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Innovative Neanderthals: Results from an integrated analytical approach applied to backed stone tools

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ABSTRACT

The production of prepared backed artifacts during the Paleolithic is recognized as an important step in the design of ~~artifacts~~ tools for manual activities and the development of human tool ergonomics. Backed artifacts are generally identified as proxies of so-called "modern" behavior, partly because they tend to be associated with systematic hafting, but mostly because they are widespread within Middle Stone Age (MSA) or Early Upper Paleolithic (EUP) assemblages attributed to anatomically modern humans. However, in Europe these tools were first manufactured by Neanderthal groups associated with the Mousterian of Acheulean Tradition (MAT) techno-complex and Discoid and Levallois technologies, using a range of flake blanks. Investigating the reasons for this behavioral leap forward can help to unravel the development and diffusion of various aspects defining the behavioral complexity of Paleolithic humans. In this paper we present a detailed analysis of one of the oldest and richest collections of prepared backed items preserved in Europe. We study several dozens of what – in a broad sense – are considered backed artifacts, with both natural and predetermined knapped backs, recovered from unit A9 at Fumane Cave, which is dated to at least 47.6 cal ky, and is characterized by discoid technology. Our methodology integrates results obtained from technological, techno-functional and use-wear analyses, further supported by experimental data. Two distinctive types of anthropogenic modifications have been identified, both aimed at creating a back or at modifying and accommodating an already existing back. By cross-checking our results with use-wear data, we show that some of these modifications were aimed at adjusting the shapes of the tools (knives and/or scrapers) for manual handling, although traces consistent with hafting have been recognized on a few specimens. Contextual information allows us to infer that these adjustments involved mainly tools used in precision activities, whose design and production implies varying levels of expertise and technical skills. Although still not systematic or standardized, the kinds of complex tool-making implied by backing can be considered as typical feature in the technological repertoires of late Neanderthals.

1. Introduction

The design of Paleolithic stone tools underwent a complex evolutionary path dotted with successful innovations and their consequent spread, characterized by an improvement of maintenance technologies, but also marked by the persistence of archaic forms. The mental pattern and practical construction of each lithic implement combine requirements originating in the physical-biological environment, as well as the economic and socio-cultural contexts (Leroi-Gourhan, 1971, 1973; Lemmonier, 1983; Simondon, 1989). The form and structure of any lithic object are related both to the actions performed by the implement on some material and to its contact with the human agent, the source of energetic effort and mechanical performance. Different morpho-technical features and different active zones of the tool are subject to stresses from both the material worked and the tool user (Lepot, 1992/1993; Geneste and Plisson, 1996; Bourguignon, 1997; Boëda, 2013). This is particularly the case of tools shaped on flakes. When the first expressions of knapping technology appeared among African hominins, artifacts were "designed" in the simplest possible way, with a cutting edge and an areas suitable for direct gripping by hand (Harmand et al., 2015). From this basic structure, the efficiency of the tools' working edge could be enhanced by retouching. Moreover, tools gained in ergonomic effectiveness through enhanced direct prehension and hafting that improved the force transmission to the functional edge of the artifact.

Hafting has been viewed as a key step in the evolution of human technologies. It implies a complex array of knowledge of the material and of the procedures required to produce composite tools. Hafting of lithic tools ~~has been recognized as~~ a ~~common~~ practice among early and late Neanderthals, ~~despite the fact that~~ evidence from the Middle Pale-

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olithic is still rare (Anderson-Gerfaud and Helmer, 1987; Beyries, 1987a; 1987b; Hardy et al., 2001; Rots, 2009, 2013; 2015; Rots et al., 2015). Moreover, data are contradictory for a number of specific tools, such as Levallois points (Plisson and Beyries, 1998; Shea et al., 1998; Rots and Plisson, 2014) or Quina scrapers (Hardy, 2004; Rots, 2009). These artifacts were used in diverse ways, only some placing them in handles or hafts.

In most cases, hafting requires a deliberate modification of flakes by thinning (Porraz, 2002), retouching the edges, or a combination of both, to facilitate insertion in the handle (Stordeur, ed., 1987). However, many tools bearing organic residues, interpreted as adhesives for hafting, do not show traces of preparatory modifications. This is the case of the Middle Pleistocene site of Campitello, Italy (Mazza et al., 2006), the Micoquian Inden-Altdorf site, Germany (according to the illustrations in Pawlik and Thissen, 2011), or the Levallois flakes and scrapers from Umm-el-Tlel and Hummal, Syria (Boëda et al., 1998, 2008). Moreover, on many of these implements, the portion of the tool fixed in the haft is the thickest one and, in the case of core-edge removal flakes (*éclats débordants*), it includes the striking platform and a portion of the core's edge. The quartzite scraper found at Gura Cheii-Râsnov Cave, Romania, the back of which was irregularly retouched, is a case in point (Cârciumaru et al., 2012).

While there have been many studies of adjustments to artifact morphology as accommodations to hafting the effectiveness of direct manual prehension can also benefit by adjustments to an artifact's morphology. Pre-shaping of the blank before it has been detached or later modification through retouch (Rots, 2009) can make a blank more suitable also for direct prehension. Much less work has been done on morphological accommodations to manual prehension in stone tools.

More generally, the technological variability through time and space that characterizes the long-lasting occupation of the Western Eurasian continent by Neanderthals is direct evidence of their complex, flexible and innovative behavioral strategies. One consequence of this variability is that the same functional needs may have been fulfilled by using morphologically and technologically comparable objects which themselves were obtained through diverse manufacturing strategies. Differences in how similar implements were produced may reflect constraints imposed by the ecosystem and/or cultural constraints imposed by tradition (Boëda, 2013). The detection and understanding of poorly known behavioral patterns could tell us much more about the existence of cultural traditions and their impact on the technological systems adopted by Neanderthals.

The techno-functional group of implements consisting of unretouched backed tools (*couteaux â dos naturel*; Bordes, 1961) and invasively or partially retouched backed tools (*couteaux â dos typiques* or *couteaux â dos atypiques*; Bordes, 1961) ~~encompasses~~ this techno-typological variability. Such artifacts have been recovered in many contexts dating back to the early Middle Paleolithic (Bordes, 1984). The category includes a very large diversity of artifacts that share the same basic ergonomic characteristics. In fact, their design and usability suggest the function of a knife, efficient and easy to handle (Beyries and Boëda, 1983). The behavioral significance of backed tools depends on the broader technological entities in which they functioned. For example, the existence of a standardized retouched back can be related to systematic tool hafting, which in turn implies complexity in design and advanced problem-solving capacities in manufacture (Ambrose, 2001; Barham, 2002).

Because of their simple and intuitive form, with a sharp active edge opposed by a thick, passive back, backed tools also have special significance in the definition of specific Middle Paleolithic technological traditions. They are considered as defining features of diverse late Mousterian techno-complexes, including Keilmessergruppen, Mousterian of Acheulean Tradition Type B, and various assemblages derived from Levallois and Discoid knapping technologies. Keilmessergruppen assemblages are characterized by the eponymous asymmetric bifacial backed knife, the *Keilmesser*, and appear to be restricted to central Europe, from Eastern France to western Ukraine (Bosinski, 1967; Jöris, 2006). The Mousterian of Acheulean Tradition, characterized by the presence of retouched backed knives, especially in the later Type B assemblages, is widespread in Western Europe (Bordes, 1984; Soressi, 2002). Mousterian assemblages with backed flakes obtained through Discoid and Levallois technologies are more pan-European, having been reported in southern, western and northern regions (Freund, 1968; Boëda, 1995; Delagnes et al., 2007; Locht and Swinnen, 1994; Lemorini et al., 2003; Slimak, 2008).

To shed light on the potential cultural significance of backed tools during the Late Mousterian in Europe from the first half of MIS 3, we integrated a techno-morphological and use-wear analysis of a Discoid assemblage in Italy in order to explore the design and function of this ‘type’ of tool in the large assemblage from unit A9 at Fumane Cave.

2. Fumane Cave and the Discoid industry from unit A9

Fumane Cave has produced a finely layered late Middle and Early Upper Paleolithic sequence with Mousterian, Uluzzian, and Aurignacian levels (Broglio et al., 2006; Peresani, 2012; Peresani et al., 2008, 2016). Within the Mousterian sequence, unit A9 records the appearance of an exclusively Discoid industry between two Levallois cultural units - A10 below and A6 above. A9 (~~with its top horizon~~ formerly labelled unit A8) is separated from the unit A6 by the sterile layer A7 (Peresani, 1998). The industry is ~~typically~~ represented by thick flakes, pseudo-Levallois points, backed flakes with a sharp opposing edge, polygonal and triangular flakes, and few scrapers, points, and denticulates. The stone artifacts were produced through the application of Discoid technology on ~~using~~ cherts derived from several different sources (Fig. 1; S.I. Table 1) (Delpiano et al., 2018). The use of multiple raw material sources, combined with the presence of chert and fossil gastropods collected from sources located at least 80 km and 110 km respectively ~~far~~ from the site and the recycling of old patinated artifacts, indicate a complex and diversified use of raw materials, encompassing logistical planning of the economic organization (Peresani et al., 2013, 2015; Delpiano et al., 2018). Previous functional analyses based on macroscopic use-wear have shown that tools from unit A9 were being used for different purposes, on soft, medium-hard, and hard materials (Lemorini et al., 2003). The faunal assemblage is dominated by cervids (red deer, giant deer and roe deer), with smaller amounts of bovids and caprids (ibex and chamois) and other mammal species, as well as birds (Peresani et al., 2011; Fiore et al., 2016; Romandini et al., 2016). Actions that can be attributed to different stages of the butchery process, such as skinning, dismembering, and filleting, were identified (Romandini et al., 2014). The A9 unit has provided a micromammal assemblage (López-García et al., 2015) and a minimum radiocarbon age at 47.6 ky cal BP (Peresani et al., 2008; Higham et al., 2014). ~~New~~ radiocarbon ~~dates are~~ currently ~~in~~

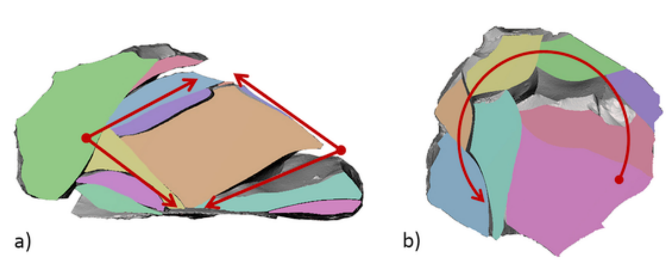

Fig. 1. Fumane unit A9 Discoid technology reconstructed by means of 3D multiple refitting: a) cross-sections show alternate exploitation of the two core faces and b) how the continuous centripetal flaking develops with core reduction (by Delpiano and Peresani, 2017).

~~progress.~~ Human remains demonstrate the presence of at least one young Neanderthal individual (Benazzi et al., 2014).

3. Materials and methods

3.1. Morpho-technical analysis

A sample of 83 backed tools, including artifacts with both natural, predetermined and prepared backs, was selected from an initial screening of the whole assemblage of backed implements. Our selection criteria were based mainly on the specific type of backing, which resulted either from intentional modification (i.e. retouch) or from macroscopic detachments that can possibly be referred to use. Each of these tools is a part of a technological and techno-economic framework (Peresani, 1998; Delpiano et al., 2018) where different stages of core reduction are not equally well represented at the site. The parts of reduction sequences that are present depend on the type of chert used and on the strategy adopted for its exploitation. Long artifact use-lives and the subsequent tool retouching and re-shaping characterize only some techno-types and specific raw materials.

The identification of working techniques used to modify the artifact~~s~~ backs was based on experimental protocols developed by Pelegrin (2004), Duches et al. (2018) and Fasser et al. (2019), which analyze a number of morphological and technical parameters (sequence of removals, longitudinal and transversal profile, morphology, initiation and termination of scars, presence of incipient cones). However, this protocol was developed mainly to distinguish traces of percussion ~~techniques from~~ pressure ~~with soft stone or organic tools,~~ on Late Upper Paleolithic backed points. Pressure retouch is missing in Fumane. Consequently, additional technological features, such as the presence of dorsal contra-bulbs, parasitic or orthogonal fractures, and bulb scars were taken into account. Experimental replication of backed implements has confirmed that these attributes can help identify the use of direct percussion, percussion on anvil or abrasion in creating backs.

For the purpose of analysis, the supposed active zones of receptive/prehensive contacts were treated separately from the transformative part (or active working edge of the tool). By zone of receptive/prehensive contacts we mean the portion of the blank opposite or adjacent to the working edge which most likely served as a place to hold the artifact. This could include the striking platform, a natural or worked back, or a shaped or thinned part of the artifact's margin. The flat, thick butts of the discoid blanks sometimes act as a reception/prehension zone and may be connected to the back when it is adjacent. Both natural and worked backs show ergonomic forms, even if isolated. ~~So retouch~~ was also be performed for ergonomic purposes, contributing to the optimization of receptive/prehensive contacts. The transformative contact (active cutting edge) may include one or more edges, either isolated or adjacent to one another, and can be described in terms of general contours (e.g. point, trapeze, etc.). The edge itself generally involves several techno-functional units that can be distinguished through shape, sagittal profile and transversal cross-section.

The morpho-technical features ~~which were~~ analyzed are linked to the blank's structure and size, as to elements such as: back, butt, thinning, and presence of ~~rough~~ or retouched edge. We have based our analysis of edge features on M. Lepot's (1993) and L. Bourguignon's (1997) protocols: variables recorded include plane outline or shape (straight, convex, concave, broken, sinuous), sagittal profile (straight, convex, concave, convex-concave, etc.), dihedral edge (e.g. transversal cross-section: combination of flat, concave, convex surfaces), angle formed by the ventral/dorsal face and the first series of retouches, and the secant plane perpendicular to the dihedral edge. Edge angles were measured using a manual goniometer according to ~~classes of~~ 5° ~~range.~~ Available experimental data show that grouping edge angle measurements into 5° intervals does not affect the interpretation of functional characteristics (Lemorini et al., 2003). When one techno-functional unit had different angles, we calculated the minimum, the maximum and the average of the values recorded both at the center and at the ends of the edge. On retouched edges, the following features have been recorded: plane outline (straight, convex, concave, broken, sinuous, denticulate), sagittal profile (straight, convex, concave, convex-concave, denticulate), invasiveness (very marginal, marginal, invasive, variable), scar morphology (concave, convex, flat and notched; the latter, in turn, can be more or less re-elaborated), order or series (from one to three), angle (measured on the last series of retouches, also in intervals of 5°). Finally, in order to correctly distinguish the different parts of individual tools and to establish an operational and techno-functional scheme, we compared and investigated the relationship between the different contact zones on the same object, which were obtained by measuring the outline shape and the transverse section.

3.2. Functional analysis

Tools were gently cleaned with hot water and soap before being analyzed under the microscopes. Subsequently, an ultrasonic bath was performed for 15 min using demineralised water with 2% neutral phosphate detergent. Finally, tools were rinsed again under running water to remove any detergent residues (Pedergnana and Olle, 2017).

Use-wear analysis was performed at the DANTE laboratory ~~by~~ applying both low and high-power approaches (Keeley, 1980; Tringham et al., 1974; Odell, 1981; Vaughan, 1985; Lemorini, 2000; van Gijn, 2010; Rots, 2010). Following the low-power approach, the objects were observed at up to 90× magnification using a Zeiss Axio ZoomV16 Digital Stereoscope with reflected light, equipped with Zeiss Axiocam 506 color digital camera. The analysis of the tools at a low magnification allowed us to identify edge damage associated with use, ~~which is~~ represented by micro scarring and edge-rounding ~~which formed~~ on the tool's functional areas. The morphological features of edge micro scars, namely the initial and terminal part along with their location and distribution on the edge surface, allow the reconstruction of the motion of the activity ~~that was~~ performed (e.g. transversal or longitudinal) and ~~determine~~ the hardness (soft, medium and hard) of the substance which was processed (Odell, 1981; Odell and Odell-Vereecken, 1980).

Subsequently, the specimens were observed under reflected light at 100× and 400× magnifications, using a Zeiss AxioScope A1 metallurgical microscope, equipped with 10× ocular and 10×, 20× and 40× objectives. Pictures were taken using Zeiss Axiocam 305 color digital camera. High magnification observations allowed us to identify wear such as micro-polish, striations and abrasions related to use. The features of the micro-polish, such as topography, texture and orientation patterns of micro striations, provide information about the materials that were processed. Unfortunately, the sample analyzed in this study was affected by post-depositional modifications (PDSM) which prevented the identification and interpretation of micro wear. Specifically, the PDSM identified consisted of heavy edge rounding and fractures/crushing caused by the movement of the artifact within the soil, and surface patination such as glossy appearance and soil sheen. These latter (glossy appearance and soil sheen) affect the entire analyzed assemblage and are related to the acidic nature (pH < 4) of the sediments in which the artifacts were embedded (Burroni et al., 2002; Levi Sala, 1986; van Gijn, 2010).

4. Results

4.1. Morphology, morphometry and technology of the backed pieces

The sampled artifacts are mainly core-edge removal flakes (CERF; Geneste, 1988; Mellars, 1996) or pseudo-Levallois points produced using the Discoid method (Boëda, 1993; Bourguignon and Turq, 2003). Core blanks included both nodules and flakes. Flakes, selected for 76 tools, were equally divided between pseudo-Levallois points and ordinary flakes equipped with a natural or predetermined knapped back opposed to a sharp edge. An additional seven blanks were obtained from Kombewa-type reduction (S.I. Table 2). Flakes obtained during the early stages of the reduction sequence were seldom selected as blanks for retouched backs, and are rare in our sample. This is interesting because cortical flakes and flakes featuring cortical backs would seem to be well suited for transformation into or use as backed tools (Peresani, 1998). Only 23 out of 83 flakes are partially covered with cortex. Of this number, 20 have less than 25% dorsal cortex cover, and only one has more than 50% cortex cover. The backs of these artifacts analyzed, whether on the right or left side of the blank were, in most cases, formed by removal of part of the core-edge adjacent to the striking platform. Finally, on 11 tools the back was almost entirely manufactured by retouching, as in "typical" backed tools (Fig. 2; S.I. Table 2).

The dimensions of the selected artifacts vary depending on the degree of the core reduction, the combination of previous detachments and the knapping objective (Fig. 3). The average length is 36.3 mm. The sample splits into two groups: small flakes (24–33 mm), mostly produced during the final core reduction phases, and large flakes (36–48 mm), the only ones bearing portions of cortical surfaces. Among the smallest flakes, mainly latero-transverse (*dejeté*) points with ~~opposite~~ backs (pseudo-Levallois points) and short and wide quadrangular or triangular flakes with latero-proximal backs and latero-distal cutting edges are present. The latter are often characterized by convex cutting edge, that can be interrupted by small trihedrons/spines coinciding with the ridges of previous negatives. Larger flakes are generally elongated, with lateral and parallel, or sub-parallel, edges showing variable profiles from straight to convex. Edges converge to a point in only a few cases.

4.2. Deliberate modification of the backed edges

A wide range of tactics and techniques were used to create backs, all of which to create or refine a thick and blunt portion of the blank opposite the functional active edge. These modifications, which include detachments probably caused by use itself, are divided into 5 "types", as follows (Fig. 4; S. I. Table 2).

TYPE 1. In thirteen cases the back is clearly manufactured by means of direct, continuous and abrupt or semi-abrupt retouch. This usually occurs ~~when~~ lacking a natural back formed by cortex or the preservation of the core edge. Small Kombewa-type flakes were sometimes selected for this design. In general, half of the backs were manufactured by percussion on the obverse face and then used without any further interventions; on the other hand, the remaining half were manufactured by abrupt retouching on anvil and then further rectified through an extended abrasion in order to remove the uneven parts of the edge. Normally, "Type 1" retouch modulates the thickness of the back, which is on average 8.6 mm (ranging from 2 to 20 mm), with predominantly sub-rectilinear to slightly wavy/convex profiles and lower angles that range from 70° to 90°. In particular, direct percussion creates angles averaging 72°, with large detachments that create a convex transversal profile of the back. Anvil percussion creates ~~more open~~ angles (85°) and produces backs with rectilinear transversal profiles.

TYPE 2. Several flakes (20) were marginally retouched in order to regularize and correct protrusions or to adapt the back to the requirements of manual prehension. Manufacturing techniques include direct percussion, percussion on anvil (usually without further regularization) and, more rarely, abrasion. The original blanks are either quadrangular flakes, pseudo-Levallois points or, sometimes, elongated CERF.

TYPE 3. The ventral face of 17 pieces was thinned by using the back as a striking platform or, alternatively, by detachments from the base/butt of the tool, affecting partially and indirectly the back. These kinds of modifications, aimed at modifying the back's lower profile, were frequently observed on pseudo-Levallois points, small Kombewa-type flakes and wide and partially cortical CERFs.

TYPE 4. Approximately 30 tools are characterized by continuous and repeated detachments, which either begin from the upper back's edge and continue along the back (rarely - type 4b) or are present on the dorsal surface (more frequently). Although some of these detachments may have been used to smooth and prepare the discoid core's peripheral ridge before striking, specific sequences have been identified in the pattern of scars, as have incongruences in the design of the core exploitation, suggesting that the modifications were created to facilitate prehension.

TYPE 5. Some of the selected pieces bear tiny and/or discontinuous detachments and traces of abrasion on the back, which initiate from the lower face. These modifications require further study, combining technological and use-wear analyses, in order to establish whether they represent intentional modifications, the byproducts of use of the presumed prehensive portions, or post-depositional alterations.

It is important to note that, although various techniques could be applied by themselves, a large number of products display a combination of the modifications described above, located on different portions and designed to serve a variety of purposes or to contribute towards the same objective.

4.3. Experimental replication and use

An experimental protocol, based on the replication and employment of archaeological backed implements, was developed in order to evaluate ~~and enhance~~ the results which were obtained from the technologi-

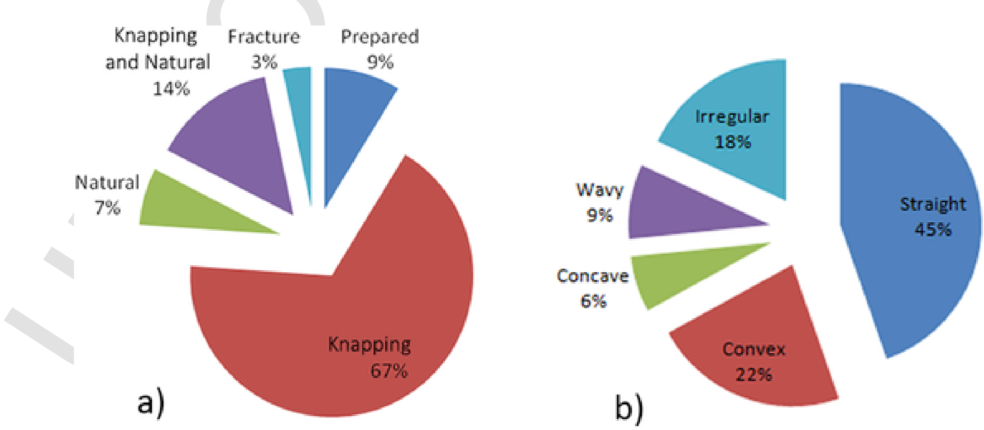

Fig. 2. a) Technological origin of the back of the artifacts, b) longitudinal profile of the whole backed side.

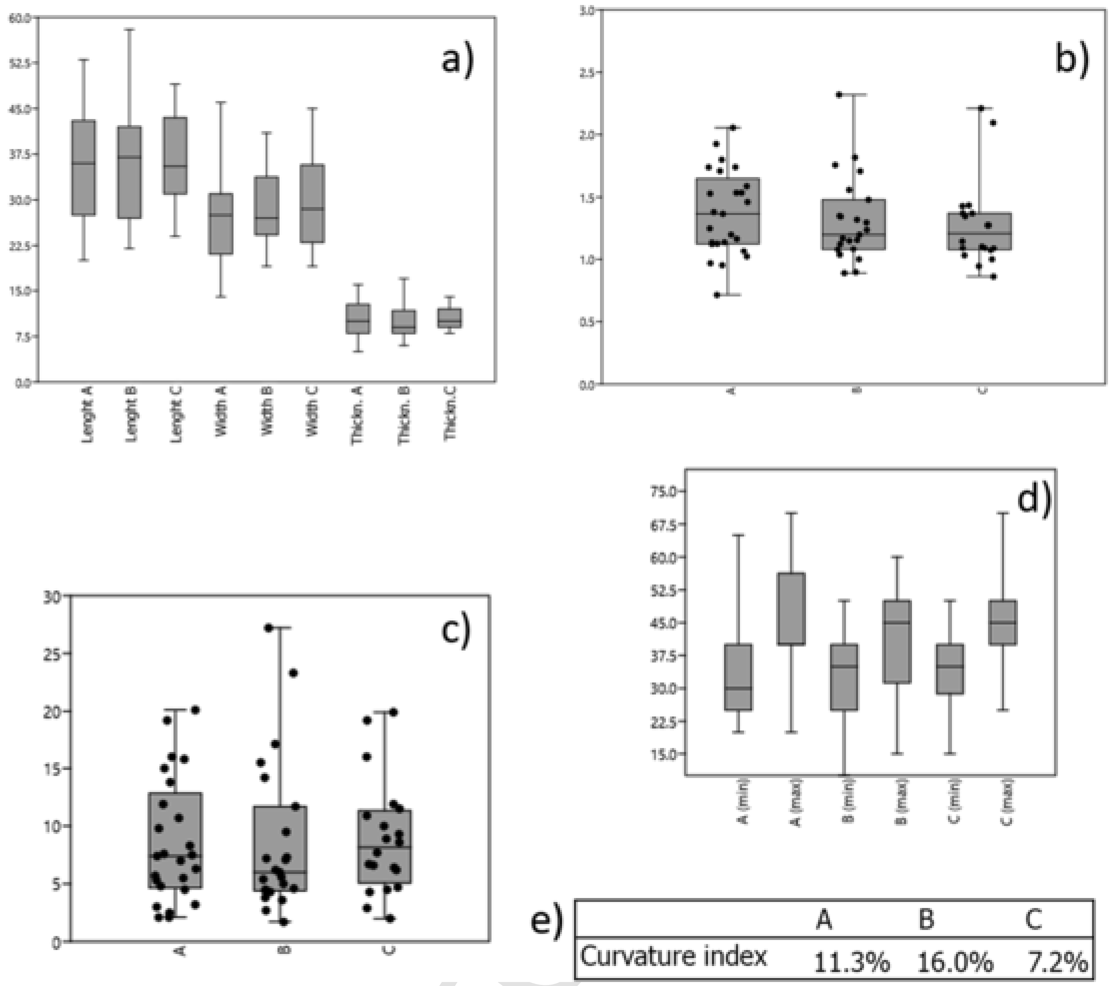

Fig. 3. Morphometric data taken on backed items from Fumane A9 unit divided into three main categories. "A": artifacts with retouched backs (Type 1 + Type 2); "B": artifacts with thinned backs (Type 3 + Type 4b); "C": artifacts with minor detachments on the back (Type 4 + Type 5). Data on dimensional range (a), elongation index (length/width) (b), weight range (c), minimum and maximum angle of active edges (d) and curvature index of the back portion (e) are displayed.

cal, techno-functional and use-wear analyses of the archaeological assemblage. Over 30 backed tools were produced with chert available in the area surrounding Fumane cave, the same raw material that was often exploited with a Discoid technological system. Experimentally-produced core-edge removal flakes, pseudo-Levallois points and centripetal flakes were then modified and retouched by creating, regularizing or rejuvenating the back. Retouching was carried out mainly by direct percussion using stone or organic hammers, and by abrasion. In a few cases, we used percussion on anvil.

Fourteen out of the 32 replicas were used for a variety of activities and to process different materials. The activities and materials were selected after a preliminary examination of the archaeological assemblage, which suggested that the tools from Fumane A9 were used to process soft and medium-soft materials mostly with longitudinal motions, but also with several examples reflecting transversal gestures. The experimental framework was set up and performed by D.D. (right-handed) and A.Z. (left-handed) and included the processing of both animal and vegetal tissues mainly through longitudinal or mixed longitudinal/transversal motions (Table 1). During the experiments, most tools were held in the hand, with the exception of two (experiments #5 and #22), which were hafted using split and juxtaposed hafts. These experiments allowed us to test the efficiency of backed items in a variety of activities and in processing various materials, to set up a use-wear reference collection (Table 2), and to evaluate the interpretation of the traces identified on the archaeological tools.

4.3.1. Materials of animal origin

Experiments ~~devoted to~~ the processing of animal tissues were conducted with meat, fresh hide and dry hide. Meat was removed from sheep ribs and three cow humeri. During the processing of the rib cage, tools were used, at first, to separate each rib with longitudinal bi-directional movements. Active and passive zones of the tools emerged as being extremely useful. Likewise, the thickness of the back allowed for a very comfortable and secure grip during the entire test.

During the second stage, the meat was removed from each rib. Tools proved to be highly efficient throughout the entire process, despite a lowering in grip efficiency. This was caused by the meat residues that had adhered over the prehensive area, making it slippery to handle. The processing of cow bones consisted in meat removal and tendon cutting (Fig. 5a–b). Meat and tendons were split with longitudinal uni- and bi-directional motions. Usually, transversal gestures were performed to remove the smallest meat residues from the bone (Fig. 5d). This demonstrated the potential of these tools when high precision was needed (e.g. while cutting tendons on articulations or slicing meat). However, when greasy/fatty substances were processed, tool handling became more difficult. Also, tool efficiency decreased during meat removal with transversal motions as a consequence of quick edge rounding or of the formation of fractures caused by frequent contact with the bone surface.

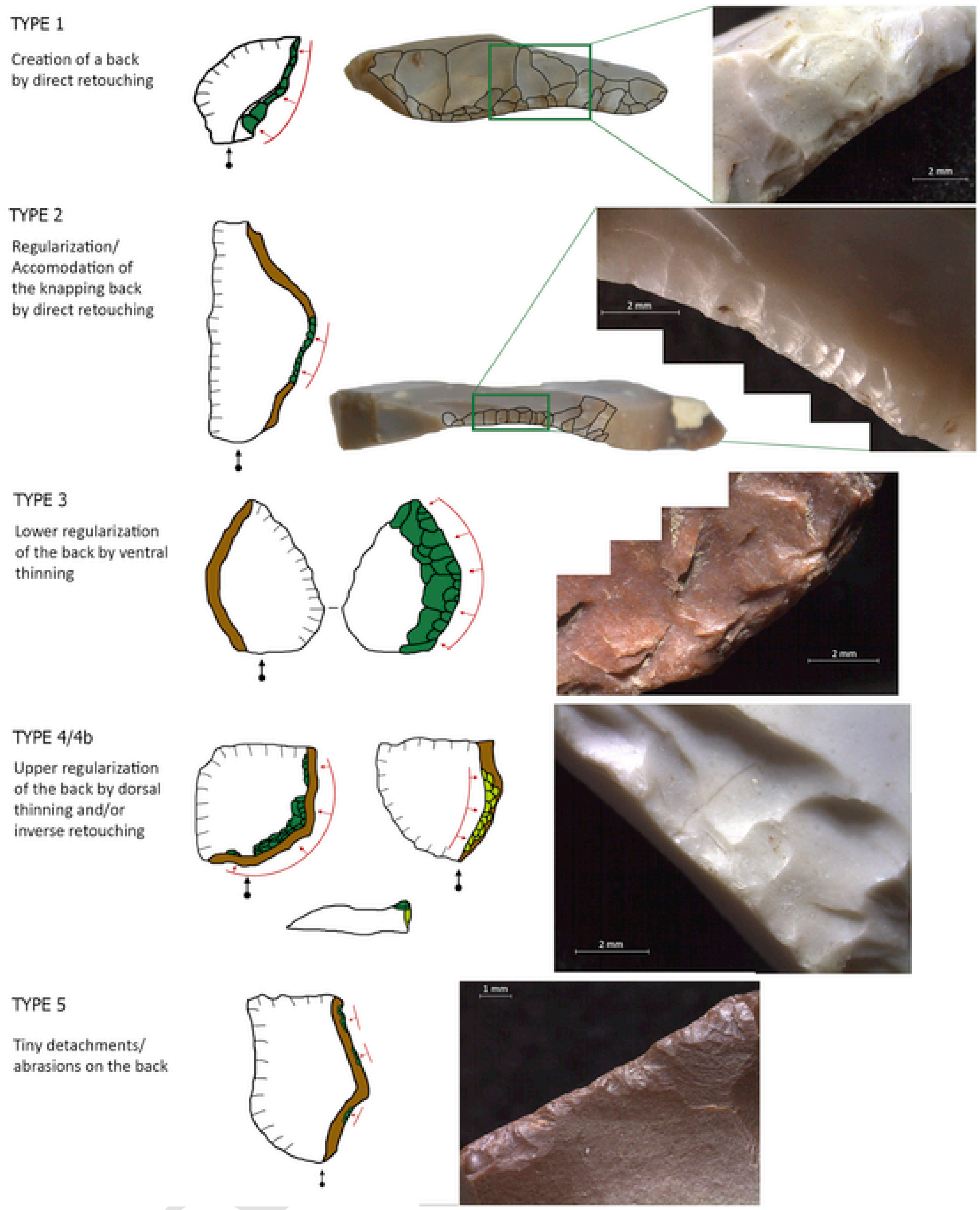

Fig. 4. Attested variability of anthropic interventions on the backs in Fumane A9 unit. Schematic, graphic and photographic representations of the artifacts are shown.

The tools used to process the sheep ribs showed a marked edge rounding, as well as small and medium sized micro-scars with feather and step terminations, which were characterized by a close and regular distribution over both the ventral and dorsal surfaces of the edge (Fig. 6a). In this case, the orientation of the micro-scars tended to be oblique and bidirectional. Snap fractures, due to contact between the tool and the bone during meat removal, also modified several areas of the edges.

The tools used on cow bones suffered edge snapping caused by the frequent contact of the edge with the bone. The snapping of the edge occurred during the first stage of the experiment and was then followed by a moderate rounding of the snapped edge area. Furthermore, small feather and step terminating scars were visible and evenly distributed over the same portion of the edge. When tools were used to remove vestiges of meat and cut tendons, micro-scars exhibited a mixed orientation pattern.

Wild boar and sheep hide were worked in both fresh and dry states by cutting with uni- and bi-directional movements, aimed at producing hide strips (Fig. 6c). The overall efficiency of the tools was evaluated positively during dry hide processing, even though, in the case of dry wild boar hide, the toughness of the material did not permit a fine control of the cutting process, which often meant that the strips were irregular. Efficiency was found to be higher on dry sheep hide, which is softer than the boar hide. Tools came in contact with the material at an angle ranging between 75° and 90°, and handling was found to be very comfortable and firm during the experiments, including experiment #24, when the tool had to be handled in different manners because of

Table 1
Main features of the experimental backed items used during the trials. Size values are in mm, working time in seconds/minute. "BK": backed knife; "CERF": core-edge-removal flake; "PLP": Pseudo-Levallois point; "S": straight; "I": irregular; "Cx": convex; "Cv": concave; "Cut": cutting; "Scr": scraping; "Bdi": bi-directional; "Uni": unidirectional; "D": dorsal; "V": ventral; "H.H.": hand-held; "Haft": hafted.

Exp.	Tool Type	Back type	Len.	Wid.	Thick.	Edge Shape	Edge Sagit. Profile	Transv. Cross Section	Edge Angle	Activity	Motion	Worked Material	State of Worked Material	Contact Angle	Contact Surface	Tool Handling Mode	Efficiency	Working Time
21	BK	1	50	24	12	S	Cv	S-S	35	Cut	Bdi	Meat	Fresh	75	D + V	H.H.	High	40
32	CERF	2 + 4	30	22	7	I	S	S-S	30	Cut + Scr	Mixed	Animal Tissues	Fresh	50	V	H.H.	Average	30
4	PLP	2 + 4	50	40	15	S	S	S-Cx	35	Cut	Bdi	Animal Tissues	Fresh	90	D + V	H.H.	Average	45
29	BK	2 + 4	48	24	11	I	Cv	S-S	35	Cut	Bdi	Meat	Fresh	75	D + V	H.H.	Medium	30
16	BK	1	50	23	11	I	I	S-Cx	40	Cut	Uni	Meat	Fresh	65	D + V	H.H.	Very High	35
1	BK	1	64	27	12	S	Cx	S-Cx	55	Scr	Bdi	Meat	Fresh	40	V	H.H.	Very High	38
12	CERF	3	28	25	7	S	S	S-Cx	35	Cut	Bdi	Animal Tissues	Fresh	40	D + V	H.H.	High	25
30	CERF	2	45	30	14	Cx	S	S-S	50	Cut	Bdi	Hide	Dry	90	D + V	H.H.	Low	10
24	CERF	Raw	36	30	16	I	S	S-S	45	Cut	Bdi	Hide	Dry	90	D + V	H.H.	Very High	18
20	CERF	3	57	41	16	I	I	S-Cx	45	Cut	Bdi	Wood	Soaked	90	D + V	H.H.	Very High	42
19	BK	4	57	27	10	Cv	S	S-Cx	38	Cut	Bdi	Wood	Soaked	90	D + V	H.H.	High	60
22	PLP	Raw	45	36	16	Cx	S	S-S	38	Cut	Uni	Plant	Fresh	90	D + V	Haft	Very High	30
5	CERF	4b	43	23	11	S	I	S-Cx	42	Cut	Uni	Hide	Fresh	90	D + V	Haft	Very High	25
13	CERF	2	52	26	14	S	Cv	S-Cx	50	Scr	Uni	Wood	Dry	60	D	H.H.	Average	35

Table 2
Morphological features of the damage occurred during the experimental processing of the various materials. "Lo": longitudinal; "Tr": transversal; "H": high; "M": medium; "V": ventral; "D": dorsal.

Contact Material	Activity	Gesture	Edge Rounding Degree	Micro Scars Termination	Micro Scars Orientation	Micro Scars Localisation	Micro Scars Distribution	Micro Scars Size
Meat and Bone (Sheep ribs)	Separating ribs and removing meat from bone	Lo + Tr	H	Feather and Step	Oblique and Transversal	V + D	Close Regular	Small
Meat, Bone and Tendons (Cow humeus)	Removing meat from bone and cutting tendons	Lo + Tr	M	Feather and Snap	Oblique bidirectional	V + D	Close Regular	Small and Medium
Fresh Hide	Cutting hide strips	Lo	M - H	Step	Oblique unidirectional	V + D	Close Regular	Small and Medium
Dry Hide	Cutting hide strips	Lo	H	Step and Snap	Oblique bidirectional	D	Close Irregular	Small and Medium
Soaked Wood	Cutting to make a haft	Lo	M	Step and Snap	Oblique bidirectional	V + D	Close Regular	Small
Woody Plants	Cutting	Lo	H	Step and Feather	Oblique unidirectional	V + D	Close Regular	Small and Medium
Dry Wood	Scraping	Tr	H	Step	Transversal	D	Close Irregular	Medium and Large

the uneven morphology of the tool's passive area. Edge-damage patterns proved similar on both types of material (Fig. 6b): small and medium step-terminating micro-scars developed on the edges along with several snaps. The processing of wild boar hide generated micro-scars mostly on the dorsal face of the edge, while sheep hide generated micro scars on both the dorsal and ventral faces of the edge. This difference is probably linked to the variation of the contact angle, which was greater (ca. 90°) in the case of sheep hide. In both cases, micro-scars were unevenly distributed along the edges and showed an oblique bi-directional orientation. The greater thickness of the wild boar hide could also have produced differences in the degree of the tools' edge rounding. To cut fresh sheep hide, a thin-edged tool was fixed in a wooden handle using a split haft (Fig. 7a). Both the tool and the handle proved to be very efficient during the experiments for precise and controlled cutting with longitudinal unidirectional movements, obtaining thin hide strips. After use, a medium to high degree of rounding was observed on the tool's edge, and small and medium sized micro-scars with step termination originated on the ventral and dorsal faces. Their orientation was oblique and unidirectional, and their distribution was close and regular along the edge. Several snapped edge portions were recorded as well (Fig. 6c).

4.3.2. Materials of botanical origin

Soaked wood was cut to produce two different types of handles: the first one by using a split arrangement, while the second one by using a juxtaposed hafting solution (Fig. 7c). Split shafts were produced by cutting the branch at the desired length after manual removal of the bark, and by making a 15 mm incision at the top of one end (Fig. 5e). The juxtaposed hafts were manufactured by cutting a 13 mm socket in one end (Fig. 5f).

Tools equipped with a regularized back demonstrated to be very efficient in making hafts. Handling was very comfortable, as they allowed a firm grip on the curved shaped backs. Wood cutting was performed by longitudinal bi-directional gestures, with a 90° contact angle between the tool and the material, which meant an elevated edge efficiency, although the sinuous profile of experimental implement #20 made it more uncomfortable the deeper the incision was made. Regardless of this, the task was still successfully completed. A medium edge rounding on both tools and several snaps along the very thin edge of #20 were identified. Micro-scars are small and exhibit step terminations. Their orientation is oblique and bidirectional, and distribution along the edge is close to regular (Fig. 6d).

Dry wood was scraped, in order to remove the bark from the branch and to create a pointed item. Overall, the tool resulted to be not very effective. Indeed, the edge rounded very fast with a corresponding decay in its efficiency. This, however, did not prevent the debarking of the branch and the carving of a point at one of its ends. Scraping was performed through unidirectional transversal movement, with a 60° contact angle between the edge and the processed matter. After use, medium and large micro scars with a step termination are visible over the edge of the tool. The orientation of these latter is transversal and their distribution along the edge is close to irregular (Fig. 3e). Furthermore, the recorded edge rounding is high.

Woody plant (*Phylirrea angustifolia*) tissues were processed as well. In this case, the tool was hafted in a wooden handle using a juxtaposed arrangement. Plant branches were cut with unidirectional motions (Fig. 7b), presenting elevated tool and handle performances throughout the experiment. The tool's edge developed intense edge rounding, as well as small and medium sized micro-scars with step and feather terminations over both the ventral and dorsal faces of the edge (Fig. 6f). Their orientation is oblique and unidirectional, and their distribution is close to regular along the edge.

4.3.3. Prehension and hafting traces

All experimental backed tools were held directly in the hand with no intervening material or padding (Fig. 5), with the exception of the two hafted pieces (Fig. 7). Several patterns in the modifications of the backs were identified. For instance, on retouched backs, the ridges of the retouch scars became intensely rounded. As this was particularly visible on tools used to remove meat and to cut tendons, we suggest that animal fat may have increased the degree of ridge rounding. Ridge rounding was, in fact, also recorded on the back of tools which were used to process vegetal material and dry hide, although to a lesser degree.

In contrast, micro-scars were identified on tools with unretouched backs. They are very small in size, with a close regular distribution and feather terminations (Fig. 6i). As for the hafted experimental replicas, in the case of #22, which was equipped with juxtaposed hafting, distinct patches of small and medium-sized micro-scars with triangular and scaled morphology are visible on the back (Fig. 6h). Scar patterns were also identified on larger specimens at the center of the patch. Scars with oblique and narrow-to-wide morphologies (Fig. 6g) were identified on the back of the tools hafted with a split arrangement (#5). Distinct patches are also visible and feature different patterns which consist of micro-scars that terminate in well-defined lines. Overall, the

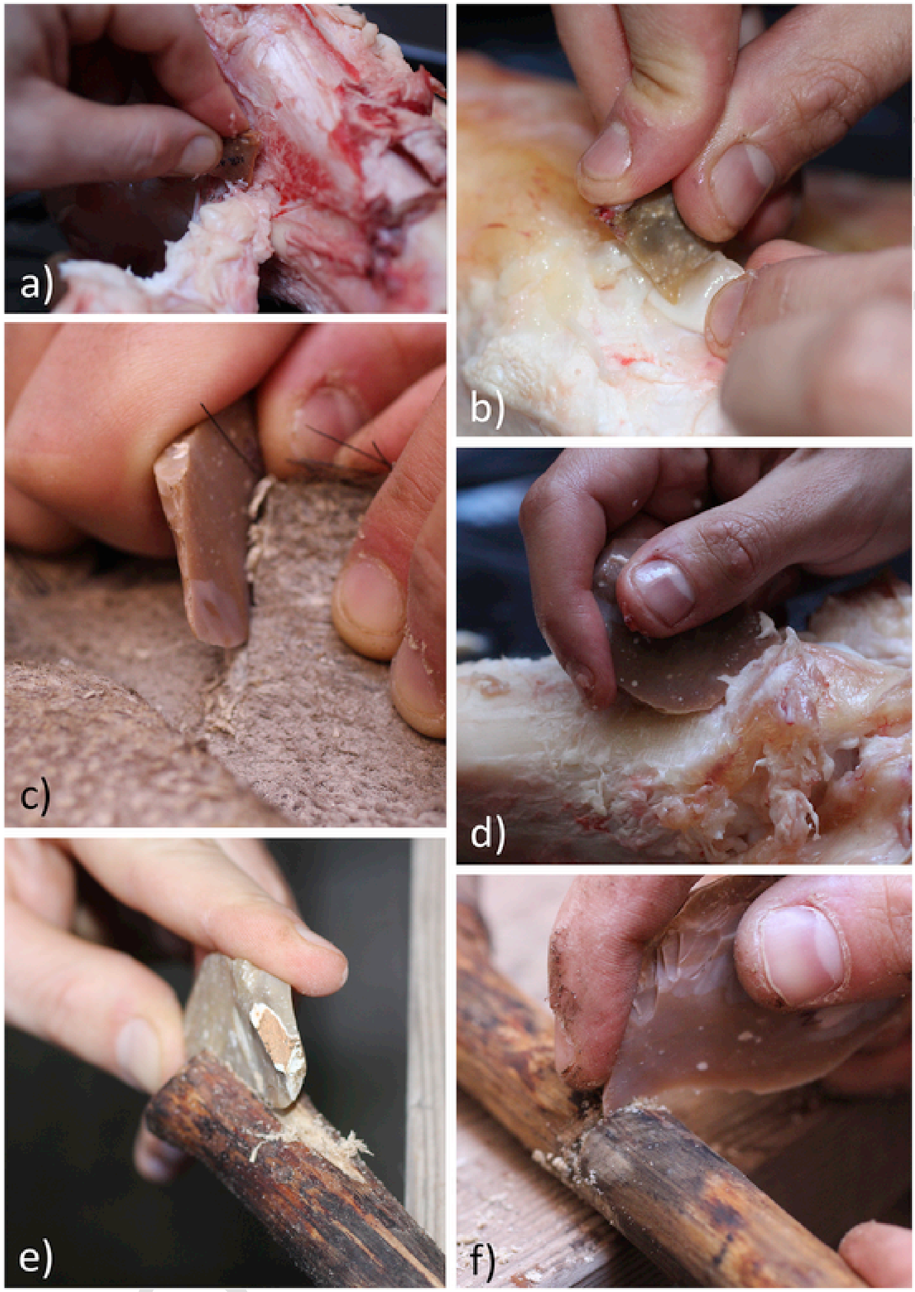

Fig. 5. Experimental use of manually handled backed items for various kinds of tasks: a) meat butchering, b) tendon cutting with low-power precision grasping, c) dry skin cutting with high-power grasping, d) bone cleaning and animal tissue parting, e-f) wood cutting in order to manufacture e) split or f) juxtaposed haft.

patterns observed on the experimental sample, and related to the modification of the back caused by prehension or hafting are very specific in terms of morphology, distribution patterns and orientation. They can be ~~fairly~~ distinguished, as Rots (2010) has stated, from the wear observed over the active areas of the tools.

4.4. Use-wear analysis of the archaeological sample

Among the 86 backed tools coming from unit A9 and correlates, 56 specimens were randomly selected and analyzed to identify use-wear traces. Diagnostic use-related damage ~~has been~~ observed on 30 artifacts. Unfortunately, all items suffered moderate to intense post-depositional\surface alteration such as glossy surfaces and soil sheen, which hamper the observation of micro-wear at high magnification (Table 3). However, data obtained from the analysis of edge damage at low magnification provides insights regarding the use of tools, particularly the hardness of the materials worked and the activities performed (Fig. 8).

Micro-chipping is characterized mostly by oblique and transversal orientation patterns, the former being the most ~~represented.~~ This suggests that tools were used to perform longitudinal and transversal motions that can be attributed to cutting and scraping activities. Most of the use-related micro-chipping scars exhibit step terminations which are often associated with moderate to intense edge rounding. This evidence suggests that most of backed items were used to process materials of medium hardness. Evidence for soft and moderately soft material processing was recorded as well. Several tools are in fact characterized by use-wear scars with feather terminations and light edge rounding (Fig. 9). Given the similarities regarding ~~the~~ morphology (~~scar~~ termination and dimensions) and orientation, between the edge damage observed on several archaeological items and on experimental replicas,

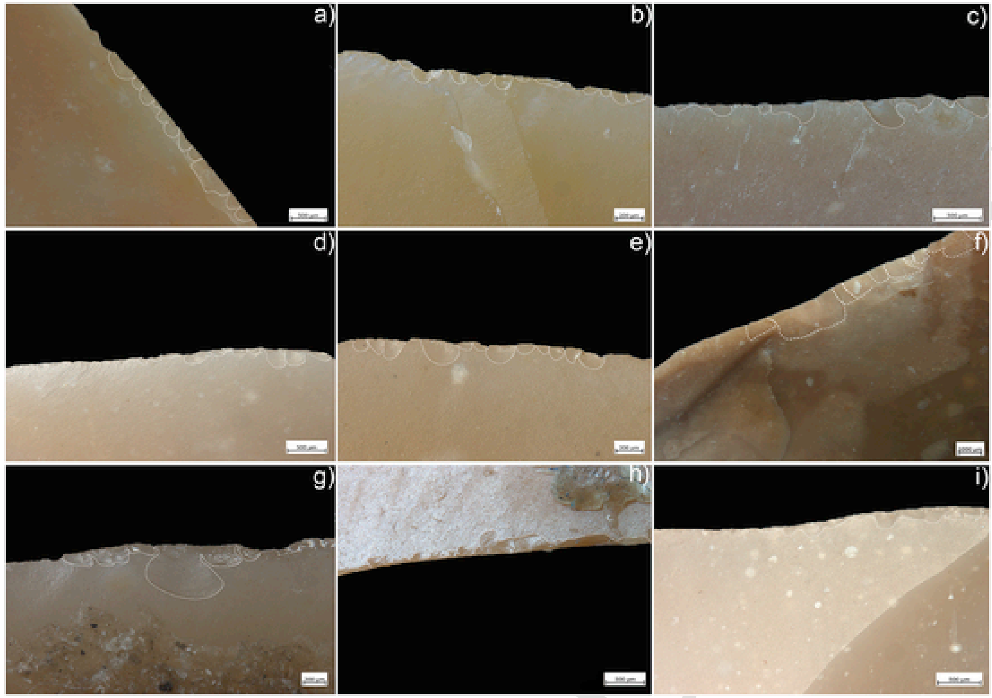

Fig. 6. Edge damage developed on experimental backed items used to work: a) animal tissues, b) dry hide, c) fresh hide, d) soaked wood, e) dry wood, f) woody plants; g) split haft, h) juxtaposed haft and i) manual prehension. a-e) traces left on the cutting edge; f-h) traces left on the back.

used to process fresh hide, dry hide and meat, we suggest that backed tools from unit A9 were employed in the processing of soft and medium-hard animal matter. ~~Cases in point are~~ archaeological specimens #314, #501 and #5824 (Fig. 10 a; b;f). Moreover, fresh hide processing can be hypothesized in the case of #705, while the working of dry hide is suggested for #333 and #411. In both cases, edge damage is similar to the one developed while processing sheep hide (both dry and fresh) in the experiments. It can therefore be suggested that the treated hide was relatively thin. Finally, edge damage which is comparable to damage on the experimental tools used for woody plant processing was identified on #1886 and #3613 (Fig. 10d–e).

When worked material and performed activities are cross-compared, it ~~emerges~~ that scraping actions were used mainly on materials of medium hardness and, in several cases, on soft to medium substances. On the other hand, cutting was mostly performed on soft and medium-soft materials, with materials of medium hardness being slightly less well represented. Moreover, when the performed activities are compared to the edge plan, it ~~emerges~~ that straight edges are more often associated with cutting actions than convex edges (Fig. 11). Additionally, both convex and straight edges were exploited with transversal motions. An interesting pattern concerns the functional significance of the retouch. From the analyses performed so far, we were able to observe that use-wear is in most cases distributed on unretouched active zones and that ~~the retouched edge only~~ rarely corresponds to the ~~transformative techno-functional part~~ of the object. ~~In any case, we are talking about transformative unit not located on the back but on a cutting/scraping edge opposed or adjacent to the back.~~ We consequently suggest that, among these tools, the major aim of retouching was to improve tool prehension, rather than to enhance the edge's cutting potential.

In this matter, our experiments demonstrate how a retouched back increases the gripping potential of the tools, especially during activities where hands get covered in greasy or fatty matter, as seen during the processing of material of animal origin. Although the alteration of tool surfaces did not allow an exhaustive analysis of the micro-wear produced by hafting and prehension, we were able to provide new insights thanks to low magnification observations. Localized moderate to intense rounding was frequently observed on the backed edges of the tool, which are mostly retouched (n. 8). This rounding is probably related to the prehension of the tool, given its similarities with what was recorded on the experimental specimens which were hand-held. This further supports the notion that retouching/shaping of the backed edge was intended to enhance gripping. Rounding occurs at comparable degrees on the retouch scar ridges of the experimental replicas, in particular those used for the processing of animal matter (Fig. 12). In order to exclude a post-depositional origin of the backed edge rounding, it is important to stress that it occurs only on this specific portion of the tool and it is not observed elsewhere (e.g. on the active edge). Indeed, rounding caused by Post Depositional Modifications (PSDMs) alters almost the entire surface of the tool and is often associated with impact scars, a pattern which has not been identified on any of the analyzed specimens. Moreover, the fact that the rounding of the backed edges was ~~associated to~~ tools which were used to process soft and medium-soft materials of probable animal origin, supports the idea that this modification is related to use and, as observed on our experimental replicas, to the contact between hand and greasy materials.

A comparable technological behavior was inferred from bifaces found at the Middle Paleolithic site of Saint-Armand-les-Aux, where the edges of biface-shaping flakes were intentionally blunted to facilitate grip during use (Claud, 2015). The preference for freehand manipulation of backed tools in unit A9 of Fumane is also indicated by the paucity of edge damage associated with hafting, which was observed only on two specimens (#335 and #1333). In particular, on #1333, superimposed small and medium-sized rectangular scars, which can be attributed to its insertion in a haft, are visible on the backed edge. A similar pattern is visible on # 335, where small, partially superimposed rectangular scars are visible all over the backed edge of the tool, indicating a possible insertion of this piece into a handle (Fig. 8). Unfortunately, the edge damage identified on these two archaeological specimens does not find any similarity with that observed on our experimental replicas used as hafted items. Further tests focused on potential hafting solutions and hafting materials (e.g. hard animal material) ~~need to~~

Fig. 7. Experimental use of hafted backed items: a) cutting of fresh sheep hide, b) cutting of *Phylirrea angustifolia* wood, c) after split and juxtaposed hafting.

Table 3
Post-depositional modifications identified on the archaeological artifacts.

PDSM	N.	%
Surface abrasion and intense rounding	11	20
Fractures and crushes	9	16
Thermic alteration	2	4
Glossy appearance	21	38
Soil sheen	13	23
Total	56	100

~~be performed in order~~ to better investigate the possible use of backed items as hafted tools at Fumane. At this stage in our experiments, we can only underline the high functionality of these tools when inserted into a handle.

5. Discussion

5.1. Direct preparation or accommodation of the back (types 1–2) at Fumane and within the Discoid technological frame/context at a larger scale

Deliberate modifications of the passive portions of backed tools from Fumane Cave unit A9 occur on a few types of flake blanks, mainly CERF and pseudo-Levallois points. This assemblage was produced using the Discoid knapping system, which typically produces several kinds of flake with natural or predetermined knapped backs (Boëda, 1993; Locht and Swinnen, 1994; Jaubert and Mourre, 1996; Slimak, 2008; Peresani ed., 2003). However, despite the abundance of pieces with blunt edges suitable for manual prehension, the Fumane assemblage includes 33 artifacts which were modified by retouching type 1 or 2 (Figs. 13 and 14). The blunting of the prehensive edge is presumably intended to facilitate manual handling or hafting. Where a blank presented an excessively thin, sharp or irregular edge ~~that did not allow direct gripping, then occurred the production of a retouched back~~.

The presence of these types of modification resembles a technical behavior largely found in south-western France, associated with Mousterian of Acheulean Tradition type B, where typical backed knives are common (MAT-B) (Bordes, 1954–55; Pelegrin, 1990; Soressi, 2002). The legitimacy of this techno-complex has recently been questioned, as it seems to be related to different technical systems, including Discoid or Levallois (Turq et al., 2011; Faivre et al., 2014; Gravina and Discamps, 2015). However, in the (few) assemblages characterized by a high frequency of typical backed knives - mainly layer 7 of La Rochette (Soressi, 2002) and layer 7 of Pech de l'Azé I (Soressi et al., 2008) - the flaking system is based on a non-Levallois unipolar technology which produced elongated, thick and triangularly symmetrical laminar flakes. Consequently, abrupt retouching was necessary to allow prehension on such supports, which have two sharp

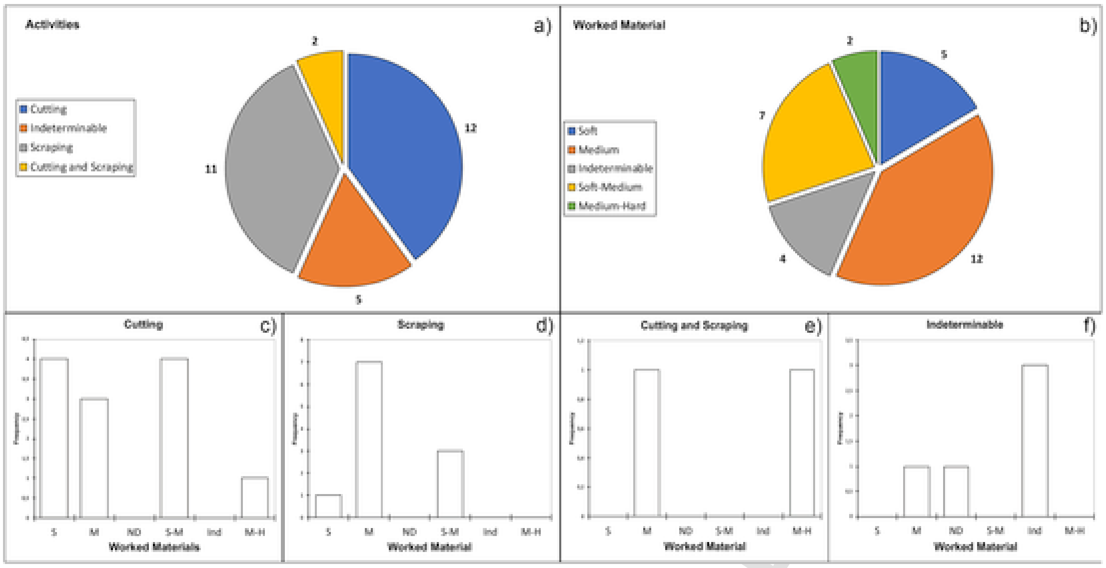

Fig. 8. a) Activities performed at Grotta di Fumane using backed items. "C": Cutting; "S": Scraping; "Mi": Mixed; "Ind": Indeterminable. b) Activities performed by edge delineation in plan. "S": Straight; "Cv": Concave; "Cx": Convex; "I": Irregular. c) Range of identified worked materials. "S": Soft; "S-M": Soft-Medium; "M": Medium; "M-H": Medium-Hard; "Ind": Indeterminable.

margins. The backs on these tools were almost always created by marginal and continuous retouches, and are typically convex in outline (Soressi, 2002). Use-wear analysis on the similar Pech-de-l'Azé I assemblage confirms that this type of back is generally associated with manual prehension (Anderson-Gerfaud, 1981). For this reason, hafting traces should be present much more often in MAT-A assemblages, due to their high tool diversity and the scarcity of typical backed knives (Soressi, 2002). Conversely, the technical specialization of MAT-B assemblages, when it is applied to long blanks, facilitates manual prehension and avoids investing time in the manufacturing of a haft.

However, ~~according to~~ Mellars (1996)~~, it is important to emphasize~~ that Mousterian backed knives are not an exclusive feature of laminar blanks and MAT assemblages. This author stressed that backed knives are more common compared to other retouched tools in these assemblages (mainly >4% and up to 20%, although some assemblages are now considered unreliable or biased (Gravina and Discamps, 2015), while in other Mousterian complexes they would account for around 1–4% of shaped pieces, at most. As also confirmed by Fumane A9 where backed tools, mostly made on short flake blanks, represent 6–7% of the complete tool assemblage, there is presumably no direct correlation between ~~the~~ elongated ~~supports~~ and the backed implements (Roussel, 2013; Gravina and Discamps, 2015).

Recently, a reassessment of the assemblages from late Mousterian sequences of south-western France (Gravina, 2016) has documented the presence of backed pieces on flake tools and pseudo-Levallois points. These were shaped through partial or total retouch, and sometimes refined on a stone anvil to remove the butt and part of the proximal end of the flake. The same author also noted great variability in backing techniques in different layers of Le Moustier, dating to MIS3. Direct retouch was recognized in layer H (~45 ky Cal BP), which is characterized by backed pieces on CERF/pseudo-Levallois blanks in a technologically Discoid assemblage. Conversely, bipolar retouch on stone anvil has been identified for the assemblages found in the late Mousterian layer K (~42 ky Cal BP) after the examination of convex backed tools made on Levallois blanks. The regular backed outline suggests its possible employment in hafting and ~~therefore~~ requires use-wear analyses.

Backed tools are also documented in other French assemblages where Discoid technology is present or dominant. These include the late Mousterian EGPF level of Saint Césaire, dated to ~41 Cal ky BP, which yielded CERFs that were marginally retouched on the side opposite to a cutting or denticulate edge (Thiebaut et al., 2009). On some backs this retouch creates a curved outline. Few comparable blanks were shaped in backed knives even in the latest Mousterian layer (1) of Combe Grenal (Faivre et al., 2014), which was also produced primarily by Discoid method. Two open-air sites in northern France deserve special mention. At Beauvais, an exclusively discoid industry was manufactured on local raw material, mostly to produce unretouched CERFs, as part of an opportunistic strategy. In a few cases, these flakes were shaped by direct retouch in order to develop or rectify the back (Locht and Swinnen, 1994; Locht, 2003). A comparable technique was suggested by the study of small CERFs and pseudo-Levallois points from the nearby site of Les Bossats at Ormesson (45–50 ky cal BP): modifications consisted in an oblique, mostly partial retouch on certain portions of the piece that needed to be rectified and regularized ("*retouche d'accomodation*", Bodu et al., 2014). Modified backs have also been described by L. Slimak (2008) at the Quina Rhodanien open-air site of Champ Grand, in the upper Loire valley. In addition to only two typical backed knives, ~~there is the presence of~~ atypical backed artifacts manufactured using irregular, marginal or scaled retouch on various blanks. Among the common features, the right lateralization of the back and an evident convexity of the distal profile has been noted (Slimak, 2008). All of these examples indicate a wide adoption of techniques aimed at modifying or accommodating blanks that already had natural or predetermined knapped backs. This is a different system from the one associated with MAT backed knives on elongated blanks: in the latter, the creation of a retouched back is indeed necessary for their use as hand-held tools.

At Fumane unit A9, elongated or laminar blanks are extremely rare, and are never retouched on the back. In contrast, most artifacts equipped with a back are short, wide and thick, with asymmetric triangular or trapezoid sections (Fig. 9). The further technical investment, detected on a few dozen tools, would have been useful in shaping or regularizing an already thick prehensive area, in blunting a thin edge and increasing the ventral angle, or in creating an accommodation for the insertion in a haft. Among these artifacts, eight present use-wear on the backed part: six indicate manual prehension, such as #1866 and #5824 (Fig. 10 e-f), where a finger support which is enhanced by the meso-distal rounding of the back is evident (Fig. 14c). Manual prehension has been recognized also in #266 and #3842, with backs that

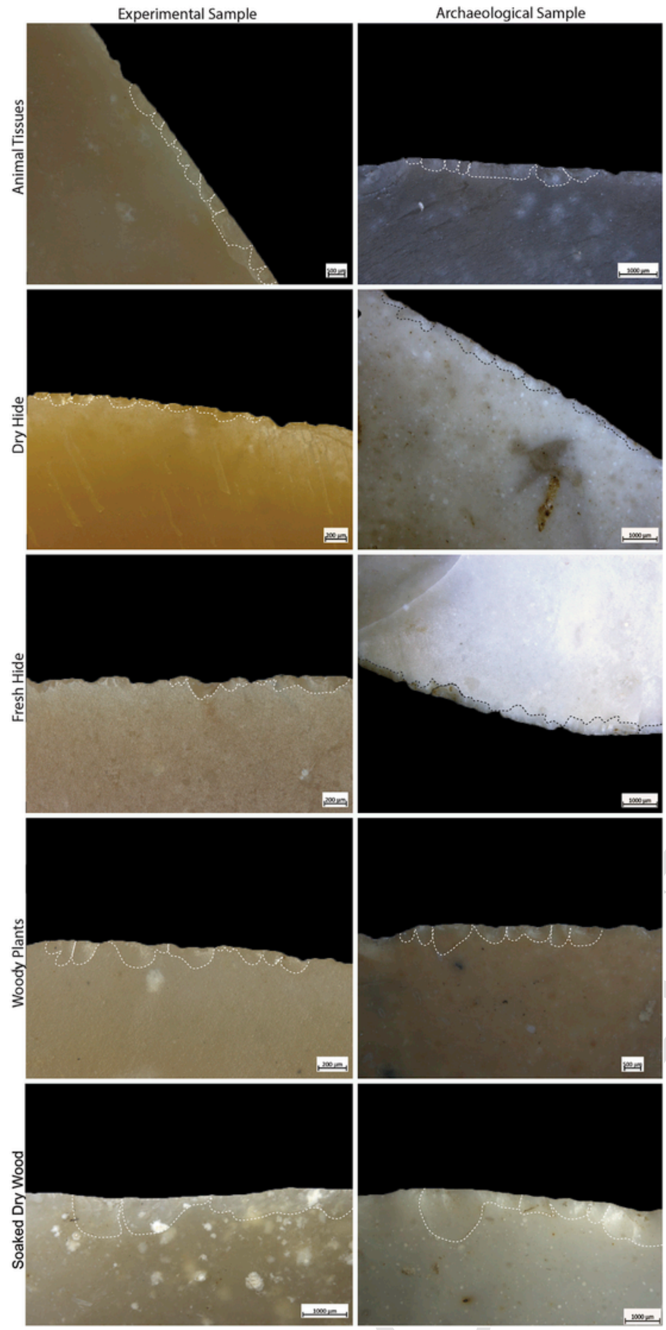

Fig. 9. Comparison between edge damage observed on experimental backed items (left) and on archaeological specimens (right).

were manufactured completely by direct and inverse abrupt retouch~~ing~~ (Fig. 13e–f), and on two CERFs (#44 and #659) with a back which was partially or totally blunted by a marginal abrupt retouch (Fig. 14a).

Experimentation allows us to propose how a retouched back would have been more functional that a blank equipped with a naturally blunt or steep edge.

- An unmodified back could be uncomfortable or even too sharp to hold, even when characterized by comparatively ~~open~~ (80–90°) angles. Therefore, blunting by means of retouching can be useful to protect fingers or fibers used to lash the artifacts to a handle.
- The possible alteration of the longitudinal profile of the back is equally important for functional reasons. Convex backs proved to be very efficient, in particular where moderate force is required, such as for scraping, cutting of medium-hard material, or for activities performed with typical multifunctional tools which are equipped with a sharp point and an edge. On the contrary, in tasks that require greater strength and a very firm grip, the prehensive scheme changes: fingers are placed on the two faces of the flake with the thumb inwards, therefore avoiding direct contact with the back, which consequently does not require a specific shape.

These suggestions are consistent with the traces preserved on the archaeological artifacts. The activities identified are quite diverse - including scraping (n = 4), cutting (n = 5), or both (n = 1) - but the processed materials were mainly of soft and medium hardness. Only one ~~single~~ tool seems to have been used to cut a medium to hard material with oblique motions. Furthermore, given the traces which were observed on the prehensive area of the tools, we can suggest that all artifacts used for cutting were hand-held. Given their small size (max. length: 27–35 mm), the length of the transformative area on the tool and the limited extension of the traces along the edge, some of these artifacts could be interpreted as tools specialized in precision cutting tasks (#1866 and #3842) (Fig. 14c; Fig. 13f). Other pieces are finer, longer and more regular knives, with sharp edges that are slightly to markedly convex (#486 and #659). Conversely, one of the two possibly hafted ~~artifact~~ bears a retouched ~~transformative~~ edge and use-wear indicative of scraping (# 1333). Cutting and scraping with small tools implies precision tasks performed with hand-held tools. Recent studies highlight the capabilities of Neanderthals of performing precision grips relying on the thumb and the index finger (Niewoehner et al., 2003; Karakostis et al., 2018). Experimental evidence suggests that some of the archaeological artifacts may also have been handled in this way.

5.2. Thinning and minor interventions aimed at or caused by prehension

Although not as invasive as retouching, all "minor" modifications carried out on backs represent sources of indirect information on the tool's use patterns and morphological adaptations to the activities performed. For this reason, these modifications require a specific classification and analysis. Back thinning, either on ventral (Type 3) or dorsal (Type 4b) sides, is particularly significant (Fig. 15).

Thinning of flake or blade tools is usually associated with a regularization of the blank and with the removal of thick parts such as the bulb of percussion, and it is often a morphological adjustment to improve hafting (Stordeur, 1987; Mellars, 1996; Porraz, 2002). This is the case of the MIS 5 site of Bettencourt layer N2b, where Levallois points used as spear tips were often thinned at the base. Similarly, two artifacts from Sesselfelsgrotte G-Complexes (MIS 3) were basally thinned prior to hafting: a Levallois point, probably used as a thrusting spear point, and a Keilmesser-like tool, interpreted as a projectile (Rots, 2009, 2015). Mousterian points were thinned, hafted and used as projectiles at Cotte de St. Brelade (Callow, 1986). Adjustment for manual prehension is the hypothesis for some of the thinned tools from Baume des Peyrards (Porraz, 2002), despite the fact that use-wear traces were not identified in that assemblage. Conversely, in the adjacent site of La Combette, hafting traces are associated with the ventral thinning of a scraper (Texier et al., 1998). As for Quina scrapers, evidence of hafting is rarely mentioned in the literature, despite the fact that basal thinning is a common feature of this tool type.

In the Fumane sample, regularization of the proximal end occurs on #411 and #1211, two *dejeté* points on which traces of manual grasping were also recognized - as on artifact #3078 (Fig. 15b). Partially or completely thinned lateral ~~sides~~ are, however, much more common

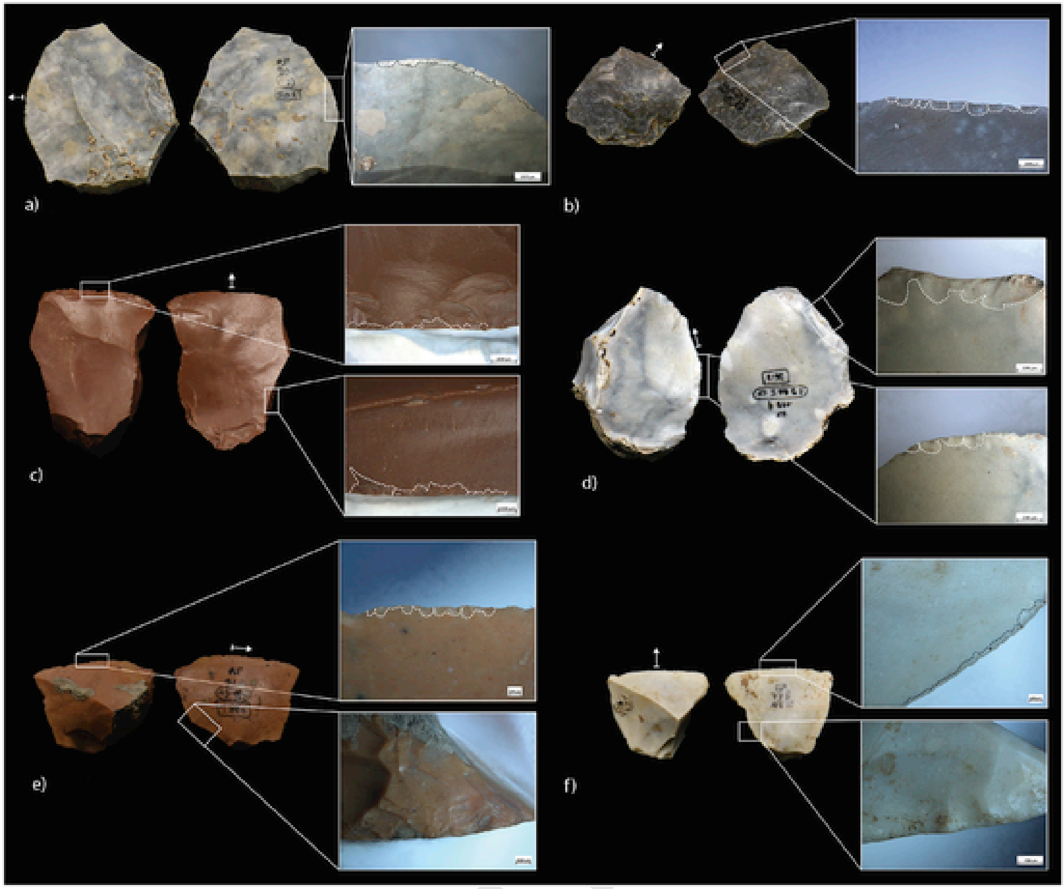

Fig. 10. Selection of use-wear traces identified on the archaeological sample: a) artifact #501, processing of soft-medium hardness material through transversal motions, b) a. #314, processing of soft-medium hardness material through transversal motions, c) a. #1333, processing of medium hardness material along with edge damage possibly related to hafting, d) a. #3613 and e) a. #1886, processing of soft-medium hardness material through transversal motions and rounding localized over its backed edge, possibly related to tool handling, f) a. #5824 processing of soft material through transversal motions and rounding localized over its backed edge.

(Fig. 15 a; c-f). Nevertheless, prehensive and use patterns on thinned pieces are very diverse: hafting has been inferred only for #335 and #1333. These two pieces were subjected to several modifications, including ventral thinning around the back.

Our experiments have confirmed the effectiveness of back thinning associated with different types of handles. Standardized patterns are not required: specific modifications adapted to the morphologies of the tool and the haft are more effective. When the tool is designed to be inserted into a split haft, uniform thinning is at times necessary as well as the bevelling of the proximal end. In the case of juxtaposed hafting, a partial and even thinning provides a functional accommodation in line with the sagittal profile of the cutting edge and orients the working edge and the hafted portion along the same ~~virtual~~ axis. Overall, the great variety of supports suggests that there can be multiple hafting patterns (Fig. 16), although two are documented in the sample from Fumane.

- on #335, a quadrangular flake with hafting traces, the modification of the back regularizes the thickness. In this case, a juxtaposed hafting on the upper face is indicated (Fig. 16c). Use wear on the working edge indicates that the tools was used for cutting medium-hard materials.
- #1333, instead, seems to have been used with a terminal hafting arrangement, with the active edge perpendicular to the insertion. Back thinning and direct retouching, appearing opposite the functional edge, are indicative of an accommodation in a split haft. It appear to have been used with a scraping motion. This pattern is comparable to that observed on Quina scrapers, which was described in a previous paper (Zupancich et al., 2016) (Fig. 16a).

On five specimens that were hand-held, local modifications have blunted a natural back, probably to accommodate the finger. This is suggested by small, fairly regular and systematic detachments from one of the backed edges, associated with light abrasion. The experiments were useful for interpreting these minor interventions, since they showed that manual prehension produces different traces on retouched and raw edges. On retouched edges, contact with the hand produced rounding, while on ~~raw~~ edges it generated micro-scars. This also means that intentional abrasion occurring before use can be clearly differentiated from abrasion caused by use itself.

5.3. Integration of the techno-functional data with the economic and ecological setting

Given the apparent over-production of implements with similar techno-functional schemes in the discoid assemblage from Fumane, it ~~could be~~ interesting to explore the factors that gave rise to such a technical and time-consuming production. The design, production, recycling, and discard of lithic tools is intimately linked to forager land-use practices, which in turn are closely tied to environmental and resource exploitation strategies (Andrefsky, 2008). For this reason, the variables that can influence choices in the production of different types of retouched tools are diverse, and include factors such as mobility patterns, food procurement strategies and ecological and environmental constraints (Rolland and Dibble, 1990; Meignen et al., 2009).

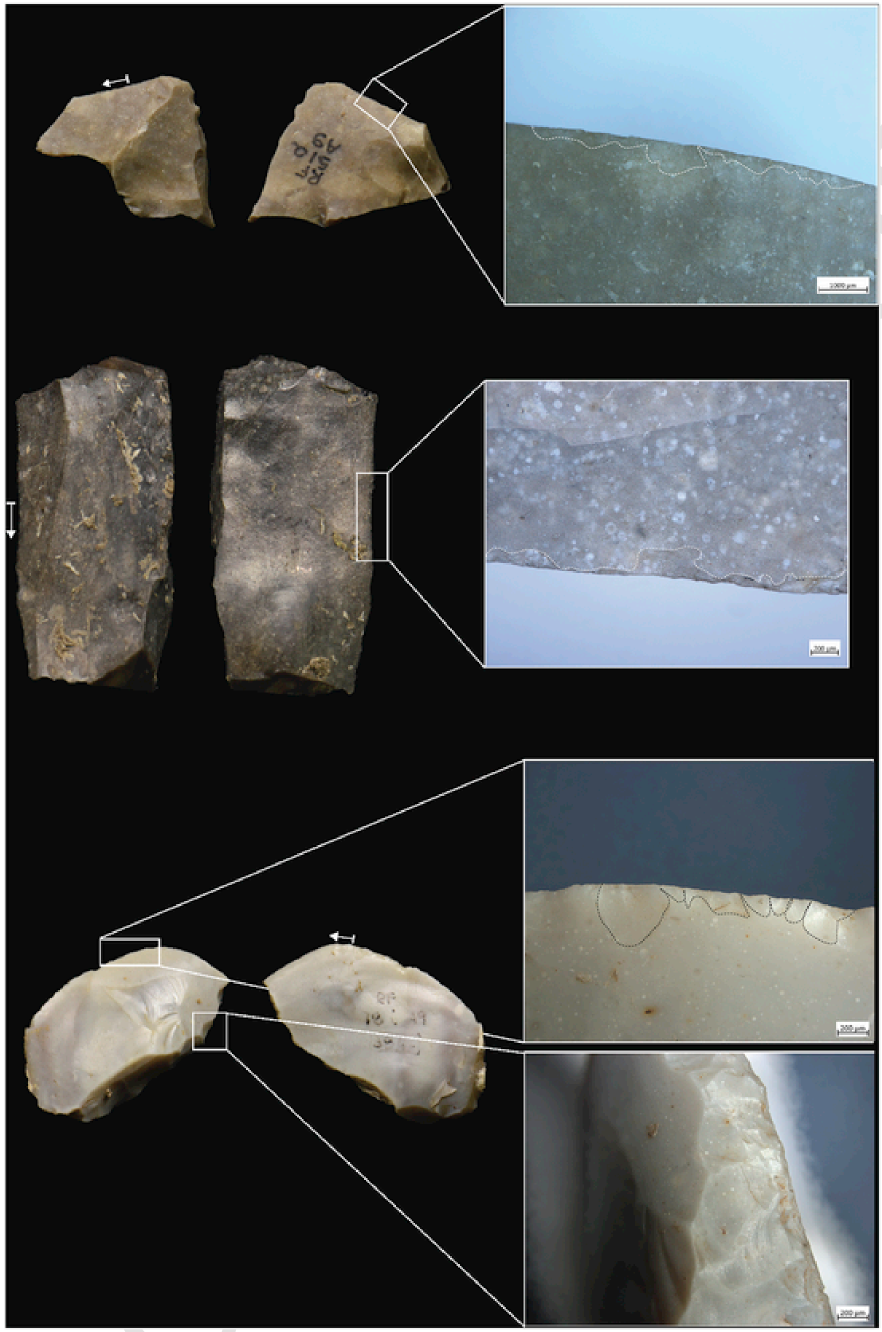

Fig. 11. Archaeological backed tools with edge damage associated to cutting activities: a) artifact #1649 showing feather terminating scars associated to medium degree of rounding caused by cutting soft material; b) a. #4855 showing step and feather terminating scars associated to high edge rounding caused by cutting soft-medium hardness material; c) a. #3842 showing feather terminating scars associated to a high degree of edge rounding caused by cutting soft material. The tool exhibits a very high degree of rounding over its backed edge.

Many researchers view discoid technology as a response of human groups practicing cyclical and seasonal mobility (Delagnes and Rendu, 2011) and an adaptation to local conditions (Turq et al., 2016). Raw flake blanks appear versatile and multi-functional (Lemorini et al., 2003; Arrighi et al., 2009; Locht, 2003), although characterized by a short life and therefore apparently not designed to be part of transportable tool-kits (Delagnes and Rendu, 2011). A proxy for this is the low incidence of retouched tools (Faivre, 2011; Faivre et al., 2017; Gravina and Discamps, 2015; Bourguignon and Turq, 2003; Thiebaut et al., 2009; Lorenzo Martinez et al., 2014), usually between 2% and 8% of the total assemblage. This technology makes it possible to maintain highly productive technical systems with the potential for flexibility in the operational sequence, resulting in a range of core forms (Faivre et al., 2014; Turq et al., 2013; Romagnoli et al., 2018). In discoid systems the focus is on producing new flakes to get fresh edges, rather than on renewal of tools.

As in other discoid-based assemblages, the retouched tools from A9 at Fumane make up less than 5% of the pieces >2.5 cm. It is likely that various types of discoid core would have made up a significant proportion of the artifacts transported away from sites, because of their productive potential and the limited investment required in their shaping and maintenance (Bourguignon and Turq, 2003; Peresani, 1998; Faivre et al., 2014). It is interesting that Kombewa-type production in A9 is related to the introduction of cores-on-flake made of semi-local or allochthonous raw materials. Reduction sequences in these materials

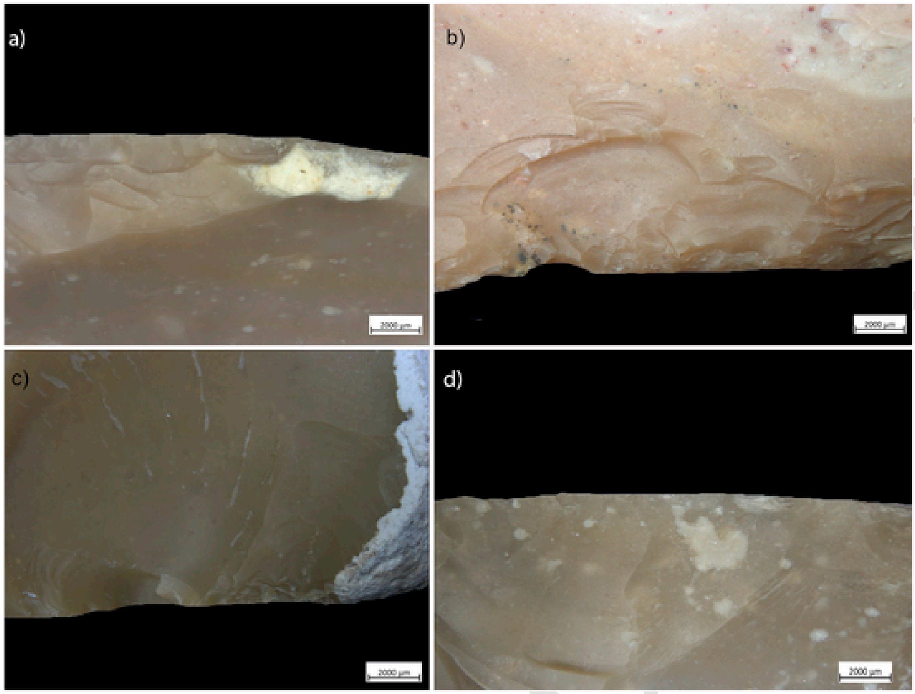

Fig. 12. Experimental backs. Comparison of different degrees of rounding according to the type of substances worked: a) cutting tendons and removing meat from cow humeri, b) removing meat from ribs, c) cutting dry hide, d) cutting soaked dry wood. Note the higher degree of rounding on the backs of the tools used to process fresh animal materials in comparison to the rounding on the backs of tools used to process dry animal material and vegetal matter. All pictures have the same magnification (7×).

are incomplete, with the early stages occurring off-site, presumably at the lithic sources (Delpiano et al., 2018).

The frequent association of prepared and modified backs with Kombewa-type CERFs sheds new light on the possible variability in blank reduction strategies. Fumane unit A9 is a palimpsest of superimposed occupations, clearly illustrated by dozens of combustion features, portions of anthropogenic soils and a diversity of material related to the collection of food and other resources (Basile et al., 2014; Peresani et al., 2014; Romandini et al., 2014, 2016; Fiore et al., 2016). In the kind of mobility system represented, needs may have arisen unpredictably along the route from the source to the site. These needs could be met by producing specific sorts of blanks from transported cores, that would end in the ramification of reduction sequences. It is worth stressing that one of the most extensively modified pieces (#1333, which was also hafted) is made of allochthonous flint from the Rosso ad Aptici formation, which outcrops at least 80 km to the west of Fumane (Delpiano et al., 2018). Therefore, it can be assumed that some of these implements in the assemblage arrived at the site as parts of mobile toolkits, and were modified by humans during daily or seasonal movements before being discarded at Fumane.

5.4. Behavioral perspective on innovation

The manufacturing of backed implements represents an innovative type of technical behavior, one not always associated with hafting. Backed tools were part of the Neanderthal repertoire, and they are found in diverse periods and associated with different forms of lithic technology. However, their frequencies vary, and they are completely absent in entire regions (Fig. 17). In French multi-layered sites, they are mostly found in the very late Mousterian, just before Chatelperronian occupations (Le Moustier's layer K, Saint-Césaire's layer EGPF, La Grotte XVI's layer C, La Rochette's layer 7) or, more generally at the end of Mousterian sequences (Combe-Grenal's layers 1–4, Pech de l'Azé I's layer 7) (Table 4). In both MAT and Discoid/Levallois contexts, their appearance dates to MIS 3. Very few and isolated cases of MIS 5 backed tools are mentioned in Tönchesberg (Conard, 1990) and in some contemporary sites in northern France (Deloze et al., 1994) and Poland (Cyrek et al., 2014), even if they are sometimes associated, according to the figures, to apparently pseudo-retouched blanks. Conversely, as far as we know at present, in the rim of the Po Plain and along the Italian peninsula these types of tools are missing in Mousterian assemblages. At Fumane they are present only in unit A9, which does not mark the last Mousterian occupation, being followed by A5-A6 and A4. The first of these units, characterized by recurrent unipolar Levallois, has no backed tools, but they reappear in different forms in A4, associated with centripetal Levallois and with novel lithic production systems and tools that are broadly ascribed to the Uluzzian techno-complex (Peresani et al., 2016, 2019). Therefore, the association of backed tools with a Discoid production at Fumane dates back to at least 47.6 ky cal BP. The Discoid layers in French cave and rockshelter sites range between 46 and 41 ky. The open-air sites in the Paris basin (Les Bossats) could be coeval or slightly older. The site of Beauvais is dated to 50–55 ky (Locht et al., 2006). Although the Mousterian occupation at Champ Grand is currently not directly dated, geological and stratigraphic information suggests it can be placed in the first half of MIS 3. At this stage, backed tools also appear in south-western France, however within MAT-A contexts, dated at Grotte XVI, layer C, La Rochette 8, Pech de l'Azé I, layer 4. At Le Moustier, the MAT-A defined by Bordes in layer G, dated between 55 and 50 ky, has been shown to reflect collection biases in older excavations and therefore does not actually represent with certitude this sort of assemblage. A recent revision, based on substantially more representative assemblages, demonstrates that sub-layers G1 and G2 exhibit exclusive use of Levallois technology, while G3 and G4 are dominated by the production and management of bifaces and lack backed tools (Gravina and Discamps, 2015; Gravina, 2016).

It is worth noting that at Fumane, as well as at the end of regional Mousterian sequences in south and south-western France, there is no standardization of backing techniques and of the overall form of backed implements (though they are often lunated/curved). This is in

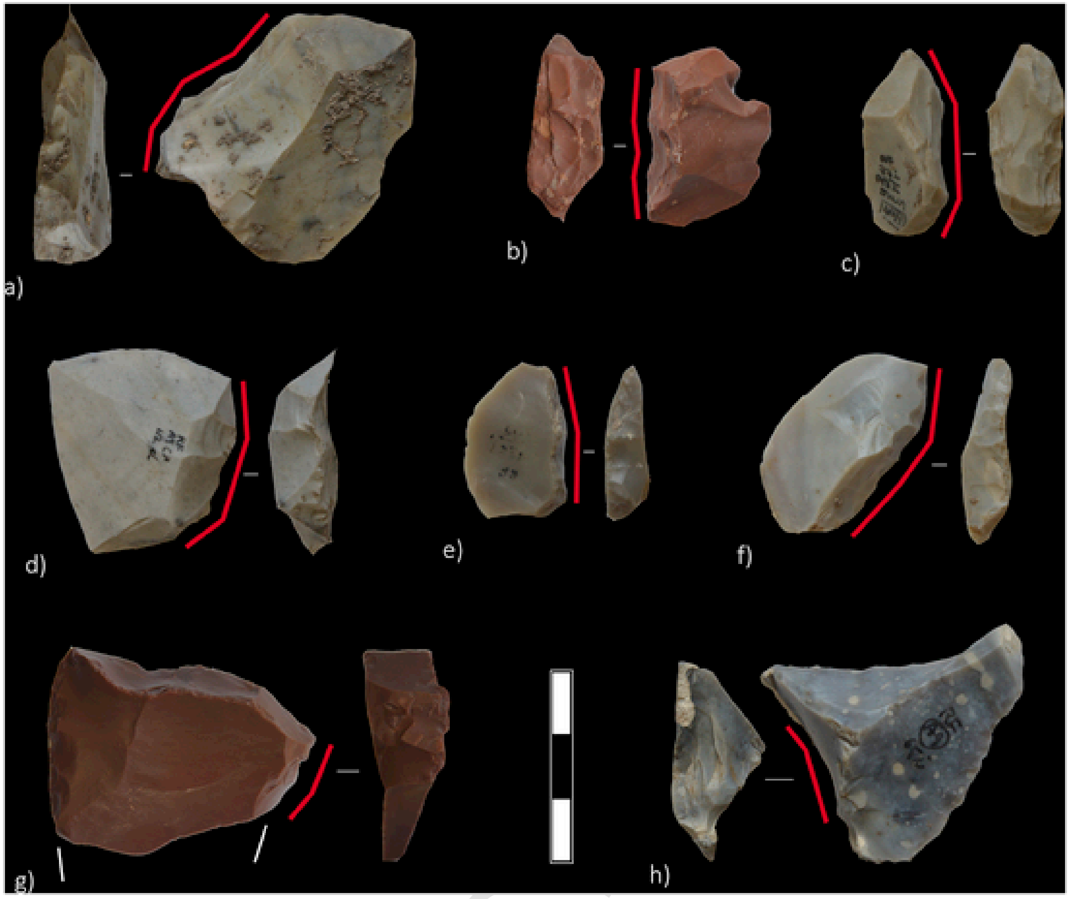

Fig. 13. A selection of artifacts showing type 1 modifications on the back: a) artifact #4856 is a technological pseudo-Levallois point with abrupt retouching on the back's mesial-distal length, b) #1032 and c) #4699 are small CERFs with backs created by bipolar retouching on anvil, d) a. #1778 is a quadrangular CERF with a retouched back that was created by means of wide and continuous detachments with an organic hammer, e) a. #266 and f) a. #3842 are small Kombewa-type CERFs with backs completely manufactured by abrupt retouching, g) a. #1333 is a fractured scraper that shows tiny detachments on a distal fracture that might have served as a back, and direct retouching and ventral thinning on the lateral back, h) a. #427 is a pseudo-Levallois point with clear traces of bipolar abrupt back retouching on anvil.

contrast with the European MP-UP transitional industries, such as the Uluzzian (Riel-Salvatore, 2009; Moroni et al., 2018; Peresani et al., 2019) and the Chatelperronian (Pelegrin, 1995; Roussel et al., 2016), or the Howiesons Poort and Post-Howiesons Poort complexes in South Africa (Soriano et al., 2007; Villa et al., 2010), where backed pieces typically fit standardized classes. These standardized tools are sometimes interpreted as evidence for symbolic behavior, or as social markers ~~within ethnic exchanges~~ (Barham, 2002; Soriano et al., 2007). Backed tools from late Mousterian contexts also differ from the recurrent shape of some types of backed bifacial knives (Keilmesser) and the already mentioned curved backed knives on laminar blanks from MAT contexts. At Fumane and in the other Discoid or Levallois assemblages, the production process of these implements does not seem to have been planned around a fixed conceptual scheme. This means that functional requirements of handling and use, rather than cultural definitions of preferred shapes, were fundamental in determining their design. The variability of the modifications to produce a useful back allows a certain versatility that does not affect the level of efficiency, as confirmed by wear-traces observed on the various parts of the archaeological specimens as well as experimental observations. With the Discoid method, planning and design are not reflected so much in the shapes of individual implements. The advantage of this system is its high productivity and adaptability. This method allows production of numerous raw blanks or a stock of blanks from which more mobile implements can be selected.

The presence of two hafted implements in the Fumane A9 sample is further evidence of the tool makers' capacity to create elaborate tools. The probable presence of two different hafting schemes, adapted to the blank's size and shape, as well as intended function, may suggest a wider basis of knowledge. Hafting and composite tools have been generically considered in the literature as a marker for modern behavior (McBrearty and Brooks, 2000), even though Shea and Sisk (2010) limited this term to the hafting of points or barbs in thrown spear or arrows. Although this hypothesis requires further evidence, this appears to be the use-pattern of the geometric backed tools from the Howiesons Poort (Villa et al., 2010) or MP-UP transition complexes (Sano et al., 2018). However, hafting in Fumane A9 did not involve points, but tools used in other activities. As such, hafting was not strictly necessary, as the tools could have been used without handles. Thus, it is a choice that reflects technical knowledge, technological expertise and a sort of "modern" behavior. According to Rots (2015), the first "evolutionary phase" of hafting is when it becomes a prerequisite for the tool's function (e.g. for projectiles). The cases from Fumane represent a successive phase, since knives and scrapers do not necessarily need a handle to be used, although hafting can improve their performance in terms of strength or precision (Rots, 2015; Zupancich et al., 2016). On the other hand, this is not the earliest example of this sort of hafting: the use of hafted butchering knives has been recognized by Rots as early as MIS7 and MIS6 at Maastricht-Belvedere and Biache-St-Vaast.

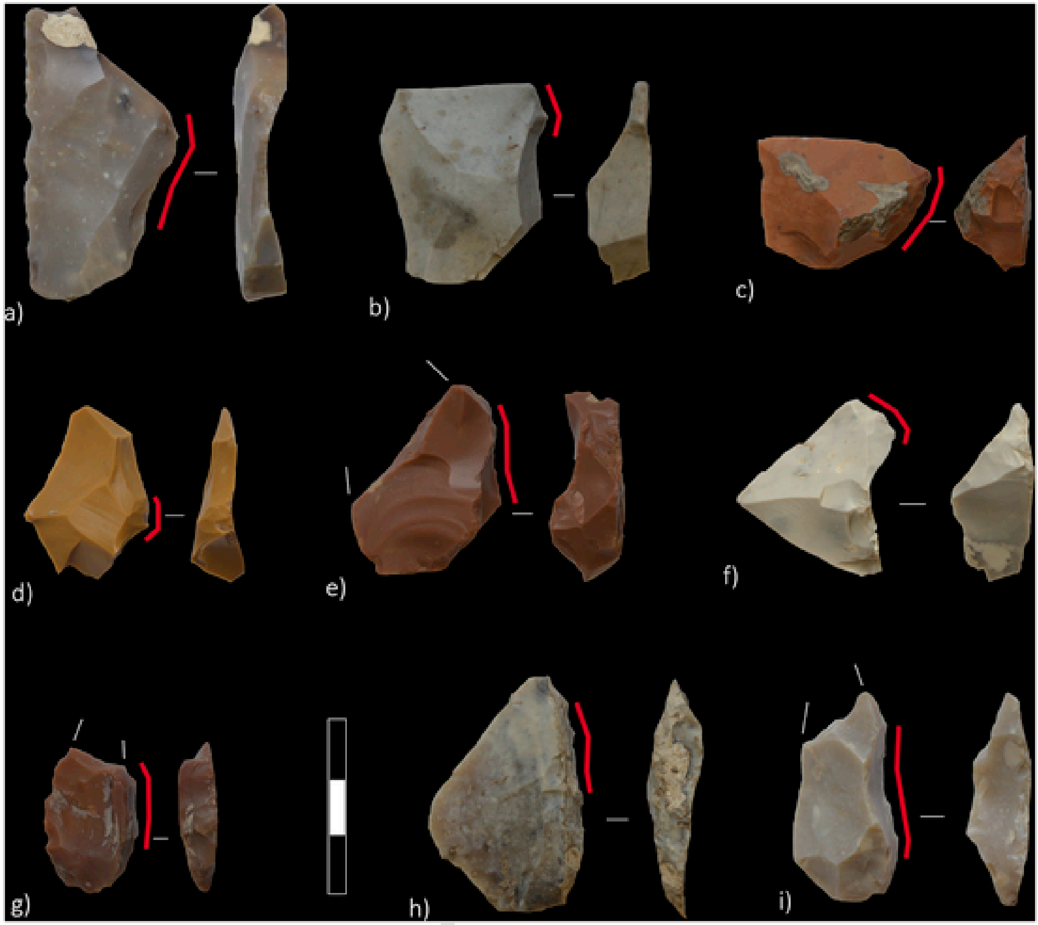

Fig. 14. A selection of artifacts showing type 2 modifications on the back: a) artifact #44 is a long CERF with a back that was blunted in the mesial length through direct retouching with an organic tool, b) a. #4073 is a quadrangular CERF showing direct rounding of an irregular portion of the back, c) a. #1866 and f) a. #4370 are two pseudo-Levallois points showing direct retouching of the backs only on the distal portion in order to facilitate handling, d) a. #3794 shows rounding and blunting on the mesial portion of the back to facilitate handling, e) a. #1310, g) a. #4567 and h) a. #4717 are CERFs with partially manufactured backs through direct retouching, i) a. #430 shows direct retouching in order to blunt the lower portion of the back.

6. Conclusion

The analysis of backed pieces from Fumane unit A9 was carried out with a combination of technological, techno-morphological and use-wear analyses, and was corroborated by experimental replication and use. This enabled a detailed investigation of a pattern of cultural innovation, backing to accommodate manual prehension as well as hafting, in the European Late Middle Paleolithic.

Systematic evidence from across Europe during MIS 3 supports the independent appearance of this innovation in different regions. Usually associated with discoid technological systems at open-air sites and occupations in natural shelters, this cultural feature was identified in northern France and in the southern Alpine fringe at Fumane, as well as in several late Middle Paleolithic assemblages and in the MAT techno-complex in south-western France. The technical competence and behavioral flexibility of late Neanderthal populations are well illustrated by these tools, which are related both to ecological factors and functional needs. There is little systematic patterning in the prehension and use of these backed tools, which suggest that the behavior was a response to disparate needs. In this sense, backed tools in Discoid Mousterian assemblages could represent the "expedient" variant of the much more standardized elongated backed knives typical of the MAT techno-complexe.

The diversity of influences on manufacture of backed tools is reflected in the variety of techniques used in the manufacturing or modification of the backs. Among these, we identified direct percussion on anvil, direct percussion with organic tools, and abrasion. These different techniques were used according to the type of support and intended function. Hafting, recognized on a small number of specimens, represents a considerable time investment. It is worth noting that the documented tool functions, for cutting and scraping, do not strictly require hafting, although this technical feature may improve their performance significantly.

In conclusion, late Neanderthal groups who created the A9 assemblage at Fumane reserved backing modification for specific, relatively elaborate tools that, in some cases, formed part of their mobile tool-kit. These groups were characterized by considerable – but mainly local – residential mobility and behavioral variability. An extensive comparison of the Late Middle Paleolithic ~~scenario~~ suggests that the backed tools represent, ~~albeit in~~ their peculiarities and regional differences, an independent innovation of European Mousterian groups.

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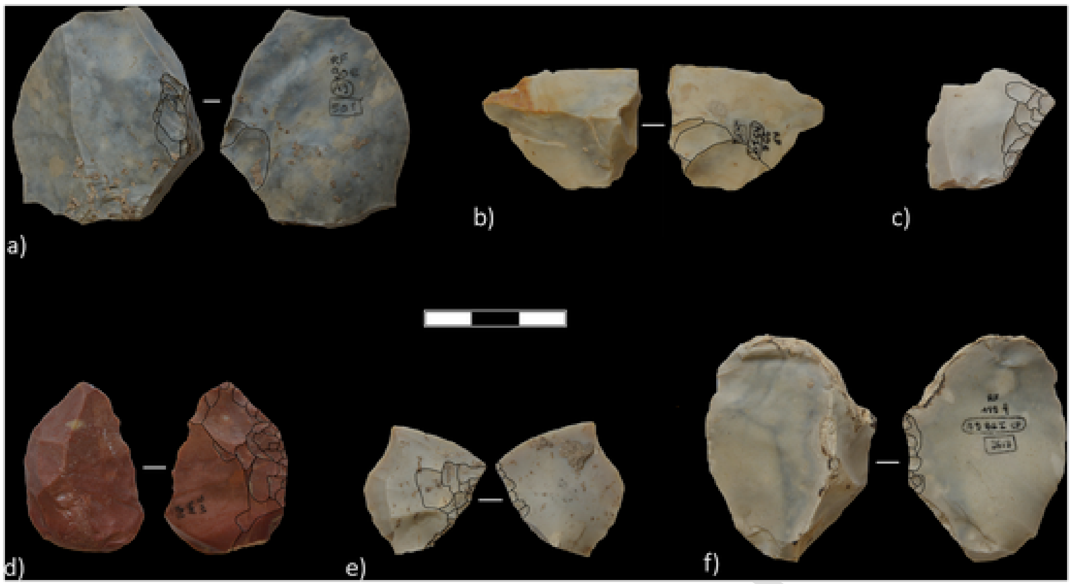

Fig. 15. Sample of artifacts showing type 3 and type 4b modifications on the back; a) artifact #501 is a large CERF showing both ventral and dorsal detachments in order to thin out the mesial portion of the back, with abrasions on the distal area; b) a. #3078 is a pseudo-Levallois point showing ventral thinning at the base and part of the back; c) a. #1798 shows widespread detachments on the dorsal face of the back; d) a. #1984 is a CERF with a cortical back showing widespread detachments which thinned out the lower face from the base to the point; e) a. #4829 is a small CERF with a lateral-distal protrusion showing thinning on both dorsal and ventral surfaces in correspondence to the back; f) a. #3613 is a large, partially corticated CERF showing tiny detachments on the ventral face on the mesial portion.

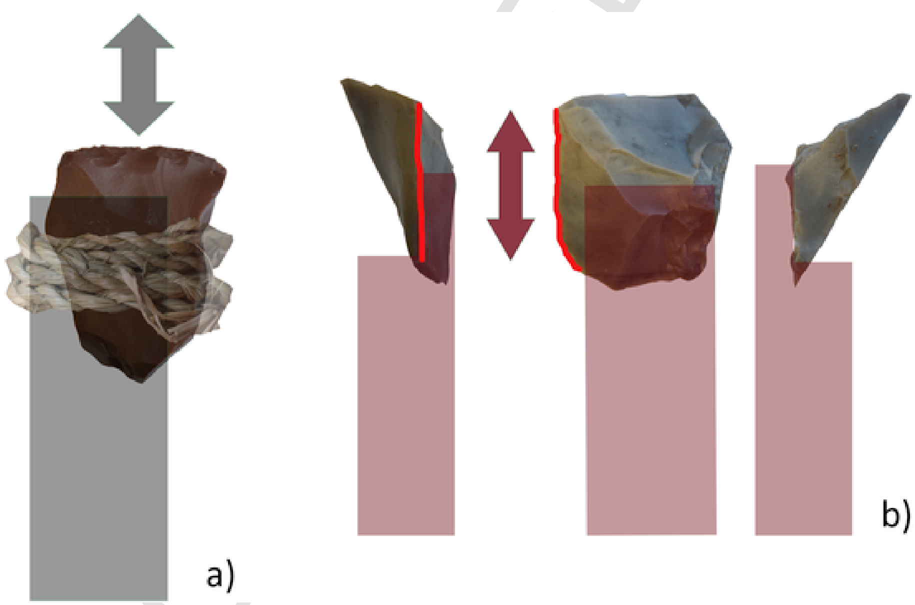

Fig. 16. Artifacts showing wear traces associated with a probable haft; patterns are assumed from techno-functional data and use-wear traces; a) artifact #1333, was probably inserted in a terminal split haft and fixed with organic strings; the scraper was used with a transverse motion; b) a. #665 is a knife ~~which was~~ used with longitudinal motions, probably fitted in a juxtaposed haft after partial thinning on the upper surface.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2019.105011.

Uncited reference

~~Simondon, 1958.~~

Fig. 17. Map of central-western Europe with main sites mentioned in the text. Assemblages with retouched backed artifacts produced in discoid technological systems are indicated with black stars.

Table 4
MIS3 dated Mousterian assemblages with prepared backed artifacts/backed knives in Western Europe.

Site	Layer	Techno-complex	N° backed items	Chronology	References
La Rochette	8	MTA – A	38	50-55 ky	Soressi (2002)
	7	MTA – B	73	52.5–42.6 ky	Soressi (2002)
Le Moustier	G	Levallois ~~Mousterian~~ (G1-G2) MTA-A (G3-G4)	78 (layer G: Peyrony collection) 1 (G1-G2) + 35 (G3-G4) (Geneste & Chadelle collection)	>47 ky	Soressi (2002); Gravina and Discamps (2015) Higham et al. (2014)
	H	Discoid ~~Mousterian~~	36	46-47 Ky	Gravina and Discamps (2015) Higham et al. (2014)
	K	Levallois ~~Mousterian~~	16	>42 Ky	Gravina (2016) Higham et al. (2014)
Pech de l'Azé	4	MTA – A	18	>43 ky	Soressi (2002) Soressi et al. (2007)
	6 + 7	MTA – B	61 + 51	41-51 ky	Soressi (2002) Soressi et al. (2007)
Grotte XVI	C	MTA – A	15	64.6 ky	Soressi (2002) Guibert et al. (1999)
Combe Grenal	1	Discoid ~~Mousterian~~	7	~40 Ky?	Faivre et al. (2014)
Saint Césaire	EGPF	Discoid ~~Mousterian~~	?	40.9 Ky	Thiebaut et al. (2009)
Champ Grand	\	Discoid/ Quina ~~Mousterian~~	2 (+11?)	55–45 Ky?	Slimak (2008)
Les Bossats	4	Discoid ~~Mousterian~~	4 (?)	50–45 Ky?	Bodu et al. (2014)
Beauvais	N1	Discoid ~~Mousterian~~	2 (?)	50–55 Ky	Locht (2003) Locht et al. (2006)
Fumane	A9	Discoid ~~Mousterian~~	33	>47.6 Ky	Peresani et al. (2008)

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