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Projectiles and the abuse of the use-wear method in a search for impact

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ABSTRACT

Projectiles have enjoyed a lot of attention over the last few years as an indication of the existence of hafted hunting technology and as one of the arguments in discussions on complex human behaviour. More and more frequently, the identification of projectile points is based on a limited range of macro-fractures, despite the diversity and variability in wear features from projectile use. Such a methodological simplification does not support the wide-ranging interpretations often proposed. We address the many difficulties involved in reliably identifying projectiles and we suggest how these should preferably be dealt with.

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1. Introduction

Lately, we have seen the publication of research related to the identification of the "first" or "earliest" evidence of projectile use by prehistoric humans. Given the broader issues at stake, these articles are published in high-impact journals, while often being based on questionable methodologies. Methods are used that are derived from the principles and goals of use-wear methodology, but they generally incorporate a simplification of this methodology in order to be able to respond to broader questions more quickly. Far-reaching identifications of tool use are made while suggesting that these are based on an application of the principles of a use-wear analysis; in practice this is not the case.

As use-wear analysts, we consider certain results as questionable. While we recognize the problem that a use-wear analysis is hard and time-intensive, and while we appreciate the search for possible alternatives or improvements, we consider some of the solutions that are currently proposed as counter-productive. Over the years, use-wear analysts have invested significant efforts in developing their method and founding it on a firm basis. It is a method that is based on analogical reasoning: experimental stone tools are produced and used and the resulting wear traces are subsequently compared to archaeological examples (Fig. 1) (e.g., Щелинский, 1977 in Plisson, 1988; Keeley, 1980; Vaughan, 1985). It is assumed that wear traces formed in the same way in the past as they do today and the similarity in trace types and wear characteristics is used as a basis for the identification of archaeological stone tool uses. The reliability of the analogy depends on the size of the reference collection. The method requires an intense learning curve in order to be able to grasp the variability in the wear traces that can form as a result of different processes, including those related to tool production, hafting, use and post-depositional features. Without a close examination of a large reference set of experimental tools, it is impossible to appreciate and correctly understand the variation in wear characteristics and trace patterns and thus to adequately interpret the archaeological variability.

We critically examined some of the recent studies and their methodologies and we identified the following most common problems: a weak experimental basis, a misidentification of wear features, a low representation of diagnostic impact features within assemblages in spite of the broad implications attributed to them, a misuse of hafting evidence, a proposition of methods that have not been tested, and an over-interpretation of the available evidence with often far-reaching conclusions. As an answer to these problems, we discuss some basic definitions, the many difficulties involved in reliably recognising armatures and how these should preferably be dealt with.

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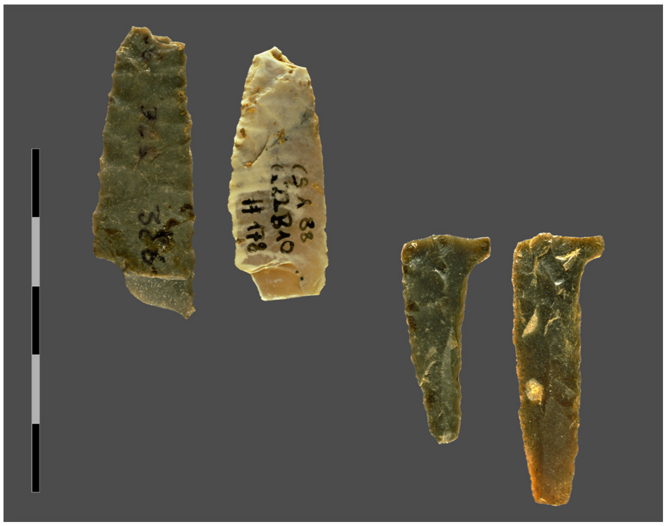

Fig. 1. From left to right, comparison between apical and basal fragments of experimental copies of Solutrean shouldered points (made by S. Maury) used as spear tips (shot with a calibrated crossbow onto a cow), and archaeological samples from the site of *Combe Saunière* (France). The replicas were fixed with glue (pine resin + beeswax + ochre) and sinew, which induced multiple fragments upon impact as well as a fragmentation at a few millimeters above the shoulder which never occurs without binding. (TFPS Research program).

1.1. Definitions

Given the various implicit or explicit definitions of projectile points in the literature, we use the following definitions. "Armature" is used as the most general term to refer to tips and barbs of any weapon system. We chose to use armature as a synonym of "projectile point" to avoid any confusion. This contrasts with researchers wanting to limit the term to points that are actually projected and thereby excluding thrusting spear points, and, depending on the author, also throwing spear points (Shea, 2006). The term "tip" always refers to the "head" of the weapon system, while "barb" refers to laterally positioned pieces. With regard to specific weapon systems, the term "spear point" includes all thrusted or thrown arrangements, including those projected with a spear-thrower. No or little evidence currently exists to reliably distinguish among them. When a specific projecting mode is referred to, it will be mentioned accordingly. Arrow point is used as a general term to refer to armatures projected with a bow.

1.2. Background

As pointed out by the philosopher Gilbert Simondon (1958), there is no pure technical device free from symbolic meaning. Among the most evident examples are projectile points (e.g., Pétrequin and Pétrequin, 1990; Knecht, 1997), for which the suggestive power has continued through millennia and through different cultures. Today, armatures have taken a central position in debates on human evolution, and in particular the oldest examples of different weapon systems have triggered much attention. Throughout the Old World projectile points have been used to argue for either an absence or presence of complex behaviours. Recently, the debate has shifted towards specific projecting modes and their potential link with certain behavioural capacities. Shea (2006), for instance, has recently argued for a distinction between "simple" and "complex" hunting weapons, the former consisting of thrusting and throwing spears, the latter referring to the use of a spear-thrower or bow. In his view, only the latter weapon systems can be linked to early modern humans given their "complexity". The more objective distinction between close-range and long-range hunting weapons may perhaps be more appropriate (Churchill and Rhodes, 2009). Because of the role that projectile points may fulfil in a search for an improved understanding of human evolution and behavioural complexity, it is essential that these items are correctly recognised in the archaeological record. The weapon delivery systems themselves rarely survive archaeologically due to the organic nature of their components; therefore, only the stone armatures can inform us about past technologies.

An increasing diversity and standardisation of projectile points in the Eurasian Upper Palaeolithic (morphology, size, raw material) make them quite distinguishable in the archaeological lithic and bone assemblages, but this is not the case with many earlier examples in Europe or in Africa. Various reasons could explain such difference (diversification of throwing techniques, rise of an artefact's symbolic value, increasing specialisation, etc.). While morphology may provide some basic ideas about the possible uses of an artefact, one could just as well argue, as humorously underlined by F. Bordes, that bronze spear points were used for cutting circles in the pie (Bordes, 1952: 646). In a fundamental paper, F. Sigaut explained why a knife is not used for cutting but serves by cutting (Sigaut, 1991): function is the product of functioning. Consequently, the use of an archaeological implement cannot be deduced from its shape (what it could have done) but needs to be deduced from its use-wear (what it did). Therefore, a pointed form or microlith should not be equalled with a projectile point as was recently done once more (Hauck et al., 2013, Brown et al., 2012) in spite of functional studies that repeatedly observe varied uses for certain pointed forms (Plisson and Beyries, 1998) or certain microliths (Moss and Newcomer, 1982; Caspar and De Bie, 1996).

2. Armatures and wear formation

Since the pioneering work of Semenov (Семенов, 1957; Semenov, 1964), use-wear analysis, is a well-established discipline of archaeological science. It is based on continuously improving experimental reference collections which illustrate the relationship between use-wear patterns (combination of striations, polishes, edge damage, etc.) and conditions of use (motion, worked material, use context, etc.). When the motion of a tool is regular, as in craft activities, its use-wear will be regular too and its variation, which is essentially quantitative, will be proportionate to its length of use. This is why specific use-wear patterns can be defined for various actions such as cutting, scraping, whittling, grooving or boring, and various worked material such as wood, bone, antler, meat, hide, etc., the features of which are mainly microscopic. Even for adzes, axes and other types of percussive tools which have more or less important macroscopic damage, the lengthy repetition of the action produces a constant wear. This is explained by the required result of the action that depends on precise and stable technical parameters (for sharp tools: cutting edge, cutting angle, force, motion, etc.) and when these are poorly controlled the working edge or the tool itself can be rapidly damaged (Moss, 1983a). So, for common tools, use-wear analysis can establish a direct link between use-wear patterns and how the tools were used (worked material and motion).

For projectile points there is no such fixed recipe: the relation between the use of an armature and its wear patterns is not so simple because of the great variability of extrinsic and intrinsic techno-functional parameters. Intrinsic parameters relate to weapon design and include a point's shape, its fixation on the shaft, the weight of the whole projectile, etc. Extrinsic parameters relate to the conditions of use (projecting mode, target distance, game, environment, etc.). A first important difference with other tools is that armatures are not exposed to repetitive motion: 5 min of scraping, for example, means hundreds of strokes, while an armature can be damaged or destroyed in a few shots. Consequently, the relevant use-wear on lithic armatures is mainly, if not exclusively, macroscopic or visible under low magnification. The only microscopic traces on the active part are scarce striations produced by embedded chips coming from the damage to the tip itself (i.e., microscopic linear impact traces or "MLIT's"; Moss, 1983b) (Figs. 2 and 6-below). Contact with hide and meat is generally too brief for perceptible polishing of the edge and/or surface. A second important difference with other tools is that the impacted material is very variable (soil, rocks, trees, flat bone, curved bone, hide, flesh, etc.) as is the incidence of the contact (perpendicular, under an angle, tangential). It is evident that a point is not subjected to the same stress when passing between the ribs as when crashing into a shoulder.

In addition, the force of the impact varies according to the distance of the target, the weight of the projectile, and the projecting mode, but still these are not the only parameters influencing the stress to which the point is submitted. For example, we observed that a slim Solutrean shouldered point at the tip of an arrow is more prone to slide on a rib and pass through the thoracic cage than a Solutrean leaf point attached to a heavy spear (Fig. 3), because of the difference in the width of the point, the inertia of the shaft and the trajectory of the flight. When the energy cannot be dissipated by an elastic deformation, the impact results in the breakage of the weakest element: either in the anatomy of the prey or in the structure of the projectile. Consequently, when the impacted bone is stronger than the projectile, the degree of damage to the stone point depends on the resistance of the hafting arrangement. There is less damage when the point separates from the shaft, and more damage when it stays firmly attached.

The consequence of this broad variability in parameters is that damage from projectile use is far from being uniform.

3. Diagnostic impact wear?

Many authors have based their analysis on existing experimental references such as the one published by Fischer et al. (1984). This has led to the use of isolated wear phenomena as so-called diagnostic criteria to identify projectile use. It explains the overemphasis on the tip and on step-terminating bending fractures, spin-offs and burinations (Fig. 4) as unique "guiding" wear features to identify armatures (e.g., Lazuén, 2012; Wilkins et al., 2012; Villa et al., 2009a,b, 2010; Villa and Lenoir, 2006, 2009; Iovita et al., 2013). The range of impact features from projectile use, however, depends on the morphology of the point and a single experimental reference to microliths (i.e., Fischer's experiment) cannot simply be transposed to any archaeological situation. For example, we observed that slim points are less prone to lateral edge crushing

Fig. 3. Experimental copy of a Solutrean leaf point (made by J. Pélegrin) used as spear tip and shot with a calibrated crossbow onto a cow. The lateral edges have been irregularly notched by the contact with the ribs while the distal bending fracture is not diagnostic. Bending fractures with long termination are less prone to develop without dorsal ridge. (TFPS Research program).

than large and triangular points (Fig. 5), a criterion that is surprisingly rarely considered for Levallois points (see also Plisson and Beyries, 1998) while it is at the same time the most evident distinctive criterion for bladelets used as lateral spearhead inserts (Fig. 6) (Odell, 1981; Dockall, 1997). Also, the length of the termination of bending fractures is less discriminant for points with flat faces (Fig. 3) than for those with a triangular section. Therefore a simple extrapolation of diagnostic wear features from published studies is not always relevant.

The diversity of macroscopic traces on projectile points is far larger than for any other use; they vary both in type and dimension, as well as in their combination (see also Odell, 1981; Dockall, 1997). Any tool's edge of the same shape and raw material shows the same specific pattern of macroscopic and microscopic traces when used for the same task (e.g., for processing meat, hide, bone, antler, wood, etc.), while a series of identical points, hafted and shot in an identical way, exhibits a great variation of damage between the pieces. Consequently, the range of trace combinations that are characteristic for a use as a certain kind of armature (form, dimension, material, etc.) cannot be illustrated by one single specimen. It is thus essential to reason and found one's arguments on a series and not on individual pieces.

Among the frequently highlighted macroscopic wear features are bending fractures with long termination (Ho Ho Committee, 1979; Fischer et al., 1984), but these fractures only indicate a

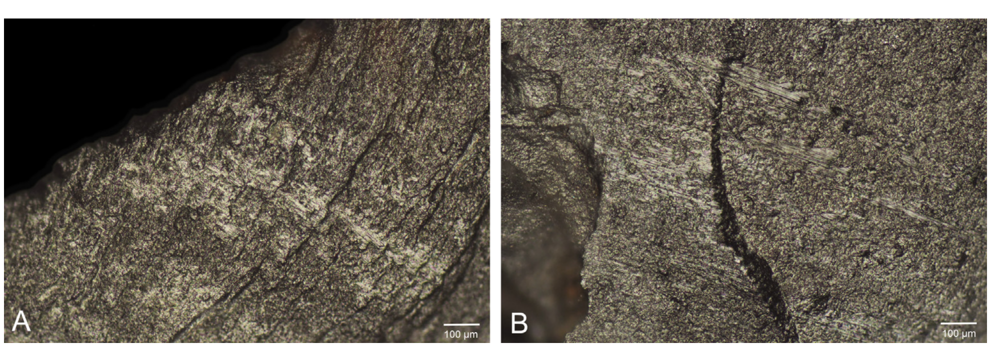

Fig. 2. (a + b) MLIT's visible on the ventral distal tips of experimental arrow tips in association with tip damage (100×). (Experiments V. Rots).

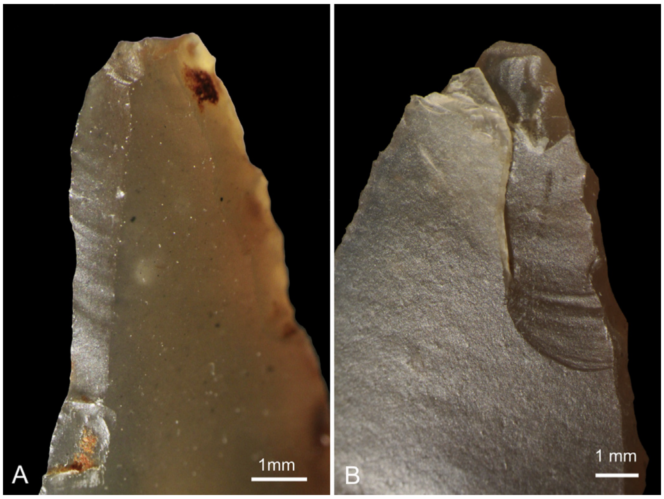

Fig. 4. a. Burination with step termination on the ventral right tip of an experimental arrow tip (12,5×); b. step-terminating spin-off on the ventral tip of an experimental arrow tip (10×). (Experiments V. Rots).

mechanical stress in the longitudinal axis of the artefact (buckling) and not specifically the use as a projectile tip. Bending fractures can occur in various situations: knapping or shaping accidents, hard butchering, a use as a dagger or as a projectile, trampling, etc. (Fig. 7). A criterion that is often used for differentiating use-related bending fractures is their termination length, but there is no “magical” value, since, for a given energy and orientation of the force, such length depends on the morphology of the point, its size, its thickness and its material. For each case study, only a large experimental collection that tackles the different factors allows fixing the threshold between bending fractures from functional and non-functional causes.

Aside from the over-emphasis on diagnostic impact fractures (DIF) and tips, some authors also appear to have difficulties in correctly identifying them, probably given the lack of formal training, the reliance on published pictures or drawings, and the absence of a personal large experimental reference collection. The most explicit example is provided by Wilkins et al. (2012) and is very clear when examining their published pictures in detail. All pictures concern convergent blades that remained unretouched; in comparison to retouched points, the edges are thus more fragile and damage should be more visible. The two pictures that supposedly document step-terminating bending fractures (Wilkins et al., 2012: Figs. 2A and B), do not show a bending initiation, and an essential condition thus remains unfulfilled. Step-terminating bending fractures are actual breaks that cut through both faces with a smooth convex profile at the initiation and an abrupt (stepped) termination (e.g., Odell and Cowan, 1986). One of the pictures instead shows a snap fracture that cuts through the initiation of a step-terminating scar, while the other picture shows a clear ridge on the fracture negative, demonstrating that two separate features are present. The depicted damage could be caused by various factors, including butchering, as suggested by the adjacent edge damage visible on one of the pictures, or other activities (Fig. 7). The other two pictures do not show reliable examples of DIF’s either. They supposedly document diagnostic burinations (Wilkins et al., 2012: Figs. 2C and D), but these are generally associated with a tip fracture, or they should at least be initiated from the distal extremity and show a step termination. On one of the depicted examples, a crushed tip removes a potential initiation of an elongated removal, but as far as is visible, the removal has a ventral initiation and thus qualifies as a break. The other depicted removal seems to have resulted from a dorsal blow with an orientation that is not axial. Neither of them qualifies as diagnostic burination from projectile use. Undoubtedly, the authors chose to illustrate the most explicit examples within their dataset, therefore the actual presence of truly diagnostic impact fractures within their assemblage is very questionable.

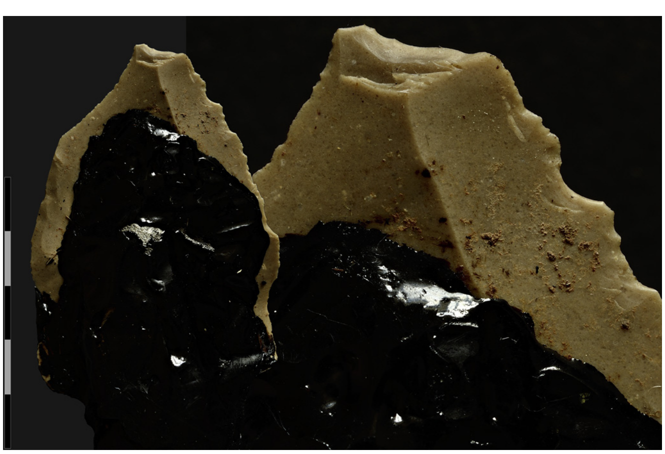

Fig. 5. Experimental copy of a Levallois point (made by E. Boëda) used as thrusted spear tip (Plisson and Beyries, 1998). Despite a fragile target, a young chamois, the typical crushing of one of the two edges is evident; nevertheless, this kind of DIF is rarely mentioned on archaeological samples identified as projectile points.

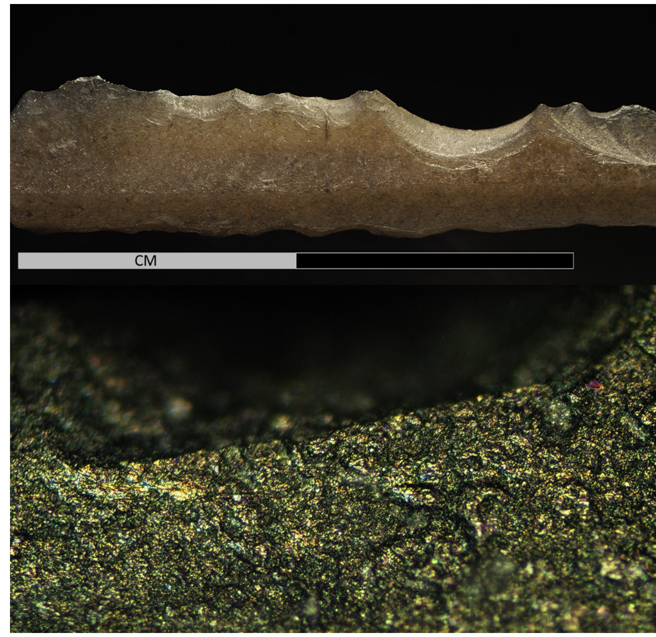

Fig. 6. Backed bladelet from the Late Paleolithic site of *Minino* 2 (Russia) with edge crushing typical from projectile use (lateral insert). A MLIT is visible under microscopic examination (100×). (H. Plisson).

Another problem is that many broader interpretations appear to rely on the observation of just one DIF per piece (Villa et al., 2009a,b; Wilkins et al., 2012). For instance, the overview of all observed DIF’s that is included in the table of Wilkins et al. (2012: Table S3) mentions 29 individual impact features. The authors identified 29 spear tips within a total assemblage of 210 points based on the occurrence of DIF’s, which implies that only one DIF occurs per point.[1] No use identification is reliable that relies on just

[1] In the table, the authors mention that one point shows 2 DIF’s. This would imply that one of their inferred projectiles does not show a DIF at all, or that only 28 potential projectiles were identified.

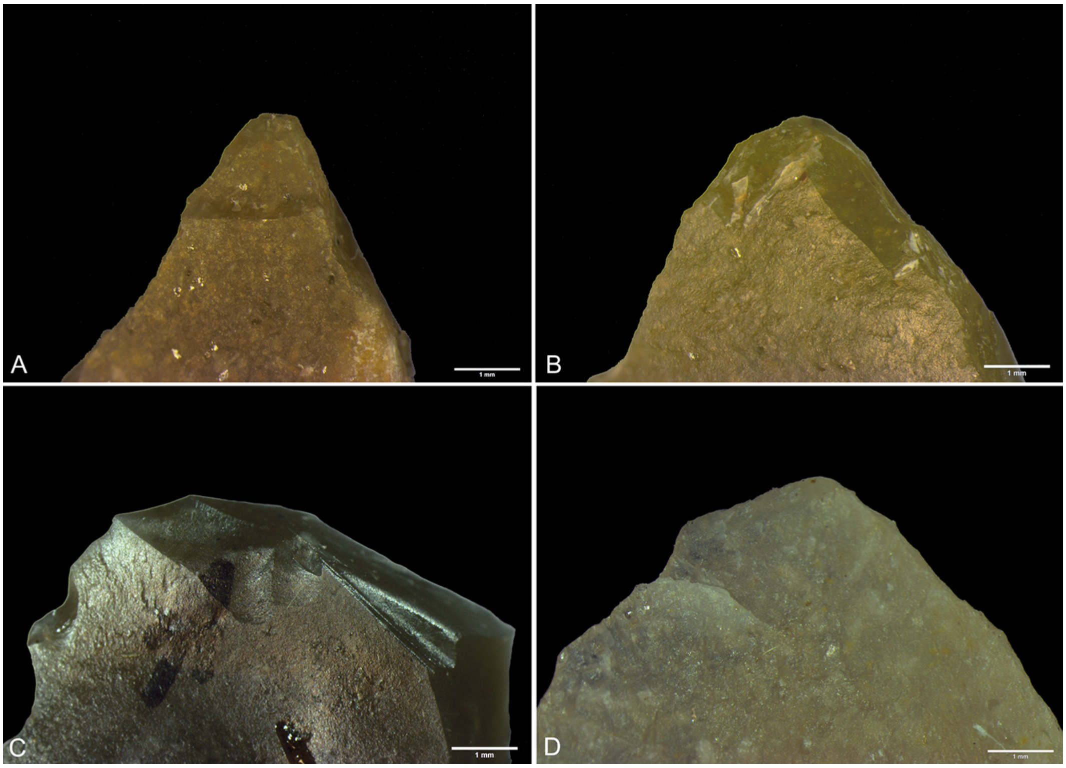

Fig. 7. Damage similar to Fig. 2 in Wilkins et al. (2012) but caused by other factors than spear use. A. Step-terminating fracture initiated from the distal extremity (see Wilkins et al., 2012: Fig. 2A and B), here caused by a use as a drill on fresh bone. B. Crushed tip with burination initiated from the distal extremity and terminating in step (see Wilkins et al., 2012: Fig. 2C and D), here caused by a use as drill on fresh bone. C. Step-terminating fracture associated with scars with a bending initiation caused by knapping. D. Step-terminating bending fracture (see Wilkins et al., 2012: Fig. 2B) caused by butchering. (Experiments V. Rots).

one feature per point (e.g., Plisson and Beyries, 1998; Rots, 2013a). In addition, given the questionable archaeological context in the Wilkins case (cf. on-line comment on Wilkins article by Gargett), different processes certainly contributed to the formation of tip damage in this sample, especially given the significant amount of damage that appears to be present on the edges (see below).

Also edge damage distributions have lately been used to argue for a projectile use. It was a method that was initially developed by Bird et al. (2007), but it is especially applied by Schoville (Schoville and Brown, 2010; Wilkins et al., 2012). It intends to record all scarring on an implement, without any distinction between those linked to production, retouch, use or post-depositional causes. Based on the distribution of damage over the tip and edges, tool use is inferred. Schoville argues it to be more "objective" than a use-wear analysis as no causation is attributed to each individual scar (Schoville and Brown, 2010: 380). Several problems can be raised however. First of all, retouched and unretouched points are mixed in the analysis, even though retouched and unretouched edges evidently do not resist equally well to mechanical stress and they do not allow the same precision when trying to distinguish damage. Secondly, post-depositional scars are recorded like any other scar. This seems to ignore the fact that each tool is differentially affected by production, use, hafting and other trace causes, and importantly, also differentially affected by post-depositional alterations. The latter damage is not uniformly distributed over a tool as a kind of background noise that can easily be "subtracted". Nor is it equally distributed over all pieces in a lithic assemblage (see Locht, 2002 for an example). Consequently, why would a meaningful and necessarily functional pattern suddenly appear out of the blur of edge damage data? Thirdly, damage patterns are here attributed to a specific tool use based on a minimal experimental reference sample, consisting of two tool uses only: projectile use and cutting. A damage distribution concentrated on the tip is inferred as linked with projectile use, when it is not, cutting is inferred (Schoville and Brown, 2010; Wilkins et al., 2012) (in spite of the fact that the tip is often used in cutting activities (e.g., butchering), which leads to more intense damage on the tip). When the variability is reduced to two possibilities, things easily look the same. The authors seem to ignore the existence of other tool uses that may result in a damage concentration on the tip, as well as the fact that tips are fragile and susceptible to damage caused by various factors. Searching for a more quantitatively oriented and potentially more "objective" method is fine, but it needs to be based on extensive experimentation and it needs to undergo specific testing. Such a testing phase (including blind testing) is totally lacking and we therefore do not see any grounds to accept the proposed interpretations.

4. Armatures and hafting

The morphology and extension of a fracture's termination has enjoyed a lot of attention with regard to armature identification (e.g., step terminations), but it is surely not the only criterion that needs to be considered. Even with no termination, a fracture's location can be significant, for instance, when it occurs repeatedly in the same part of the point or in a part where it could not have formed without an abutment (Fig. 1 – right) (Plisson and Geneste, 1989). In both cases this indicates the limit of a firm attachment, but by itself this does not necessarily need to be a projectile shaft. However, when the flexion is lateral (Fig. 8), there is no doubt about the cause: only the sway of a long shaft at the end of a point stuck into the carcass, acting as a lever arm, can produce a laterally-induced width-wide breakage (Fig. 9). This phenomenon is hardly observable when test shots are done with very short shafts thrown at very close distance onto an artificial flat target such as in the experiments of Iovita et al. (2013). The type and number of fragments are also informative about the amount of energy absorbed by the projectile tip, either by separation of the point from the shaft, or by its fragmentation. For flint points such as Solutrean shouldered points, Gravettian or Azilian points, predominant apical breakage does not suggest the same attachment as numerous mesial fragments (e.g., Caspar and De Bie, 1996; Soriano, 1998; Plisson, 2005).

The part of the artefact which was inserted in the shaft can exhibit particular traces. However, as is the case for use-wear identifications, an identification of hafting wear needs to rely on a large experimental reference collection that includes a broad variety of tool uses and hafting systems (see Rots, 2010). Hafting wear is not simply wear that is located in the non-active part of a stone tool. Many other processes lead to various kinds of wear traces in that area, production is an obvious example, but also transport, trampling, post-depositional processes, etc. Nor is hafting wear simply wear that cannot be understood otherwise. Attributing a particular wear feature to a hafting cause needs to be based on reliable experimentation. As stated in earlier publications, hafting traces always occur in a particular pattern opposite the working edge and generally demonstrate higher concentrations or intensities around the haft boundary (e.g., Rots, 2004). Similar to armature identification, there is not one trace or trace feature that can reliably argue for hafting. The exact hafting traces that can be expected depend on the chosen hafting arrangement, the hafting materials used, and a tool's use (Rots, 2010).

In the case of armatures, adhesives were frequently used. These may be preserved as residues, or they may have resulted in quite typical resin friction wear. When resin is not used, and the piece is not tanged to some degree, bindings are generally necessary. These result in quite typical scar formations (Rots, 2010). Wear is generally most explicit around the haft boundary. It is also an area where there is less possible confusion with other trace causes in comparison to, for instance, the proximal extremity where production may have resulted in trace formation. The link of intentional basal (or other) modifications with hafting is not supported and needs to be argued for based on an association with explicit hafting wear. Again, such evidence is often misused in arguing for the existence of hafted projectiles. Wilkins et al. (2012), for instance, mention

Fig. 8. Castelperronian backed point from the Upper Palaeolithic site of *Quinçay* (France) with width-wide bending fracture. (H. Plisson).

Fig. 9. Width-wide bending fracture on an experimental Solutrean shouldered point (made by S. Maury) used as a spear tip, shot with a calibrated crossbow onto a cow. The point was fastened with glue (pine resin + beeswax + ocher) and sinew. Such width-wide fracture resulting from a lever effect predominantly occurs with long shafts. (TFPS Research program).

evidence of modifications near the bases of about 23 points within their KP1 assemblage. Based on their pictures (Wilkins et al., 2012: figure S5), the actual presence of intentional proximal modifications can be seriously questioned. Intentional retouch is not always easy to distinguish (Kamminga, 1982), but for individual scars, it generally requires a visible negative bulb and some crushing at the initiation. The depicted scars do not show these features. In addition, proximal modifications in view of hafting are intended to facilitate hafting. It is hard to imagine how the depicted removals (Wilkins et al., 2012: fig. S5A and C) would qualify for that. On the contrary, such removals are often an unintentional consequence of the production process itself (Fig. 10). In spite of experimental studies that have systematically demonstrated the recurrent presence of damage around the haft boundary in the case of high-pressure motions such as armature impact (Rots, 2003, 2010, 2013a), the assumed presence of proximal modifications is the sole argument for hafting in the Wilkins study.

5. Armature experimentation

Given the large number of parameters that any experiment devoted to projectiles needs to take into account, setting-up the experiments needs to be done with care. An experiment involving just a few pieces can never comprehend the variability of the wear traces formed. It may be suitable for answering a specific small issue, but it is unsuitable as a reference for identifications on archaeological samples. Several experiments have been undertaken in the past, the one of Fischer et al. (1984) is no doubt the best-known considering the frequent recent references to this study. In most cases, these experiments addressed specific archaeological sites and periods, limiting the possible variation that can be expected for improving the feasibility of the undertaking. Most experiments were performed with arrows and those also prove to contain the most experimental tools, but there is much variation in the experimental designs, tool numbers and targets used (see Table 1). In many cases, the resulting wear features are insufficiently described. While the number of projectiles is often low, we understand that it is not always possible to undertake large-scale experiments. Therefore, we want to focus on other crucial aspects in the set-up of an armature experiment.

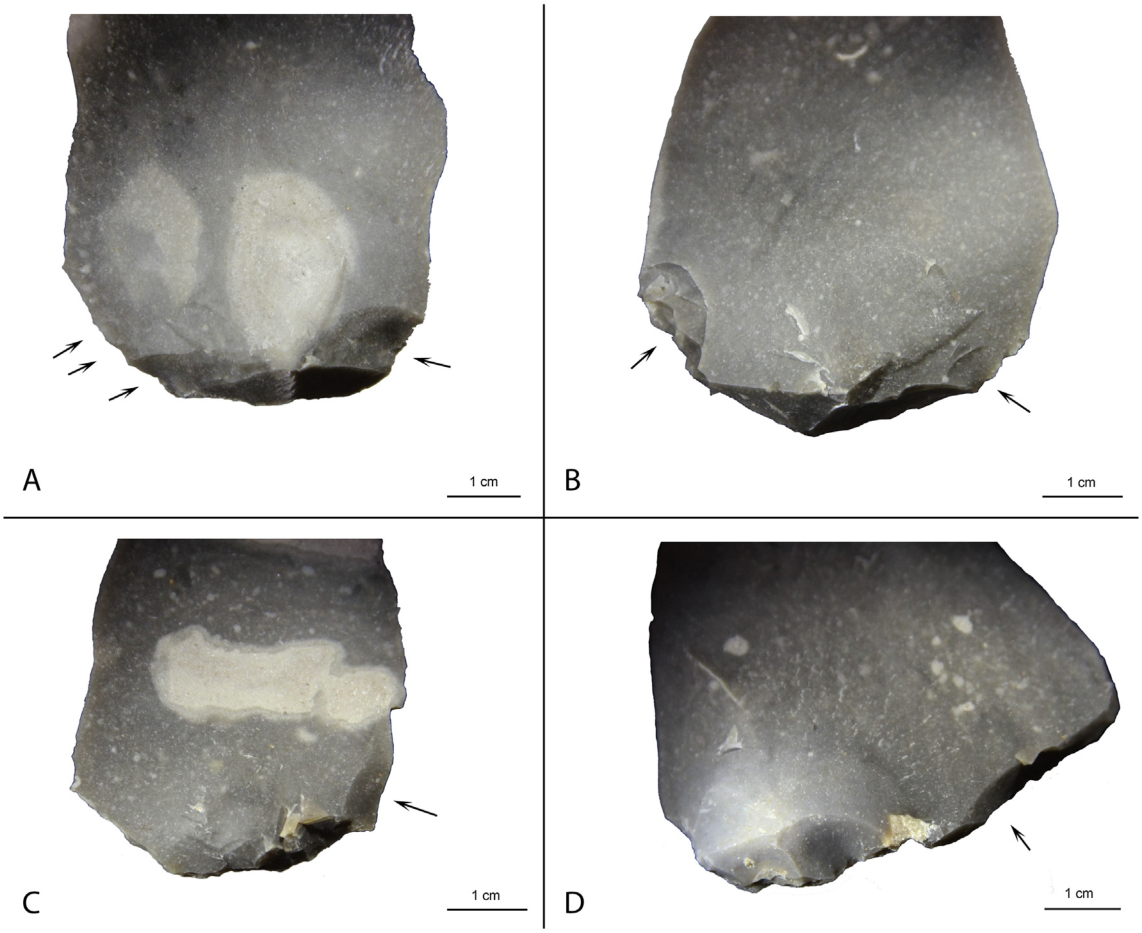

Fig. 10. Proximal damage similar to figure S5 in Wilkins et al. (2012) but caused by production. The depicted experimental pieces were all freshly knapped, immediately inserted in separate plastic bags and they remained unused. (V. Rots).

It is important that armature experiments are not performed in isolation, i.e. without the back-up of a reference collection containing experimental tools that document other kinds of processes (use in craft activities, production, trampling, post-depositional processes, etc.). This is a problem as one is often not aware of the resemblance of the observed wear patterns with traces resulting from other causes. When the possible trace variation is unknown, things may easily look the same (see Schoville and Brown, 2010; Wilkins et al., 2012).

If the experimental set-up is specifically aimed at resolving a problem of an archaeological case study, it is crucial that the experimental tools correspond to the archaeological tool types, morphologies, sizes and raw materials. As tool morphology affects the formation of diagnostic impact wear, results obtained with morphologies that differ from the archaeological ones may not be so reliable, in particular not when trying to evaluate the frequency of a particular trace feature.

A subsequent issue is the choice of the projecting mode. One important choice pertains to using a "prehistoric type of projecting mode" or a mechanical device. We believe the latter to be useful in the context of experiments that specifically address an understanding of a particular parameter for which it is important to keep all other variables constant. However, for evaluating differences between projecting modes, care needs to be taken. The variation between the four classic systems (thrusting, throwing, spear-thrower, bow) does not limit itself to difference in, for instance, speed or draw weight (*contra* Iovita et al., 2013). To name just two, the flight trajectories and the degree of rotation in flight differ significantly between the systems, and this will obviously affect the impact damage. One thus needs to carefully reflect upon the actual goal of the experiment. When a specific archaeological case study is under question, a prehistoric type of projecting mode may be the most appropriate choice, if the experimenter has sufficient experience with using such devices. In the absence of the necessary expertise, correctly balanced mechanical devices may be preferable. In order to permit a comparison and evaluation of the wear traces that form during the experiment, it is essential to keep as many experimental parameters constant as possible (however, we must keep in mind that in real hunting conditions the dynamic parameters are quite variable).

The target used is also important. One can opt for an animal target or an artificial target. Similar to the choice for the weapon used, this choice depends on the kind of experiment one performs. When dealing with an archaeological case study, an animal target is to be favoured, preferentially a type of animal that corresponds to the animal that may have been hunted at the site (if that is possible). Artificial targets may be useful when testing specific parameters, but it is essential that one critically reflects on their exact composition. Using a bone plate, even if included in a ballistic gel or meat will significantly affect the results. It is similar to shooting the projectiles against a wall. While it is of less importance when one studies flight trajectories or other projecting related features, it is unsuitable for evaluating the formation of diagnostic impact fractures and in particular their frequency (*contra* Iovita et al., 2013). Only an artificial target that entirely mimics the variation in contact materials of an animal target may prove to be a

Table 1
Overview of published projectile experiments with the available details regarding experimental set-up and goal.

Author	Publication year	Topic/research context	Projecting mode	Shooting distance	Nr of pieces	Tool type	Raw material	Fixing	Projectile weight	Target	Other experiments	Description of fracture types
Moss and Newcomer	1982	Magdalenian of Paris Bassin	45 lbs self bow	~3 m	15 + 16	Backed bladelets and Azilian points	Chalk flint	Pine resin + beeswax	Light arrow		Variety of materials cutting	Partial + microwear
Barton et Bergman	1982	Southern England Mesolitic	40 lbs long bow (copy of Mesolithic)	4 and 8 m	17	Non geometric microlith points	English chalk flint	Pine resin + beeswax and/ or sinew	Light arrow	Juvenile fallow deer	–	Partial
Bergman and Newcomer	1983	Upper Palaeolithic/ Levant	48 lbs long bow (copy of Mesolithic)	1–4.5 m	26	Ksar Akil point, point à face plane	English and French flint	Pine resin + beeswax	–	Meat and bone artificial target (bone plate)	–	Yes
Fischer et al.	1984	Late Palaeolithic – Mesolithic – Neolithic	50 lbs laminated recurve bow	–	135	Various points (e.g., Brommian points, small transverse arrowheads)	Flint	Birch bark tar or fish glue with flax-thread	–	Animal and parts of animal	Shooting on trunks, bushes, wet grass, soil, dense reed	Yes
			Spear	–	11	Brommian points	Flint	Flax-thread	–	Animal and parts of animal		Yes
Odell and Cowan	1986	Method	Hand hurled spear	4–5 m	40	Bifacially retouched points, unmodified or min. modified flakes	Chert	Natural hemp and mastic of synthetic glue	–	Stacked dogs	_	Yes
			45 lbs bow	10–12 m	40	Bifacially retouched points and unmodified or minimally modified flakes	Chert	Natural hemp and mastic of synthetic glue	–	Stacked dogs	–	Yes
Frison	1989	Clovis weaponry	Spear-thrower	15 m	7	Clovis points	Obsidian and chert	Sinew and pine pitch	400–1000 g	Elephants	–	No
Geneste et Plisson	1990	Solutrean	45–55 lbs long bow Calibrated crossbow	18 m 9 m		Shouldered points	Same flints than in the site of Combe Saunière	Pine resin + beeswax + ocher with or without sinew binding	40 g 150 g	Goats	Butchering and other tasks	Partial
Caspar and De Bie	1996	Late Palaeolithic, arch-backed pieces	Bow	–	No data	Arch-backed pieces	Flint	Resin with or without ligature	–	Animal	Large referential background	Yes, but not published
Plisson and Beyries	1998	Levantine Mousterian	Thrusted spear	1 m	12	Levallois points	Flint from El Kown bassin (Syria)	Bitumen + ochre	(480–900 g)	Young chamois	Butchering + large referential background	Yes
Soriano	1998	Microgravettes/ Perigordian France	28 and 45 lbs long bow	13 m	80	Microgravettes	Flint	Sinew and natural glue (pine pitch + ash + beeswax)	Light arrow	Sheep and wild boar without viscera	–	Yes
Crombé et al.	2001	Early Mesolithic/ Belgium	60 lbs walnut self bow	20 m	183	Various microliths (tips and barbs)	Fine-grained flint	Pine resin	Light arrows	Sheep	–	Yes
Shea et al.	2001	Levantine Mousterian	Calibrated crossbow	–	45	Levallois points	Israelian flint	Synthetic paving tar alone or with vegetal fibres.	–	Adult goats	–	No
O'Farrell	2004	Fench Gravettian	Calibrated crossbow	9 m	51	Gravettian backed points	Flint	Pine resin + beeswax + ocher	200 g	Cow	Manufacturing, trampling	Yes
Lombard et al.	2004	South African MSA	Thrusted and thrown spear	at contact/3 –4 m	35	Convergent flakes	Chert, hornfels, mudstones and quartzites	Binding with sinew, leather or plant fibres	–	Forequarter of a wild wildebeest	Various tasks on vegetal and animal materials	Yes
Pargeter	2007	South African MSA	Calibrated projectile machine	4 m	33	Microlithic segments	European flint	Cyanoacrylate glue	292 g	Impala without viscera	–	No (yes, in Lombard and Pargeter, 2008)
Sisk and Shea	2009	Levantine Mousterian	40 lbs modern recurved bow	4 m	51	Slightly retouched triangular flakes	Cenomanian and Turonian flint	Commercial adhesive	–	Leather covered archery target and goat skin	–	No

(*continued on next page*)

Table 1 (*continued*)

Author	Publication year	Topic/research context	Projecting mode	Shooting distance	Nr of pieces	Tool type	Raw material	Fixing	Projectile weight	Target	Other experiments	Description of fracture types
										stretched over a rack of ribs		
Yaroshevich et al.	2010	Epipalaeolithic/ Levant	35 lbs modern recurved bow	8–13 m	265	Various microliths	Flint	Beeswax + resin + gypsum or ochre powder + some fibre binding, commercial water-basedglue	Light arrows	Complete goat and encased skinned sheep thorax	–	Yes
Schoville and Brown	2010	Middle Stone Age	Calibrated crossbow	–	22	Convergent flakes	Quartzite	Acacia karroo mastic + cow tendon	–	Springbok		Only localisation of damage
Hutchings	2011	Fracture velocities/ Paleo-Indian	Spearthrower darts – calibrated crossbow		53	Clovis points	Obsidian	–	167–295 g	Several layers of fresh beef ribs	Accidental dropping	No
			Arrow – calibrated crossbow		15	Clovis points	Obsidian	–	45–56 g	Several layers of fresh beef ribs		No
			Javelin – calibrated crossbow		45	Clovis points	Obsidian	–	135–296 g	Several layers of fresh beef ribs		No
			Spear – calibrated crossbow		32	Clovis points	Obsidian	–	258–335 g	Several layers of fresh beef ribs		No
Pétillon et al.	2011	Magdalenian	Spear thrower	12 m	18 antler + 51 stone insets	Microliths	Antler and flint	Beeswax + resin + ochre, birch-bark pitch	180–230 g	Young female deer	–	Yes
Lazuén	2012	European Mousterian	–	–	8	Mousteria points	Quartz and quartzite	–	–	–	–	No
Wilkins et al.	2012	Late EarlyStone Age South Africa	Calibrated crossbow	–	32	Retouched points	Banded ironstone	Acacia resin + cow tendon	–	Springbok	–	No
Iovita et al.	2013	Middle Palaeolithic/Levant	Compressed air-gun	93 cm	Unknown, at least 53?	Levallois points	Glass	Natural beeswax	266 g	Ballistic gelatin and plates of bone-like polyurethane	–	Yes
Rots	2013a	Method (hafting)	Thrusting spear	0	5	Levallois points	Flint	Various	–	Deer	Large referential background	Yes
			Throwing spear	6–8 m	6	Levallois points	Flint	Various	–	Deer	Large referential background	Yes
			35 & 60 lbs bow	18–20 m	100 (100 tips, 104 barbs)	Various microliths	Flint	Resin with or without ligature	Light	Sheep	Large referential background	Yes, partially

valid replacement of a dead animal. Ideally the target should in fact be a living animal, but this would be ethically and statistically problematic. A dead animal is the best alternative, but it must be as fresh as possible and complete (including the viscera).

6. Identification of the projecting mode

A stone point can be mounted on various types of weapons, from heavy thrusting spears to light arrows. Recently, efforts have been invested for examining ways of distinguishing between them. After all, as only modern humans are now supposedly associated with "complex" weaponry (Shea and Sisk, 2010), it has become crucial to be able to distinguish points shot with a spear-thrower or bow. In a sense, this debate is not new (Browne, 1940) and weight has been a parameter that was often used to distinguish among them (e.g., Rozoy, 1978). Recently, other criteria have been proposed; the tip cross-sectional area (TCSA) is most frequently referred to. As argued by Shea (2006) based on an ethnographic reference set, TCSA values may allow a distinction between different projecting modes, which actually builds on the work of Hughes (1998). Even though the ethnographic case study is in itself interesting, it has recently been heavily contested (Clarkson, 2013). Unfortunately, various authors have uncritically applied these TCSA values to archaeological assemblages for samples consisting of any form that could potentially be a projectile point (e.g., Costa, 2012; Villa and Lenoir, 2006, 2009; Wadley and Mohapi, 2008). Instead of first demonstrating a use of the pieces as armatures and subsequently examining the specific morphologies in order to evaluate how the data compare to the ethnographic reference, which could be interesting, a leap is taken and a specific projecting mode is immediately argued for. Needless to say that TCSA data resulting from such studies have questionable value for understanding past hunting technologies.

Experimentally, it is possible to distinguish between stone spear points (thrusting, throwing, and spear-thrower) and stone arrow tips when the series are large enough (Fischer et al., 1984; Geneste and Plisson, 1990, 1993; Caspar and De Bie, 1996; De Bie and Caspar, 2000), since the former are more severely damaged because of the greater energy involved. However, such kind of relative criteria are difficult to apply to an archaeological assemblage as many other factors can influence the degree of breakage of the projectile head (Pétillon et al., 2013): type of hafting, target distance, frost (Guthrie, 1983), etc. Moreover experimental and archaeological collections cannot be directly compared since their formation process is not the same (Chadelle et al., 1991), and we cannot exclude that points of the same type may have concurrently been used on spears with foreshaft and arrows. The laterally induced width-wide breakage (Figs. 8 and 9), predominantly occurring on points hafted on longer shafts (i.e., not arrows), is the only qualitative distinctive criterion which has been evidenced in experimentation involving 500 replicas of Solutrean lithic points (Chadelle et al., 1996, 1997; Magontier and Geneste, 1998); so far, positive evidence for arrow tips is missing. Perhaps Wallner lines will offer possibilities in the future for distinguishing between projecting modes on very fine-grained materials (e.g., obsidian) (Hutchings, 2011), but for now, we do not yet have any experimental reference that allows a reliable distinction.

7. Discussion

The severe methodological problems in a recently published study in a high-impact journal obliged us to review the difficulties involved in examining projectiles and the potential danger of some recent approaches. Results may be misleading when based on flawed methods. Published macro-fracture data may superficially appear reliable for most readers but it generally requires a close examination of the described wear features by specialists in order to dissect the argumentation. The publication of Wilkins et al. (2012) was an exemplary case that proved deficient on nearly all levels. Wilkins et al. recently argued that the appearance of hafted hunting technology dates to about 500,000 years ago, at least 200,000 years earlier than currently thought. This claim was based on an analysis of a point assemblage from Kathu Pan 1, South Africa. Aside from the problematic archaeological context, we have argued that the presented evidence on the points is unreliable due to significant methodological problems in the analysis. Failure to accurately identify wear traces seems to have led to an over-optimistic interpretation of the actual evidence. None of the lines of evidence proposed by the authors as being in support of the existence of an early hafted hunting technology is sufficiently robust. The use identification is unreliable and hafting evidence is absent. Morphological aspects are most certainly insufficient to make their claims, as has been sufficiently demonstrated for Levallois points (Plisson and Beyries, 1998). Even though the authors argue that their interpretation is reliable given the combination of different lines of evidence, one has to conclude that the combination of different lines of unreliable and poor evidence does not result in a robust conclusion. This implies that current *reliable* evidence of hafted spear tips is still not older than about 250,000 years (e.g., Rots, 2013b). The Wilkins et al. (2012) study is, of course, not the only one suffering from the problems highlighted above, but it is the most explicit recent case of a misinterpretation of available evidence.

8. Conclusion

Projectiles have always greatly inspired people and many efforts have been undertaken to recognise projectile points in the archaeological record. Lately, projectile research has seen the publication of articles with rousing titles. Some prove to make use of methods derived from the use-wear methodology but aimed to obtain functional data quickly through a superficial examination of tip fractures and the misuse of more statistically-based approaches. Experimentation and detailed functional studies have by contrast stressed the difficulties in recognising projectiles and the multitude of factors influencing trace formation. There is not one single fracture type or attribute that is diagnostic for a use as armature and a reliable identification requires a close examination of all wear features on an armature. It also requires an examination of these wear features throughout a larger sample of the archaeological assemblage in order to be able to propose meaningful interpretations. While reliable research on projectiles has also been accumulating over the last few years, we want to warn of the risks of getting into a race for the oldest evidence of projectiles through quick and superficial procedures. With this article, we hope to stimulate a more detailed study of potential armatures in the future, following the methodological rigour that has been proposed in former functional studies.

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References

Barton, R.N.E., Bergman, C.A., 1982. Hunters at Hengistbury. Some evidence from experimental archaeology. World Archaeol. 14, 237–248.

Bergman, C.A., Newcomer, M.H., 1983. Flint arrowhead breakage: examples from Ksar Akil. J. Field Archaeol. 10, 238–241.

Bird, C., et al., 2007. Edge damage distribution at the assemblage level on Middle Stone Age lithics: an image-based GIS approach. J. Archaeol. Sci. 34 (5), 771–780.

Bordes, F., 1952. A propos des outils à bord abattu. Quelques remarques. Bull. Soc. Préhist. Fr. 49, 645–647.

Brown, K.S., Marean, C.W., Jacobs, Z., Schoville, B.J., Oestmo, S., Fisher, E.C., Bernatchez, J., Karkanas, P., Matthews, T., 2012. An early and enduring advanced technology originating 71,000 years ago in South Africa. Nature 491, 590–593.

Browne, J., 1940. Projectile points. Am. Antiq. 5, 209–213.

Caspar, J.P., De Bie, M., 1996. Preparing for the hunt in the late paleolithic camp at Rekem, Belgium. J. Field Archaeol. 23, 437–460.

Chadelle, J.P., Geneste, J.M., Plisson, H., 1991. Processus fonctionnels de formation des assemblages technologiques dans les sites du Paléolithique supérieur. Les pointes de projectiles lithiques du Solutréen de la grotte de Combe Saunière (Dordogne, France). In: 25 ans d'études technologiques en Préhistoire. Bilan et perspectives. APDCA, Juan-les-Pins, pp. 275–287.

Chadelle, J.P., Geneste, J.M., Plisson, H., 1996. Technologie fonctionnelle des pointes de projectiles solutréennes. In: l'archéologie, S.r.d. (Ed.), Bilan Scientifique Aquitaine 1995. Ministère de la Culture, Bordeaux, pp. 131–132.

Chadelle, J.P., Geneste, J.M., Plisson, H., 1997. Technologie fonctionnelle des pointes de projectiles solutréennes. In: l'archéologie, S.r.d. (Ed.), Bilan Scientifique Aquitaine 1996. Ministère de la Culture, Bordeaux, pp. 142–143.

Churchill, S.E., Rhodes, J.A., 2009. The evolution of the human capacity for "killing at a distance": the human fossil evidence for the evolution of projectile weaponry. In: Hublin, J.J., Richards, M.P. (Eds.), The Evolution of Human Diets. Integrating Approaches to the Study of Palaeolithic Subsistence. Springer, pp. 201–210.

Clarkson, C., 2013. Testing archaeological approaches to determining past projectile delivery systems using ethnographic and experimental data. In: Iovita, R., Sano, K. (Eds.), Multidisciplinary Scientific Approaches to the Study of Stone-Age Weaponry. Springer, Mainz (in press).

Costa, A.G., 2012. Were there stone-tipped armatures in the South Asia Middle Paleolithic? Quat. Int. 269, 22–30.

Crombé, P., Perdaen, Y., Sergant, J., Caspar, J.-P., 2001. Wear analysis on early Mesolithic microliths from the Verrebroek site, East Flanders, Belgium. J. Field Archaeol. 28, 253–269.

De Bie, M., Caspar, J.P., 2000. Rekem, a Federmesser Camp on the Meuse River Bank. Leuven University Press, Leuven.

Dockall, J.E., 1997. Wear traces and projectile impact: a review of the experimental and archaeological evidence. J. Field Archaeol. 24, 321–331.

Fischer, A., Vemming Hansen, P., Rasmussen, P., 1984. Macro and microwear traces on lithic projectile points. Experimental results and prehistoric examples. J. Dan. Archaeol. 3, 19–46.

Geneste, J.M., Plisson, H., 1990. Technologie fonctionnelle des pointes à cran solutréennes: l'apport des nouvelles données de la grotte de Combe Saunière (Dordogne). In: Kozlowski, J.K. (Ed.), Feuilles de pierre. Les industries à pointes foliacées du Paléolithique supérieur européen. Université de Liège, Liège, pp. 293–320.

Geneste, J.M., Plisson, H., 1993. Hunting technologies and human behavior: lithic analysis of solutrean shouldered points. In: Knecht, H., Pike-Tay, A., White, R. (Eds.), Before Lascaux, the Complex Record of the Early Upper Paleolithic. CRC Press, Boca Raton, pp. 117–135.

Guthrie, R.D., 1983. Osseous projectile points: biological considerations affecting raw material and design among paleolithic and paleoindian people. In: Clutton-Brock, J., Grigson, C. (Eds.), Animals and Archaeology. Hunters and their Prey. B.A.R, Oxford, pp. 273–295.

Hauck, T., Connan, J., Charrié-Duhaut, A., Le Tensorer, J.-M., Sakhel, H.A., 2013. Molecular evidence of bitumen in the Mousterian lithic assemblage of Hummal (Central Syria). J. Archaeol. Sci., 3252–3262.

Ho Ho Committee, 1979. The Ho Ho classification and nomenclature committee report. In: Hayden, B. (Ed.), Lithic Use-Wear Analysis. Academic Press, New York.

Hughes, S.S., 1998. Getting to the point: evolutionary change in prehistoric weaponry. J. Archaeol. Method Theor. 5, 345–408.

Hutchings, W.K., 2011. Measuring use-related fracture velocity in lithic armatures to identify spears, javelins, darts, and arrows. J. Archaeol. Sci. 38, 1737–1746.

Iovita, R., Schönekeß, H., Gaudzinski-Windheuser, S., Jäger, F., 2013. Projectile impact fractures and launching mechanisms: results of a controlled ballistic experiment using replica Levallois points. J. Archaeol. Sci.

Kamminga, J., 1982. Over the edge: functional analysis of Australian stone tools. University of Queensland Anthropology Museum.

Keeley, L.H., 1980. Experimental Determination of Stone Tool Uses: a Microwear Analysis. University of Chicago Press, Chicago and London.

Knecht, H., 1997. Projectile Technology. Plenum Press, New York and London.

Lazuén, T., 2012. European Neanderthal stone hunting weapons reveal complex behaviour long before the appearance of modern humans. J. Archaeol. Sci. 39, 2304–2311.

Bettencourt-Saint-Ouen (Somme). In: Locht, J.-L. (Ed.), Cinq Occupations paléolithiques au début de la dernière glaciation. Editions de la Maison des sciences de l'Homme, Paris. Documents d'archéologie française.

Lombard, M., Pargeter, J., 2008. Hunting with Howiesons Poort segments: pilot experimental study and the functional interpretation of archaeological tools. J. Archaeol. Sci. 35, 2523–2531.

Lombard, M., Parsons, I., van der Ryst, M.M., 2004. Middle Stone Age lithic point experimentation for macro-fracture and residue analyses: the process and preliminary results with reference to Sibudu Cave points. S. Afr. J. Sci. 100, 159–166.

Magontier, P., Geneste, J.M., 1998. Le temps des chasseurs solutréens. France, p. 52 minutes. ADDC Archéolud; Delta Image; France 3 Aquitaine; Vision Age.. Retrieved from: http://www.canal-u.tv/video/cerimes/le_temps_des_chasseurs_solutreens.11542.

Moss, E.H., 1983a. Some comments on edge damage as a factor in functional analysis of stone artefacts. J. Archaeol. Sci. 10, 231–242.

Moss, E.H., 1983b. The Functional Analysis of Flint Implements. Pincevent and Pont D'Ambon: Two Case Studies from the French Final Palaeolithic. BAR, Oxford.

Moss, E.H., Newcomer, M.H., 1982. Reconstruction of tool use at Pincevent: microwear and experiments. In: Cahen, D., CRA, U.d. (Eds.), Tailler! Pourquoi faire: Préhistoire et technologie lithique. Musée Royal de l'Afrique Centrale, Tervuren, pp. 289–312.

O'Farrell, M., 2004. Les pointes de La Gravette de Corbiac (Dordogne) et considérations sur la chasse au Paléolithique supérieur ancien. In: Bodu, P., Constantin, C. (Eds.), Approches fonctionnelles en préhistoire. Société préhistorique française, Paris, pp. 121–138.

Odell, G.H., 1981. The Mechanics of use-breakage of stone tools: some Testable Hypotheses. J. Field Archaeol. 8, 197–209.

Odell, G.H., Cowan, F., 1986. Experiments with spears and arrows on animal targets. J. Field Archaeol. 13, 195–212.

Pargeter, J., 2007. Howiesons Poort segments as hunting weapons: experiments with replicated projectiles. South Afr. Archaeol. Bull. 62, 147–153.

Pétillon, J.-M., Bignon, O., Bodu, P., Cattelain, P., Debout, G., Langlais, M., Laroulandie, V., Plisson, H., Valentin, B., 2011. Hard core and cutting edge: experimental manufacture and use of Magdalenian composite projectile tips. J. Archaeol. Sci. 38, 1266–1283.

Pétillon, J.-M., Plisson, H., Cattelain, P., 2013. Thirty years of experimental research on the breakage patterns of Stone Age osseous points. Overview, methodological problems and current perspectives. In: Iovita, R., Sano, K. (Eds.), Multidisciplinary Scientific Approaches to the Study of Stone-age Weaponry. Springer, Mainz (in press).

Pétrequin, A.M., Pétrequin, P., 1990. Flèches de chasse, flèches de guerre. Le cas des Danis d'Irian Jaya (Indonésie). Bull. Soc. Préhist. Fr. 87, 484–511.

Plisson, H., 1988. Technologie et tracéologie des outils lithiques moustériens en Union Soviétique: les travaux de V.E. Shchelinskij. In: Otte, M. (Ed.), L'Homme de Neandertal. ERAUL, Liège, pp. 121–168.

Plisson, H., 2005. Examen tracéologique des pointes aziliennes du Bois-Ragot. In: Chollet, A., Dujardin, V. (Eds.), La grotte du Bois-Ragot à Gouex (Vienne).- Magdalénien et Azilien. essais sur les hommes et leur environnement. Société Préhistorique Française, Paris, pp. 183–189.

Plisson, H., Beyries, S., 1998. Pointes ou outils triangulaires? Données fonctionnelles dans le Moustérien levantin. Paléorient 24, 5–24.

Plisson, H., Geneste, J.M., 1989. Analyse technologique des pointes à cran solutréennes du Placard (Charente), du Fourneau du Diable, du Pech de la Boissière et de Combe Saunière (Dordogne). Paléo 1, 65–105.

Rots, V., 2003. Towards and Understanding of Hafting: the macro- and microscopic evidence. Antiquity 77 (298), 805–815.

Rots, V., 2004. Prehensile wear on flint tools. Lithic Technol. 29 (1), 7–32.

Rots, V., 2010. Prehension and Hafting Wear on Flint Tools. A Methodology. Leuven University Press, Leuven.

Rots, V., 2013a. Projectiles and hafting technology. In: Iovita, R., Sano, K. (Eds.), Multidisciplinary Scientific Approaches to the Study of Stone-age Weaponry. Springer, Mainz (in press).

Rots, V., 2013b. Insights into early Middle Palaeolithic tool use and hafting in Western Europe. The functional analysis of Level IIa of the early Middle Palaeolithic site of Biache-Saint-Vaast (France). J. Archaeol. Sci. 40, 497–506.

Rozoy, J.G., 1978. Les derniers chasseurs. L'Epipaléolithique en France et en Belgique. Essai de synthèse. Société archéologique champenoise, Reims.

Schoville, B., Brown, K.S., 2010. Comparing lithic assemblage edge damage distributions: examples from the late Pleistocene and preliminary experimental results. Explor. Anthropol. 10, 34–49.

Semenov, S.A., 1964. Prehistoric Technology; an Experimental Study of the Oldest Tools and Artefacts from Traces of Manufacture and Wear. Cory, Adams & Mackay, London.

Shea, J.J., 2006. The origins of lithic projectile point technology: evidence from Africa, the Levant, and Europe. J. Archaeol. Sci. 33, 823–846.

Shea, J., Sisk, M., 2010. Complex projectile technology and *Homo sapiens* dispersal into western Eurasia. Paleoanthropology 2010, 100–122.

Shea, J., Davis, Z., Brown, K., 2001. Experimental tests of Middle Palaeolithic spear points using a calibrated crossbow. J. Archaeol. Sci. 28, 807–816.

Sigaut, F., 1991. Un couteau ne sert pas à couper mais en coupant. Structure, fonctionnement et fonction dans l'analyse des objets. In: 25 ans d'études technologiques en Préhistoire. Bilan et perspectives. APDCA, Juan-les-Pins, pp. 21–34.

Simondon, G., 1958. Du mode d'existence des objets techniques. Aubier, Paris.

Sisk, M.L., Shea, J.J., 2009. Experimental use and quantitative performance analysis of triangular flakes (Levallois points) used as arrowheads. J. Archaeol. Sci. 36, 2039–2047.

Soriano, S., 1998. Les microgravettes du Périgordien de Rabier à Lanquais (Dordogne), analyse technologique fonctionnelle. Gall. Préhist. 40, 75–94.
Vaughan, P., 1985. Use-wear Analysis of Flaked Stone Tools. University of Arizona Press, Tucson.
Villa, P., Lenoir, M., 2006. Hunting weapons of the Middle stone Age and the Middle Palaeolithic: spear points from Sibudu, Rose Cottage and Bouheben. South. Afr. Humanit. 18, 89–122.
Villa, P., Lenoir, M., 2009. Hunting and hunting weapons of the Lower and Middle Paleolithic of Europe. In: Hublin, J.-J., Richards, M. (Eds.), The Evolution of Hominid Diets: Integrating Approaches to the Study of Palaeolithic Subsistence. Springer Science & Business Media B.V, pp. 59–85.
Villa, P., Boscato, P., Ranaldo, F., Ronchitelli, A., 2009a. Stone tools for the hunt: points with impact scars from a Middle Paleolithic site in southern Italy. J. Archaeol. Sci. 36, 850–859.
Villa, P., Soressi, M., Henshilwood, C.S., Mourre, V., 2009b. The still Bay points of Blombos Cave (South Africa). J. Archaeol. Sci. 36, 441–460.
Villa, P., Soriano, S., Teyssandier, N., Wurz, S., 2010. The Howiesons Poort and MSA III at Klasies river main site, Cave 1A. J. Archaeol. Sci. 37, 630–655.
Wadley, L., Mohapi, M., 2008. A Segment is not a Monolith: evidence from the Howiesons Poort of Sibudu, South Africa. J. Archaeol. Sci. 35, 2594–2605.
Wilkins, J., Schoville, B., Brown, K.S., Chazan, M., 2012. Evidence for early hafted hunting technology. Science 338, 942–946.
Yaroshevich, A., Kaufman, D., Nuzhnyy, D., Bar-Yosef, O., Weinstein-Evron, M., 2010. Design and performance of microlith implemented projectiles during the Middle and the Late Epipaleolithic of the Levant: experimental and archaeological evidence. J. Archaeol. Sci. 37, 368–388.
Семенов, С.А., 1957. Цервобытная техника. Академия Наук СССР, Москва, ЛенинҐрад.
Щелинский, В.Е., 1977. ЛксЦериментально-трасолоҐическое изучение функций Цалеолитическич орудий. In: Цраслов, Н.Д. (Ed.), Цроблемы Цалеолита Восточной и Центральной ЕвроЦы. Наука, ЛенинҐрад, pp. 182–196.