Chapter 12
Projectiles and Hafting Technology

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Abstract Stone tool hafting has always been considered important, but its interpretative potential has not yet been sufficiently recognized. While wear studies have recently demonstrated the possibility of deriving hafting data from the stone tools themselves, it is essential that these kinds of data are now also integrated with regard to armature identifications. New experiments with spears and arrows show that armature identifications are complex and that no single feature on its own is diagnostic of projectile impact. Also the distinction between different projecting modes is still seriously hampered by the lack of a reliable reference. It is argued that hafting wear is essential for more adequate identifications of armatures and their projecting mode. The analysis of a number of archaeological Middle Palaeolithic and Late Palaeolithic assemblages in North West Europe allowed identifying the existence of hafted spear points for the Middle Palaeolithic sites and arrows armed with tips and barbs for the Late Palaeolithic sites.

Keywords Hafting • Armature • Projectile • Breakage • Experiments • Wear traces • Impact traces • Middle Palaeolithic

Introduction

Knowing whether and how stone tools were hafted improves our understanding of past human behaviour (Keeley 1982; Ambrose 2001, 2010; Rots 2003, 2010a; Barham 2013). It provides insight into the organic tool component that is rarely preserved, and it allows understanding the complete life cycle of stone tools, including discard patterns (Rots 2003). The choice to haft a stone tool depends on various factors, amongst which expertise with working organic materials to produce hafts and fixation agents (bindings, glues) is a necessary first step.

While hafting has often been dealt with as an inseparable category, recent functional data indicate that different degrees of hafting may play a role on a behavioral level (Rots 2015). Aside from the development of hafted tools, also the elaboration of hafting towards different tool functions and the development of differing articulations between stone tool and haft are crucial. Therefore, it seems valid to distinguish between tool uses that necessarily require a haft – if the task has to be performed with stone tools – and tools for which the addition of a haft "only" improves a tool's efficiency. Armatures are obviously examples of the former, next to hafted stone axes. Stone points cannot be used as armature if they are not hafted. This implies that any stone point that was used as armature should evidently show remains of this former hafting. Consequently, a reliable identification of armatures not only depends on knowledge regarding what use-wear evidence could be considered as diagnostic, it also requires insight into hafting wear.

When reflecting on which tools use might have stimulated the development of hafting techniques, it appears likely that it may first have concerned tools for which hafting was a necessity. These tools would first have consisted of organic material only (i.e., no hafting), like the wooden spears that were in use from about 400–300 ka onwards [e.g., *Schöningen* (Germany) (Thieme 1997; Behre 2012), *Clacton-on-Sea* (UK) (Oakley et al. 1977)]. Adding a stone element to a spear in order to produce a hafted spear point demands expertise on how it can be fixed. One may assume that the incentive to be able to use a stone tip on wooden spears or a stone blank for percussion implements is higher than for any other stone tool that can perform well without being hafted. In that case, the first attempts to haft stone tools may have concerned armatures and percussion implements, and only applied to other stone tools later on. Current archaeological evidence seems to support such a scenario (Rots and Van Peer 2006; Rots et al. 2011; Rots 2015) (see also below).

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Hafting Evidence

Both direct and indirect evidence have been used to identify hafting, independent of tool use. *Preserved hafts* are the most direct and reliable evidence of hafting. Most examples however date to the Neolithic period. The earliest evidence of *adhesive* use dates to the late Middle Pleistocene site of Campitello (Italy) (Mazza et al. 2006). Aside from this early evidence, most current direct evidence for the use of adhesives broadly dates to around 70 ka in the Old World (Boëda et al. 1996; Hedges et al. 1998; Boëda 2008; Wadley et al. 2009; Rots et al. 2011). Recently, it was established that hafting is also identifiable based on *microscopic wear patterns* (including polish, scarring, striations, rounding) and that also the hafting arrangement can be inferred when the preservation state of the material is sufficient (Rots 2002a, 2010a). The method proves to be a reliable means to identify the existence of stone tool hafting based on the stone tools themselves, which allows for an improved understanding of both the timing and nature of hafted stone tools, independent from the preservation of organic material. The identification of the hafting arrangement is appreciably more difficult than the identification of hafting itself, in particular for older assemblages, but it is nevertheless possible. In general, *use-wear traces* never provide direct evidence of hafting; they can at most provide indirect evidence. For instance, for armatures (i.e., arrow/spear tips, barbs), a haft is a necessity and the use-wear evidence thus indirectly indicates hafting. As a result, the identification of diagnostic impact wear on a stone tool (e.g., Fischer et al. 1984) necessarily implies that the stone tool was used while hafted and that hafting evidence should be present too.

Aside from these direct arguments, several **indirect arguments** have been used over the years to argue for the existence of hafting. *Morphological adjustments* such as the removal of bulbs, proximal thinning, proximal width reduction (Rots 2005), notches, tangs (Rots 2002b), etc. have predominated. Tangs in particular have been a source of much discussion, especially with regard to Aterian points (e.g., Clark 1970). However, it is not just the choice to haft a stone tool but the chosen hafting arrangement that determines the relevance of morphological adaptations. While certain hafting arrangements set low demands on a stone tool's morphology, allowing the hafting of various morphologies and sizes; other hafting arrangements may gain significantly from specific morphological features. These morphological features thus potentially indicate the existence of a particular hafting method. By contrast, they have no value for identifying the timing of hafting as sufficient hafting modes exist that have no truly detectable requirements on the level of a stone tool's morphology.

Standardization has also been used as an argument in favor of hafting (Marks et al. 2001). However, if one wants to argue for a potential link with hafting, one first needs to differentiate between the active and non-active tool part. While hafting may have necessitated the production of more morphologically similar pieces (Bar-Yosef and Kuhn 1999), this morphological similarity essentially concerns the non-active part of a stone tool, and "standardization" in view of hafting – if it exists – may not be so easily visible in the archaeological record. Characteristics referring to the complete stone tool may create a visual perception of "standardization" without being necessarily relevant for hafting purposes (e.g., blank length, morphology of used edge, location of shaping retouch). It is clear that only a functional study can establish a potential relation between standardization and hafting.

For *small tools*, assumed problems in easy manual manipulation are generally used as arguments to advocate hafting (Bar-Yosef and Kuhn 1999). In the case of *microliths* used as projectiles, hafting can be inferred based on the presence of diagnostic impact damage from use (Fischer et al. 1984). Microliths (or bladelets) frequently proved to have been used hafted for European Late Palaeolithic and Mesolithic assemblages, but one still needs to be careful. Often, microliths are too easily assumed to represent parts of a projectile technology leading to potential interpretative errors. After all, various functions have been identified for microliths (independent of the region and period) including projectiles (tips, barbs), knives and drills (Donahue 1988; Kimball 1989; Caspar and De Bie 1996).

Some researchers have proposed that the presence of *ochre* on stone tools could be an indication of hafting (Beyries and Inizan 1982; Wadley et al. 2004). However, when no resin is found, ochre is an argument for hafting that is equally indirect as morphological adjustments are. While ochre may indeed form an ingredient of resin and potentially remain on a stone tool surface after the resin has degraded, it may have had various other functions as well and it can only be used as a valid argument for hafting in association with resin residues and/or hafting wear (Wadley et al. 2009; Rots et al. 2011).

Breakage is not frequently used as an indirect argument for hafting, but experimental studies have demonstrated that hafted use results in breakage more frequently than hand-held use (Rots 2002a, 2010a). Most hafting fractures occur at the haft limit, usually about one or two millimeters inside the haft. It is the point where the stone tool is most vulnerable when pressure is exerted, in particular in the case of thin tools. The majority of hafting fractures occurs on tools with a medial thickness of maximum 7 mm, in particular when used in high-pressure motions. The most distinctive trait for hafting fractures is abundant scarring in direct relation with the fracture (Fig. 12.1). While fractures

Fig. 12.1 High-impact related hafting fracture: experimental tool used for adzing wood

are indeed suggestive of hafting, they do not provide conclusive evidence on their own.

Diagnostic Evidence of Hunting Weapons: Wear Features and Residues

A number of armature experiments have been performed over the years, the majority concerning Late Palaeolithic and Mesolithic projectiles (Fischer et al. 1984; Odell and Cowan 1986; Bergman et al. 1988; Caspar and De Bie 1996), but some were performed on Upper Palaeolithic points (Plisson and Geneste 1989), on spear points (Odell and Cowan 1986; Plisson and Beyries 1998) or Middle Stone Age segments (Lombard and Pargeter 2008; see Rots and Plisson 2014 for an overview). Tool samples vary, but relevant data concerning potentially diagnostic wear patterns were generally obtained.

Unfortunately, armature identifications have recently suffered from a loss of rigour, both with respect to methods applied and the criteria considered as diagnostic (see Rots and Plisson 2014 for a discussion). Therefore, I will formulate some personal ideas on how a reliable armature analysis should minimally be performed and what wear features are potentially diagnostic. A macroscopic examination of scarring or fractures on potential armatures (even with the aid of a hand lens) without training and an *available* and *relevant* experimental reference collection is difficult and is not expected to significantly contribute to insights into past hunting technologies.

In my opinion, five aspects are essential on a methodological level for studies that have the intention to try and identify armatures:

– A microscopic analysis: the use of a stereoscopic binocular microscope with magnifications up to at least 50× is a minimum, and the additional use of a metallurgical microscope for high magnifications is preferable.
– One wear feature is not sufficient for a reliable identification of an armature, the wear pattern as a whole has to support the interpretation.
– An available experimental reference collection that includes reproductions of the archaeological stone tools under study or comparable examples, used for various uses, amongst which armatures but also perforating and cutting tools, for instance. If claims are made regarding the projecting mode of the armature, the collection should include experimental armatures used with different projecting modes. The experimental reference is preferrably continuously available to the analyst.
– Skill is an important element for the production of an experimental reference collection, both with regard to stone tool manufacture, hafting, ballistics and use (e.g., experienced spear-throwers and/or archers.
– The analyst requires relevant expertise regarding different wear features, not only those linked with armature use, but also those linked with other tool uses in order to adequately assess the expected and observed variability.
– The above in a sense implies that only trained microwear analysts are well-placed to perform a reliable armature analysis. This is true. On the other hand, the lack of sufficient microwear analysts and the eagerness to understand past hunting technologies have forced many researchers into using less appropriate methods, which is understandable. Nevertheless, it remains essential that every method is first rigorously tested (e.g., including blind testing) before results can be considered reliable.

Many authors have published details on what features are diagnostic to identify armatures. I particularly want to stress the importance of observing different forms of diagnostic evidence in order to produce incontestable results: not only specific wear features, but the wear pattern as a whole is crucial. One isolated tip fracture or scarring patch should *never* be considered as sufficient or reliable evidence. Aside from tip damage, also the lateral edges of armatures may suffer a lot of damage; it may perhaps not always be diagnostic on its own, but its presence is nevertheless quite characteristic. In addition, also the hafted portion may show diagnostic features that resulted from the counter-pressure against the haft or within the animal.

Step-terminating bending fractures, spin-offs and burination have frequently been cited as the most diagnostic evidence of armature use (Fig. 12.2). Far less cited are the

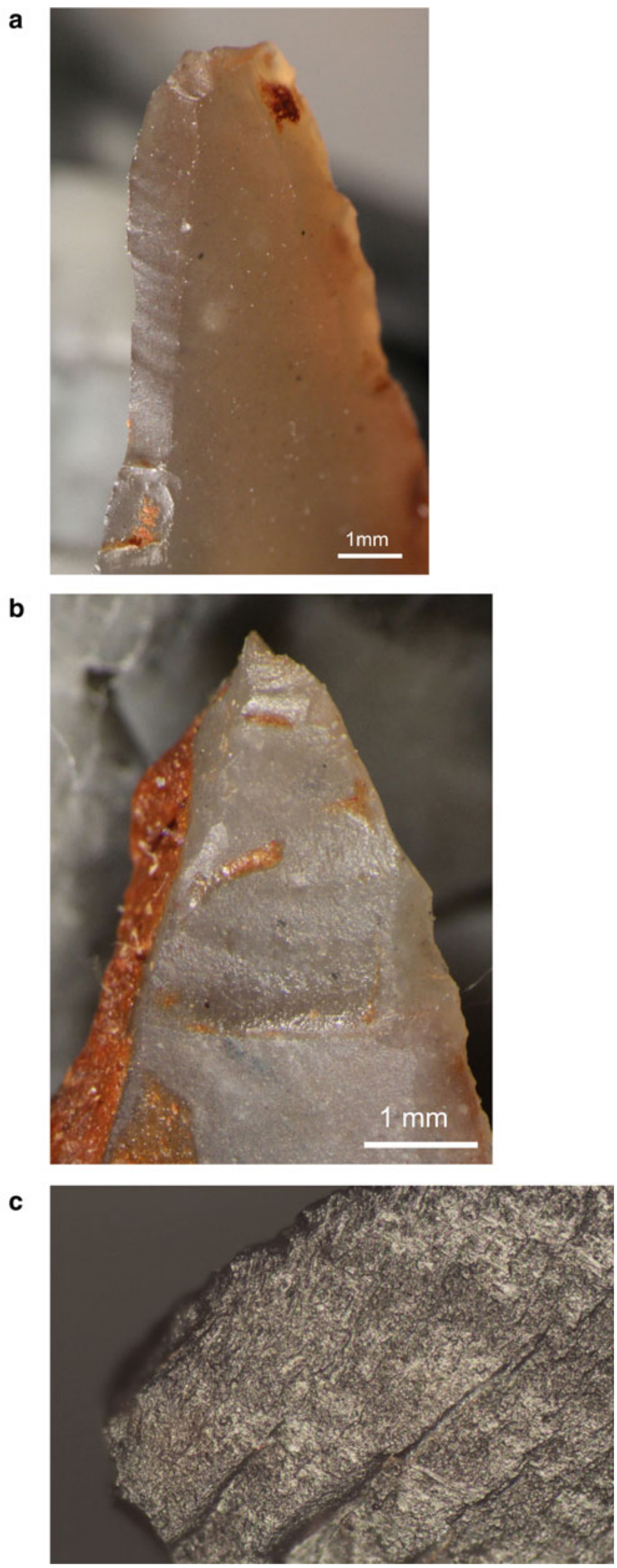


Fig. 12.2 Diagnostic impact use damage: **a** burination on the ventral right tip of tip 108 (12.5×); **b** spin-off on the dorsal tip of barb 29 (16×); **c** MLIT's on the ventral distal tip of tip 85 in association with tip damage (100×)

microscopic linear impact traces, abbreviated as MLIT's, (Moss 1983; Fischer et al. 1984) that are formed in direct association with tip damage (Fig. 12.2c). The reason is of course that their observation requires a metallurgical microscope, which is rarely used in current studies on armatures, next to a sufficiently good preservation of the material. MLIT's are formed by the scar flake that detaches upon impact and shortly scratches the stone surface during this process. As a result, they start at the termination of the impact scar or fracture and they are always oriented (broadly) parallel to the use axis. They should not be confused with other striations that can form as a result of knapping, use, hafting, or other processes, nor should they be confused with smears or other residual features. MLIT's can only be observed on pieces that were appropriately cleaned with chemicals (e.g., ethanol) in order to remove adhering residues. MLIT's are not always equally explicit, sometimes it is simply a faint, narrow bright line starting from the scar negative, in other cases multiple, parallel and explicit striations are observed (see examples below).

While step-terminating bending fractures, spin-offs and burinations may indeed form as a result of weapon use, these features should preferably not occur isolated. Even though experiments have demonstrated that diagnostic wear features do not form at each impact, it is nevertheless essential for archaeological pieces to show more than one wear feature in order to support their identification as armature. This implies that an ideal diagnostic wear pattern consists of explicit tip damage (step-terminating bending fractures, spin-offs, burinations, or a combination of these), associated with MLIT's, lateral impact-related scarring and impact-related damage on the hafted portion, preferably also in association with MLIT's witnessing the counter-pressure.

Residues alone are not sufficient evidence to provide a reliable identification. After all, butchering knives may show exactly the same set of residues and residue distributions (both on the level of use and hafting). They often also show explicit tip damage. The danger is real because independent of tool size, pointed stone tools (or bladelets) initially assumed to have been part of an armature arrangement instead often proved to have been used as butchering knife based on a microscopic wear analysis (e.g., Plisson and Beyries 1998; Caspar and De Bie 1996; Rots 2015). Therefore, a residue analysis should preferrably be combined with an analysis of other wear features that are more diagnostic.

While resin residues may witness the fact that a stone tool may have been used hafted – on the condition that the wear pattern confirms the distribution – resin is in itself not a diagnostic indication of a hunting weapon. Resin may be used to haft a various set of stone tools and there is significant overlap what the hafted area concerns between different kinds of tool uses. In addition, resin residues are not always reliable to delimit the hafted portion of the stone tool as resin tends to get all over the stone tool during hafting or de-hafting (see experiments).

Hunting Experiments

Over the years, I performed different experiments related to the use of hunting weapons in collaboration with the *Chercheurs de la Wallonie* at the *Préhistosite de Ramioul* (Liège). Two sets of experiments are dealt with here: an exploratory experiment regarding thrusting and throwing spear points, and a more elaborate experiment on arrows equipped with tips and barbs. Levallois points were used in the former experiment, while diverse microlithic points (retouched base, backed, obliquely truncated, crescents) were manufactured for the second experiment. Both use and hafting wear were examined.

Spear Point Experiment

The spear point experiment was performed in the framework of an analysis of different Middle Palaeolithic assemblages. The goal was to evaluate whether thrusting and throwing spear points could potentially be distinguished based on microscopic evidence, one aspect of which was testing whether lateral use damage from a rotating action upon insertion formed on thrusting spears only, a hypothesis that was put forward earlier (Rots 2009; Rots et al. 2011). In addition, the efficiency of different hafting methods was examined. The experiment was exploratory only and larger-scale follow-up experiments are currently in progress.

Eleven Levallois points were used for this experiment; five were used as thrusting spear tips, six as throwing spear tips (Table 12.1). All pieces were mounted on a wooden spear and fixed with the aid of bindings and/or resin (Fig. 12.3). One point was fixed against a straight wooden haft (i.e., no insertion) with a ball of resin, similar to

Table 12.1 Details of spear point experiment

ID	Sequence in exp.	Haft type	Haft material	Bindings	Fixation	Activity	Attempts	Result	Flint grain size
Exp.43/1	7	Male split	Wood	Leather	–	Thrusting spear	5	Usable	Medium
Exp.43/2	9	Male split	Wood	Intestines	–	Thrusting spear	5	Usable	Fine
Exp.43/3	1	Male split	Wood	–	Resin	Throwing spear	4	De-hafted	Fine
Exp.43/4	6	Juxtaposed	Wood	Leather	–	Throwing spear	5	De-hafted	Fine
Exp.43/5	2	Straight	Wood	–	Resin	Throwing spear	1	De-hafted	Fine
Exp.43/6	5	Juxtaposed	Wood	Leather	–	Throwing spear	2	Tip damage	Medium
Exp.43/9	10	Male split	Wood	Leather	–	Thrusting spear	5	No penetration	Fine
Exp.43/10	11	Juxtaposed	Wood	Intestines	–	Thrusting spear	5	Usable	Fine
Exp.43/11	8	Male split	Wood	–	Resin	Thrusting spear	5	No penetration	Fine
Exp.43/12	3	Male split	Wood	Tendons	–	Throwing spear	11	Point out of axe	Fine
Exp.43/13	4	Juxtaposed	Wood	Intestines	–	Throwing spear	15	Usable	Fine

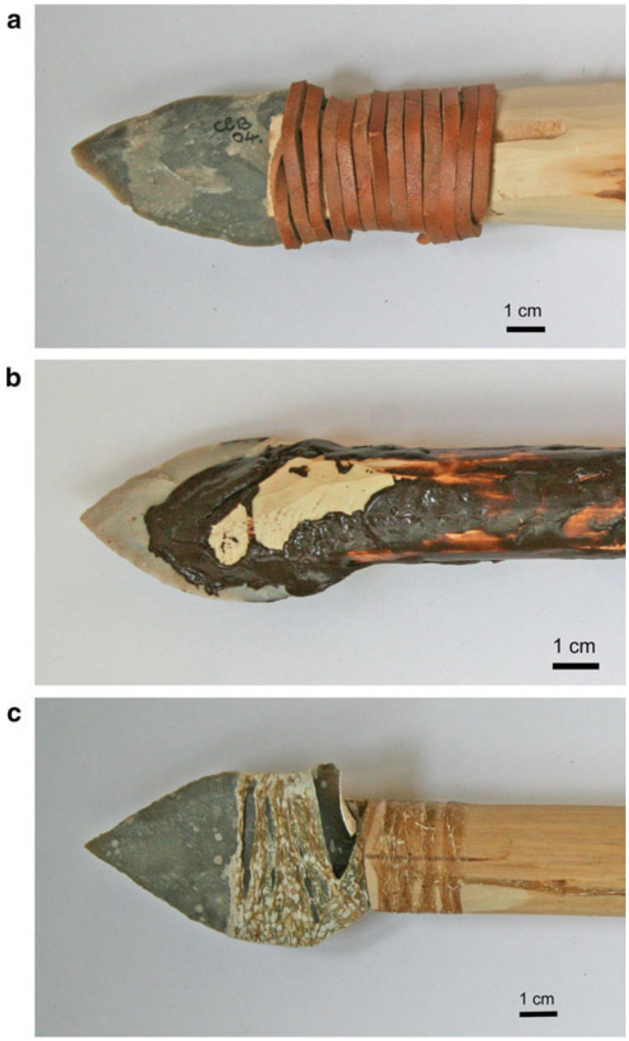


Fig. 12.3 Experimental hafted spear points, fixations with: **a** leather bindings (exp. 43/1); **b** resin (exp. 43/3); **c** intestines (exp. 43/10)

Australian Aborigines hafting modes (Hayden 1979). Throwing spear points were thrown from a distance of 6–8 m. All spears were thrown or thrusted by one and the same person, Christian Lepers, an experienced spear thrower and an overall experienced experimenter (Fig. 12.4). A freshly killed deer was used. All spears were used in 5 successful attempts, unless the point detached from the haft earlier on.

Results

Generally speaking, points proved to detach more frequently from thrown arrangements in comparison to thrusted ones. The most successful fixations proved to be resin or intestines. Wear features are most prominently present on thrown spear points, but this is also because the size of the animal and the way it was fixed as target (i.e., hung and fixed with

Fig. 12.4 Experimental setting spear point experiment: throwing spear

ropes) did not allow a high pressure to be exerted with the whole body during thrusting. Less damage is formed on retouched edges in comparison to unretouched ones. The standard impact wear features were observed on the points (Table 12.2; Figs. 12.5 and 12.6). Tip fractures diagnostic of impact were nevertheless rare, in spite of the presence of other impact-related features. This stresses the importance of examining the whole wear pattern on these points instead of focussing too much on the tip only.

A diagnostic wear pattern could be observed on about half of the spear points (3 thrusting, 3 throwing). For three of these (2 thrusting, 1 throwing), the use-wear evidence alone would not be sufficient to consider the evidence as diagnostic, while it can be considered diagnostic in combination with the evidence on the hafted portion. For three thrusting spear points and one throwing spear point, the wear evidence may be suggestive for a use as spear point, but it cannot be considered as diagnostic. At least one throwing spear point detached after one attempt without the formation of diagnostic wear features (Exp. 43/5).

Discussion

While this experiment was only exploratory in nature, interesting observations were nevertheless possible. Distinct clues with regard to the distinction between thrusting and throwing spear points were not yet obtained even though the throwing spear points were on average more intensely damaged than thrusting spear points (but see earlier comments with regard to exerted pressure) and more often show diagnostic wear features (Table 12.2; Figs. 12.5 and 12.6). This counts for both the use and the hafting evidence. More abundant and more typical hafting scarring forms on throwing spears, while

Table 12.2 Wear evidence on spear points

Wear location	Wear features	Thrusting spears (5)	Throwing spears (6)
Tip	Step-terminating fracture	0	1
	Step-terminating scarring	1	3
	Other fracture	1	1
	Spin-off	1	0
	Burination	0	0
	Crushing	1	1
	MLIT	1	0
Lateral edges	Fracture	0	1
	Step-terminating scarring	2	4
	Sliced scarring	0	1
	Burination	0	0
	Crushing	1	2
	MLIT	1	0
Hafted area (impact-related features)	Step-terminating scarring	3	3
	Sliced scarring	1	2
	Burination	0	1
	MLIT	0	0

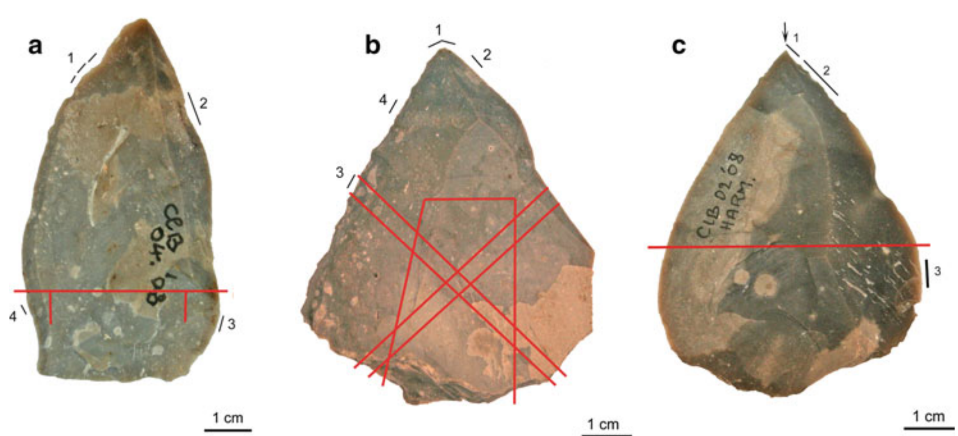


Fig. 12.5 Wear distribution on experimental thrusting spear points: **a** Exp. 43/1: *1* Impact-related step-terminating scars with curved initiation on the ventral edge, associated with MLIT's at the termination and similar scars on the dorsal edge, *2* Concentration of step-terminating scars, laterally initiated, on the ventral face, associated at the proximal side with wider and deeper scars with curved initiation, *3* Crushed scar patch on the dorsal edge, hinge- and step-terminations, *4* Scalar scars with curved initiation and feather termination (ventral edge); **b** Exp. 43/9: step-terminating scalar scar with dorsal initiation on the ventral tip, associated with spin-off on the dorsal tip, *2* Intrusive scar patch with feather- and step-terminations on the ventral edge, *3* Wide hinge-terminating hafting scar on the dorsal edge, *4* Deep scalar impact scar, partially feather- and partially hinge-terminating; **c** Exp. 43/2: *1* Faint MLIT on the ventral tip, associated with polish formation, *2* Band of bright spots, striations and polish, associated with retouch, due to knapping, *3* Sliced and sliced-into-scalar scars on the ventral edge, partially alternating, due to the contact with bindings

thrusting spear elements show few typical scars and scarring is mainly concentrated around haft boundaries. This confirms the general observation that the exerted pressure is an important factor in hafting trace formation (Rots 2002a, 2010a). It implies that hafting wear may provide relevant data for evaluating the relative amount of pressure that is exerted upon impact and thus the projecting mode.

Arrow Experiment

The goal of the arrow experiment was to examine whether a reliable distinction between tips and barbs was possible based on a microscopic analysis. In addition, the efficiency of using bindings instead of resin for hafting the pieces was tested. Two sets of experiments were performed, including 100

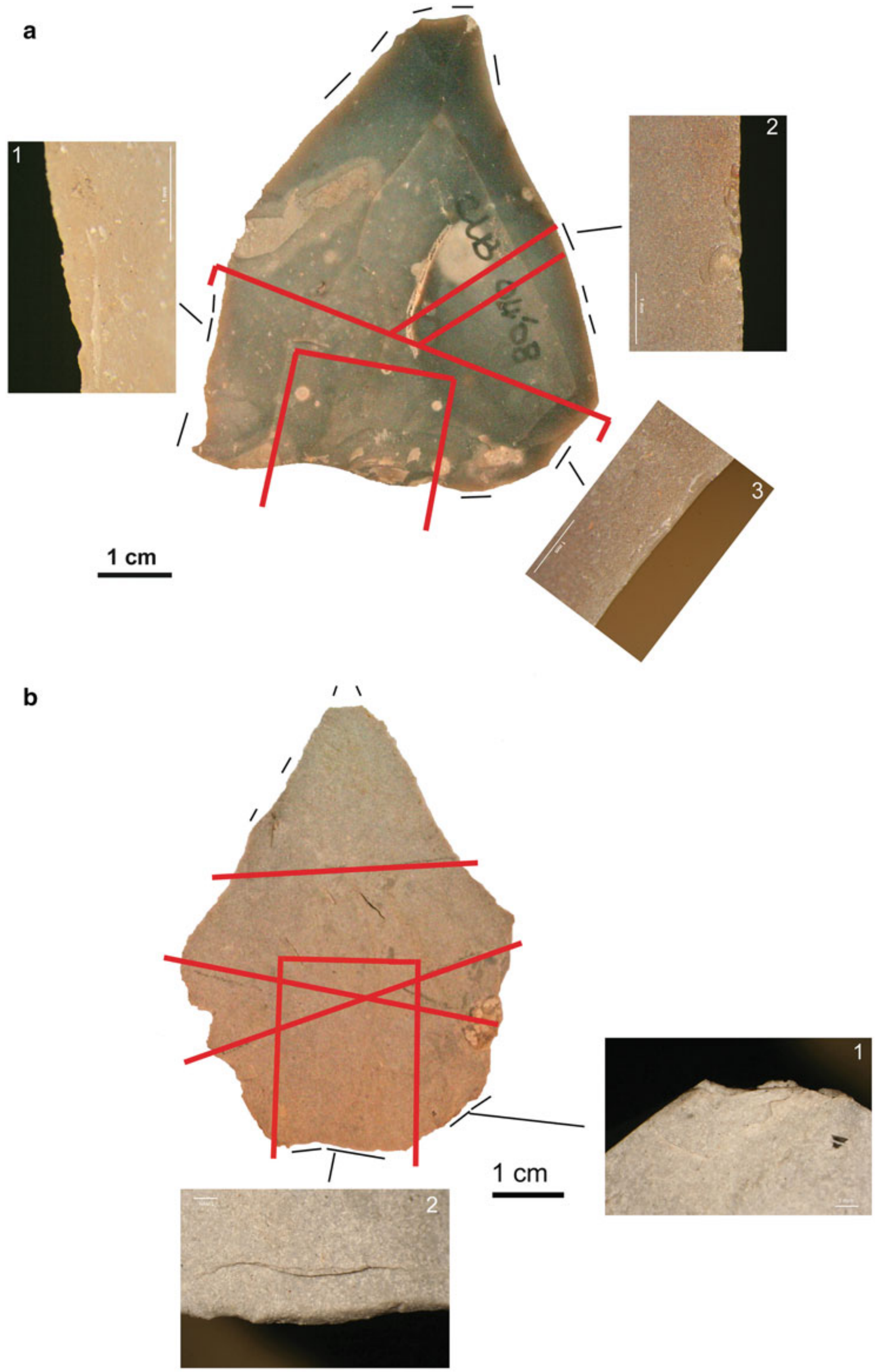


Fig. 12.6 Wear distribution on experimental throwing spear points: **a** Exp. 43/4: *1* Wide step-terminating hafting scarring on the dorsal proximal left edge (40×), *2* Hafting scar patch due to bindings on the dorsal medial right edge consisting of a large step-terminating scalar scar and smaller step-terminating scars with curved initiation (32×), *3* Sliced step-terminating non-intrusive hafting scars on the dorsal proximal right edge (32×); **b** Exp. 43/6: *1* Large scalar step-terminating scar which caused a small burination due to counter-pressure, located on the dorsal proximal right edge (10×), *2* Wide scalar scar with strongly curved initiation and step termination on the ventral base due to counter-pressure against the haft (10×)

Fig. 12.7 Experimental hafted arrowheads and barbs

Fig. 12.8 Experimental setting arrow experiment

arrows in total. In total, 100 stone tips and 104 barbs were used (Fig. 12.7). This implies that four arrows in total were equipped with two barbs. Two simple plain wooden bows were used: one of 35 pounds and another one of 60 pounds. Arrows were shot by two experienced archers (Louis Baumans, Didier Cocchi), at a distance of about 18–20 m. For each arrow experiment, a freshly killed sheep was used (Fig. 12.8). Most arrowheads were fixed with resin, with bindings securing the arrow underneath the tip, but some were fixed with bindings only. Straw was placed behind the sheep in order to protect arrows that missed their target. All arrows were shot up to minimally one successful hit, unless the tip or barb detached earlier.

Only the first experiment is included in more detail here. It consists of 49 tips, 45 of which were recovered, and 51 barbs, 37 of which were recovered.

Results

Again, points appeared to detach most frequently in the case of bindings. Most pieces actually proved too small to allow a secure hafting with bindings. A combination of bindings and resin was successful. Eight tips detached as a result of impact, five of which were recovered, two of which remained stuck in a piece of wood. Twenty-four barbs detached, 10 of which were recovered. Additional fragments were found during the butchering of the sheep, but only fragments that could be recognized as a tip or barb of a specific arrow were included.

The experiment resulted in the formation of distinctive impact damage on the majority of the tips and on a good number of the barbs (Table 12.3; Figs. 12.9 and 12.10). In nearly all cases, a combination of different wear features was observed. When different types of fractures or damage were recorded on one individual point, they were separately inventoried, with a maximum of one feature type per point. The same counts for MLIT's: when several concentrations were observed, they were only counted once per point.

Tip fractures occurred on about half of the points (47% of the tips, on 57% of the barbs), but the tip fractures on the barbs were rarely diagnostic. Step-terminating scarring did not occur on tips of barbs, while it was frequent on tips. Spin-offs and burination occured on both tips and barbs. Overall, barbs showed less diagnostic damage types than tips. Lateral scarring was frequent on both tips and barbs, but sliced scarring – typical of the cutting motion upon impact – were clearly more frequent on barbs.

MLIT's were frequent and they predominated on the tips, mainly in association with tip fractures (Fig. 12.11). They also occurred frequently on barbs where they were predominantly associated with lateral damage (Fig. 12.12a). The MLIT's differred significantly in explicitness; many were narrow and faint. While striations occurred in the hafted area of barbs, they never took the form of actual MLIT's. Resin friction striations by contrast were rather frequent on the hafted portion of barbs; they resulted from the pressure and friction upon detach under impact.

While distinctions between tips and barbs have been proposed based on the distribution of wear features and their axis (e.g., Rots et al. 2003, 2005), the experiment proves that such a distinction is possible, but not straightforward. Resin distribution, for instance, is not a reliable feature as it is also influenced by the de-hafting procedure during which resin may get dispersed in non-hafted areas. The latter particularly happens when resin is heated to allow extraction. Nor is there one type of diagnostic feature that allows a distinction

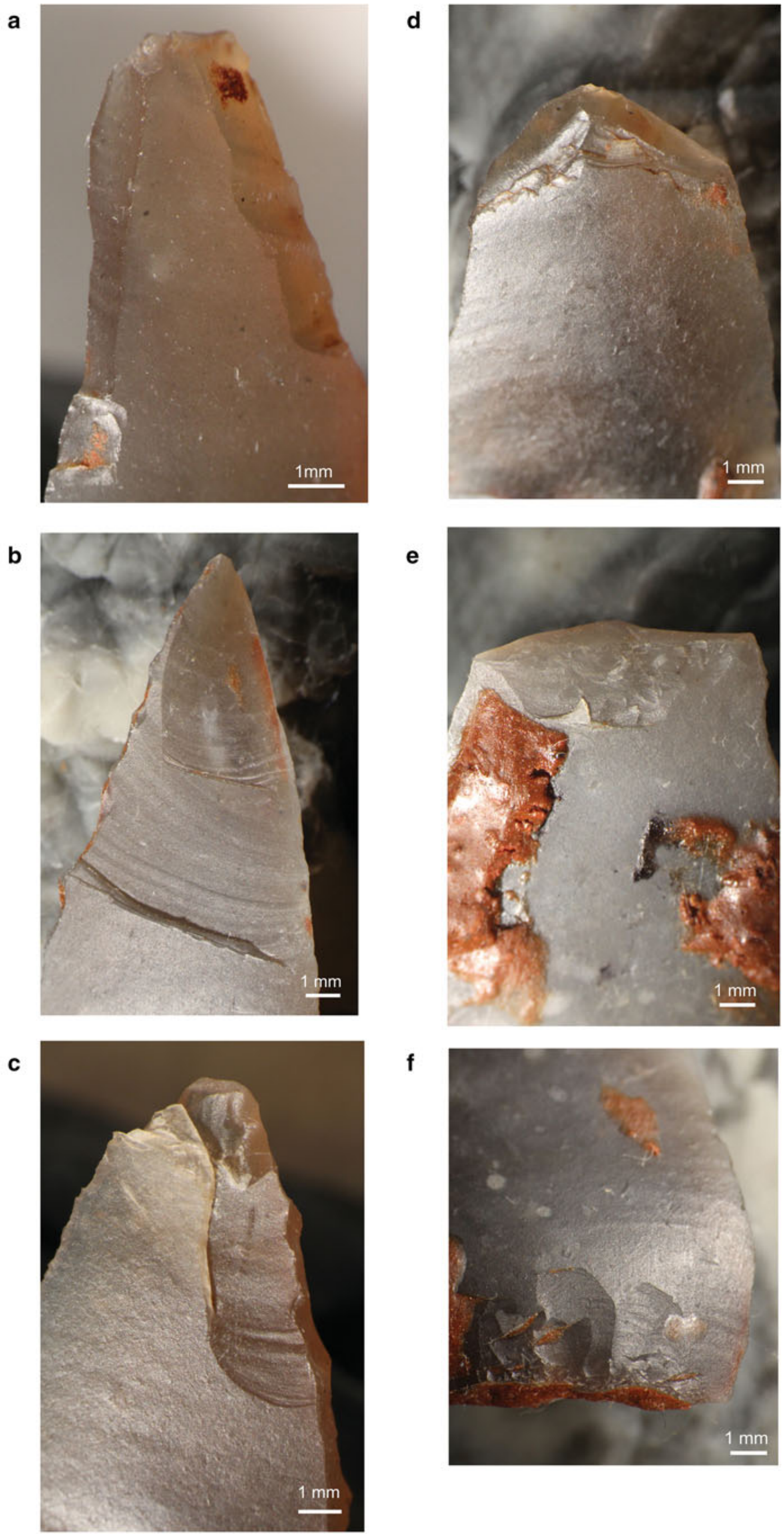
Table 12.3 Wear evidence of first arrow experiment

Total number analyzed		Tips		Barbs	
		45/49	%	37/51	%
Tip	Step-terminating fracture	14	31.1	3	8.1
	Other tip fracture	7	15.6	18	48.6
	Scarring associated with tip fracture	7	15.6	3	8.1
	Crushed tip	5	11.1	0	0.0
	Step-terminating scarring on tip	16	35.6	0	0.0
	Spin-off	7	15.6	3	8.1
	Burination	9	20.0	5	13.5
	MLIT (low power)	5	11.1	1	2.7
	MLIT (high power)	26	57.8	4	10.8
Lateral edge(s) (not hafted)	Step-terminating scarring	4	8.9	5	13.5
	Spin-off	1	2.2	3	8.1
	Burination	1	2.2	2	5.4
	Sliced scar patches	5	11.1	11	29.7
	Other lateral scarring	26	57.8	21	56.8
	Alternating scar patches	7	15.6	4	10.8
	MLIT (high power)	12	26.7	17	45.9
Hafted area (impact related features)	Sliced scar patches	4	8.9	0	0.0
	Other scarring	7	15.6	2	5.4
	Notch/explicit scarring at boundary	8	17.8	8	21.6
	MLIT (high power)	7	15.6	0	0.0
Base (counter-pressure)	Step-terminating fracture	2	4.4	1	2.7
	Step-terminating scarring	7	15.6	0	0.0
	Spin-off	2	4.4	0	0.0
	Crushing	3	6.7	1	2.7
Corners of base	Burination	6	13.3	5	13.5
	Step-terminating scarring	5	11.1	6	16.2
	Fracture	9	20.0	22	59.5

between tips and barbs. It is the combination of different features and their distribution over the piece that can be diagnostic (Table 12.4).

For instance, step-terminating tip fractures proved to be more abundant on tips, while barbs generally show a small non-diagnostic fracture at the tip, but a very high number of small fractures on one corner of the base. The frequent occurrence of tip damage on barbs is perhaps unexpected, as this part is hafted in or against the shaft, but it needs to be stressed that the fractures are generally small and rarely step-terminating. In contrast to the frequent occurrence of damage on one of the proximal corners in the case of barbs, proximal damage on tips is generally located on both proximal corners, if at all present. The latter depends on the amount of protrusion of the base from the shaft. In addition, the proximal damage on barbs witnesses a twisted motion far more frequently than the one on tips. Also sliced scarring on the lateral edge is far more common on barbs. Under high magnification, the distinction between tips and barbs is generally rather explicit with MLIT's hardly occurring on the tips of barbs, but being clearly more abundant in association with damage on the lateral edges. Also bright spots are frequently associated with lateral damage on barbs.

There may however be one type of fracture that could be typical of barbs: on a number of barbs (from the second arrow experiment), a specific type of compression fracture occurs on the tips of barbs located inside the haft (Fig. 12.13). This type of fracture was only observed on barbs and can be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◀ **Fig. 12.9** Low magnification wear evidence on tips: **a** burination on both ventral distal edges of the tip (tip 108) (12.5×); **b** double superposed step-terminating spin-off's on the ventral distal tip (tip 39) (8×); **c** step-terminating spin-off on ventral tip of a tip (arrow 4) (10×); **d** double step-terminating bending fracture with dorsal initiation on tip (tip114) (8×); **e** transversal fracture with associated step-terminating scarring (tip 118) (8×); **f** feather- and step-terminating scarring from counter-pressure on the ventral base of tip 19 (8×)

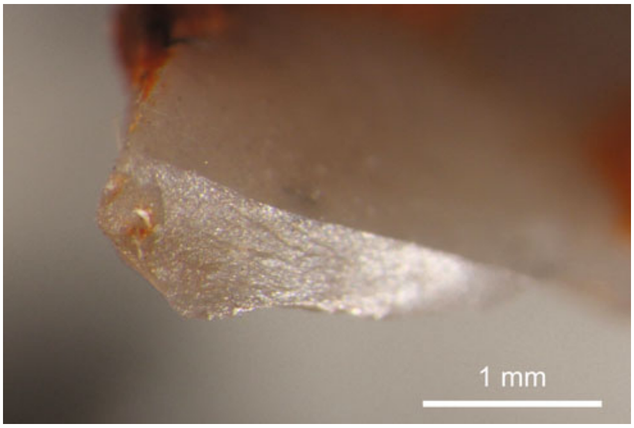

Fig. 12.10 Low magnification wear evidence on barbs: oblique burination on the ventral tip of barb 29 (25×)

attributed to a compression pressure within the haft, possibly due to a contact between the tip and the barb upon impact (i.e., tip detaching and moving backwards). This will need to be explored in more detail.

Hafting and Other Experiments

Aside from specific hunting experiments, the interpretation of hafting wear on armatures also relies on a much more elaborate experimental reference collection consisting of more than 400 used experimental tools (hand-held or hafted) (Rots 2002a, 2010a) and more than 500 experimental artifacts for technological wear patterns (knapping, retouch, etc.) (Rots 2010b). Tools were hafted in various arrangements (i.e., juxtaposed, male, male split) with different haft materials (i.e., wood, bone, antler, leather) and different fixation aids (i.e., adhesives, bindings). For more details on this experimental and methodological work, I refer to the above publications and references therein.

I only reiterate some evidence which appears relevant in this context. Resin fixation proved to result in typical resin friction wear, aside from the residues it left behind. Fixations with bindings proved to result in characteristic scarring and scar patterns. Generally speaking, resin resulted in less traces

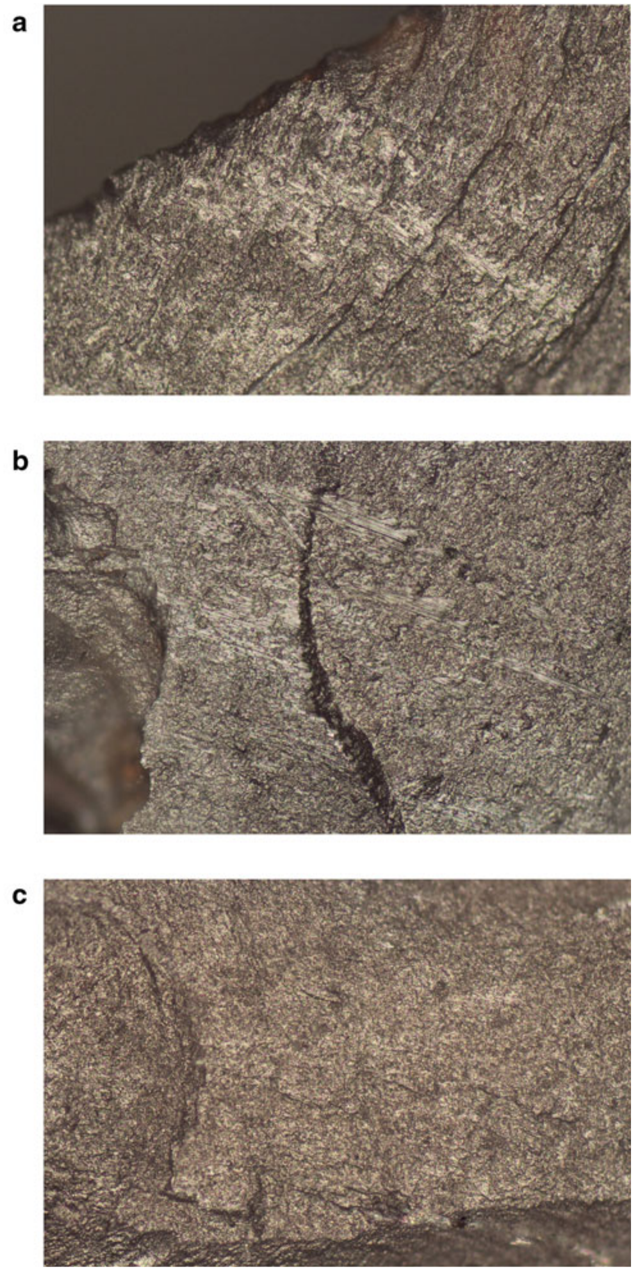

Fig. 12.11 High magnification wear evidence on tips: **a** MLIT's on ventral distal tip (tip 85) in association with tip damage (100×); **b** MLIT's on ventral distal tip (tip 114) associated with tip damage (100×); **c** faint MLIT on ventral distal tip (tip 22) associated with tip damage (100×)

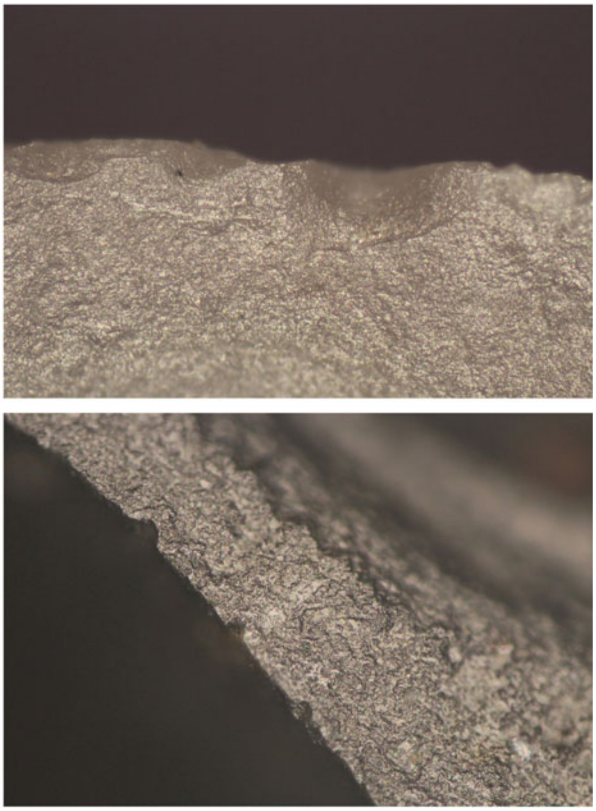

Fig. 12.12 High magnification wear evidence on barbs: **a** MLIT parallel to edge and associated with edge scarring on the dorsal medial right edge of a barb (barb 88) (100×); **b** MLIT's at the termination of a large spin-off that nearly reaches up to the other ventral edge (barb 45), the short MLIT's connect the termination with the opposite ventral edge (200×)

than bindings applied wet, which in turn caused less trace formation than bindings applied dry. Juxtaposed handles proved to result in a different wear pattern between the dorsal and ventral face, while a male handle resulted in a similar wear pattern on both faces and an explicit impact on the lateral edges. Male split handles result in a wear pattern that differs between the centre of the tool and the lateral edges.

Archaeological Case Studies

The experimental work described above has been used as a basis for the identification of armatures on different Palaeolithic sites in Europe and Northeast-Africa. It appears relevant to briefly explore the current state of knowledge on hunting weapons in the Palaeolithic based on these new functional results.

The existence of hunting weapons in the Middle Palaeolithic has been a heavily debated topic. In the past, the capacity to hunt effectively was denied for Neanderthals and they were mainly portrayed as scavengers. Due to new discoveries (Thieme 1997; Boëda et al. 1999) and results from faunal analyses (Gaudzinski and Roebroeks 2000), functional analyses (Shea 1988a; but see Plisson and Beyries 1998) and isotope studies (Richards et al. 2000), Neanderthals were considered to be expert hunters relying mainly on animal foods for their subsistence. At the same time, this expert hunting was assumed to have been undertaken with simple weapons, such as thrusting or throwing spears, while more complex weapons (e.g., spear-thrower, bow) were by definition reserved for anatomically modern humans only, with an assumed earliest introduction in Africa (Shea and Sisk 2010). Independent of the existence of supportive evidence, Neanderthals were thus once again portrayed as incapable of complex technology, in sharp contrast to behaviourally modern humans.

Such interpretations are fine if supported by actual evidence, but overall the argumentation used is rather poor. For instance, TCSA (tip cross-sectional area) values are in themselves insufficient to indicate a use as weapon and they are thus only relevant for points for which a use as armature was first demonstrated. Nor is there any support yet for the reliability of such values to infer a particular projecting mode. Similarly, the existence of a bow-and-arrow technology in South Africa around 70 ka is based largely on the small size of the segments, and on a range of indirect arguments (e.g., the assumed existence of snares – no organic remains; Lombard and Phillipson 2010).

Table 12.4 Results of the wear analysis on the microliths of a number of Dutch Late Palaeolithic sites

	Sample	Used as point	*Tips*	*Barbs*	*Combined*	Used as drill
Zeijen	35	31	*18*	*8*	*1*	2
Siegerswoude II	21	18	*15*	*3*	*0*	0
Emmerhout	13	10	*7*	*2*	*0*	possibly 1
Luttenberg	17	13	*10*	*3*	*0*	3
Total	86	72	*50*	*16*	*1*	**6**

Numbers indicate the counts of pieces identified as point or drill, for points a position and orientation is also inferred based on the observed wear patterns

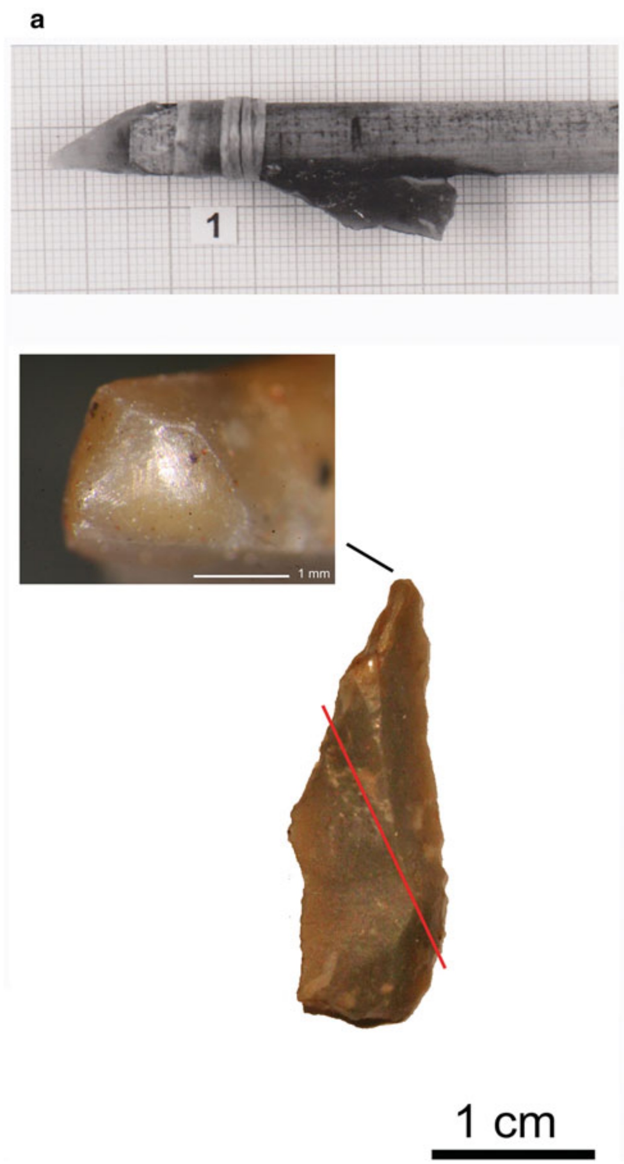

Fig. 12.13 Specific kind of tip fracture on tips of barbs located inside the haft due to a compression within the haft (arrow experiment 2): **a** compression fracture on the tip of barb 208; **b** compression fracture on the tip of barb 172, also a small oblique fracture with dorsal initiation and minor feather termination on the left proximal base

Up to now, the projecting mode of armatures has never been inferred based on a large-scale experimentation that actually supports the existence of specific diagnostic criteria that would allow such interpretations. While it is tempting to use more straightforward and more easily available arguments to advocate a certain projecting mode, such interpretations risk to be misused. While the existence of wooden spears is supported from about 400–300 ka (Movius 1950; Oakley et al. 1977; Thieme and Veil 1985; Thieme 1997), the question remains whether and when stone points

Fig. 12.14 Spear points at Biache-St-Vaast: **a** Elongated Moustier point (E8-513): *1* Burination on dorsal tip (16×), *2* Striation associated with scar on the ventral medial left edge (haft boundary) (100×), *3* Hafting scarring around the haft boundary (16×), *4* MLIT due to counter-pressure on the ventral proximal surface, initiated from the termination of the large proximal fracture (100×), *5* Large proximal fracture due to counter-pressure against the haft upon impact (8×), *6* Hafting scarring around the haft boundary on the dorsal medial right edge (8×), *7* Hafting scarring around the haft boundary on the dorsal medial right edge (8×); **b** Elongated Moustier point (I8-507): *1* Scar on the ventral tip initiated from the distal extremity, it continues into a burination on the ventral distal left edge (12.5×), *2* Hafting scarring with oblique orientation on the ventral medial left edge (16×), *3* Burination on the ventral proximal left base, initiated from the left (counter-pressure within the haft) (16×) ▶


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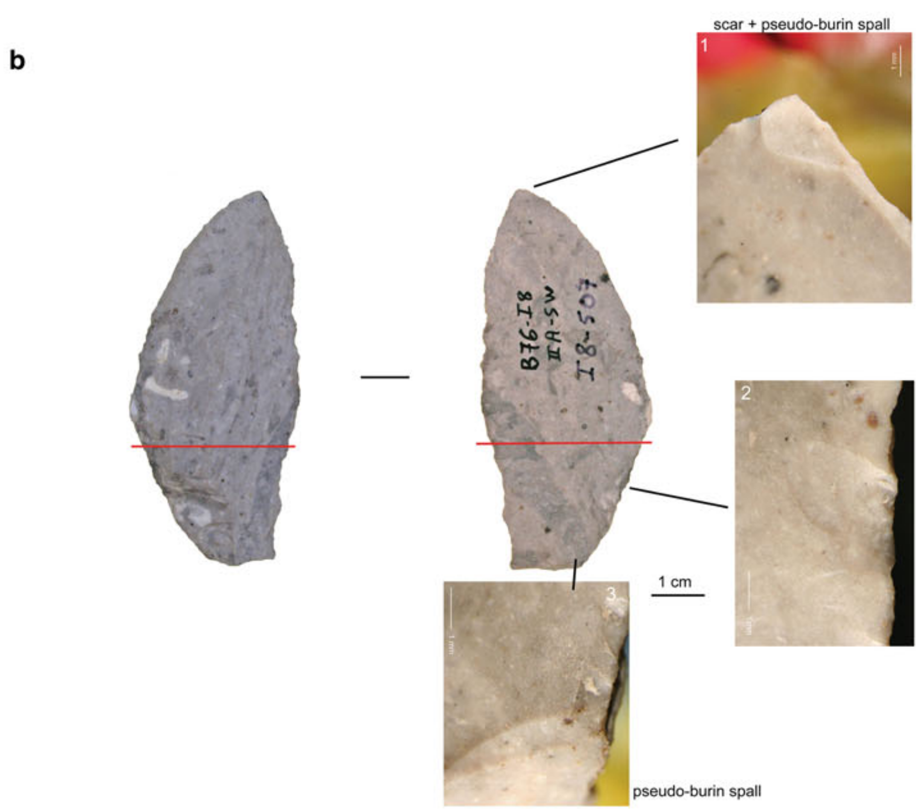
b
scar + pseudo-burin spall
1
2
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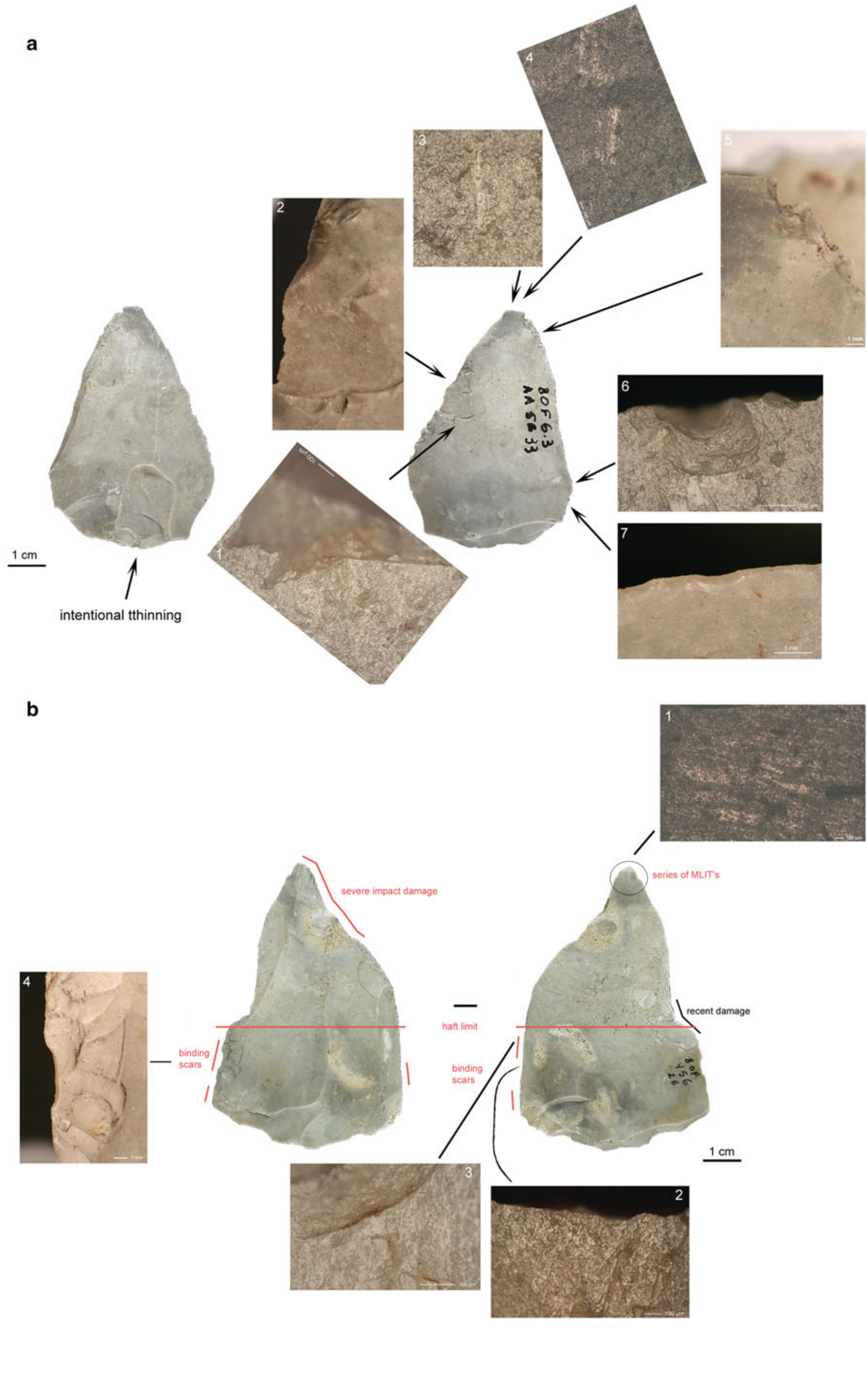
1 cm
pseudo-burin spall


a
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severe impact damage
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recent damage
haft limit
binding scars
binding scars
1 cm

◀ **Fig. 12.15** Spear points at Bettencourt: **a** Levallois point (AA 5a33): *1* MLIT's associated with the large ventral impact scarring on the right edge (100×), *2* Large ventral step-terminating impact scar with curved initiation on the ventral right edge (8×), *3* MLIT on the ventral distal tip (100×), *4* MLIT's on ventral distal tip (50×), *5* Use scarring on the ventral distal left edge, *6* Bright spot associated with hafting scarring on the ventral medial left edge (around haft boundary) (200×), *7* Sliced scars due to a contact with bindings on the ventral proximal left edge (20×); **b** Levallois point (Y56/26): *1* Series of MLIT's on the ventral distal tip (50×), *2* Bright spot zone due to friction within the haft on the ventral proximal right edge (100×), *3* Bright spot associated with hafting scar on the ventral medial right edge (haft boundary) (200×), *4* Hafting scar concentration on the dorsal proximal left edge consisting out of step-terminating scalar scars with curved initiation (8×)

were mounted on wooden spears. This necessitates sufficient expertise with regard to hafting and an acknowledgement of the advantages it may offer. Direct evidence for the existence of hafted stone tips was provided by the Levallois point embedded in a vertebra (Boëda et al. 1999). Given the unique nature of such finds, a reliable and broader insight in the issue is only possible based on detailed functional studies.

Based on new results from the functional analysis of *Biache-St-Vaast* (Tuffreau and Sommé 1988; Rots 2013), it is clear that hafted spear points are in use from about 200 ka. Explicit diagnostic wear patterns were observed on 16 pieces on an examined assemblage of 157 pieces (Fig. 12.14). Aside from thrusting spear points, the slender and light nature of some of the points in combination with explicit use and hafting damage, suggests that at least part of these points were also used in thrown arrangements (Fig. 12.14a). However, the typical distinction between spear points with or without damage from a rotating motion on the distal lateral edge is not observable at *Biache-St-Vaast*, even though it was observed at *Sesselfelsgrotte* (Rots 2009) and at *Sodmein Cave* (Vermeersch et al. 1994; Van Peer et al. 1996; Rots et al. 2011). While the evidence observed at *Biache-St-Vaast* is the oldest one that is currently observed, spear points were also identified at later Middle Palaeolithic sites. At *Bettencourt* (75–85 ka BP), at least 6 spear points were identified in a set of 27 examined Levallois points (Rots, In prep.) (Fig. 12.15). At *Sesselfelsgrotte* (40–46 ka BP), 17 spear points and 11 spear point fragments were identified in a total examined assemblage of 292 pieces (Rots 2009). While this only provides a very sketchy, anecdotic insight into Middle Palaeolithic hunting technology, it supports nevertheless that spear point evidence exists. It was observed on each of the examined sites, in varying numbers, which was determined by the site's function (Rots 2015). It is to be expected that more spear points will be identified in future functional studies, which will hopefully provide a more complete and balanced picture.

While my personal examination of Upper Palaeolithic sites is still on-going, I also want to draw attention to the danger of considering any microlithic point as an arrowhead or barb, and the feasibility of distinguishing arrow tips and barbs in a Late Palaeolithic context. A set of 35 tools classified as points by the excavators were examined from the Creswellian site of *Zeijen* (Rots et al. 2003), next to 21 points from the Creswellian site of *Siegerswoude II*, 13 points from the Creswellian site of *Emmerhout* and 17 points from the Hamburgian site of *Luttenberg* (Rots et al. 2005) (Table 12.4). Aside from the identification of drills among the pieces classified as points (7%), the majority showed diagnostic evidence of projectile use. Of the pieces used as projectiles, 69% proved to have been mounted as tip, against 22% as barb. Given the high rate of detachment of barbs in experimental use conditions, it is likely that a large part of the archaeological barbs was never recovered. No inferences could however be made regarding the combined or separated use of tips and barbs.

Discussion

While tip damage is a crucial aspect that is often visible on used armatures, it is important to stress that armature identifications should rely on the damage pattern visible over the whole piece. One wear feature is never sufficient for a reliable identification. Above all, a macroscopic identification of armatures is generally not reliable, as it tends to rely on fracture types only, for which criteria on what to call diagnostic are often applied insufficiently strict.

Aside from tip damage, such as step-terminating fractures, burination, and spin-off's, also lateral damage is important on the used portion. Sliced scars, for instance, witness the cutting motion upon insertion and are thus frequent. MLIT's have unfortunately been neglected recently due to the focus on what is visible under low magnification (or with the aid of a hand lens). It has been stressed that this is a regrettable evolution. MLIT's are generally only observable under high magnification, but they are actually the most reliable proof of the impact-related nature of the damage features they are associated with. Only when assemblages are heavily alterated or patinated may MLIT's no longer be visible. The hafted portion should not be neglected either because several impact-related wear features occur there as a result of the counter-pressure against the haft or within the animal. In addition, it allows determining the haft boundaries and the fixation mode used. The combination of the wear features on the used and hafted portion often allows a far more secure identification of armatures.

Also the position of the element in the shaft can only be determined based on a combination of use and hafting wear evidence, and specific wear patterns were proposed. It is clear that the occurrence of a tip fracture is not sufficient to consider an implement as a tip instead of a barb, and also the resin distribution is not reliable on its own.

With regard to the distinction between different projecting modes of hunting weapons, no reliable diagnostic identification criteria are yet available, in spite of some suggestive elements that still need to be tested on their value. There is a high need for more elaborate, large-scale experimentation in order to provide further insight and to determine the potential of wear traces for making such distinctions. TCSA values do not provide a reliable alternative and while Wallner lines (if confirmed through blind testing) may provide a solution (Hutchings 2011), it unfortunately concerns some raw materials (i.e., obsidian) only.

Conclusion

Experimental results that have been produced over the years, including the ones presented here, have allowed the proposition of a set of diagnostic microscopic wear features and patterns that allow a reliable identification of armatures in archaeological assemblages. However, these criteria have recently been used far less rigorously and analytical procedures have gradually been moving away from microscopic approaches. Here, the importance of microscopic examinations for a reliable identification of armatures is stressed and new experimental results were discussed. It is stressed that examinations of armatures should not rely on one wear feature only. Attention needs to be devoted to the association between wear features in the used and hafted portion, and to the damage pattern as a whole.

While functional results remain overall too infrequent for an adequate insight into past hunting technology, it was nevertheless demonstrated based on a microscopic functional study that hafted spear points occur from at least about 200 ka years ago in Europe. This appears to concern both thrusting and throwing spear points. The identification of the earliest weapons that were projected with a spear-thrower or bow is currently still dependent on the recovery of organic finds: no reliable diagnostic identification criteria are yet available. More elaborate and systematic experimental work seems essential if progression in this matter is to be made.

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