

Hunting evidence from stone artefacts from the Magdalenian cave site Bois Laiterie, Belgium: a fracture analysis

Nachweis von Jagd an Steinartefakten der Magdalénien-Höhlenfundstelle Bois Laiterie, Belgien: Eine Bruchanalyse

Katsuhiro SANO*

Forschungsbereich Altsteinzeit des Römisch-Germanischen Zentralmuseums Mainz, Schloss Monrepos, D-56567 Neuwied & Universität zu Köln, Institut für Ur- und Frühgeschichte, Weyertal 125, D-50923 Köln

ABSTRACT - Bois Laiterie is a unique cave site which represents an important component of Magdalenian settlement-subsistence systems in north-western Europe. The small cave is unsuitable as a residential site due to its small size and northward facing entrance and of use only for limited activities. Considerable numbers of backed bladelets imply the existence of hunting activity around the cave. The present study examines this hypothesis on the evidence of a fracture analysis of lithic artefacts. A series of experiments with projectiles revealed that specific fracture patterns occur due to impact. However, the exclusiveness of these impact fracture patterns has so far not been sufficiently discussed. Experiments were conducted to examine the possible formation and frequency of pseudo-impact fracture occurrence during manufacturing and due to post-depositional processes. Diagnostic impact fractures are presented here according to the results of these experiments. Macroscopic examination of stone artefacts from Bois Laiterie reveals that backed bladelets indeed show diagnostic impact fractures. Additionally, backed points, blades and some fragments also exhibit evidence for hunting activities. The fracture analysis confirms that occupation of this small cave was closely related to hunting activity.

ZUSAMMENFASSUNG - Bois Laiterie ist eine einzigartige Höhlenfundstelle, die einen wichtigen Teil des Siedlungs- und Subsistenzsystems des Magdalénien in Nordwesteuropa repräsentiert. Die Höhle ist aufgrund ihrer geringen Größe und der nördlichen Ausrichtung des Eingangs nicht als Wohnplatz und nur für eingeschränkte Aktivitäten geeignet. Eine beachtliche Zahl von Rückenmessern weist auf Jagdaktivitäten im Umkreis der Höhle hin. Die vorliegende Untersuchung überprüft diese Hypothese mit Hilfe einer Bruchanalyse der Steingeräte. Eine Reihe von Experimenten zeigte das Auftreten spezifischer Bruchmuster durch den Aufprall von Projektilen. Die Besonderheit diese Aufprallbruchmuster wurde bislang jedoch noch nicht ausreichend diskutiert. Es wurden daher Versuche durchgeführt, um die mögliche Bildung und Häufigkeit von Pseudo-Aufprallbrüchen während des Herstellungsprozesses und durch Prozesse nach der Ablagerung festzustellen. Als Ergebnis dieser Versuche werden diagnostische Aufprallbrüche vorgestellt. Die makroskopische Untersuchung der Steingeräte von Bois Laiterie zeigt, dass Rückenmesser tatsächlich solche diagnostischen Aufprallbrüche aufweisen. Zusätzlich liefern auch rückengestumpfte Spitzen, Klingen und einige Fragmente Hinweise auf Jagdaktivitäten. Die Bruchanalyse bestätigt eine eng mit der Jagd verknüpfte Nutzung der kleinen Höhle.

KEYWORDS - Magdalenian, traceology, fracture analysis, diagnostic impact fractures, hunting
Magdalénien, Gebrauchsspuren, Bruchanalyse, diagnostische Aufprallbrüche, Jagd

Introduction

Investigations at Bois Laiterie have given insights into the specific nature of this small cave site within the Magdalenian sites of north-western Europe (Otte & Straus 1997; Straus & Otte 1998). Both its small size and uncomfortable conditions due to the northward-facing entrance render the cave unsuitable as a residential locality and only fit for the carrying out of limited activities. Moreover, the number of recovered backed bladelets infers that hunting may have been a

very important activity conducted around the cave (Straus 1997b; Straus & Otte 1998). The study presented here examines this hypothesis based on a macro-fracture analysis of the lithic artefacts.

Faunal remains recovered from prehistoric sites have occasionally provided direct evidence for human hunting, specifically in the form of lithic artefacts embedded in animal bones (Noe-Nygaard 1974; Boëda et al. 1999; Zenin et al. 2006). Moreover, zoo-archaeological studies indicate that hunting and subsequent carcass processing were systematically carried out by Magdalenian people in north-western Europe and that their subsistence strategies - from hunting to carcass exploitation - were consciously

* katsuhiro.s@online.de

performed at specific places (Charles 1998; Gaudzinski & Street 2003; Turner 2003). Evaluating the role of hunting at a site is therefore an important issue in the discussion of land use patterns within a specific occupied territory.

Lithic traceology can also provide evidence for human hunting and for exploitation of the hunted animals associated with lithic implements. Furthermore, it is often possible to analyse lithic artefacts even when faunal remains have completely disappeared owing to poor conditions of preservation. Numerous experiments related to projectile use have revealed the distinct fracture patterns and microscopic traces which form on lithic missiles (Barton & Bergman 1982; Moss & Newcomer 1982; Huckell 1982; Bergman & Newcomer 1983; Fisher et al. 1984; Odell & Cowan 1986; Shea 1988; Midoshima 1991, 1996a; Geneste & Plisson 1993; Caspar & De Bie 1996; Kelterborn 1999; Crombé et al. 2001; Lombard et al. 2004; Sakashita 2006). However, relatively little attention has been given to the possibility that other agencies could also form fractures resembling impact damage.

I therefore conducted experiments to investigate the accidental fractures caused during lithic artefact manufacture and by post-depositional processes in order to identify diagnostic impact fractures. The artefacts from Bois Laiterie were subsequently analysed by comparison with the recognized

diagnostic impact fracture patterns and the function of the small cave for Magdalenian humans is then discussed.

The Bois Laiterie Cave

The Grotte du Bois Laiterie is located in the western part of the Ardennes Massif within a region of Carboniferous limestone transected by the Meuse River, which contains a number of caves, some of which have delivered remains left by Magdalenian hunter-gatherer occupations, e.g. Trou de Chaleux, Trou du Frontal, Trou des Nutons and Trou da Somme (Fig. 1). The Bois Laiterie cave is also formed in this Carboniferous limestone facies and lies by the Meuse River ca. 30 km downstream from the former cave sites and ca. 80 km upstream from Upper Cretaceous flint sources (Fig. 1). Bois Laiterie is a small cave, open to the north, which lies on a steep hillside ca. 120 m above sea level and ca. 35 m above the present level of the Burnot (Straus 1997a: 25), a tributary of the Meuse River.

This hidden small cave was discovered in 1990 and excavated in 1994 and 1995. The site report was published two years after the latter excavation and provided fruitful insights into the Bois Laiterie Magdalenian occupation (Otte & Straus 1997). Most of the lithic and organic artefacts, together with faunal remains, were recovered from Strata YSS and BSC

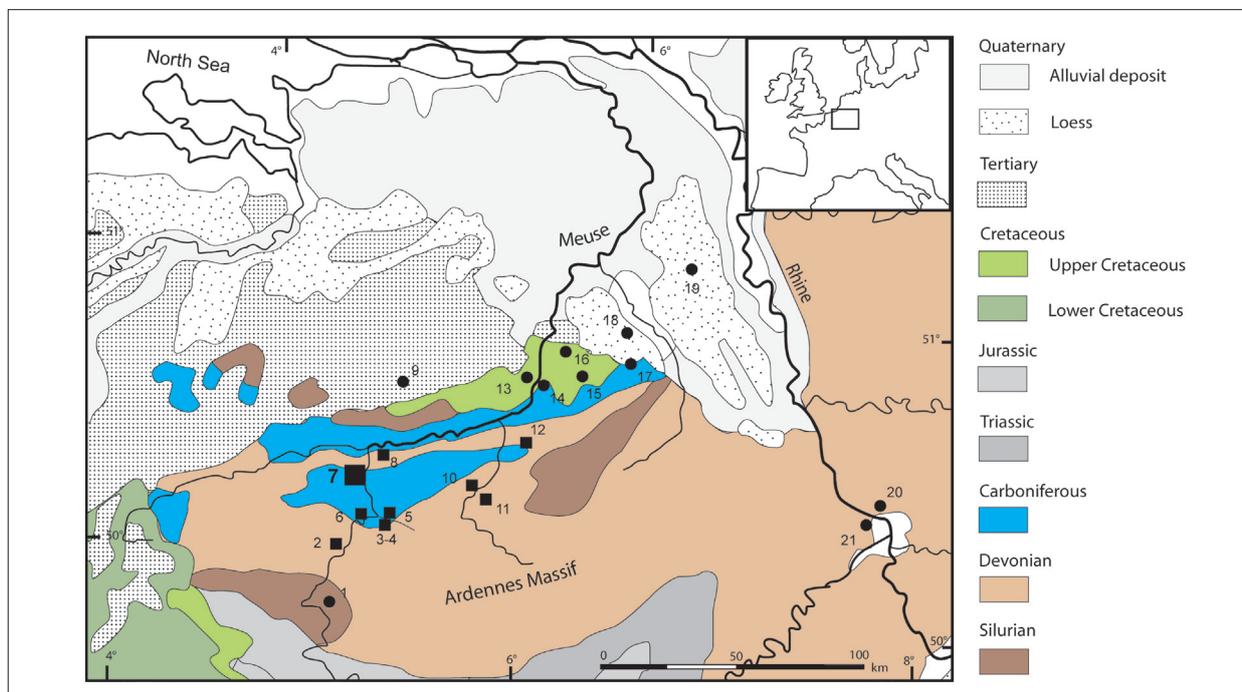


Fig. 1. Geological map showing the locations of Magdalenian sites (source of the geological information: Topel 1988, 74-75). Circle = open-air site, square = cave site. 1 - Roc-la-Tour, 2 - Vaucelles, 3 - Trou du Frontal, 4 - Trou des Nutons, 5 - Trou de Chaleux, 6 - Trou da Somme, **7 - Bois Laiterie**, 8 - Goyet, 9 - Orp-le-Grand, 10 - Verlainne, 11 - Coléoptère, 12 - Fond-de-Forêt, 13 - Kanne, 14 - Mesch, 15 - Eysersheide, 16 - Sweikhuizen, 17 - Alsdorf, 18 - Beeck, 19 - Kamphausen, 20 - Gönnersdorf, 21 - Andernach.

Abb. 1. Geologische Karte mit den Lagen der Magdalénien-Fundstellen (Quelle der geologischen Informationen: Topel 1988: 74-75). Kreis = Freilandfundstelle, Quadrat = Höhlenfundstelle. 1 - Roc-la-Tour, 2 - Vaucelles, 3 - Trou du Frontal, 4 - Trou des Nutons, 5 - Trou de Chaleux, 6 - Trou da Somme, **7 - Bois Laiterie**, 8 - Goyet, 9 - Orp-le-Grand, 10 - Verlainne, 11 - Coléoptère, 12 - Fond-de-Forêt, 13 - Kanne, 14 - Mesch, 15 - Eysersheide, 16 - Sweikhuizen, 17 - Alsdorf, 18 - Beeck, 19 - Kamphausen, 20 - Gönnersdorf, 21 - Andernach.

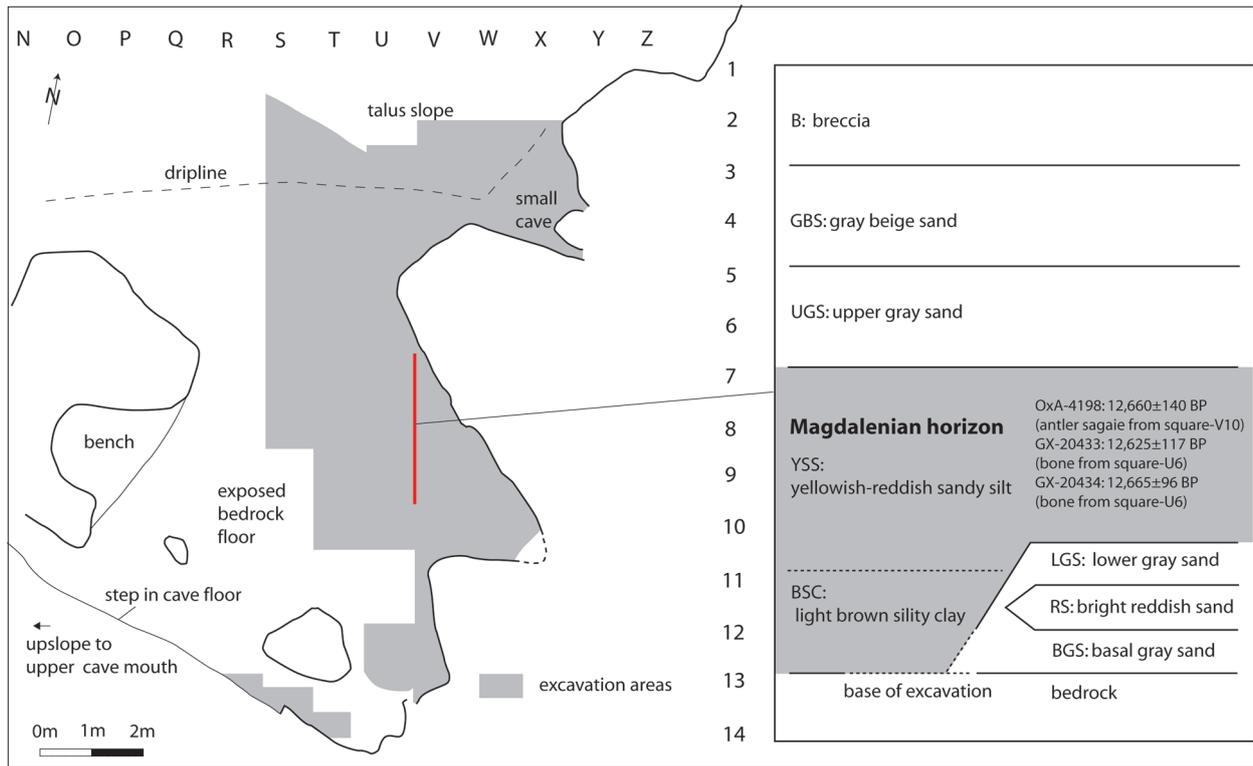


Fig. 2. Plan and schematic section (U-V/7-9) of the Bois Laiterie cave with radiocarbon dates for the Magdalenian occupation (after Straus 1997a).

Abb. 2. Plan und schematisches Profil (U-V/7-9) der Bois Laiterie Höhle mit Radiokarbon-Daten der Magdalénien-Nutzung (Straus 1997a).

(Fig. 2). Lithic refits and typological aspects of the assemblages demonstrate the unity of the archaeological remains from YSS and BSC. Additionally, radiocarbon dates obtained for an antler point from Stratum YSS and bones from YSS top and YSS base all fall around 12,650 BP (Charles 1996; Straus 1997a, 53-54). Analysis of the alignment of artefacts suggests that, while they may have been subject to some local movement, no major rearrangement due to running water, solifluction or trampling occurred (Straus & Martinez 1997). Results of the micro-stratigraphic analysis do not contradict this interpretation (Courty 1997). Consequently, Straus & Martinez (1997) concluded that the artefact assemblages probably derive from one or several "closely-spaced" human occupation(s) of the cave and that "this Magdalenian horizon cannot be analytically subdivided and therefore must be treated as one unit".

In total, 3,369 lithic artefacts were recovered from Bois Laiterie. The lithic raw materials present are of non-local, high quality flint and the material of approximately 90% of the lithic artefacts was probably obtained from Upper Cretaceous chalk sources (Straus & Orphal 1997). The presence of very little cortical debitage and only three small, exhausted cores suggests that the flint was mainly transported in the form of blade blanks. The inventory of the modified artefacts contains backed bladelets (91), retouched blades (43), burins (35), truncated pieces (24), end scrapers (22) and perforators/becks (21)

(Straus & Orphal 1997). Based on the large number of backed bladelets and the existence of several lithic and antler points, Straus (1997b) concluded that Bois Laiterie was a hunting camp.

Analyses of large mammal remains show that a minimum of four reindeer, three horses, two ibex, two small ruminants and two musk oxen were probably hunted (Gautier 1997). Only two bone fragments show traces of modification by humans, these being butchering marks on a reindeer astragalus and on a horse mandible fragment. Gautier noted that neither hyena nor wolf frequently occupied the cave, as there were few remains of these species and little evidence for carnivore gnawing on the recovered bones.

Methods

Traceology

Artefacts can be defined as objects formed by the human modification of raw materials and then transformed by various factors prior to their analysis by archaeologists. Thus, archaeological remains are secondarily transformed records of the human past (Schiffer 1976). Moreover, these extraneous agencies can leave evidence of their modifying influence on the material of the artefact in the form of recognizable traces. Thus, if a correlation exists between the trace formation patterns and their specific causative agencies, analysts could inquire into the sources of the traces found on artefacts. Use-wear analysts have paid

attention to traces caused not only by human use factors but also by non-use factors and have also tested experimentally the possibility of trace formation on artefacts during their manufacture (Brink

1978; Keeley 1980, 25-28; Moss 1983b; Vaughan 1985; Geneste & Plisson 1993; Midoshima 1996b; Byrne et al. 2006), due to post-depositional processes (Tringham et al. 1974; Keeley 1980, 28-35; Vaughan

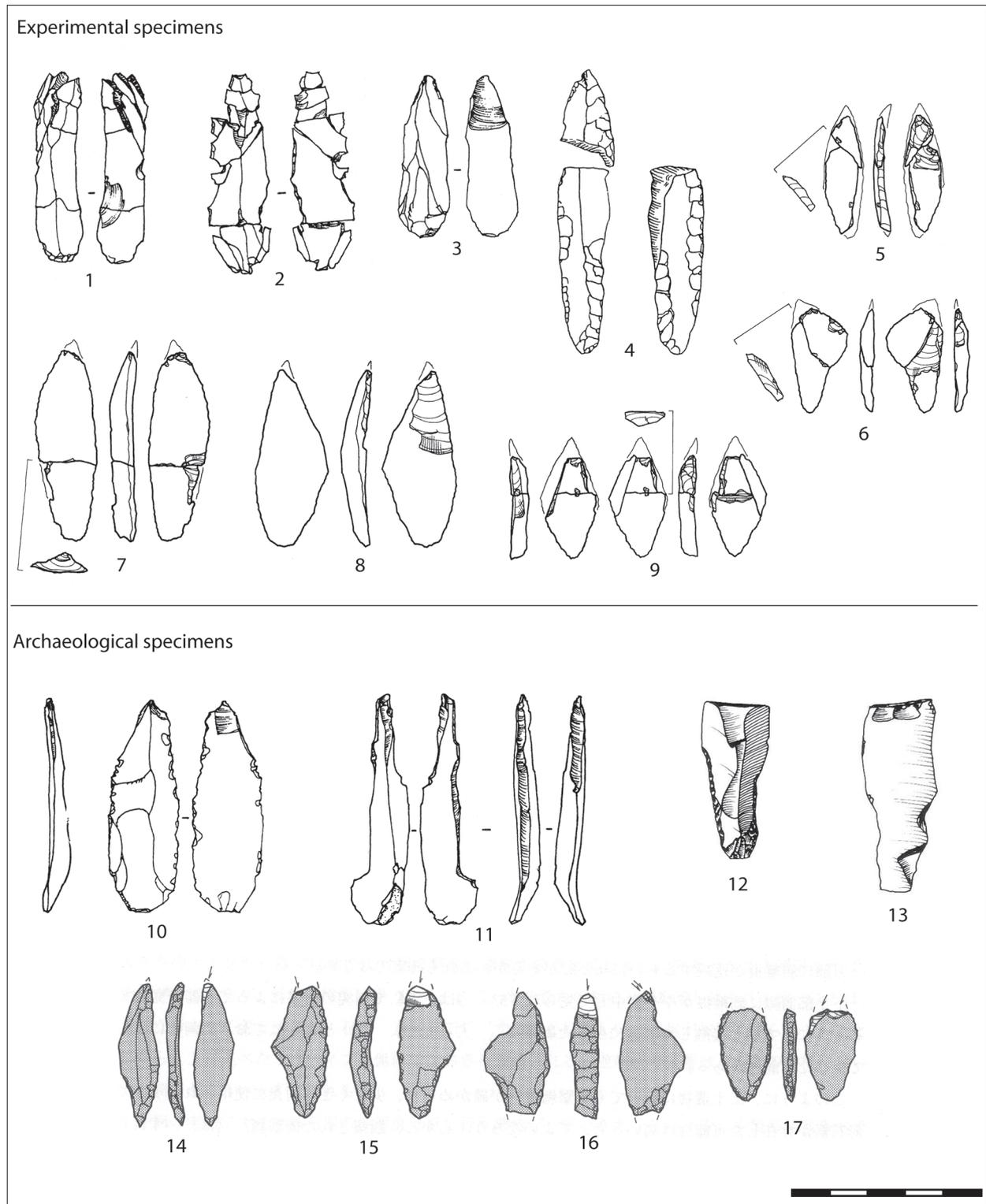


Fig. 3. Impact fractures on archaeological and experimental specimens. Experimental specimens: 1-9 (1-3 from Bergman & Newcomer 1983; 4 from Geneste & Plisson 1993; 5-9 from Midoshima 1996a). Archaeological specimens: 10-17 (10, 11 from Bergman & Newcomer 1983; 12, 13 from Fischer et al. 1984; 14-17 from Midoshima 1996a) (1/3 nat. size).

Abb. 3. Aufprallbrüche an archäologischen und experimentellen Stücken. Versuchsstücke: 1-9 (1-3 aus Bergman & Newcomer 1983; 4 aus Geneste & Plisson 1993; 5-9 aus Midoshima 1996a). Archäologische Stücke: 10-17 (10, 11 aus Bergman & Newcomer 1983; 12, 13 aus Fischer et al. 1984; 14-17 aus Midoshima 1996a).

1985; Levi-Sala 1986, 1993; Plisson & Mauger 1988; Shea & Klenck 1993; Midoshima 1994; Steguweit 2003: 85-91) and those created post-excavation (Wylie 1975; Gero 1978). Examination of traces resulting from non-use factors allows a more reliable interpretation of the function of the studied artefacts by reducing the number of opportunities for misreading extraneous non-use traces.

The attempt to discover the relationship between traces and their causative agencies can lead us to recognize principles of trace formation dynamics and the experimental approach makes it possible to test the regularity of their correlation empirically. Traceology, in its broad sense, covers studies of all trace formation processes on artefacts (Midoshima 2001; Donahue & Burroni 2004; Longo & Skakun 2008; Plisson & Lompré 2008; cf. Sullivan 1978) and by contributing to the technological study of artefacts represents an important methodology within technological research overall (e.g. Semenov 1964; Flenniken & Garrison 1975; Hutchings 1999). Moreover, traceology has the potential to give insights into site formation processes (e.g. McBrearty et al. 1998; Burroni et al. 2002; Sergant et al. 2006). Use-wear analysis, in the narrow sense, forms one element of traceology which aims specifically to reveal the function of artefacts by analysing use-wear traces as well as non-use-wear traces present upon them. Experimental traceology employs procedures comprising (1) the confirmation of correlations between specific cultural and natural agencies and trace formation patterns produced on experimental specimens, (2) the analysis of traces found on archaeological specimens based on these confirmed correlations and (3) the interpretation of the history of the studied archaeological artefacts.

Impact fractures

Impact fractures observed on archaeological specimens have often been interpreted as indicators for hunting. Witthoft (1968) emphasises the importance of analyses of artefact breakage patterns, since breakage patterns allow an interpretation of the function of artefacts. Through analyses of Alaskan Eskimo arrow points he recognized particular types of fractures on the points which resembled fluting or burin scars. Similar fracture patterns have been also confirmed on North American prehistoric arrow points (Frison 1974; Ahler & McMillan 1976).

First series of experiments revealed that shooting projectile points into animal targets indeed produces such burin- and flute-like fractures (Barton & Bergman 1982; Moss & Newcomer 1982; Huckell 1982; Bergman & Newcomer 1983). Additionally, Barton & Bergman (1982), as well as Bergman & Newcomer (1983) reported that fractures occurred not only at the tip but also on the medial portion, from which the upper portion was broken away transversely. Flute- and burin-like fractures and transverse fractures were

often observed during experiments by further researchers, independent of the morphology of the artefacts, which included arrow tips, unifacial points and Clovis points and of the employed lithic raw materials, such as flint, quartzite and obsidian (Fisher et al. 1984; Odell & Cowan 1986; Shea 1988; Midoshima 1991, 1996a; Geneste & Plisson 1993; Caspar & De Bie 1996; Kelterborn 1999; Crombé et al. 2001; Lombard et al. 2004; Sakashita 2006). This experimental research demonstrated quantitatively that these types of fractures often occur due to impact on animal targets (Fig. 3: 1-9) and the same fracture types have been recognized on archaeological specimens (Fig. 3: 10-17).

However, all this does not directly imply that these fracture patterns are automatically diagnostic as evidence for projectile use because they could also be due to other factors. Comprehensive experiments by Fisher et al. (1984) showed that types of fracture termination and "spin-off fractures" are subject to additional interpretations. The "spin-off fracture" is a secondary fracture which initiates due to contact between the two primarily formed fracture surfaces (Fischer et al. 1984, Fig. 6). Analyses of impact fractures and accidental fractures (due e.g. to trampling) by Fischer et al. (1984) revealed that "step terminating bending fractures" as well as bifacial spin-off fractures or unifacial spin-off fractures larger than 6 mm are diagnostic for projectile activity, as these fracture types never occurred in the case of accidental damaging processes. On the other hand, in addition to step terminating fractures, Caspar & De Bie (1996) also placed "feather and hinge" terminating fractures and numerous spin-off fractures larger than 3 mm into the group of diagnostic impact fractures. Nevertheless, they too regarded snap terminating fractures as a non-diagnostic feature, since this type of fracture often occurs during the lithic reduction process or due to trampling.

While quantitative data on projectile experiments have already been presented, only limited attempts have been made so far to compare them with accidental fractures. I therefore conducted experiments into fracture patterns associated with lithic reduction and with syn-/post-depositional processes in order to demonstrate that "the traces to be used as evidence were not caused by other processes" (Schiffer 1987, 23).

Experiments

Plots

The experiments conducted are flake production, flake modification and flake trampling. As Magdalenian people mainly prepared blades for tool blanks, I produced blades exclusively. The experiments into flake modification used blades or elongated flakes; for the trampling experiment, modified artefacts (backed points), blades and flakes were used. All artefacts were made of Upper Cretaceous flint.

The three experiments cover the main agencies during lithic artefact manufacture and the syn-/post-depositional processes which might produce fractures on lithic artefacts resembling those due to impact.

Dropping an artefact during lithic manufacture or utilisation could also lead to fractures and Moss (1983b) reported a burin-like fracture formed on a specimen dropped from a height of around 80 cm onto a pile of debitage. This is not surprising because both shooting and dropping result in impact onto an object; it is therefore theoretically impossible to distinguish fractures between them. Nevertheless, since there is a great difference in the impact energy created by shooting and dropping, I suggest that dropping does not produce typical impact fractures as frequently as projectile activity, so that the effects of dropping would have no major influence on the evaluation of assemblages.

Heat treatment during lithic production or accidental burning post-deposition can also create fractures on artefacts. However, heat treatment and burning produce irregular fractures or "cremated" fractures (Purdy 1975) and it is relatively easy to exclude heated or burned artefacts on the basis of their colour, lustre or pot-lid damage.

With regard to factors other than projectile activity during the utilisation processes, tools used as wedges are exposed to similar fracture mechanisms as those caused by projectile impact and fractures caused by wedging thus show some similarities with impact fractures. However, experimental flint samples used as wedges with bone or antler show that wedging leads to substantial flute-like fractures on the working edge and simultaneously produces edge-removals on

the opposite end which is struck by a stone hammer, both of which differ from features on projectile points. Moreover, the striking edges present an extremely battered appearance. Hence, wedging tools are distinguishable from projectile artefacts.

Perforating an object, whether with or without a rotary action (boring), often leaves flute- and burin-like fractures on the tips of the used tools (see Grace 1989, 143). However, these fractures are basically very small and the morphology of the tools used for perforating can also help to avoid misinterpretation. Carving and engraving can also produce similar fractures to impact, but again, it is possible, albeit not perfectly, to distinguish impact fractures from incidental damage during carving or engraving due to the dimension of the fractures and the morphology of the artefacts.

Similarly, even if damage resembling impact fracture might occur post excavation, this is not a problem since the impact fractures formed during hunting are easily distinguished from the latter fractures by the differential development of patination.

The experiments examined whether and how frequently flake production, flake modification and trampling produce flute- and burin-like, transverse and spin-off fractures. Flute-like fractures extend as shallow features from the tip across the surfaces of the artefact (Fig. 3: 3, 6, 8, 10, 15) and a cluster of small flute-like fractures is sometimes formed on the lateral side. Burin-like fractures extend from the tip along the lateral edges of the artefact (Fig. 3: 1, 5, 9, 11, 14, 16). Transverse fractures are formed across a surface some distance down from the tip and extend from edge to edge (Fig. 3: 1, 2, 7, 9, 12, 13). All these primary

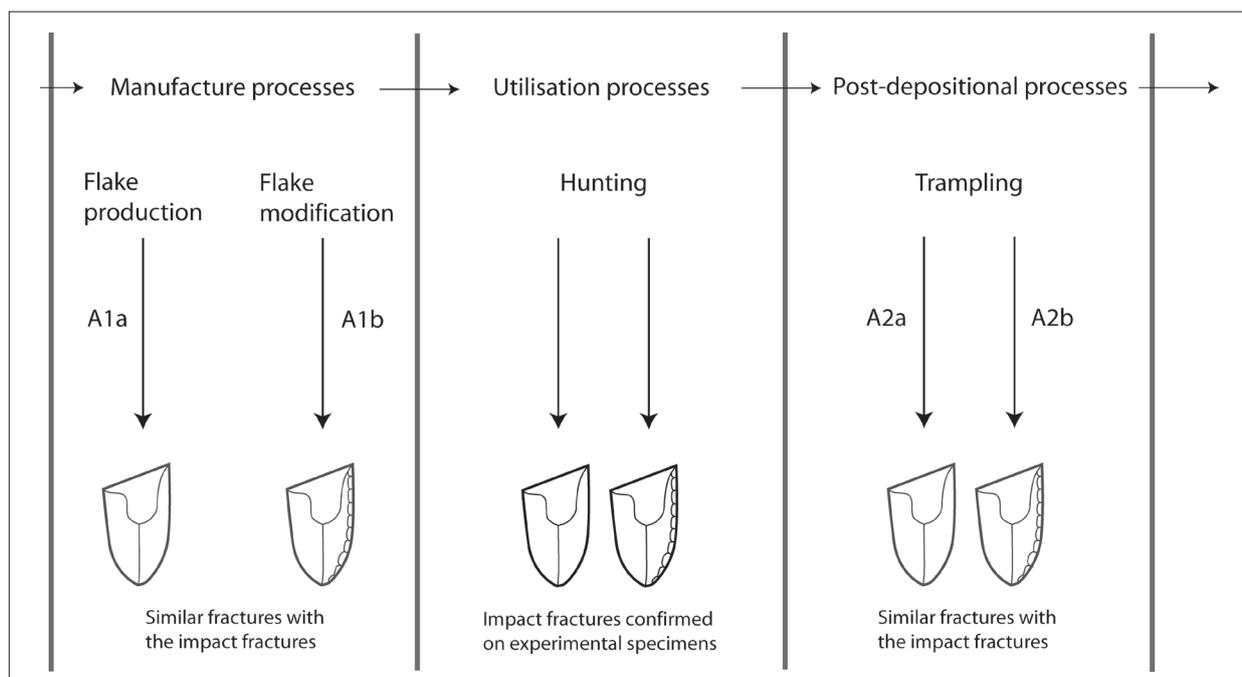


Fig. 4. Schematic representation of the conditions for impact damage duplication examined in this paper.

Abb. 4. Schematische Darstellung der Bedingungen zur Reproduktion von Aufprallbeschädigungen, die im Artikel überprüft werden.

Blade production by wood hammer	n	%
Specimens with fractures	32	70
Specimens without fractures	14	30
Total	46	100
Blade production by soft stone hammer	n	%
Specimens with fractures	20	48
Specimens without fractures	21	51
Total	41	100

Fig. 5. Frequency of primary fracture types which occurred during experimental blade production by wooden and soft stone hammers.

Abb. 5. Häufigkeit der primären Bruchtypen bei experimenteller Klingenerstellung mit Holzhammer und weichem Steinhammer.

fractures are not cone fractures but bending fractures (Fischer et al. 1984). Thus, both flute-like and burin-like fractures are distinguishable from those produced intentionally due to the absence of a negative bulb of percussion. Other features diagnostic as evidence for impact are bifacial spin-off fractures or unifacial spin-off fractures larger than 6 mm (Fischer et al. 1984). Fischer et al. (1984) assumed that "continued force from the ends presses the surfaces of the fracture against each other" and induces large spin-off fractures; they describe spin-off fractures as "cone fracture". On the other hand, Lombard (2005) notes these as "cone or other fracture types". I classify all secondary fractures which initiate from the primary fracture and which remove parts of the surface of the artefact as spin-off fractures, since a number of secondary fractures were too minute to decide whether they are cone or bending fractures.

The experiments examine the possibility that flake production (Fig. 4, A1a), flake modification (Fig. 4, A1b) and trampling (Fig. 4, 2a, 2b) can produce features mimicking impact fractures. This has several implications. If the possibility of duplication can be excluded it will be possible to identify lithic elements as projectile points even if they were not retouched or only lightly modified (A1a and A2a). On the other hand, if the possibility of duplication of features cannot be excluded, the correct identification of projectile elements must be considered doubtful, even when these "impact fractures" are recognized on modified points (A1b and A2b).

Flake (blade) production

Lithic knappers often have the experience that flakes or blades accidentally break into two or several pieces during their removal. Crabtree (1968, 474-476) recorded a blade that broke owing to excessive outward pressure by taking series of high-speed photographs. Roche & Tixier (1982) showed blades removed by wooden and antler hammers that were transversely broken into several segments.

In this study 87 blades in total were removed by wooden and soft stone hammers. Of the 46 blades produced by wooden hammer, 32 specimens bear fractures (Fig. 5). (It should be noted that the

Blade production by wood hammer	n	%
Primary fractures (PF)	45	100
PF with spin-off fractures	14	31
PF with bifacial spin-off fractures	0	0
Blade production by soft stone hammer	n	%
Primary fractures (PF)	25	100
PF with spin-off fractures	8	32
PF with bifacial spin-off fractures	0	0

Fig. 6. Frequency of spin-off fractures produced during experimental blade production by wooden and soft stone hammers.

Abb. 6. Häufigkeit der Nebenbruchtypen bei experimenteller Klingenerstellung mit Holzhammer und weichem Steinhammer.

frequency of breakage occurrence during blade production by the author seems to be somewhat higher than in the case of a skilful knapper with more than 20 years experience of stone-knapping.) Of these 32 specimens, 22 pieces have one fracture and are broken into two segments; eight specimens bear two fractures and two blades suffered more than two fractures, with a total of 45 primary fractures produced during blade production by wooden hammer. There are no flute- and burin-like fractures among the produced fractures, which are represented exclusively by transverse fractures. Around half of the transverse fractures terminate in a snap, which is

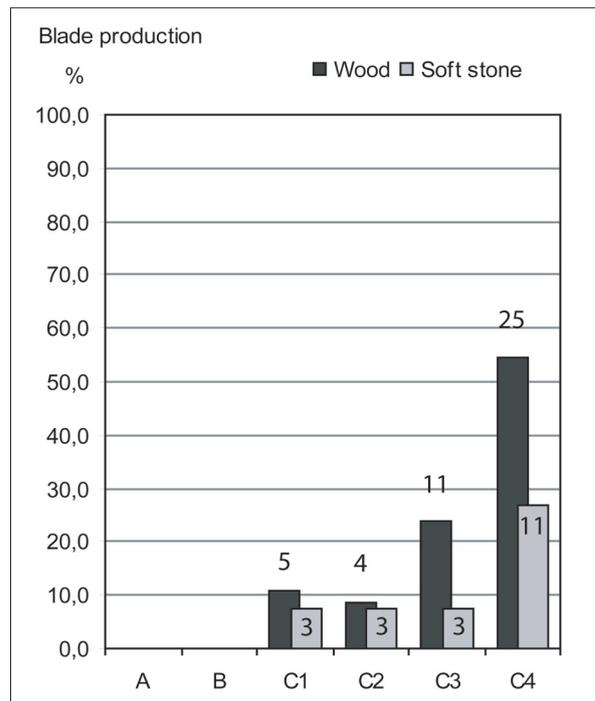


Fig. 7. Frequency of primary fracture types produced during blade production by wooden and soft stone hammers. A: flute-like fracture, B: burin-like fracture, C: transverse fracture; C1: feather termination, C2: hinge termination, C3: step termination; C4: snap termination.

Abb. 7. Häufigkeit der primären Bruchtypen bei Klingenerstellung mit Holzhammer und weichem Steinhammer. A: rinnenartiger Bruch, B: stichelartiger Bruch, C: Querbruch; C1: spitzes Ende, C2: Angelende, C3: Stufenende; C4: durchgeschlagenes Ende.

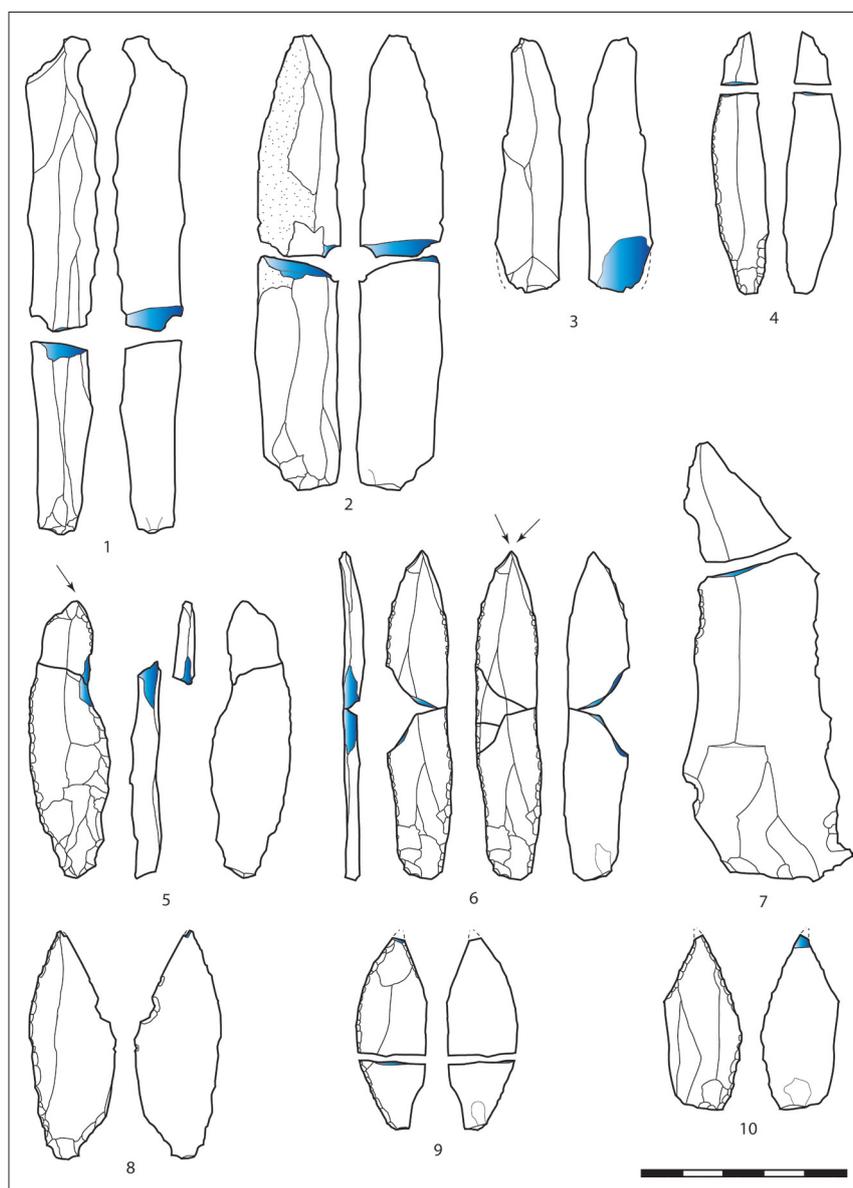


Fig. 8. Accidental fractures to experimental specimens. 1 - 3 due to removing the blade, 4 due to blunting, 5 - 6 due to a burin-blow, 7 - 10 due to trampling.

Abb. 8. Zufällige Brüche an experimentellen Stücken. 1 - 3 durch Klingenschlag, 4 durch Stumpfung, 5 - 6 durch Stichschlag, 7 - 10 durch Darauftreten.

commonly regarded as non-diagnostic for projectile traces by many analysts (Bergman & Newcomer 1983; Fischer et al. 1984; Odell & Cowen 1986; Caspar & De Bie 1996; Lombard 2005). However, other types of termination, such as feather, hinge and step, thought by Caspar & De Bie (1996) to be diagnostic of impact, were also produced by striking off the blades (Fig. 7). Furthermore, more than 20% of the fractures terminate in a step (Fig. 8, 1-2), which Fischer et al. (1984) regarded as a feature diagnostic of projectiles.

Soft stone percussion left somewhat lower frequencies of fractures. Of the 41 blades removed by soft stone hammer 20 specimens demonstrate fractures (Fig. 5). Altogether, 25 primary fractures were produced by the soft stone hammer, among which were no flute- and burin-like fractures (Fig. 7). Striking by a soft stone hammer often causes an

"*esquillement du bulbe*" (Pelegrin 2000, Fig. 3f), which was observed on four samples in this experiment. It may be worth noting that the scars rather resemble flute-like fractures when the percussion point is missing because of breakage (Fig. 8: 3). However, the impact induced flute-like fracture is basically distinguishable from an "*esquillement du bulbe*", since the impact flute-like fracture often initiates at the distal tip of artefacts. As in the case of the wooden hammer, the fractures produced are of transverse type and among these snap termination dominates (Fig. 7). While the frequency of transverse fractures of feather, hinge and step terminations is lower than those for the wooden hammer, their number is still appreciable. The number of the total "pseudo-impact fractures" (fracture types A, B and C1-3) reaches 20 pieces (43%) by wooden hammer and 9 pieces (22%) by soft stone

Blunting	n	%
Specimens with fractures	10	9
Specimens without fractures	105	91
Total	115	100
Burin-blow	n	%
Specimens with fractures	4	9
Specimens without fractures	39	91
Total	43	100

Fig. 9. Frequency of primary fractures produced during flake modification: blunting and burin-blow.

Abb. 9. Häufigkeit der primären Brüche bei Abschlagmodifikation: Stumpfung und Stichschlag.

hammer, an overall frequency of 33%. Consequently, it should be assumed that, in the case of transverse fractures of feather, hinge and step termination types, condition A1a (Fig. 4) is reproduced and that these fracture types on non-modified artefacts can not therefore be interpreted as diagnostic evidence for hunting.

The knapping of blades accidentally produced 14 spin-off fractures on the specimens struck by wooden hammer and 7 spin-off fractures using a soft stone hammer, but no bifacial spin-off fractures were produced on any of the specimens (Fig. 6). The spin-off fractures produced by wooden hammer measure 1 mm in average and a maximum of 2.7 mm, while those produced by soft stone hammer measure 2.0 mm in average and 4.7 mm maximum. These results do not contradict the claim of Fischer et al. (1984) that spin-off fractures larger than 6 mm are diagnostic for projectile traces.

Flake modification

Accidental fractures during lithic modification (retouch) were experimentally confirmed by Geneste & Plisson (1993) in the case of Solutrean shouldered points modified by pressure retouching. Their experimental specimens showed snap terminating transverse fractures both with and without finials (Cotterell & Kamminga 1986, 1987). In view of the considerable number of backed points excavated at Bois Laiterie, the present study examines the frequency of fracture occurrence during the production of backed points by blunting retouch.

Additionally, the possibility that a burin-blow can produce an unintentional medial fracture was tested. Some burins excavated from Magdalenian sites show transverse breakage or a Corbiac type facet, which often takes an s-shaped form. These fractures are bending fractures since they have no negative bulb on the surface and refits between fractured pieces prove that fractures occurred accidentally at the medial portion during the burin-blow. However, projectile experiments also produced similar fracture patterns (Fig. 3, 4-6). Several pieces from Bois Laiterie bear similar s-shaped fractures at their medial portion and this study therefore conducted experiments with the aim of confirming the frequency of accidental fractures produced during a burin-blow.

Of the total of 115 blunted pieces, just 10

Blunting	n	%
Primary fractures (PF)	10	100
PF with spin-off fractures	0	0
PF with bifacial spin-off fractures	0	0
Burin-blow	n	%
Primary fractures (PF)	6	100
PF with spin-off fractures	0	0
PF with bifacial spin-off fractures	0	0

Fig. 10. Frequency of spin-off fractures produced during flake modification: blunting and burin-blow.

Abb. 10. Häufigkeit der Nebenbrüche bei Abschlagmodifikation: Stumpfung und Stichschlag.

specimens generated fractures (Fig. 9), all of them breaking into two segments. Transverse fractures with snap termination dominate, with only one exception (Fig. 11). The overall frequency of fracture occurrence is just 8.7%, while the frequency of the single possibly "diagnostic impact fracture" is only 0.9%. Furthermore, the primary fractures were accompanied by no spin-off fractures (Fig. 10). Therefore, it would seem safe to claim that the experiments exclude the possibility that breakage during blunting could mimic "impact fracture".

Burin-blows were applied to a total of 43 specimens, the process continuing until the pieces either obtained a useful burin facet or fractured. 39 specimens were successfully modified into burins and four blanks broke into several segments (Fig. 9).

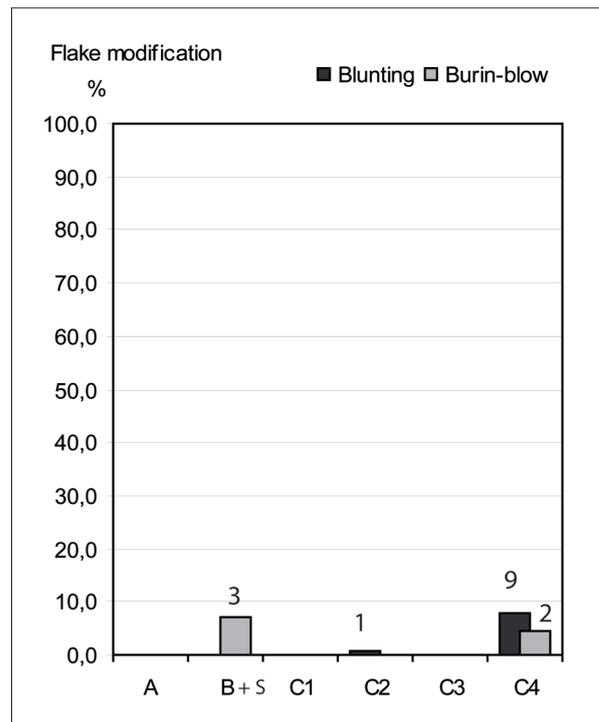


Fig. 11. Frequency of primary fracture types produced during flake modification: blunting and burin-blow. A: flute-like fracture, B: burin-like fracture, C: transverse fracture; C1: feather termination, C2: hinge termination, C3: step termination; C4: snap termination. S: s-shaped fracture.

Abb. 11. Häufigkeit der primären Bruchtypen bei Abschlagmodifikation: Stumpfung und Stichschlag. S: s-förmiger Bruch. A: rinnenartiger Bruch, B: stichelartiger Bruch, C: Querbruch; C1: spitzes Ende, C2: Angelende, C3: Stufenende; C4: durchgeschlagenes Ende.

Flakes trampled	n	%
Specimens with fractures	41	31
Specimens without fractures	92	69
Total	133	100
Points trampled	n	%
Specimens with fractures	19	14
Specimens without fractures	31	23
Total	50	37

Fig. 12. Frequency of primary fractures produced during trampling on flakes and backed points.

Abb. 12. Häufigkeit der primären Brüche durch Treten auf Abschläge und Rückenspitzen.

Two artefacts exhibit transverse fracture as a snap termination and two specimens show s-shaped and both s-shaped and burin-like fractures respectively (Fig. 8, 5, 6; Fig. 11). The fractures are similar to those which occurred during projectile experiments (Fig. 3, 4-7). Although the frequency of s-shaped and burin-like medial fractures is not very high, the experiments nonetheless suggest caution in the interpretation of artefacts with these types of medial fracture.

Trampling

Numerous trampling experiments have been carried out and the edge-damage formed, which could mimic deliberate modification ("pseudo-tools") has been repeatedly discussed (Tringham et al. 1974: 192; Flenniken & Haggarty 1979; Keeley 1980: 34-35; Gifford-Gonzales et al. 1985; Nielsen 1991; Shea & Klenck 1993; Midoshima 1994; McBrearty et al. 1998). However, few researchers have focused on fractures formed due to trampling (Fischer et al. 1984; Midoshima 1994). Trampling experiments were therefore performed in order to observe not only the edge-damage caused, but also the fractures and these results are presented in this paper.

133 flakes (including blades) and 50 backed points (a total of 183 specimens) were scattered on the ground over an area measuring approximately 50 x 50 cm. The backed points lay above the flakes. The lithic concentration was trampled by one person wearing rubber-soled shoes for 30 minutes with alternating transects crossing the concentration.

Fractures occurred on 41 flakes and on 19 backed points (Fig. 12). Most of the fractures on flakes are transverse fractures with snap termination, with just three feather termination fractures (2.3%) (Fig. 8: 7 & Fig. 14). In the case of the backed points, transverse fracture with snap termination is again the dominant fracture type, although possibly "diagnostic impact fractures" also occurred (including two flute-like fractures, one burin-like fracture and two transverse feather and step terminated fractures) (Fig. 8: 8-10; Fig. 14). Nevertheless, these latter fractures were all formed on a limited area of the tip and do not extend onto the medial portion, unlike in the case of true projectile specimens (Fig. 3: 1-9). Such restricted micro-damage should be excluded as diagnostic of impact fracture.

Flakes trampled	n	%
Primary fractures (PF)	41	100
PF with spin-off fractures	4	10
PF with bifacial spin-off fractures	0	0
Points trampled	n	%
Primary fractures (PF)	19	100
PF with spin-off fractures	3	16
PF with bifacial spin-off fractures	0	0

Fig. 13. Frequency of spin-off fractures produced during trampling on flakes and backed points.

Abb. 13. Häufigkeit der Nebenbrüche durch Treten auf Abschläge und Rückenspitzen.

Spin-off fractures occur on seven of the total of 60 specimens with primary fractures. The spin-off fractures measure 0.8 mm in average with a maximum of 1.2 mm and are all formed on only one side. There are thus neither projectile-diagnostic unifacial spin-off fractures larger than 6 mm nor bifacial spin-off fractures.

Evaluation of the experiments: diagnostic impact fractures

The experiments in this study show that flake blunting (retouch) and trampling produce mainly transverse fractures with snap termination and only infrequently exhibit pseudo-impact fractures, such as flute-like, burin-like and transverse fractures with feather, hinge and step terminations. Moreover, neither bifacial spin-off fractures nor unifacial spin-off fractures larger than 6 mm were produced on the specimens. It is worth

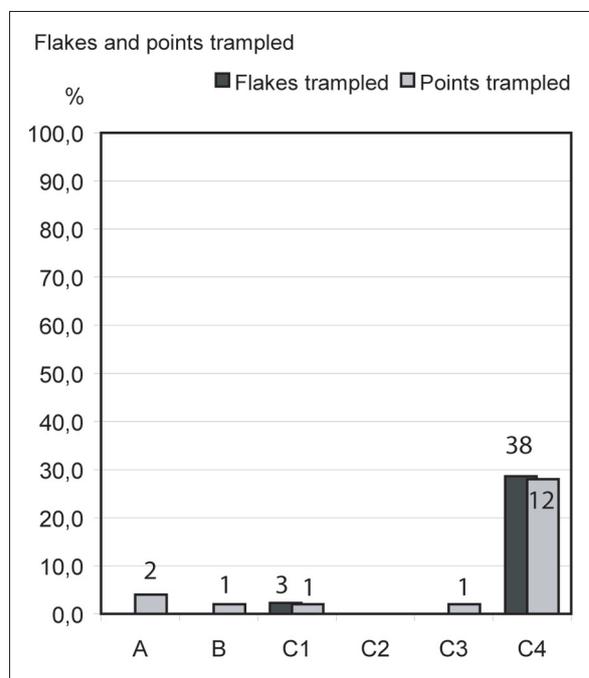


Fig. 14. Frequency of primary fracture types produced during trampling on flakes and backed points. A: flute-like fracture, B: burin-like fracture, C: transverse fracture; C1: feather termination, C2: hinge termination, C3: step termination; C4: snap termination.

Abb. 14. Häufigkeit der primären Bruchtypen durch Treten auf Abschläge und Rückenspitzen. A: rinnenartiger Bruch, B: stichelartiger Bruch, C: Querbruch; C1: spitzes Ende, C2: Angelende, C3: Stufenende; C4: durchgeschlagenes Ende.

noting that while tiny flute-like and burin-like fractures due to trampling may occur infrequently at the tip of backed points, the large flute- and burin-like fractures which can be seen in the projectile samples were never produced.

Application of the burin-blow left two s-shaped medial fractures and one burin-like medial fracture. While this fracture type appeared experimentally at only a relatively low frequency, we should pay particular attention to the morphology of the artefacts were this fracture type to be found on archaeological specimens. Consequently, it might be summarized that, with the exception of the tiny flute- and burin-like fractures on the tip of backed points and the s-shaped or burin-like fractures at the medial portion of artefacts, flake modification and trampling basically produced no specimens which mimic impact fractures.

However, blade production often automatically creates pseudo-impact fractures. Whereas flute-like and burin-like fractures, unifacial spin-off fractures larger than 6 mm and bifacial spin-off fractures never occurred during blade production, a significant number of specimens did show transverse fractures

with feather, hinge and step terminations. This result warns that transverse fractures with feather, hinge and step terminations cannot automatically be accepted as evidence for impact fracture if the specimens were not or only slightly retouched.

To sum up, while possibility A2a was rejected in the case of trampling (Fig. 4), possibility A1a must be partially accepted, since at least the transverse fractures with feather, hinge and step terminations can be produced during blade production. At a positive level, this means that other fracture types, specifically flute- and burin- like fractures, unifacial spin-off fractures larger than 6 mm and bifacial spin-off fractures, can be accepted as diagnostic of impact (even if specimens are not modified into points by retouching), since these features have never arisen during blade production or due to flake trampling.

The possibilities shown by conditions A1b and A2b (Fig. 4) can be almost totally rejected, with some exceptions, such as the tiny flute- and burin-like fractures at the tip of backed points and the s-shaped or burin-like fracture of the medial portions of artefacts. The former fractures should be rejected as diagnostic and the s-shaped and burin-like fractures

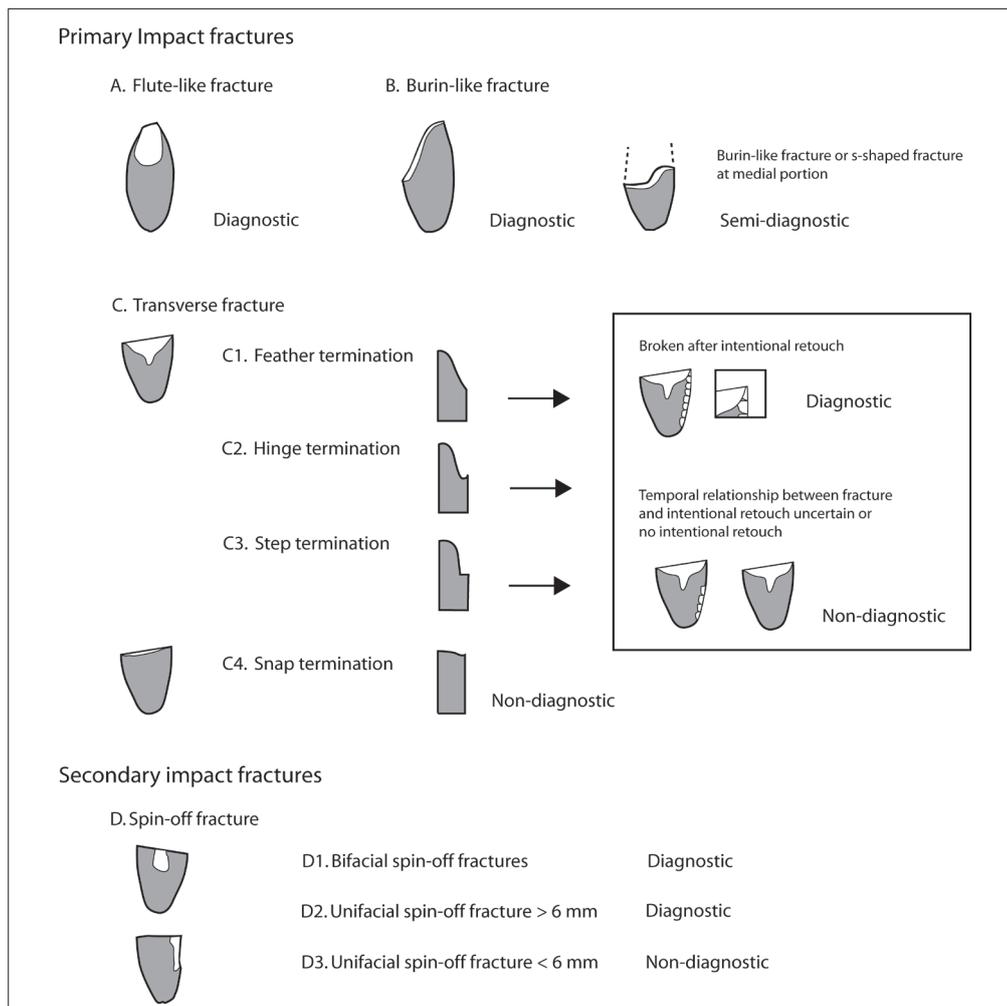


Fig. 15. Diagnostic, semi-diagnostic and non-diagnostic impact fractures.

Abb. 15. Diagnostische, teildiagnostische und nichtdiagnostische Aufprallbrüche.

of the medial portion must be considered relative to the morphology of the artefacts. In the case of modified (retouched) artefacts, should it be demonstrated that transverse fracture with feather, hinge and step termination occurred subsequently to the lateral retouching, these fracture patterns could also be interpreted as due to use as hunting tools in addition to the automatically diagnostic flute- and burin-like fracture types.

In conclusion, the experiments conducted during this study reveal that the following fracture types are reliable diagnostic evidence for projectile impact (Fig. 15). Flute- and burin-like fractures of a certain dimension are definitely diagnostic traces. Additionally, bifacial spin-off fractures and unifacial spin-off fractures longer than 6 mm are certainly diagnostic for impact evidence, as was concluded by Fischer et al. (1984). Evaluation of the transverse fractures with feather, hinge and step terminations depends on the temporal relationship between the fracture and the intentional retouch along the lateral sides of the piece. If these fractures were produced after the intentional retouch, they would be regarded as diagnostic for impact, since flake modification (retouch) and trampling have hardly induced these types of fracture. On the contrary, if the temporal relationship is uncertain or the specimens show no deliberate retouch of the lateral sides, these fracture types can not be considered reliable diagnostic impact fractures, as they could equally have formed spontaneously during blade production and only then have been retouched for utilisation of the unwillingly fractured pieces.

Results

Sample

Giner (1997) already carried out a traceological analysis of a total of 24 specimens from Bois Laiterie; however, the sample for his study includes only two lithic points and two backed bladelets. For the present

study, all of the excavated lithic artefacts (excluding the collections in the permanent exhibition and micro-debitage) were scanned and a total of 256 samples selected for traceological analysis. (These samples were analysed based on the High Power Approach and Low Power Approach. The results of these analyses are under preparation for publication.)

Microscopic linear impact traces (MLITs) which are useful for identifying hunting marks (see Moss 1983a; Fischer et al. 1984) were also analysed at magnifications ranging from 100x to 400x using a metallographic microscope, but the surfaces of most of the samples were so patinated that a microscopic analysis was impracticable. No MLITs were identified on the relatively fresh surface of some samples. The material was also examined for hafting wear based on distinctive traces, such as bright spots within scarring and on the convex surface (Rots 2003, 2004). But again, the heavy patina on the lithic surface prevented identification of hafting evidence. Therefore, this paper presents only the results of the fracture analysis of backed bladelets, backed points, blades and fragments for which diagnostic impact fractures were documented. The sample treated here consists of 76 backed bladelets, 22 backed points and 66 blades (including fragments). The backed points include a variety of morphological types and some of them might be classified as *bipointes* (Fig. 16: U5-65). Blades and fragments include completely or partially retouched as well as non-retouched pieces.

Artefacts with diagnostic impact fractures

Fracture analysis revealed that most of the backed points found at Bois Laiterie have been utilised for hunting. Diagnostic impact fractures were observed on 54.2% of the backed points (Fig. 17). Fig. 18 provides five examples of hunting evidence in the form of flute- and burin-like fractures. Specimen U6-256.2 bears a flute-like fracture with large

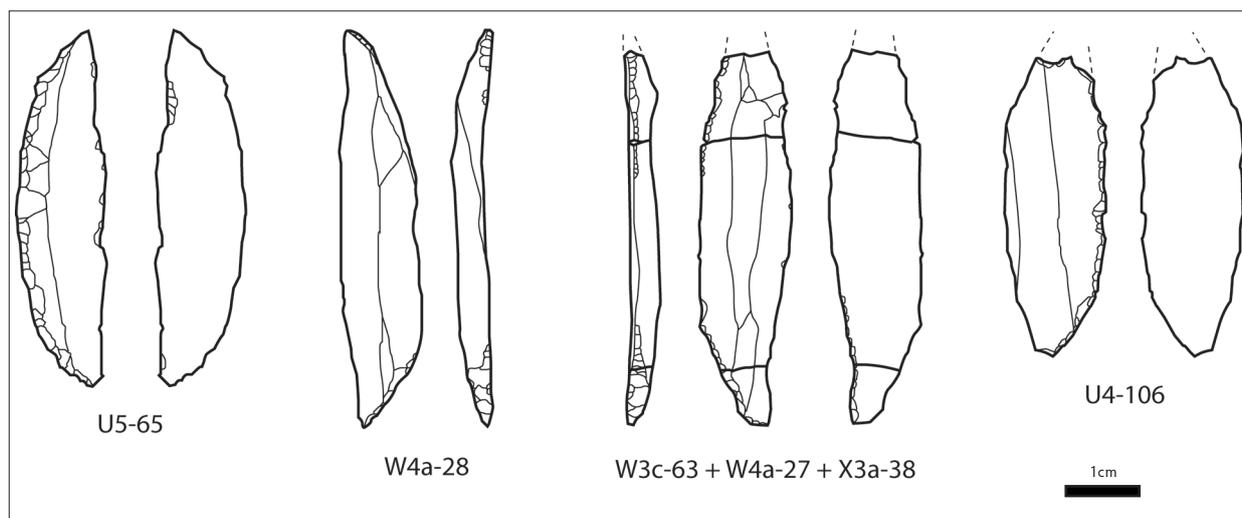


Fig. 16. Backed points from Bois Laiterie.
 Abb. 16. Rückenspitzen von Bois Laiterie.

	NAS	DIF	%	SDIF	%	NDIF	%
Backed points	22	13	54	1	4	8	33
Blades and fragments (with/without retouch)	66	13	20	3	5	50	76
Backed bladelets	76	24	32	0	0	52	68
Total	164	50	31	4	2	110	67

Fig. 17. Results of the macrofracture analysis. NAS = Number of analysed samples, DIF = number of artefacts with diagnostic impact fractures, SDIF = number of artefacts with semi-diagnostic impact fractures, NDIF = number of artefacts with no diagnostic impact fractures.

Abb. 17. Ergebnisse der Makrobruchanalyse. NAS = Anzahl analysierter Proben, DIF = Anzahl Artefakte mit diagnostischen Impaktfrakturen, SDIF = Anzahl Artefakte mit teil-diagnostischen Impaktfrakturen, NDIF = Anzahl Artefakte ohne diagnostische Impaktfrakturen.

dimensions which was never produced on any experimental specimen in this study. The burin-like fracture on the tip of specimen V3-33 is also well developed, unlike the samples produced by trampling (Fig. 8: 8).

The burin-like fractures on U4-113 and V2-7.2 are

not well developed; however, both the specimens present more than one diagnostic impact fracture: U4-113 has four burin-like fractures and the burin-like fracture of V2-7.2 is accompanied by a spin-off fracture and a cluster of small flute-like fractures on

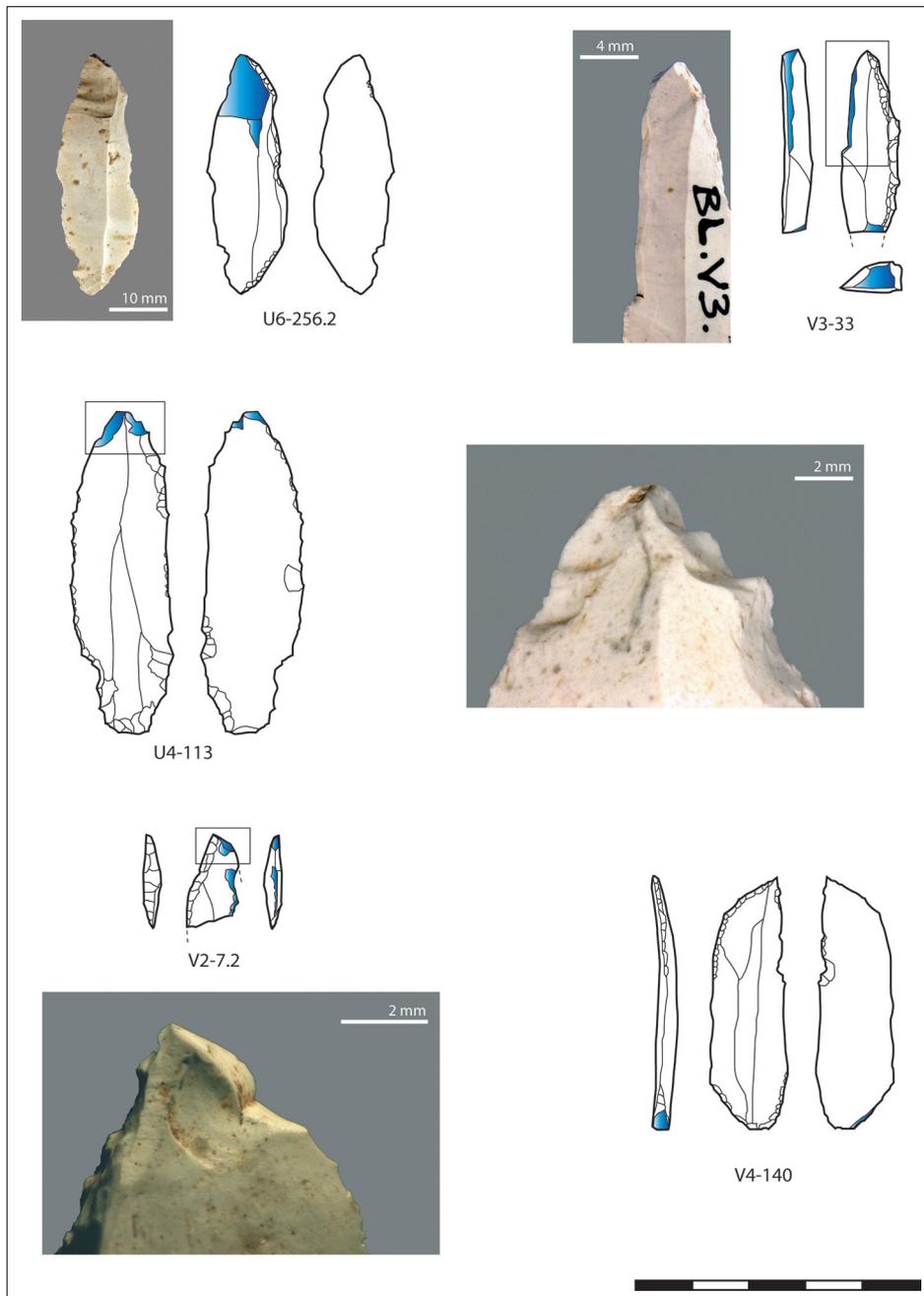


Fig. 18. Backed points with diagnostic impact fractures.

Abb. 18. Rückenspitzen mit diagnostischen Aufprallbrüchen.

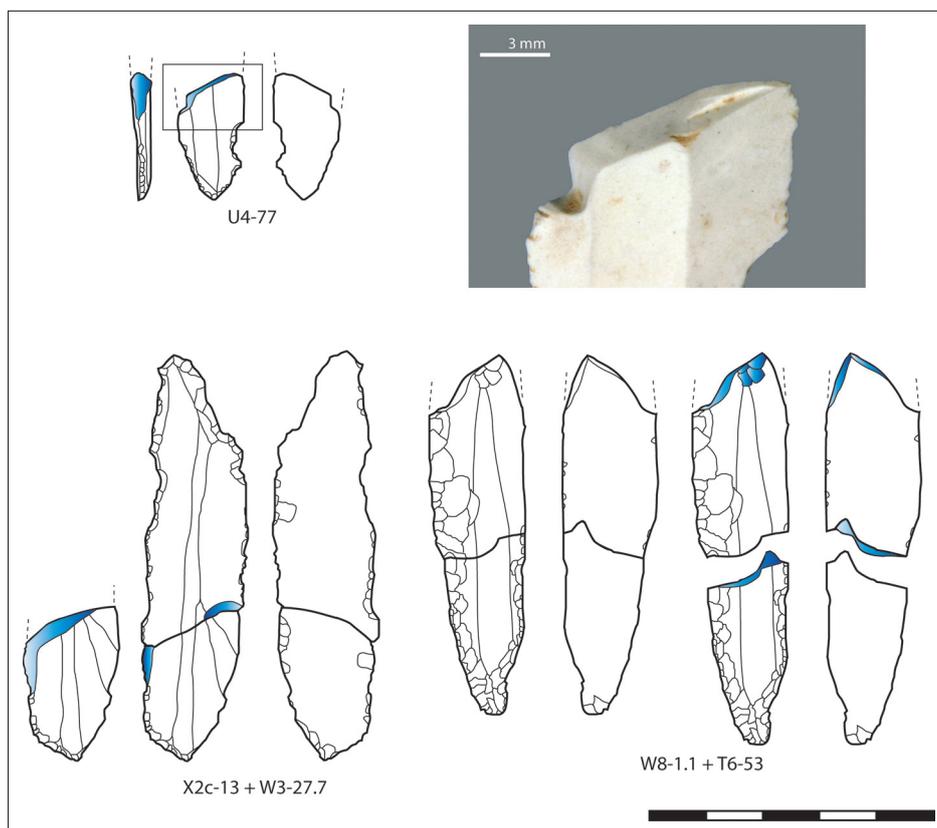


Fig. 19. Backed points and retouched blades with semi-diagnostic impact fractures.

Abb. 19. Rückenspitzen und retuschierte Klingen mit teildiagnostischen Aufprallbrüchen.

the lateral side. The retouch on the right base of specimen V4-140 was applied after formation of the burin-like fracture at this proximal end, which may suggest that this backed point was rejuvenated at Bois Laiterie Cave. An s-shaped fracture is also present on the medial portion of one backed point (Fig. 19: U4-77). Although the s-shaped fracture alone should not be regarded as a clear indicator for hunting, from the morphological point of view, the fracture is likely to have occurred due to impact.

33.3% of the backed points show no diagnostic impact fractures. However, this does not mean that these points have not been fired against animal targets, since a high ratio of experimental projectile points also acquire only transverse fractures with snap terminations or no impact fractures at all (Fischer et al. 1984; Midoshima 1991, 1996a; Crombé et al. 2001; Lombard et al. 2004; Sakashita 2006).

19.7% of the sample of blades and fragments in the Bois Laiterie assemblage bears damage probably due to projectile impact (Fig. 17). As most of the blades and fragments show no clear temporal relationship between the fractures and lateral retouch, or show no intentional retouch along their lateral sides, transverse fractures with feather, hinge and step terminations on these specimens cannot be accounted for by impact.

Specimen U3-55 exhibits a burin-like fracture at the tip and a small flute-like fracture on the dorsal surface of the opposite end (Fig. 20) and these traces can demonstrate a function as a hunting weapon,

though this blade has not undergone any intentional modification. T6-33 refits to U7-63.1 and shows that this piece has broken across the medial portion with an s-shaped fracture (Fig. 20). In addition, the specimen bears a flute-like fracture, as well as a transverse fracture with step termination at the distal end and another flute-like fracture at the proximal end. The combination of s-shaped and flute-like fracture was also observed on the samples W2c-33 and V7-68. While the formation of an s-shaped fracture alone remains equivocal evidence for projectile use, the existence of multiple fractures indicates that the damage resulted from hunting.

On the contrary, samples W2c-13 + W3-27.7 and W8-1.1 + T6-53 (Fig. 19) are example in which s-shaped fractures were possibly due to a burin-blow. There are striking scars and abrasion at the proximal ends of both specimens and, additionally, the morphology of both proximal ends might be accounted due to their preparation for the burin-blow. Whilst the burin-like and s-shaped fracture with numerous spin-off fractures on the upper part of the medial portion (Fig. 19: W8-1.1 + T6-53) might be designated impact marks, this interpretation remains open to question, since the number of experimental samples with the s-shaped or burin-like fractures at the medial portion is still insufficient for certainty here.

Among the total of 76 backed bladelets analysed, approximately one third of the samples exhibits diagnostic impact fractures (Fig. 17). As the backed

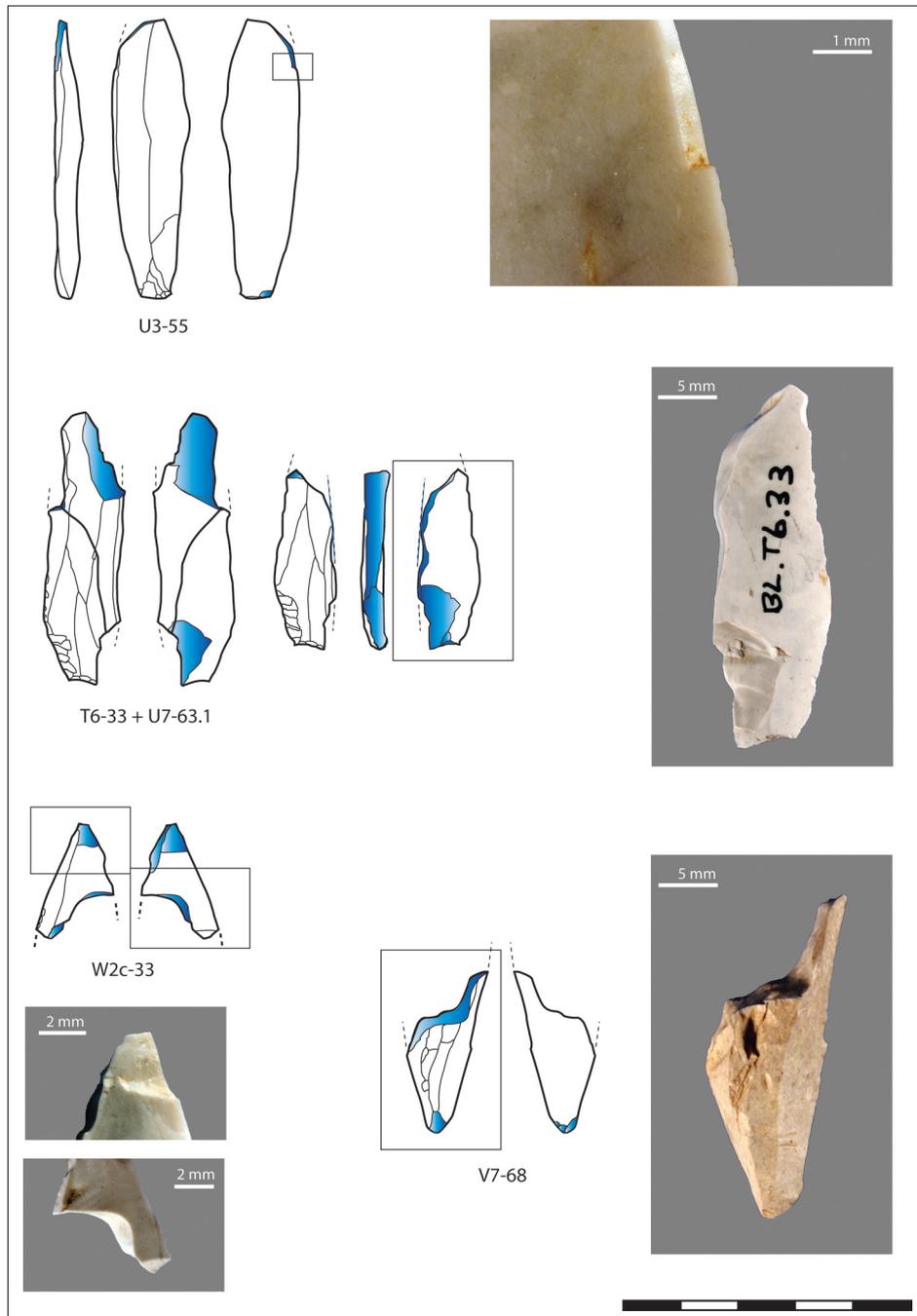


Fig. 20. Blades and fragments with diagnostic and semi-diagnostic impact fractures.

Abb. 20. Klingen und Fragmente mit diagnostischen und teildiagnostischen Aufprallbrüchen.

bladelets were most probably intentionally broken before they were inserted into the shaft, the largest number of backed bladelets shows snap terminating transverse fractures. Presumably for this reason, the flute- and burin-like fractures observed on the backed bladelets are predominantly initiated from the transverse fractures and it is therefore difficult to decide whether they are spin-off fractures or "primary" fracture owing to impact.

Fig. 21 shows examples of backed bladelets interpreted as projectile items. Specimens W10b-71 and U5-26.1 bear diagnostic impact fractures, such as flute-like fracture (W10b-71) and burin-like fracture

(U5-26.1). The transverse fractures with step termination on specimens V4-40.1 and V3-104 interrupt the blunting on the lateral side and this damage therefore probably occurred through projectile impact.

Non-diagnostic fractures or no fractures were observed on 67.1% of the backed blades. However, as mentioned above, this does not mean that none of these pieces were used for hunting tools. Projectile experiments by Crombé et al. (2001) showed that lithic points fixed as barbs exhibited impact damage at a very low frequency. The lower frequency of diagnostic impact fractures on backed bladelets contrasted with that on backed points in the Bois

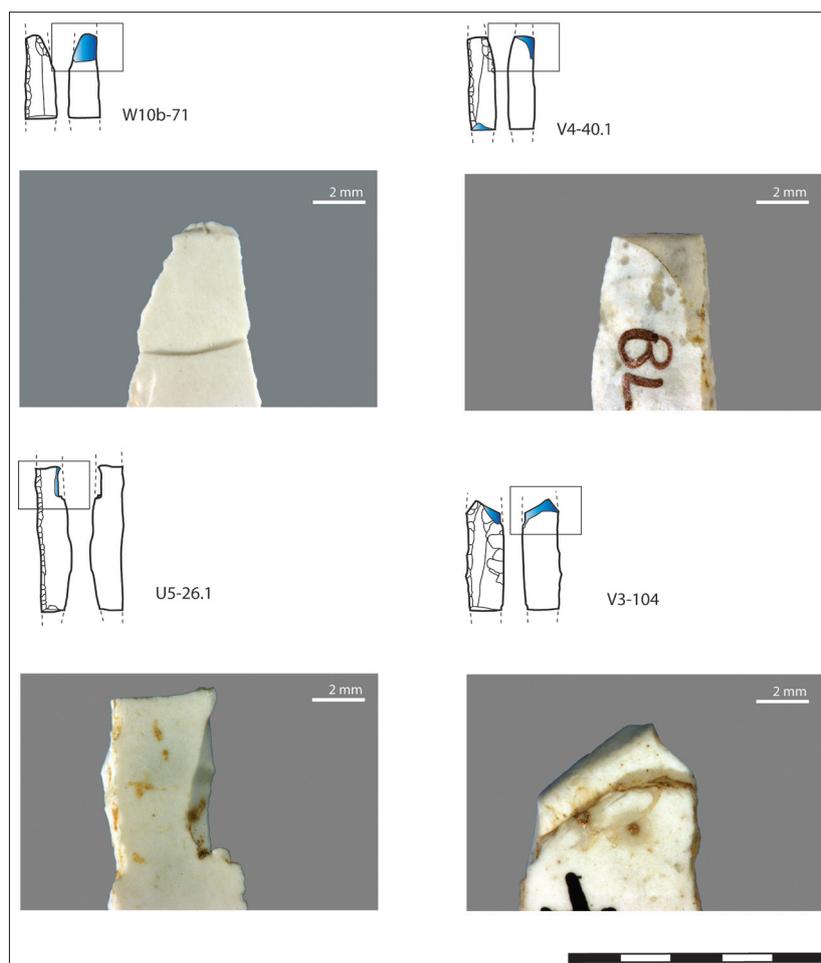


Fig. 21. Backed bladelets with diagnostic impact fractures.

Abb. 21. Rückenmesser mit diagnostischen Aufprallbrüchen.

Laiterie assemblages might result from attaching them as barbs or be due to their small dimensions, however, further interpretations should wait until additional experiments with backed bladelets have been carried out, since the frequency of diagnostic impact fracture occurrence on backed bladelets is still uncertain due to the limited experimental work done on this aspect (Moss & Newcomer 1982).

Discussion

Straus & Otte (1998) deduced that Bois Laiterie served as a short-term occupation site, since the site is small, dark, humid and therefore uncomfortable cave. The lack of constructed hearths and other pits as well as the limited number of lithic and organic artefacts and faunal remains recovered also encouraged this interpretation. The excavators recognised no evidence for long-term and multi-purpose residence. Moreover, abundant backed bladelets and several lithic and antler points suggest that hunting activities must have been very important around the cave.

The results of the fracture analysis presented here support their hypothesis. A total of 50 lithic artefacts displayed clear hunting evidence. The number of

specimens with diagnostic impact fractures reflects only a minimum number for the lithic artefacts which have been used for hunting, since the fractures presented in this study as diagnostic are strictly established as typical for damage during impact of hunting projectile points and which never or hardly occurs due to other agencies. Consequently, some fracture types which can also often form due to projectile impact are disqualified from consideration. Hence, a much large number of artefacts may have been potentially shot into game; that is, a considerable proportion of lithic specimens from Bois Laiterie must have been involved with hunting.

It is worth noting the fact that broken projectile points were brought from hunting locations to the Bois Laiterie Cave. Keeley (1982) paid much attention to the economics of hafting and introduced a number of ethnographic studies which document that hunters tried to gather up their arrows since manufacture of a shaft needs much effort and time than that of a point. Shafts are in general curated tools because of the costs and therefore require maintenance in order to be used over a longer period. The broken projectile head must be replaced with a new one, or alternatively removed, rejuvenated and then fixed onto the shaft

again. The replacing of projectile tips was probably conducted near a hearth because the adhesive needed to be heated to melt it and this might lie behind the observation that numerous backed bladelets are often recovered around hearths (Moss & Newcomer 1982). Following the same logic, fragmented projectile heads which cannot be resharpened would have been discarded at the place where hunters replaced them. Hence, artefacts upon which diagnostic impact fractures are confirmed should be distributed around the hearth.

Although no stable constructions were found in the Bois Laiterie Cave, "latent structures" were reconstructed based on the distribution of stone plaques and burned objects (Straus & Martinez 1997). The burned bones and flints show a concentration outside the cave mouth to the right of the terrace and this area of burning (centred on V-W/4-3) was surrounded by plaques. In addition, this area overlaps with a dense distribution zone of lithic debris and faunal remains. Straus & Martinez (1997) supposed that the concentration of the burned materials

indicates "bonfire building" which was simply built on the surface of the rock shelter.

Figure 22 shows the distribution of the lithic artefacts bearing diagnostic impact fractures and it can be seen that the greater number of such specimens was distributed over the area in which the burned objects were concentrated. The fact that not only backed bladelets but also backed points and blades/fragments relate to the traces of fire may support the supposition that projectile maintenance has been conducted around fire. The used projectiles were most likely transported to the cave with hunted game, some of them perhaps embedded in the carcasses. The hunters may have then simply lit a fire and replaced the damaged projectile points next to this.

The burins and some of the blades recovered at Bois Laiterie may have been used for repairing the projectiles. The appreciable number of truncations might be due to re-modification of broken lithic points, since Witthoft notes that truncation is "...a common method of re-pointing projectile points

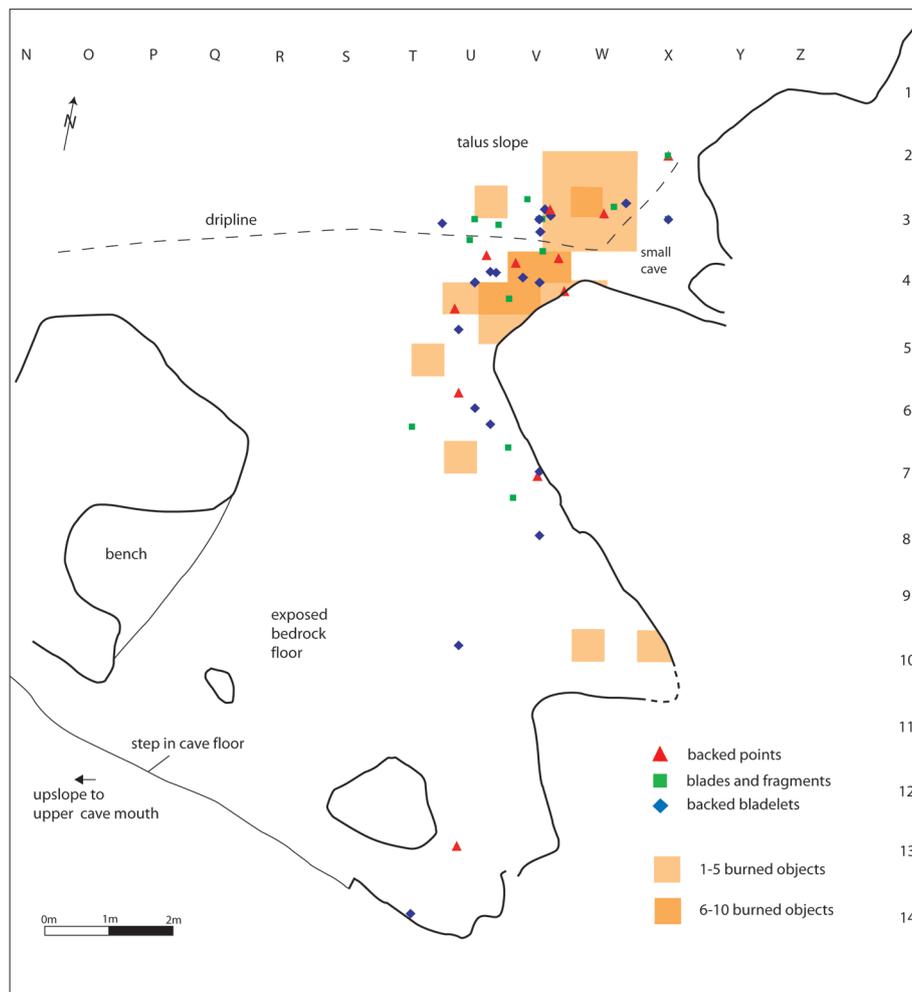


Fig. 22. Spatial distribution of lithic artefacts with diagnostic impact fractures (plan after Straus 1997a, Fig. 21; distribution of burned objects after Straus & Martinez 1997, Fig. 29).

Abb. 22. Räumliche Verteilung der Steinartefakte mit diagnostischen Aufprallbrüchen (Plan nach Straus 1997a, Fig. 21; Verteilung der verbrannten Stücke nach Straus & Martinez 1997, Fig. 29).

when a broken tip was repaired in the field" (Witthoft 1968). Further to these activities involving projectiles, some of the stages of carcass processing would probably have taken place at the cave. Indeed, the lateral sides of one end scraper which preserves an unpatinated surface exhibit traces of butchery in the form of "bone-polish" (which is partially formed, with striations on the high spots of the surface), polish from contact with hide and "generic weak polish" (Vaughan 1986). However, the limited number of the faunal remains and the butchery marks upon them suggest that the main sequence of carcass processing did not take place here but elsewhere, unless this scarcity of evidence is the result of taphonomic factors. Many portions of the hunted carcasses were probably transported to a residential camp and consumed there. This scenario of the Bois Laiterie Cave provides a distinct contrast with the results of the analysis of the large mammal assemblage from the Trou de Chaleux (Charles 1998), which revealed that a variety of large mammal species was exploited at this cave. Furthermore, analysis of the representation of body parts indicated that the preliminarily butchery of horse carcasses had already taken place elsewhere and only selected elements of them brought to the cave. Moreover, the large numbers of pièces esquillées (21 after Straus & Orphal 1997) which may imply a longer duration of the occupation (Löhr 1979) might support the interpretation of Chaleux as a residential camp. By contrast, Bois Laiterie provided just two pièces esquillées. The two contrasting cave sites may thus provide a glimpse of complementary site functions within the Magdalenian subsistence strategies of this region.

Conclusion

Examining fracture patterns based on experiments into spontaneous fracture during flake production, due to modification and by trampling made it possible to identify more reliable diagnostic criteria for impact fracture. Furthermore, this even allows the identification of impact marks on lithic artefacts with no morphological indication that they were projectiles.

Fracture analysis based on the identified diagnostic impact fractures demonstrates the validity of the previously proposed hypothesis that "Bois Laiterie was fundamentally a hunting camp" (Straus 1997b; Straus & Otte 1998). The reliable and quite considerable evidence for hunting identified on backed bladelets and backed points, as well as on blades and fragments, indicates that the Magdalenian occupation at this small cave was indeed closely related to hunting activities.

Bois Laiterie illustrates one important component of the overall Magdalenian settlement-subsistence system in north-western Europe. The small cave might have been one of the important stations on the route

between quarry work shops at the flint sources located downstream (e.g., Eysersheide, Schweikhuizen, Mesch, Kanne and Orp) and the cave-rich area upstream containing e.g. the site of Trou de Chaleux (Straus & Otte 1998). During journeys between these regions, Magdalenian humans may naturally have needed to hunt and the Bois Laiterie site might have been occupied specifically for this purpose. Alternatively, Bois Laiterie may represent a logistic camp at which a party of hunters stopped, probably repeatedly, while travelling between their base camp and hunting locations.

ACKNOWLEDGEMENTS: I thank Marcel Otte and Lawrence Guy Straus for permission to examine the lithic assemblages from the Bois Laiterie Cave and to publish the results. I am also grateful to Rebecca Miller for her kind help and arrangement of the raw data of lithic artefacts. I am thankful to Jürgen Richter and Akira Ono for their attention to my research and their constant support. Thanks are due to Ursula Tegtmeier for technological support with the equipment used for the traceological analysis. I further thank Sonja B. Grimm and Luc Moreau for comments on and discussion of my work. Special thanks are due to Martin Street and Werner Müller for proof reading of this paper. A draft of this paper profited from comments by two anonymous reviewers. I am grateful to Midoshima Tadashi for teaching me the basic method of the traceological analysis and to Eric Boëda for showing me the Magdalenian blade production method. For all remaining mistakes only I am responsible. This study contains a part of my Ph.D. research and I thank the Deutscher Akademischer Austauschdienst (DAAD) for a fellowship that made it possible for me to carry out my Ph.D. study in Germany.

Literature cited

- Ahler, S. A. & McMillan, R. B. (1976). Material culture at Rodgers Shelter: a reflection of past human activities. In: W. R. Wood & R. B. McMillan (Eds.) *Prehistoric man and his environments. A case study in the Ozark Highland*. Academic Press, New York, 163-199.
- Barton, R. N. E. & Bergman, C. A. (1982). Hunters at Hengistbury: Some evidence from experimental archaeology. *World Archaeology* 14: 237-248.
- Bergman C. A. & Newcomer, M. H. (1983). Flint arrowhead breakage: Examples from Ksar Akil, Lebanon. *Journal of Field Archaeology* 10: 238-243.
- Boëda, E., Geneste, J. M., Griggo, C., Mercier, N., Muhesen, S., Reyss, J. L., Taha, A. & Valladas, H. (1999). A Levallois point embedded in the vertebra of a wild ass (*Equus africanus*): hafting, projectiles, and Mousterian hunting weapons. *Antiquity* 73: 394-402.
- Brink, J. (1978). Notes on the occurrence of spontaneous retouch. *Lithic Technology* 7: 31-33.
- Burroni, D., Donahue, R. E. & Pollard M. (2002). The surface alteration features of flint artefacts as a record of environmental processes. *Journal of Archaeological Science* 29: 1277-1287.
- Byrne, L., Ollé, A. & Vergès, J. M. (2006). Under the hammer: residues resulting from production and microwear on experimental stone tools. *Archaeometry* 48: 549-564.
- Caspar, J.-P. & De Bie, M. (1996). Preparing for the hunt in the late Paleolithic camp at Rekem, Belgium. *Journal of Field Archaeology* 23: 437-460.
- Charles, R. (1996). Back into the north: the radiocarbon evidence for the human decolonisation of the north-western Ardennes after the last glacial maximum. *Proceedings of the Prehistoric Society* 62: 1-17.

- Charles, R. (1998). *Late Magdalenian chronology and faunal exploitation in the north-western Ardennes*. BAR International Series 737, Oxford.
- Cotterell, B. & Kamminga, J. (1986). Finials on stone flakes. *Journal of Archaeological Science* 13: 451-461.
- Cotterell, B. & Kamminga, J. (1987). The formation of flakes. *American Antiquity* 52: 675-708.
- Courty, M.-A. (1997). Etude micro-stratigraphique de la Grotte du Bois Laiterie. In: M. Otte & L. G. Straus (Eds.) *La Grotte du Bois Laiterie*. ERAUL 60, Liège, 113-140.
- Crabtree, D. E. (1968). Mesoamerican polyhedral cores and prismatic blades. *American Antiquity* 33: 446-478.
- Crombé, P., Perdaen, Y., Seragnt, J. & Caspar, J.-P. (2001). Wear analysis on early Mesolithic microliths from the Verrebroek site, East Flanders, Belgium. *Journal of Field Archaeology* 28: 253-269.
- Donahue, R. E. & Burrioni, D. B. (2004). Lithic microwear analysis and the formation of archaeological assemblages. In: E. A. Walker, F. Wenban-Smith & F. Healy (Eds.) *Lithics in action*. Papers from the conference Lithic Studies in the year 2000. Oxbow Books Lithic Studies Society Occasional Paper No. 8, Oxford, 140-148.
- Fischer, A., Hansen, P. V. & Rasmussen, P. (1984). Macro and micro wear traces on lithic projectile points. *Journal of Danish Archaeology* 3: 19-46.
- Flenniken, J. J. & Garrison, E. G. (1975). Thermally altered novaculite and stone tool manufacturing techniques. *Journal of Field Archaeology* 2: 125-131.
- Flenniken, J. J. & Haggerty, J. C. (1979). Trampling as an agency in the formation of edge damage: An experiment in lithic technology. *Northwest Anthropological Research Notes* 13: 208-214.
- Frison, G. C. (1974). *The Casper site*. Academic Press, New York.
- Gautier, A. (1997). The macromammal remains of la Grotte du Bois Laiterie. In: M. Otte & L. G. Straus (Eds.) *La Grotte du Bois Laiterie*. ERAUL 60, Liège, 177-196.
- Gaudzinski, S. & Street, M. (2003). Reconsidering hunting specialisation in the German Magdalenian faunal record. In: S. Costamagno & V. Laroulandie (Eds.) *Mode de vie au Magdalénien: Apports de l'archéozoologie*. Acts of the XIVth UISPP Congress, University of Liège, Belgium, 2-8 September 2001, Colloque/Symposium 6.4. BAR International Series 1144, Oxford, 11-21.
- Geneste, J.-M. & Plisson, H. (1993). Hunting technologies and human behavior: Lithic analysis of Solutrean shouldered points. In: H. Knecht, A. Pike-Tay & R. White (Eds.) *Before Lascaux: The complex record of the early Upper Paleolithic*. CRC Press, Boca Raton, Ann Arbor, London, Tokyo, 117-135.
- Gero, J. M. (1978). Summary of experiments to duplicate post-excavational damage to tool edges. *Lithic Technology* 7: 34.
- Gifford-Gonzalez, D. P., Damrosch, D. B., Damrosch, D. R., Pryor, J. & Thunen, R. L. (1985). The third dimension in site structure: an experiment in trampling and vertical dispersal. *American Antiquity* 50: 803-818.
- Giner, P. J. (1997). Analyse tracéologique du matériel lithique de la Grotte du Bois Laiterie. In: M. Otte & L. G. Straus (Eds.) *La Grotte du Bois Laiterie*. ERAUL 60, Liège, 325-327.
- Grace, R. (1989). *Interpreting the function of stone tools. The quantification and computerisation of microwear analysis*. BAR International Series 474, Oxford.
- Huckell, B. B. (1982). The Denver Elephant project: a report on experimentation with thrusting spears. *Plains Anthropologist* 27: 217-224.
- Hutchings, W. K. (1999). Quantification of fracture propagation velocity employing a sample of Clovis channel flakes. *Journal of Archaeological Science*: 1437-1447.
- Keeley, L. H. (1980). *Experimental determination of stone tool uses: A microwear analysis*. The University of Chicago Press, Chicago, London.
- Keeley, L. H. (1982). Hafting and retooling: effects on the archaeological record. *American Antiquity* 47: 798-809.
- Kelterborn, P. (1999). Analysen und Experimente zu Herstellung und Gebrauch von Horgener Pfeilspitzen. *Jahrbuch der Schweizerischen Gesellschaft für Ur- und Frühgeschichte* 83: 37-64.
- Levi-Sala, I. (1986). Use wear and post-depositional surface modification: a word of caution. *Journal of Archaeological Science* 13: 229-244.
- Levi-Sala, I. (1993). Use-wear traces: processes of development and post-depositional alterations. In: P. C. Anderson, S. Beyries, M. Otte & H. Plisson (Eds.) *Traces et fonction: les gestes retrouvés*. Actes du colloque international de Liège 8-9-10 décembre 1990. Volume 2. ERAUL 50, Liège, 401-416.
- Löhr, H. (1979). *Der Magdalénien-Fundplatz Alsdorf, Kreis Aachen-Land. Ein Beitrag zur Kenntnis der funktionalen Variabilität jungpaläolithischer Stationen*. Ph.D. dissertation, Universität Tübingen.
- Lombard, M. (2005). A method for identifying Stone Age hunting tools. *South African Archaeological Bulletin* 60: 115-120.
- 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. *South African Journal of Science* 100: 159-166.
- Longo, L. & Skakun, N. (2008). Introduction. In: L. Longo & N. Skakun (Eds.) *'Prehistoric technology' 40 years later: Functional studies and the Russian legacy*. Proceedings of the International Congress Verona (Italy), 20-23 April 2005. BAR International Series 1783, Oxford, ix-xiii.
- McBrearty, S., Bishop, L., Plummer, T., Dewar, R. & Conard, N. (1998). Tools underfoot: human trampling as an agent of lithic artifact edge modification. *American Antiquity* 63: 108-129.
- Midoshima, T. (1991). Collisional flaking of the stone arrowhead and tanged point. *Kodai* 92: 79-97 (in Japanese).
- Midoshima, T. (1994). Influence of trampling on lithic artifacts. *Kyusekki-Kokogaku* 48: 43-55 (in Japanese with English summary).
- Midoshima, T. (1996a). Projectile experiments with backed points. *Kanagawa-Koko* 32: 77-96 (in Japanese).
- Midoshima, T. (1996b). Spontaneous retouch as a possible cause of 'edge damage' on flakes. *Kyusekki-Kokogaku* 52: 13-25 (in Japanese with English summary).
- Midoshima, T. (2001). Experimental archaeology as traceology: examples of heat treatment in stone artefact production. *Kokogaku-Journal* 479: 9-12 (in Japanese).
- Moss, E. H. (1983a). *The functional analysis of flint implements. Pincevent and Pont d'Ambon: two case studies from the French final Palaeolithic*. BAR International Series 177, Oxford.
- Moss, E. H. (1983b). Some comments on edge damage as a factor in functional analysis of stone artefacts. *Journal of Archaeological Science* 10: 231-242.
- Moss, E. H. & Newcomer, M. H. (1982). Reconstruction of tool use at Pincevent: Microwear and experiments. *Studia Praehistorica Belgica* 2: 289-312.
- Nielsen, A. E. (1991). Trampling the archaeological record: an experimental study. *American Antiquity* 56: 483-503.
- Noe-Nygaard, N. (1974). Mesolithic hunting in Denmark illustrated by bone injuries caused by human weapons. *Journal of Archaeological Science* 1: 217-248.
- Odell, G. H. & Cowan, F. (1986). Experiments with spears and arrows on animal targets. *Journal of Field Archaeology* 13: 195-212.
- Otte, M. & Straus, L. G. (Eds.) (1997). *La Grotte du Bois Laiterie*. ERAUL 60, Liège.

- Pelegrin, J. (2000).** Les techniques de débitage laminaire au Tardiglaciaire: critères de diagnose et quelques réflexions. In: B. Valentin, P. Bodu & M. Christensen (Eds.) *L'Europe centrale et septentrionale au tardiglaciaire. Confrontation des modèles régionaux de peuplement*. Actes de la Table-Ronde Internationale de Nemours 14-15-16 Mai 1997. Mémoires du Musée de Préhistoire d'Ile-de-France n°7, Nemours, 55-71.
- Plisson, H. & Lompré, A. (2008).** Technician or researcher? a visual answer. In: L. Longo & N. Skakun (Eds.) *'Prehistoric technology' 40 years later: Functional studies and the Russian legacy*. Proceedings of the International Congress Verona (Italy), 20-23 April 2005. BAR International Series 1783, Oxford, 503-507.
- Plisson, H. & Mauger, M. (1988).** Chemical and mechanical alteration of microwear polishes: An experimental approach. *Helinium* 28: 3-16.
- Purdy, B. A. (1975).** Fractures for the archaeologists. In: E. Swanson (Ed.) *Lithic technology. Making and using stone tools*. Mouton, The Hague, 133-141.
- Roche, H. & Tixier, J. (1982).** Les accidents de taille. *Studia Praehistorica Belgica* 2: 65-76.
- Sakashita, T. (2006).** Experimental use of backed knives hafted with replicated spears on Japanese Sika (*Cervus nippon*). *Dobutsu-Kokogaku* 23: 55-67 (in Japanese with English summary).
- Semenov, S. A. (1964).** *Prehistoric technology. An experimental study of the oldest tools and artefacts from traces of manufacture and wear*. Adams & Mackay, London.
- Rots, V. (2003).** Towards an understanding of hafting: the macro- and microscopic evidence. *Antiquity* 77: 805-815.
- Rots, V. (2004).** Prehensile wear on flint tools. *Lithic Technology* 29: 7-32.
- Schiffers, M. B. (1976).** *Behavioral archaeology*. Academic Press, New York.
- Schiffers, M. B. (1987).** *Formation processes of the archaeological record*. University of Utah Press, Salt Lake City.
- Sergant, J., Crombé, P. & Perdaen, Y. (2006).** The 'invisible' hearths: a contribution to the discernment of Mesolithic non-structured surface hearths. *Journal of Archaeological Science* 33: 999-1007.
- Shea, J. J. (1988).** Spear points from the Middle Paleolithic of the Levant. *Journal of Field Archaeology* 15: 441-450.
- Shea, J. J. & Klenck, J. D. (1993).** An experimental investigation of the effects of trampling on the results of lithic microwear analysis. *Journal of Archaeological Science* 20: 175-194.
- Stegeweit, L. (2003).** *Gebrauchsspuren an Artefakten der Hominidenfundstelle Bilzingsleben (Thüringen)*. Tübinger Arbeiten zur Urgeschichte Bd. 2. Verlag Marie Leidorf, Rahden/Westf.
- Straus, L. G. (1997a).** La Grotte du Bois Laiterie: The site, stratigraphy, chronology and excavation. In: M. Otte & L. G. Straus (Eds.) *La Grotte du Bois Laiterie*. ERAUL 60, Liège, 25-36.
- Straus, L. G. (1997b).** Synthesis: Bois Laiterie's place in the Stone Age prehistory of Belgium. In: M. Otte & L. G. Straus (Eds.) *La Grotte du Bois Laiterie*. ERAUL 60, Liège, 369-384.
- Straus, L. G. & Martinez, A. (1997).** Site formation/disturbance processes, spatial distributions, site structure and activity areas. In: M. Otte & L. G. Straus (Eds.) *La Grotte du Bois Laiterie*. ERAUL 60, Liège, 65-112.
- Straus, L. G. & Orphal, J. (1997).** Bois Laiterie and the Magdalenian of Belgium: inter-assembly comparisons. In: M. Otte & L. G. Straus (Eds.) *La Grotte du Bois Laiterie*. ERAUL 60, Liège, 337-359.
- Straus, L. G. & Otte, M. (1998).** Bois Laiterie cave and the Magdalenian of Belgium. *Antiquity* 72: 253-268.
- Sullivan, A. P. (1978).** Inference and evidence: a discussion of the conceptual problems. In: M. B. Schiffer (Ed.) *Advances in archaeological method and theory* Vol. 1. Academic Press, New York, 183-222.
- Topel, Th. (1988).** *Diercke Weltatlas*. Westermann, Braunschweig.
- Tringham, R., Cooper, G., Odell, H., Voytek, B. & Whitman, A. (1974).** Experimentation in the formation of edge damage: a new approach to lithic analysis. *Journal of Field Archaeology* 1: 171-196.
- Turner, E. (2003).** Horse hunting and the utilization of horse carcasses during the Magdalenian in Europe. In: S. Costamagno & V. Laroulandie (Eds.) *Mode de vie au Magdalénien: Apports de l'archéozoologie*. Acts of the XIVth UISPP Congress, University of Liège, Belgium, 2-8 September 2001, Colloque/Symposium 6.4. BAR International Series 1144, Oxford, 47-64.
- Vaughan, P. C. (1985).** *Use-wear analysis of flaked stone tools*. The University of Arizona Press, Tucson, Arizona.
- Witthoft, J. (1968).** Flint arrowpoints from the Eskimo of north-western Alaska. *Expedition* 10: 30-37.
- Wylie, H. G. (1975).** Artifact processing and storage procedures: a note of caution. *Lithic Technology* 4: 17-19.
- Zenin, V. N., Leshchinskiy, S. V., Zolotarev, K. V., Grootes, P. M. & Nadeau, M.-J. (2006).** Lugovskoe: Geoarchaeology and culture of a Paleolithic site. *Archaeology, Ethnology and Anthropology of Eurasia* 25: 41-53.