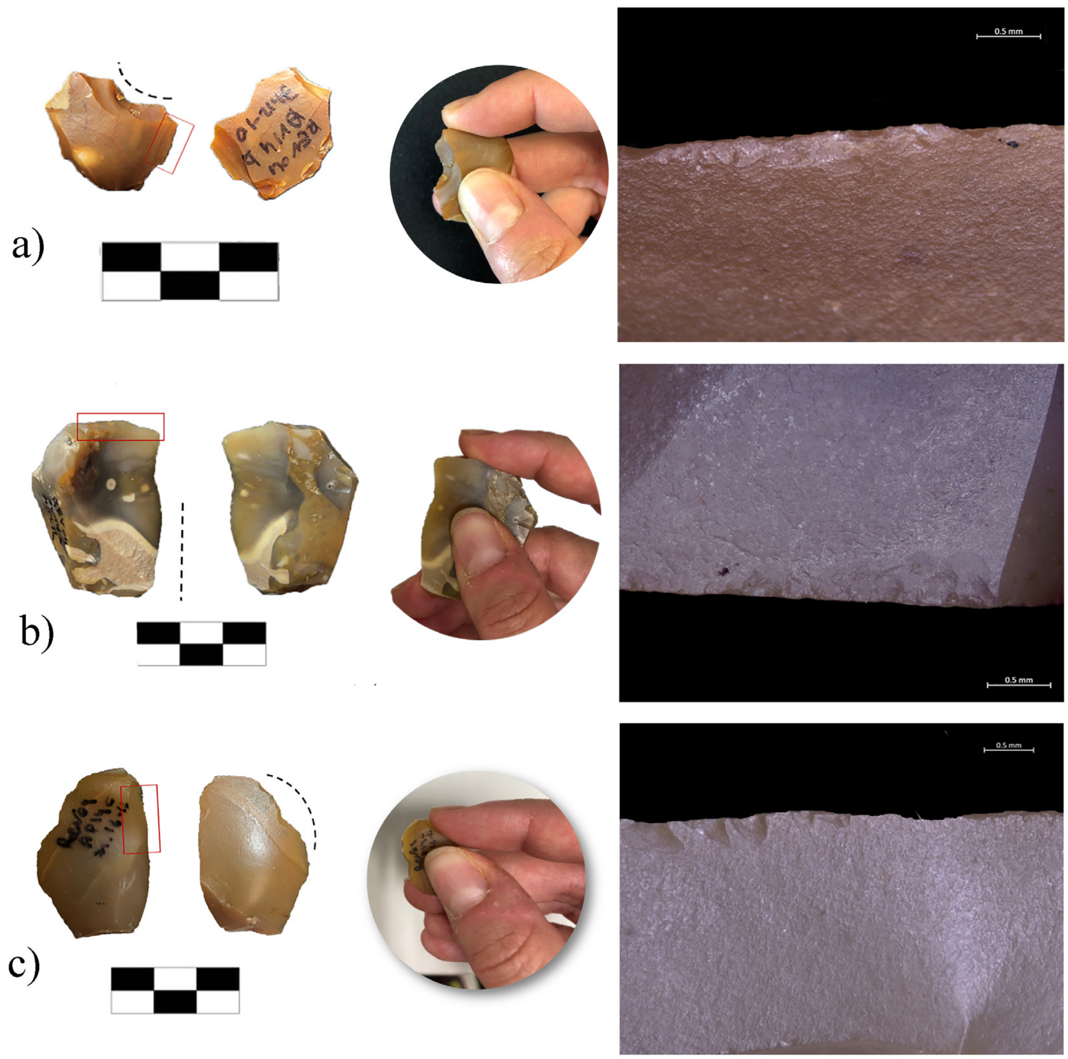


Fig. 10. Archeological small recycled flakes with the reconstruction of the hand-held gripping mode and the associated prehensile wear. a) Lateral item AV14b 71.12-10; b) Varia item AW14c 71.14-12; c) Kombewa item AP14c 71.16-12. Red square indicates the location of the prehensile wears while black-dotted lines denote the functional edge.

Hiscock, 2009; Thiébaut et al., 2010; Vaquero, 2011; Vaquero et al., 2012; Zaidner, 2003, 2013; Rios-Garaizar et al., 2015; Barkai et al., 2015; Gallotti and Peretto, 2015; Aureli et al., 2016; Rocca, 2016; Rocca et al., 2016; Santucci et al., 2016; Abruzzese et al., 2016; Borel et al., 2017; Romagnoli et al., 2018; Agam and Barkai, 2018a; Wojtczak and Demidenko, 2018).

Although the published materials mainly consist of data concerning the reconstruction of the chaîne opératoire and the knapping techniques implemented for the production of small flakes and tools, little is known about how these were used and for which purposes (Lemorini et al., 2015; Aureli et al., 2016; Santucci et al., 2016; Borel et al., 2017; Venditti et al., 2019a, 2019b).

The aim of the integrated study presented here is to provide new insights concerning the modes of production and utilization of a particular category of small implements: the tiny flakes produced from recycled COFs from Lower Paleolithic Revadim.

The functional analysis has demonstrated that COFs acted mainly as cores for the production of new small blanks, as they rarely present use-wear. Use-wear data suggest that their utilization was only occasional, when the new edges disclosed the morphological features suitable for the task at hand. The COFs at Revadim showed almost exclusive evidence of transversal motions interpreted as the scraping of medium-soft materials in association with concave outlines and a wide cross edge-angle resulting from the detachment of the small flakes. The same trend was observed by Lemorini and colleagues (2015) at the Acheuleo-Yabrudian Qesem Cave site, where evidence for the production of small sharp items from COFs by means of recycling was also detected (Parush et al., 2015). Thus, it should be stressed that this lithic trajectory seems a genuine Levantine tradition (practiced in other Near East Late Lower Paleolithic sites as well, e.g., Shimelmitz, 2015; Wojtczak, 2015), starting during the earlier Late Acheulian and protracting over the AYCC, albeit with some differences in the recycling schemes adopted (Agam et al., 2015; Agam and Barkai, 2018a).

It should be stressed that during the analysis of the COFs we observed the presence of retouch on 15 of them, indicating that these items served as tools before being recycled as core-on-flakes. Unfortunately, no clear evidence of patina differentiation which might attest a certain time span between the retouch stage and the recycling event was observed. Nevertheless, in seven cases the scar of the recycled item cuts part or the retouched edge, clearly indicating that shaped items, most probably used as tools, were further recycled as COFs.

The presence of several small recycled flakes bearing clear and well-defined use-wear and residue traces led us to confidently consider them as the final desired end-products of the recycling trajectory. Their use was oriented towards the exploitation of soft and medium materials, most likely of animal material, according to the polish characterization of five of them.

The techno-functional approach has demonstrated that despite the different typo-technological categories defined, the techno-functional units of BPCFs reflect a certain degree of homogeneity. Overall, the small recycled flakes show a straight outline commonly observed in zenithal and sagittal view. This feature fits well with their primary use which includes the performing of longitudinal motions as associated with cutting activities (mostly unidirectional). This is especially true for the technological category of regular double ventral and double ventral Kombewa flakes, characterized by straight edges which alternate thin convex morphologies and edge angles lower than 40°, ideal for working low resistance materials like fleshy animal tissues. Our experiments proved that cutting is much more efficient with straight and convex edges rather than with concave shapes which are instead more prone to performing transversal motions, especially on convex materials (e.g., bone, wooden branches), as reported by other researchers as well (Claud, 2008; Lemorini et al., 2015; Falzetti et al., 2017).

Within the whole sample, reversed lateral and overshot flakes presented a lower percentage of use despite the former category exhibiting a rather high percentage of produced items. Here, the new edges created between the two ventral faces after the detachment of the flake from the COF never showed traces of utilization. When used, they were instead recognized on one of the two lateral cutting edges formed after the detachment from the ventral face of the core-on-flake. Their edge-angle values, as for the lateral double ventral and the proximal end removal flakes, range between 44 and 54°, a feature that provides more robust and thicker edges which are well adapted to process material of medium and medium to hard consistency.

The framework emerging from the techno-functional analysis showed that the small flakes produced from COFs at Revadim were suitable to the processing of both soft and medium hardness materials according to their morphological features and the arising needs. Following the frequency of production and percentage of utilization, it seems that regular double ventral flakes were the most desired artefacts. The contribution of the experimentation highlights their affordance in performing meticulous cuts during relatively short-term actions on materials limited in volume. It is worth noting that their metrical features (thin, sharp, with short edges and with an overall small size) constitute the principal limit for their utilization, but it also represents their primary functional peculiarity. The small and sometimes minuscule used edge portions of the recycled flakes, always used unmodified, imply the high degree of precision carried out by the Revadim hominins during their daily life activities while using these tools.

The number of flakes showing evidence of macro to microscopic animal related use-wear traces, leads towards their utilization in butchery activities, albeit the exploitation of vegetal resources might also have been performed but no evidence survived. The outstanding preserved ancient animal residues found on several small recycled flaked and associated with both functional and prehensile areas have strongly contributed to increase the reliability of the use-wear interpretations (Venditti et al., 2019b). Moreover, the recurrent hydroxyapatite micro-remains detected on the lithic surfaces allowed the more precise reconstruction of the utilization of the small flakes for activities involved a repetitive contact with bone. In this regard, we found small recycled items perfectly suitable for careful actions performed during carcass processing, such as the stripping of the flesh from the bone, periosteum removal but also filleting of meat, the cutting of fresh hide or skinning procedures.

Activities and gestures involving precision and *finesse* performed with tools of small dimensions also required the use of a 'precision grip' to secure the objects at hand. Experimental works exploring the hand grip diversity highlight the influence that tool-use and tool-form may have on grip choice (Marzke, 1997, 2013; Pouydebat et al., 2009; Key et al., 2018). The prehensile wears observed on some archeological flakes at Revadim suggest a free-hand manipulation where the item is held between the fingertips and the opposing thumb. In these cases, the back portion of the item seems to be preferred because it is morphologically suitable for handling. Based on our experimental experience, the hand-held gripping proved to be the best prehensile mode for these small items, allowing a certain tilt during their manipulation for a change in edge angle and edge portion used following the required needs.

Biomechanical studies investigating hominin manipulative capabilities showed that the implementation of the 'precision grip' among our ancestors goes in parallel with their hand anatomy and dexterity (Tocheri et al., 2008; Rolian et al., 2011; Marzke, 2013; Almécija and Shwerwood, 2017). A recent study exploring manipulative behavior in the Neanderthal fossil record through the analysis of hand muscle attachments demonstrated that Neanderthals were able to use a systematic precise grasping to perform delicate manipulation of objects for activities necessitating a certain level of precision, a characteristic usually attributed to anatomically modern humans (Karakostis et al., 2018). Unfortunately, the investigation of *Homo Erectus* grip capabilities and the morphological features of their hands is limited by the paucity of insufficient fossil hand bones (Ward et al., 2013). However, the methodological approach presented here demonstrated the possibility to tackle the problem and obtain indirect information which can provide important insights into the tool-using behavior of Middle Pleistocene hominins.

5. Conclusion

The data presented in this paper, coupled with faunal, environmental and geological studies performed at Revadim (Marder et al., 2011; Rabinovich et al., 2012), suggest a scenario according to which late Acheulian hominins occupied the mild slope of the channel bank of Revadim, a location attracted also by the diverse faunal species who came there looking for water, food and shade. In the case of Revadim, the lack of direct evidence does not allow to address the questions regarding prey procurement strategies applied (scavenging versus or combined with hunting, but see Agam and Barkai, 2018b). It is clear however, that the human groups that frequented this locality produced on the spot small flakes by means of recycling satisfying immediate, brief and specific prey butchering tasks in order to obtain high energy food (e.g., meat and fat) for their sustenance and adaptive purposes (e.g. Guil-Guerrero et al., 2018).

In this context, the lithic recycling trajectory was well-adapted to conditions of immediacy providing the Revadim hominins with a large quantity of sharp cutting tools by a short sequence of removals, without a need of further modifications. Although these conditions are generally referred to expedient contexts or to scarcity in raw materials (Vaquero et al., 2015), we argue that the small flakes discussed here were not designed and used by the Revadim hominins in an opportunistic and occasional way. To the contrary, the recycling trajectory reflects the idea of a well-thought production procedure, which meets specific and meticulous needs by an educated use of available resources. The techno-functional analysis and the experimental activities highlighted the "non-versatile" character of the small recycled flakes, framing them as *'ad hoc'* implements, used *'hic et nunc'* during the butchery process. According to our experimentations on animal and vegetal materials, there are some activities that are difficult or even impossible to perform with small flakes (e.g., scraping hide, crush bones, cut hard materials into two halves etc.). The functional results show that the small recycled flakes were designed for a single-use only of rather short duration after which they were discarded (multi-working activities were never observed). The location of the use-wear traces, often on small and limited portion of the functional edge, testify the search for accuracy and meticulous motions. The butchery process is a demanding and long-lasting task where several different activities (e.g., deskinning, evisceration, disarticulation, filleting meat, tendon removing, marrow extraction) coupled with specific motions and gestures have to be carried out in order to obtain food (meat, fat, brain, marrow) and potential raw materials (bones, antler, tendons, hide). The use of the recycled small flakes during the butchery process at Revadim were not exclusive. To the contrary, we argue that small recycled flakes were used as a complement to other light and heavy-duty tools retrieved in area C layer 3 (e.g., scrapers, notches, denticulates, burins, bifaces, chopping tools, flakes), according to the task at hand. In this regard, at Revadim, a preference towards the use of unretouched implements in butchering activities has been also noticed by Zupancich and colleagues (2018) in the analysis of a sample tools from areas B (loc. 23 and 24) and C (layer 5), while more curated objects seem instead to be used in the processing of wood and vegetal resources. This peculiarity seems to reflect a repetitive pattern observed in other Lower Paleolithic sites that may be read as a cultural marker of early Pleistocene hominins (Nicoud et al, 2015; Lemorini et al., 2015; Santucci et al., 2016; Sànchez-Yustos et al., 2016; Ingicco et al., 2018; Venditti et al., 2019a). In fact, in Area C Layer 3, the small flakes constitute only one part of a diverse tool-kit produced and used by the Revadim hominins (Agam and Barkai, 2018a). We are confident that heavy-duty butchery tasks like split-carcass were carried out with more massive tools (e.g., bifaces, choppers, larger flakes) necessitating an increasing loading potential (Key and Lycett, 2014, 2015), while other stages of carcass manipulation were performed by other sets of tools (large sharp flakes, scrapers etc.). Several Lower and Middle Paleolithic sites have been interpreted as butchery localities because of the association with heavy and light duty-tools and the faunal remains showing, in some cases, evidence of cut-marks (Piperno and Tagliacozzo, 2001; Dominguez-Rodrigo et al., 2005; Delagnes et al., 2006; Solodenko et al., 2015; Mosquera et al., 2015; Sánchez-Yustos et al., 2016; Ingicco et al., 2018).

Small recycled flakes could have been employed either in performing meticulous and precise cutting activities during the final stages of the butchery process (e.g., periosteum removing, filleting meat, cleaning bone from meat) and/or aided in executing such precise cuts during specific moments in earlier stages of carcass manipulation (e.g., deskinning and defleshing processes).

The data presented in this paper, coupled with the evidence obtained thus far regarding the techno-economic behavior practiced at late Lower Paleolithic Revadim indicate the conceptual and practical employment of a varied tool-kit manufactured for anticipated specific purposes in relation to the duration of the activities, the cutting efficiency, the material to be process and the applied force. The study of small recycled flakes presented here adds another angle to the adaptability, ingenuity and practicability of Late Lower Paleolithic human groups of the Levant. Moreover, as small flakes were mostly neglected from scholarly attention in traditional lithic analyses, we hope that the results presented here will encourage more scholars to study the small fraction of Lower Paleolithic technological and functional systems.

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Author contributions

F.V. conceived and design the research, performed the use-wear analysis on the archeological and experimental materials, conceived and performed experiments, primary manuscript text writing.

A.A. performed the technological analysis and contributed to the writing of the manuscript.

R.B. contributed to the writing of the manuscript.

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