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Macro and Micro Wear Traces on Lithic Projectile Points

Experimental Results and Prehistoric Examples

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INTRODUCTION

Prehistoric flint points often show fractures and scratches. Some of these must be the result of use (cf. Hester & Heizer 1973, Paulsen 1975, Odell 1978, Moss & Newcomer 1982, Barton & Bergman 1982, Bergman & Newcomer 1983). In many cases though, the damage may as well be accidental, e.g. because Stone Age people walked on them, or because archaeologists hit them with their tools during excavation. In yet other instances they may represent the work of natural processes such as solifluction and water transport.

With the present study we have tried to discover to which extend damaged prehistoric flint points can yield information on their function. This was done on the basis of experiments the aim of which was to isolate and define types of use wear traces which could be considered diagnostic for the use as points on spears and arrows. In the following we first present the experimental work. Then types of macro- and microscopic characteristica of the projectile function are defined. Finally the experimentally derived results are tested on prehistoric points of different age, size and shape.

EXPERIMENTS

The point types employed

In the experiments we used exact copies (replica, cf. Crabtree 1966) of two completely different Stone Age point types, i.e. Brommian points and transverse arrowheads.

Brommian points date from the late glacial period, or more precisely from the centuries preceding 9000 b.c. (Fischer 1978: 31–34). So far, they have never been found attached to shafts or in any other context which conclusively establishes their field of application. Therefore, several different interpretations of functions have been possible: axe blade, knife, spear point or arrowhead (see e.g. Rust 1943: 214–215, Mathiassen 1947: 178, Becker 1971: 135, and Holm 1973: 12–15). The two first uses must be considered highly unlikely and to us the fourth possibility seems the most obvious. Consequently, in the experiments presented here Brommian points were used as tips on arrows (95 specimens), but we also mounted some on spear shafts (11 specimens).

In Denmark, transverse arrowheads were used from the late mesolithic (approx. 4500 b.c.) and up to the late Neolithic (approx. 1500 b.c.) A number of finds in Denmark and surrounding areas offer evidence for the use of the type of point in question. First it applies to 4 mounted specimens which all served as tips on arrows (e.g. Madsen 1868, pl. 22: 19, Mathiassen 1948: no. 48, Troels-Smith 1960 a: 105). Moreover, a red deer bone with imprint from a transverse arrowhead (Noe-Nygård 1974: pl. V.c, Andersen 1981: 98), and two bones with embedded transverse arrowheads (Noe-Nygård 1974: pl. VI.b, Larsson 1982: 19) (1). As these 3 small heads cannot have produced a cut broad enough for a spear shaft, it is highly likely that they were used as arrowheads. In the experiments, we only used such relatively small transverse arrowheads (33 specimens), and they were all mounted as tips on arrows.

Apart from Brommian points and transverse arrowheads, we also experimented with a few other point types. Two blade points from the Pitted Ware Culture and one late neolithic bifacially retouched point were used as tip on arrows. Furthermore, we used a lancet and a triangular microlith as tip and barb respectively

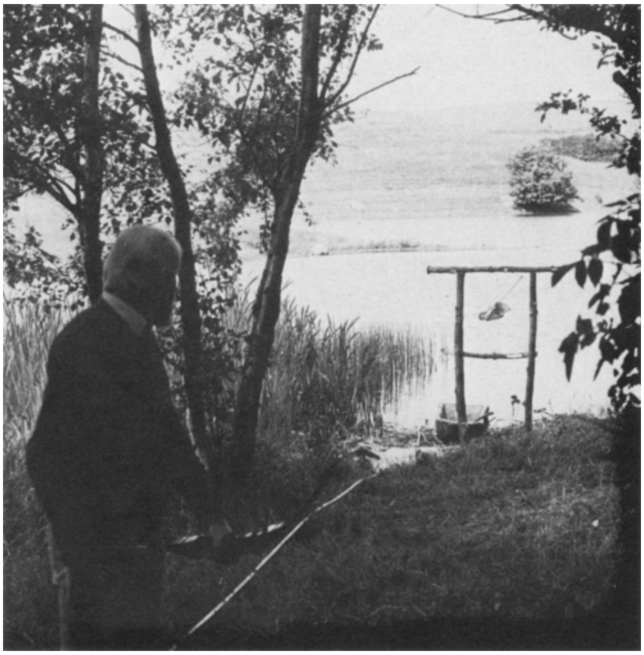


Fig. 1. Snapshot of the shooting experiments. An arrow has just been fired against a shoulder of pork suspended in a wooden frame. The lake in the background ensured that arrows missing the target remained undamaged.

on an arrow corresponding to the one found in the bog of Lilla Loshult in Scania (Malmer 1969).

Field of application

The total of 153 copies of prehistoric flint points, mounted on arrows and spears, were – as part of the experiments – shot against different targets. To evaluate whether the collision with different materials produced different wear traces, each point was shot against one object only, and normally only once. The observance of this principle was often connected with practical problems because the points could go right through the object or simply miss it. It was therefore necessary to catch these arrows in a material which could not produce wear traces. We solved this problem by placing the target in front of a lake free of vegetation (Fig. 1). During the experiments, we used the following simulated hunting objects:

- 12 joints of pork with shoulderblades, hide, fat and meat
- 1 boar head with hide, fat and meat
- 1 boned leg of boar with hide, fat and meat
- 1 newly killed and still warm boar (Fig. 2)
- 1 side of pork wih ribs, hide, fat and meat
- 7 newly killed and still warm sheep
- 4 freshly caught pikes

Moreover, we also shot against a number of objects which a prehistoric hunter could have hit by mistake. The arrows were exposed to the following:

- Collision with birch trunks
- passage through willow bushes with branches having a diameter of up to 2 cm
- passage through wet grass and collision with grass-covered, sandy soil
- passage through dense reed growth in a lake

Finally, we carried through a number of experiments, the object of which was to illuminate some of the types of fractures to which flint points could be exposed, but which had no connection with their use as projectile tips. These experiments were made at a time when we had already established that some of the most characteristic types of fractures connected with the projectile function were bending fractures perpendicular to the length (see below). Therefore, we were particularly interested in establishing whether similar fractures could be made in other ways. The following alternative damaging processes were employed:

- Skinning a boar with Brommian points hafted as knifes in wooden handles
- walking on a heap of flakes and Brommian points, placed on moist, sandy soil
- rolling of a stone, the size of a head, 20 times over a heap of flakes, placed on moist, sandy soil
- dropping of 8 hammer stones, the size of a fist, from a height of 1 m over a heap of flakes, placed on moist, sandy soil.

The manufacture and mounting of the flint points and the bows employed

To ensure that the wear traces resulting from the experimental shootings were directly comparable with the ones occurred on similar points during hunting in the Stone Age, the following considerations had to be made: The flint points had to be exact copies of the prehistoric ones and they had to be mounted as similarly to the prehistoric ones as possible. Finally, they had to be shot with a bow with roughly the same properties as the prehistoric bows.

Fig. 2. Flint-tipped arrow shot into a boar.

A skilled flintknapper produced the flint points used in the experiments (2). As to shafts and mounting of the points, two things were especially important:

1. The shaft diameter and the area of the feathers had to be coordinated in relation to the weight of the points.
2. To ensure maximum directional stability and penetration ability, the weight of the points had to be distributed symmetrically around the longitudinal axis of the shaft and the tip of the point had to be exactly in continuation of the shaft.

The above requirements could easily be complied in the case of transverse arrowheads, since there is prehistoric evidence for the mounting of this type (cf. page 19). However, the mounting of Brommian points presented large problems. Firstly, because no prehistoric examples are known and secondly, because it was difficult to mount these thick and often curved points in such a way that the directional stability of the points became optimal. In practice, the solutions described in Fig. 3 were chosen. The mounting of Brommian points as tip on spears is also shown in Fig. 3.

In the experiments we mostly used a 50 lbs. laminated recurve bow. On the basis of reconstructions (3) of the bow types known from the Danish Stone Age (e.g. Becker 1945, Troels-Smith 1960a, Petersen 1979, Andersen 1975 and 1980), it was possible to demonstrate that these bows were often very strong, but the cast, i.e. the velocity at which the limbs of the bow are straightening out, was poor compared with the employed recurve bow. The latter is not as strong as the prehistoric bow, but its cast is better. So, the discrepancy between the completely different qualities of prehistoric and modern bows was to a certain extent equalized. Therefore, it is probable that the experimental points were fired at a velocity which corresponded to the velocity of arrows fired from prehistoric bows.

MACROSCOPIC WEAR TRACES

Definition of macro fractures

The shooting experiments as well as the alternative damaging processes often resulted in wear traces which could be seen with the naked eye (fig. 7–19). A cursory inspection of the material reveals that all types of fractures are variations on a few themes. The explanation of this uniformity is found in the physical limits of the

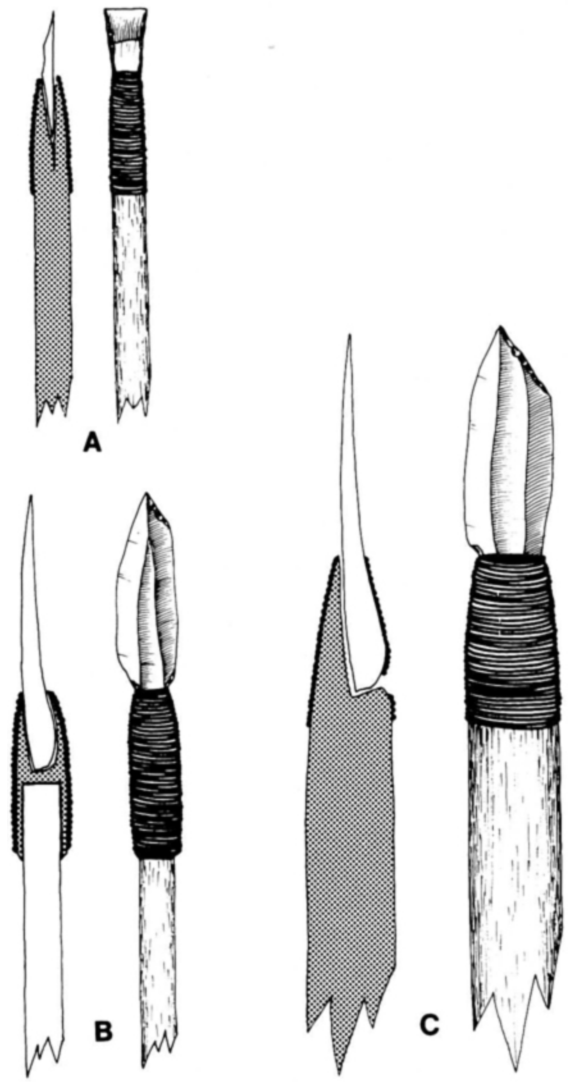


Fig. 3. Hafting principles employed in the experiments.

A. Transverse arrowhead mounted on a 8,8 mm thick pineshaft. The point was fitted into a notch which was cut athwards to the tree-rings. Here it was fixed with bitumen extracted from birch bark and finally secured with flax-thread. The shaft had 3 parabolic feathers, 125 mm long and approx. 15 mm high, mounted parallel to the longitudinal axis of the shaft.

B. Brommian point mounted as arrowhead. The point was fitted into a notch cut into a pine foreshaft, where it was fixed with bitumen extracted from birch bark or with fishglue and then secured with flax-thread.
Points weighing more than 15 g were mounted on 10 mm thick pineshafts. These had 3 feathers, approx. 140 mm long and 28 mm high, mounted parallel to the longitudinal axis of shafts. Points weighing less than 15 g were mounted on shafts similar to those used for the transverse arrowheads.

C. Brommian point mounted as tip on spear. The point was secured with flax-thread.

initiation and path of fractures in brittle materials, such as flint (Cotterell & Kamminga 1979, Lawrence 1979, Tsirk 1979). We made use of this fact when preparing a classification system which covers all macroscopic fractures observed in the experimental material. The system, which is primarily intended for fractures on flint points, follows as far as possible the definitions and nomenclature of use fractures of the Ho Ho Committee (Ho Ho Commitee 1979).

In our classification, distinction is made between two main groups of macro fractures. They are determined by fundamentally different impacts on the flint specimen. First, cone fractures which result from force applied over a relatively small area and where the fracture is found close to the contact area (Fig. 4A). Secondly, bending fractures where the force is distributed over a relatively large surface, and where the fracture does not necessarily initiate close to the contact area (Fig. 4B).

In spite of many attempts, we have not succeeded in distinguishing and defining varieties of cone fractures connected with the projectile function only. For practical reasons, the smallest cone fractures are therefore disregarded in the following. Bending fractures have been divided into 6 varieties on the basis of their path and termination (see definitions on Fig. 5). Through a further division of the different types of fractures according to size and their orientation and position on the flint objects, we are – by means of a long process of "trial and error" now working with a total of 11 characteristic and clearly definable types of fractures.

Projectile point diagnosticating macro fractures

The connection between the 11 types of fractures and the various materials and damaging processes appears from table 1. According to the table, several of the types are primarily or only combined with projectile points. The most frequent fractures – connected with the use as arrowheads and spear points only – are in the following named *diagnostic for the projectile function* (fracture types nos. 7, 8, 9, and 10 in table 1). They are all varieties of bending fractures.

The most simple projectile diagnosticating fractures are step terminating bending fractures (e.g. Fig. 7 A–D). These are a result of pressure from the ends of the flint objects, i.e. pressure parallel to the broad sides (and the length). In case of occasional damaging processes, such

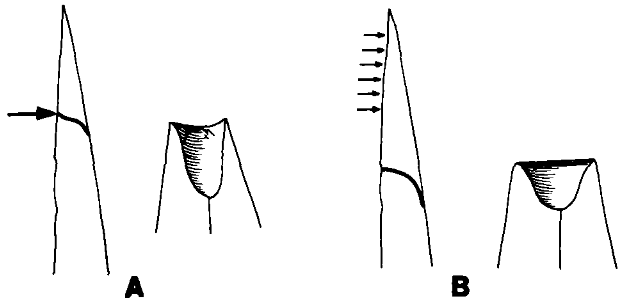


Fig. 4.
A. Example of cone fracture (seen in longitudinal section and in dorsal view). The force is applied over a relatively limited area and the fracture initiates in the immediate vicinity of the contact area.
B. Example of bending fracture (seen in longitudinal section and in dorsal view). The force is applied over a relatively large area and the fracture does not necessarily initiate in the immediate vicinity of the contact area.

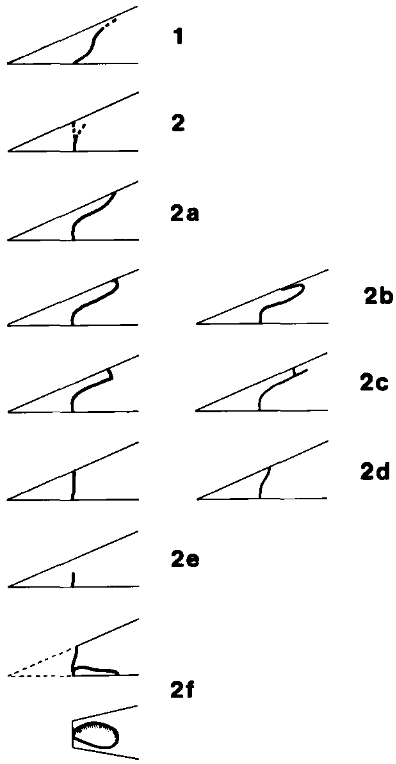


Fig. 5. Definition of macroscopic fractures on projectile points of lithic materials.
1: *Cone fracture (cone initiating fracture).* The fracture initiates from a point or a small, well-defined area, having a concave profile in the area of initiation (shown in longitudinal section).
2: *Bending fracture (bending initiating fracture).* The fracture initiates from a large area and has a straight or convex profile along its whole area of initiation.
2a: *Feather terminating bending fracture.* A bending initiating fracture which before meeting the opposite surface of the specimen runs parallel to this, and which meets the surface in an acute angle or in a curve less than or equal to 90°.
2b: *Hinge terminating bending fracture.* A bending initiating fracture which before meeting the opposite surface of the specimen runs parallel to this, and which meets the surface in a curve larger than 90°.
2c: *Step terminating bending fracture.* A bending initiating fracture which before meeting the opposite surface of the specimen runs parallel to this, and which thereafter makes an abrupt change of direction to meet the surface in a right angle.
2d: *Snap fracture (snap terminating bending fracture).* A bending initiating fracture which meets the opposite surface of the specimen without having at any point run parallel to this.
2e: *Embryonic bending fracture (unfinished bending initiating fracture).* A bending fracture where part of the fracture path ends before having reached the surface of the specimen. Thus, the fracture has not divided the specimen.
2f: *"Spin-off" fracture.* Cone fracture which initiates from a bending fracture and which removes parts of the original surface of the specimen (shown in longitudinal section and from the side).

as walking on the flint objects (e.g. fig. 19) and in connection with almost any other use than as a projectile point (4), any bending fracture will, however, initiate by means of pressure more or less perpendicular to the broad sides.

The probably most easily recognizable projectile point diagnosticating fractures are bending fractures from which "spin-offs" initiate (e.g. Fig. 8, 12, and 14). The experiments demonstrate that the size and location of the spin-offs are highly determined by the character of the forces from which the connected bending fractures derive. Bending fractures resulting from pressure perpendicular to the broad side (and length) of the flint objects will only result in spin-offs on one broad side, just as these spin-offs will be relatively limited in extent (Fig. 6 A).

But on the projectile points where the forces run parallel to the broad sides, the spin-off fractures may, however, have considerable dimensions: Immediately after the completion of the bending fracture, a considerable degree of kinetic energy may still remain in the projectile shaft. The two fracture surfaces may therefore be pressed together with much force. As the orientation of the force (perpendicular to the fracture surfaces and into the flint specimen) is almost optimum for the appearance of retouches, very long spin-offs may thus occur on one or even both broad sides (Fig. 6 B).

Spin-off fractures on both sides, initiating from one and the same bending fracture (e.g. Fig. 12), can in

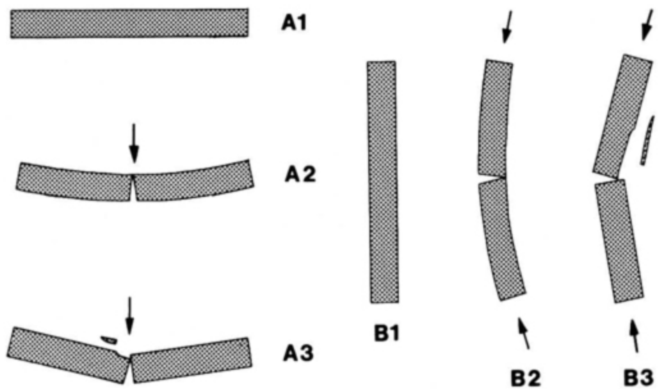


Fig. 6. Theoretical examples of the occurrence of bending fractures as a result of pressure from the broad sides and ends respectively.
A1: Flint specimen prior to pressure.
A2: Flint specimen exposed to pressure from one broad side making the specimen bend and finally break.
A3: Continued pressure from the broad side makes the surfaces of the fracture touch each other producing a small spin-off fracture.
B1: Flint specimen prior to pressure.
B2: Flint specimen exposed to pressure from the ends making the specimen bend and finally break.
B3: Continued force from the ends presses the surfaces of the fracture against each other producing a large spin-off fracture.

practise hardly occur in any other way than through the use as projectile point. This type of fracture is therefore considered diagnostic for the projectile function, irrespective of the dimensions of the fractures (Fig. 7).

If spin-off fractures occur on one side only, certain dimensions are required for them to be considered diagnostic. The larger the object, the larger is the required spin-off fracture.

The experiments shows that in the case of objects having the size of the largest Brommian points, spin-offs with a length of 6 mm or more are considered diagnostic. In the case of transverse arrowheads and similar small points, it seems safe to say that the fractures should be at least 1 mm long.

On the basis of the few experiments made so far, we cannot forward any definite proof to the effect that the types of fractures which we call projectile diagnosticating occur on spear points and arrowheads only. In case of use-wear analysis aiming at functional interpretation of prehistoric flint artifacts, it is therefore advisable to consider the morphology and general conditions of preservation of the objects before projectile points are identified on the basis of macro fractures (cf. note 4). Moreover, it should be noted that in the moment of detachment, flakes are exposed to forces very similar to the ones to which projectile points are exposed. Identification of projectile points should therefore be made on the basis of fractures which with certainty occurred after production of the flint specimens in question (5).

Type of macro fracture vs. hunting object

By means of the classification system for macro fractures presented here, it is now possible, subject to above reservations, to identify flint objects used as projectile points. However, the system affords no possibility of identifying the kind of material hit by the points. All diagnostic types of fractures occur in connection with shooting of animals as well as fish, willow branches and birch trunks (see table 2). However, subjectively it is often possible to distinguish between fractures arising from shots into soft and hard materials respectively. So, it seems that future experiments may enable us to reach a more detailed identification of the objects shot at.

Type of macro fracture vs. type of weapon

As appears from table 1, all types of macro fractures are found on spear points as well as arrowheads. So, at present we cannot identify the type of weapon. But there is a certain trend in the extent of the fractures. Some of the spear points show bending fractures which, as far as number and size are concerned, are larger than the fractures seen on the arrowheads.

Frequency of macro fractures

In table 2 we have compared the frequency of macro fractures occurring in connection with shooting into different materials. It appears from the table that projectiles shot into whole animals and into joints of animals are showing relatively high frequencies of projectile diagnosticating fractures and macro fractures generally. The most surprising result in this connection is that several of the fractures occured on points which did not hit bones (cf. table 1).

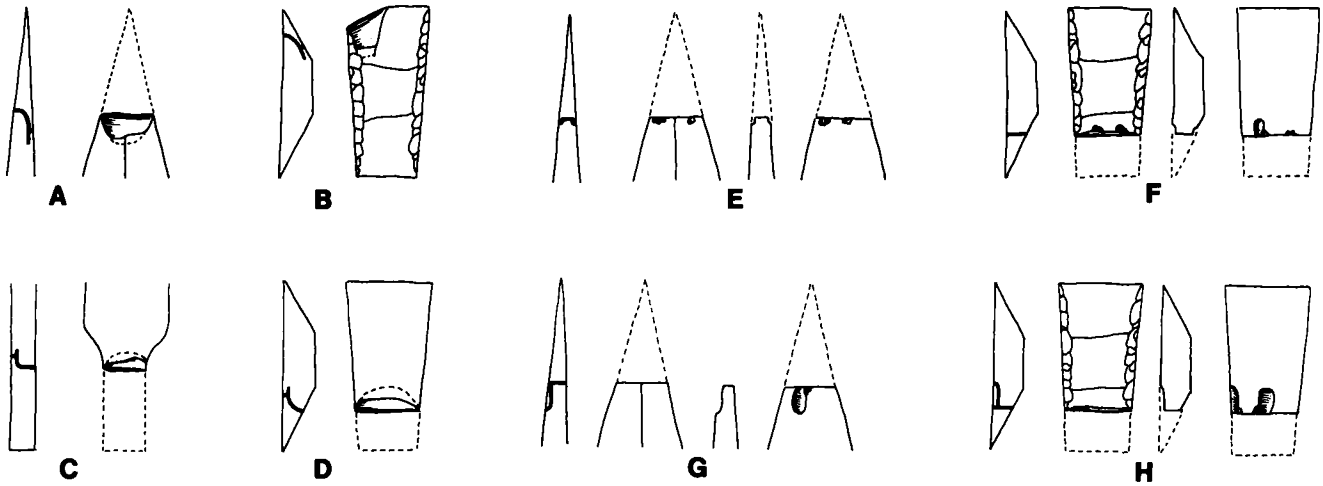


Fig. 7. Idealized examples of Brommian points and transverse arrowheads showing step terminating bending fractures (A, B, C and D), bifacial spin-offs (E and F) and unifacial spin-offs (G and H).

Macro fracture frequency vs. type of weapon

For the experiments as a whole, the frequency of projectile diagnosticating macro fractures on Brommian points used as tips on spears and arrows is 55% and 40% respectively (cf. table 2). Since the spears were not tested on as many objects as the arrows, these figures should, however, be read cautiously. More comparable figures appear from the shooting at whole, newly killed animals. Here the frequencies are 56% and 37% respectively. So, it is likely that the two types of weapons may result in different chances of fractures. But we cannot forward any definite proof on the basis of the existing material, which as for spears represents 11 points only.

Macro fracture frequency vs. hunting object

For arrows shot into simulated hunting objects such as a whole boar, whole sheep and shoulders of pork, the frequency of macro fractures is 39%, 41% and 45% respectively (cf. table 2). On this basis we assume that the frequency of diagnostic fractures on flint points shot into largish animals is generally about 40%, irrespective of the species of animal.

Macro fracture frequency vs. point morphology

In general, it applies to projectile points meant for hunting that their edges are either pointed or transverse or represent hybrids between these two basic shapes. When choosing the types of points used in the experiments, we tried to ensure that the entire spectrum of possible edge shapes were tested. So, Brommian points without retouch at the distal end represent the one extreme and the transverse arrowhead the other. Brommian points with distal retouch and the few other types used represent the intermediate shapes. With this selection of points we expect to have gained comprehensive insight into all types of macro fractures found on projectile points of flint and similar varieties of stone. This assumption is not contradicted by the outcome of the experiments, since all projectile diagnosticating fracture types are seen on pointed and transverse edges as well as on the intermediate shapes (cf. table 1). Therefore, it is very likely that the identified diagnostic macro fractures will also apply to other point types than the ones described in this article.

The frequency of projectile diagnosticating fractures on the 23 Brommian points and the 27 transverse arrowheads shot into newly killed anmals is 39% and 41% respectively (cf. table 2). On this basis it is difficult to say that the two point types have considerably different chances of being damaged when used as tips on arrows. This also applies to points shot into joints of boar and bacon meat. The fracture frequencies are here similar or a little higher. If the limited numbers of projectiles in some of these experiments are considered, the differences can be explained simply by the different

FIELD OF APPLICATION		NO. OF SPECIMENS				CONE-FRACTURE	EMBRYONIC BENDING FRACTURE	BENDING FRACTURE					SPINN-OFF FRACTURE			
								Parallel to longitudinal axis, v < 30°	Obtuse or perpendicular to longitudinal axis, v ≧ 30°				On both sides and/or edges	On one side and/or edge		
						L ≧ 1 mm (L ≧ 3 mm)			Snap-terminating	Feather-terminating	Hinge-terminating	Step-terminating		L ≧ 1 mm (L ≧ 6 mm)		L < 1 mm (L < 6 mm)
Function	Material worked	Brommian points	Transverse arrowheads	Other types of points	Flakes									on side, v < 45°	on edge, v ≧ 45°	
Arrowhead	Hide, fat and meat, warm ("alive")	7	3				2 - - -		2 - - -	- 1 - -		2 1 - -	2 - - -		1 - - -	3 - - -
	Hide, fat and meat cold ("rigor mortis")	15	1				3 - - -		5 - - -			2 - - -	2 - - -			4 - - -
	Hide, fat, meat and possibly bone	10	9			2 4 - -			1 1 - -	- 1 - -	- 1 - -	3 1 - -	- 1 - -	2 - - -		- 1 - -
	Hide, fat, meat and unspecified bone	18				7 - - -			15 - - -			9 - - -	1 - - -	3 - - -		12 - - -
	Hide, fat, meat and ribbone or soft part of shoulderblade	10	17	2		- 3 - -	1 3 - -	1 1 - -	3 7 - -			3 13 - -	5 2 - -	- 4 - -	- 5 - -	3 3 - -
	Hide, fat, meat and hard part of shoulder blade or backbone	10	2	3		1 - - -	5 - - -	1 - - -	4 - 1 -	- 1 1 -	2 1 - -	11 - 2 -	3 - 3 -	4 2 1 -	2 - - -	5 - - -
	Fish	10					1 - - -		2 - - -				2 - - -			
	Trunk of birch	5	1				8 - - -	1 - - -	7 1 - -	1 - - -	1 - - -	7 - - -	4 - - -	3 - - -		9 - - -
	Twigs and branches of willow	3										1 - - -				
	Reed growth	4														
	Grass and soil	7				1 - - -						1 - - -				
	Water	5														
Spearhead	Hide, fat, meat and possibly bone	2							1 - - -		1 - - -	1 - - -			1 - - -	1 - - -
	Hide, fat, meat and unspecified bone	9				2 - - -			3 - - -			6 - - -	3 - - -	1 - - -	1 - - -	2 - - -
Knife	Hide of a boar	2				1 - - -										
Walked upon		22			193	4 - - 67	1 - - 9		9 - - 29	- - - 2	1 - - 3					1 - - 2
Rolled upon by a stone					36	- - - 13	- - - 4		- - - 14							- - - 3
Droped stones upon					53	- - - 50	- - - 16		- - - 52		- - - 4					- - - 11
		Fracture type				No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
		Projectile diagnostic fracture type										+	+	+	+	

Table 1. The combination of damaging processes and fracture types produced. The 11 types of macro fractures are defined at the top to the right. Dimensions given in paranthesis applies to Brommian points and flakes. The types considered diagnostic for the projectile point function are marked by pluses at the bottom of the tabel. The four types of specimens involved in the damaging processes are distinguished in the following way: In each square the number of fractures on Brommian points, transverse arrowheads, other types of points and flakes are given at the top to the left, at the top to the right, at the bottom to the left and at the bottom to the right respectively.

EXPERIMENTS				Number of examened points	Number of points with diagnostic macro fractures	Number of points with non-diagnostic macro fractures only	Number of un-damaged points	Frequency of points with diagnostic macro fractures
Point type	Mounted on	Shot into	Distance (m)					
Brommian point	**Arrow**	**Whole boar**	**10**	**23**	**9**	**6**	**8**	**39%**
	Spear	Whole boar	3-4	2	2	0	0	100%
	Spear	Boar head	1-3	6	3	0	3	50%
	Spear	Whole sheep	2	3	1	1	1	33%
	Arrow	Boned leg of boar	4	5	3	0	2	60%
	Arrow	**Pork with bones**	**10**	**42**	**19**	**5**	**18**	**45%**
	Arrow	Fish	1-3	10	1	0	9	10%
	Arrow	Reed growth	-	4	0	0	4	0%
	Arrow	Grass and soil	-	7	1	1	5	14%
	Arrow	Willow bush	3	3	1	0	2	33%
	Arrow	Birch trunk	4	5	3	2	0	60%
Transverse arrowhead	**Arrow**	**Whole sheep**	**10**	**27**	**11**	**4**	**12**	**41%**
	Arrow	Pork with bones	2-10	5	4	0	1	80%
	Arrow	Tree trunk	10	1	0	1	0	0%
Other point	Arrow	Pork with bones	4-5	5	2	0	3	40%

Table 2. The combination of macro fractures and experimental shootings. The 3 experiments of highest significance are shown in bold-faced types. Five points which hit water only are not included.

properties of "living" and cold meat. The former is tougher than the latter and may thus result in somewhat higher chances of fractures on penetrating projectiles. Therefore, we assume that the frequency of diagnostic fractures on flint points shot into largish animals is approx. 40%, irrespective of the morphology of the points.

In a later paragraph, we will discuss assumptions of macro fracture frequencies vs. hunting objects and point morphology in relation to data from prehistoric finds.

MICROSCOPIC WEAR TRACES

The projectile points used in the experiments show wear traces which can be observed in a microscope only (6). We used an Olympus model BHM metallurgical microscope with magnifications ranging from 50x to 400x. Prior to the examination, the points were cleaned in potassium hydroxide (10%) as well as hydrochloric acid (10%).

An examination of micro wear traces makes heavy demands on the quality of the flint. It is e.g. impossible to see micro wear traces on light and coarse-grained flint. Some of the points forming part of the macro analysis were of such a quality and were therefore excluded prior to the examination. The micro use-wear analysis thus included a total of 58 Brommian points and 27 transverse arrowheads which all served as tips on arrows. The examination included microscopic inspection of all sides and edges of the points.

Projectile diagnosticating micro wear traces

None of the examined points show the same micro wear traces as the ones seen on e.g. knives and scrapers, where it is possible to establish whether the tools were used in meat, bone, hide etc. (Keeley & Newcomer 1977, Keeley 1980). The reason why such wear traces are not seen on the points is undoubtedly the particular

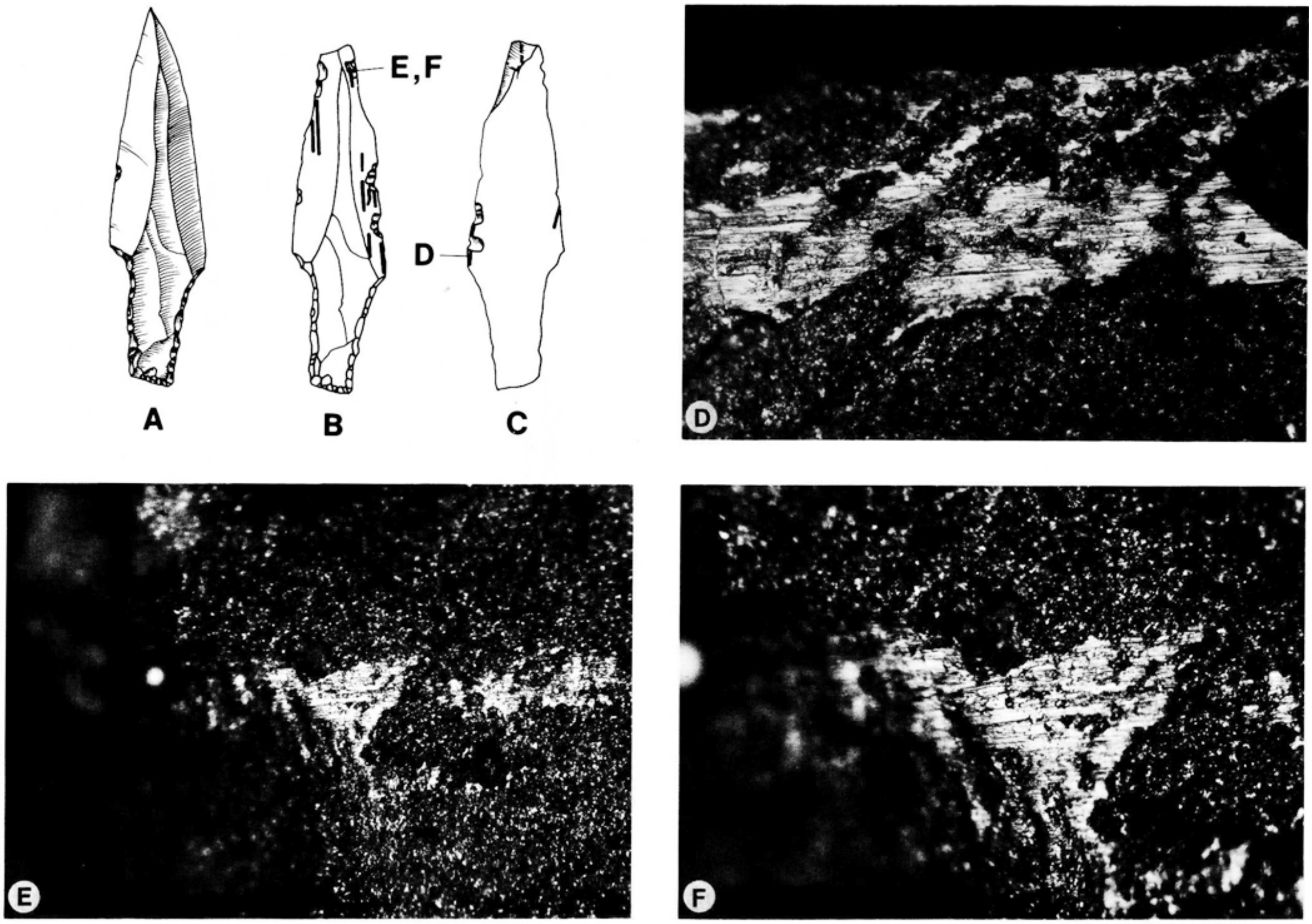


Fig. 8. Experimental Brommian point shot into a shoulder of pork. – A: Point prior to use. 2:3. – B + C: Point after use with indications of macro and micro wear traces. The dark lines indicate position and orientation of the micro wear. The tip shows a bending fracture which, in places, is step terminating and from which 1 mm long spin-offs initiate. There are also a number of cone fractures along the edges. – D: Photomicrograph of linear polish and striations. The shining part is the surface which was polished during use. In the polish are many striations oriented parallel to the longitudinal axis of the point. 1:167. – E: Linear polish with striations initiating at the bottom of a small spin-off fracture, continuing up over the edge of the fracture and running onto the surface of the point. 1:83. – F: On this photo, the focus is on the edge of the spin-off where the linear polish with striations is very developed. At the top of the picture, the polish is seen dimly at the bottom of the fracture. 1:167.

use of points. As opposed to all other tools which are normally in long and active contact with a material during use, a point is only in active contact with a hunting object in a split second. Such an extremely brief contact is apparently not sufficient to produce any of the mentioned types of wear traces. But another type of wear traces can be seen on the points, i.e. *linear polishes* and *striations*.

Linear polishes are plastic changes in the very surface of the flint, and in a light microscope they appear as long, shining stripes on the flint. Striations are very small scratches in the surface (Fig. 8D).

If the wear traces are observed in a scanning electron microscope (SEM) (7), they are not light and shining, but the SEM's three-dimensional surface view of the objects results in a far better observance of the changes in the surface of the flint (Fig. 14 G–I).

Several of the experiments clearly illustrate the reason for the occurrence of linear polishes and striations on the points: When a flint point hits the game or a similar object, small or large chips are usually separated from the point. The remaining part of the point continues into the animal and because of the resistance of the surrounding material, the chips are scoring the

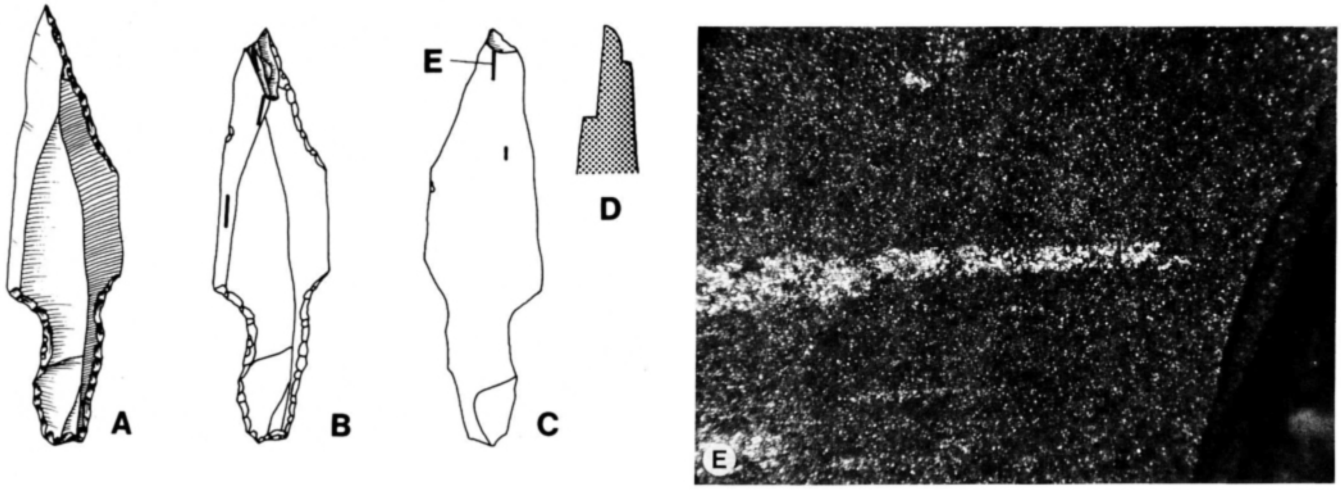


Fig. 9. Experimental Brommian point shot into a boar where it cut a rib in two and wedged between two ribs on the opposite side. – A: Prior to use. 2:3. – B + C: Point after use with indications of macro and micro wear traces. The tip shows a step terminating bending fracture initiating from the dorsal side, and running onto the ventral side. Spin-offs, up to 13 mm long, initiate from the bending fracture on the dorsal side. Further, a number of cone fractures are seen along the edges of the flint blade. – D: Cross section of the tip of the flint point. – E: Photomicrograph of linear polish and striations oriented parallel to the longitudinal axis of the point. The orientation and location of the wear traces indicate that the point was used as a projectile tip. 1:42.

point polishing and scratching its surface. The experiments demonstrate that the chips from the flint points are the cause of the occurrence of wear traces (Fig. 8E and F). The figure shows that the wear traces initiate at the bottom of a small macro fracture and continues uninterrupted up over the edge of the fracture and further over the blade of the point.

The score direction of the chips on points is normally parallel to the longitudinal axis (e.g. Fig. 9 and 15). Minor deviations from this orientation are seen in some cases. These deviations occur when e.g. an arrow hits a bone and is forced in another direction than the original (Fig. 16).

The question now is whether the linear polishes and the striations, which turned out to be connected with the projectile function can occur in any other way than through the above use. The wear traces' regular orientation parallel with or roughly parallel with the longitudinal axis of the points is important in this connection. Certain conditions must be fulfilled for wear traces to be created in such a way. The small flint chips which are the direct cause of the occurrence of micro wear traces must be exposed to a combination of pressure and movement oriented parallel with the longitudinal axis of the points. If the points are used for other purposes than as projectile points, the pressure and the move-

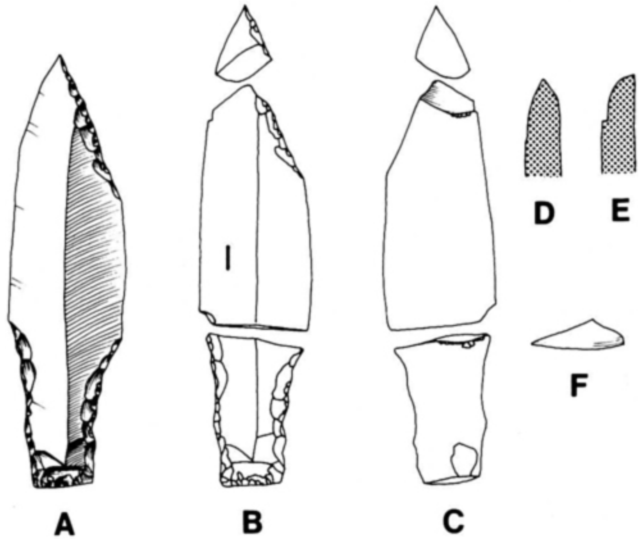


Fig. 10. Experimental Brommian point shot into a boar where it first cut a path between two ribs and then collided with a rib in the opposite side. – A: Point prior to use. 2:3. – B + C: Point after use. The proximal end shows a snap, from which several unifacial spin-offs, max. 1 mm long, initiate. The tip shows a bending fracture which is feather terminated at the one side (D) and step terminated (E) at the other. From this bending fracture, several spin-offs, less than 1 mm long, initiate. – D + E: Cross sections of bending fracture. It is step terminated at the one side, and is consequently diagnostic for the projectile function. – F: Snap fracture with faintly developed ondulations.

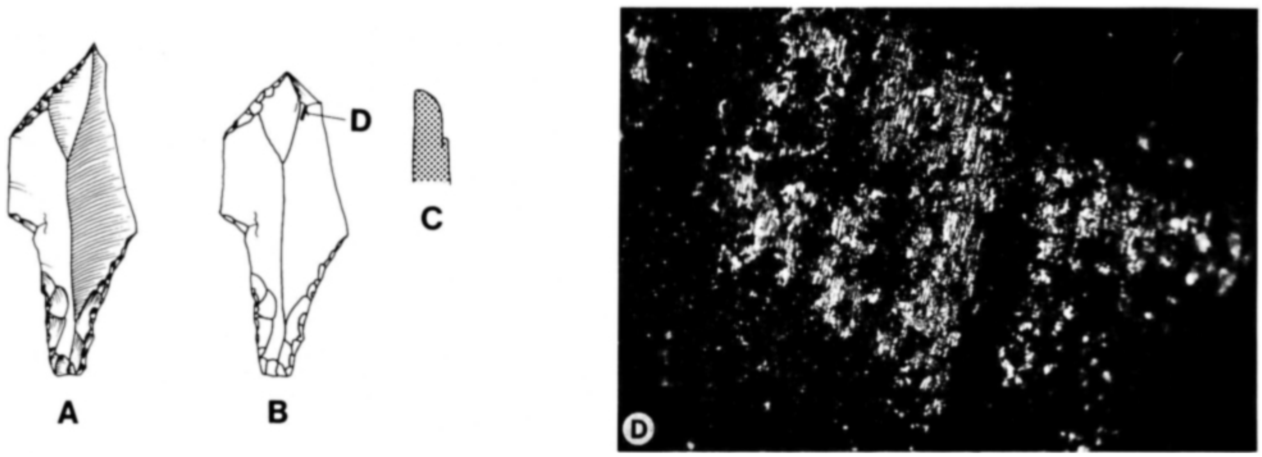


Fig. 11. Experimental Brommian point shot into a willow branch approx. 2 cm thick. – A: Prior to use. 2:3. – B + C: After use. The tip shows a step terminating bending fracture. – D: Photomicrograph of linear polishes and striations. 1:83.

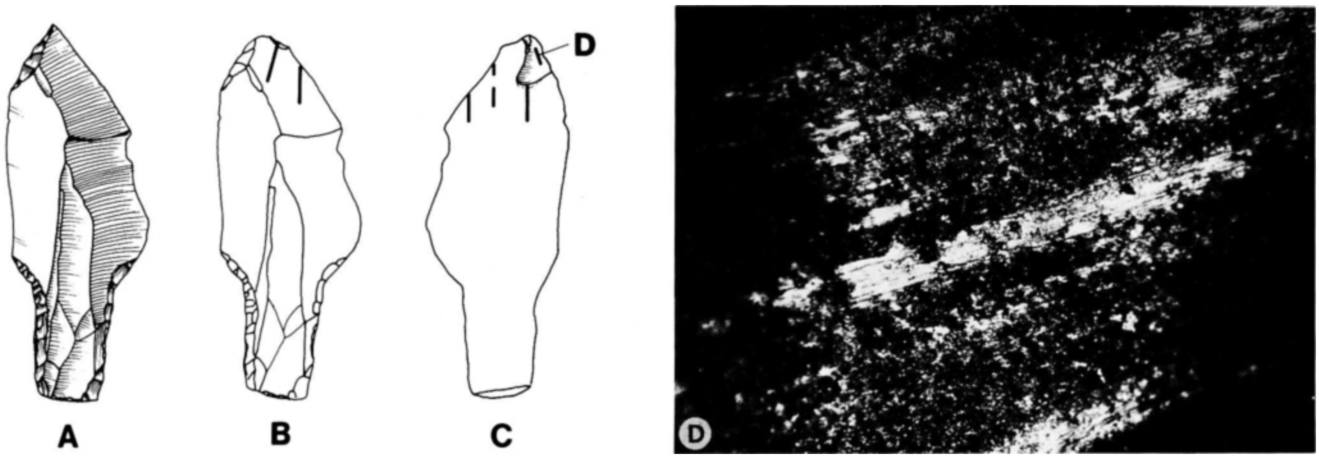


Fig. 12. Brommian point shot into a boar where it went through the chest, forced its way into the heart and stopped with the tip protruding into the thoracic cavity. – A: Prior to use. 2:3. – B + C: After use with indications of macro and micro wear traces. Two step terminating bending fractures are seen on the ventral side. From these, a spin-off fracture, well over 1 mm long, initiates on the dorsal side. – D: Photomicrograph of linear polishes and striations. 1:83.

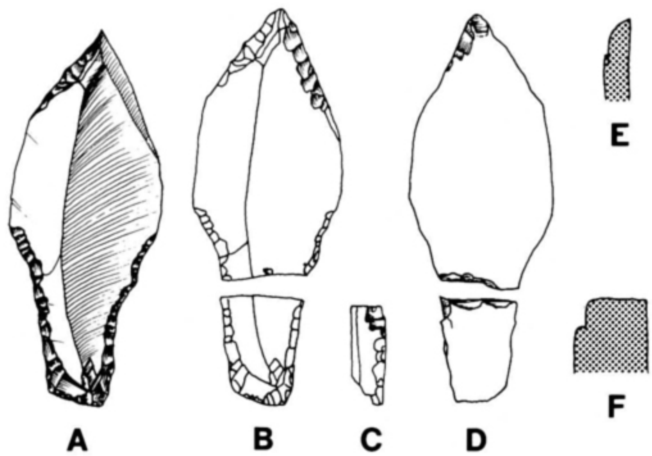


Fig. 13. Experimental Brommian point used as tip on spear. The spear was thrown against the head of a boar and the tip went through hide and meat and grazed the lower jar. – A: prior to use. 2:3. – B – D: After use. The distal end was heavily damaged on collision with the jar bone. On the tip is a small step terminating bending fracture. Moreover, a series of cone fractures is seen along the front edge of the blade. The proximal end shows a step terminating bending fracture from which several spin-offs initiate. The spin-offs on the blade are bifacial. The largest of these which removed parts of the retouch are very similar to burin blows. – E – F: Cross section of step terminating bending fractures on tip and proximal end.

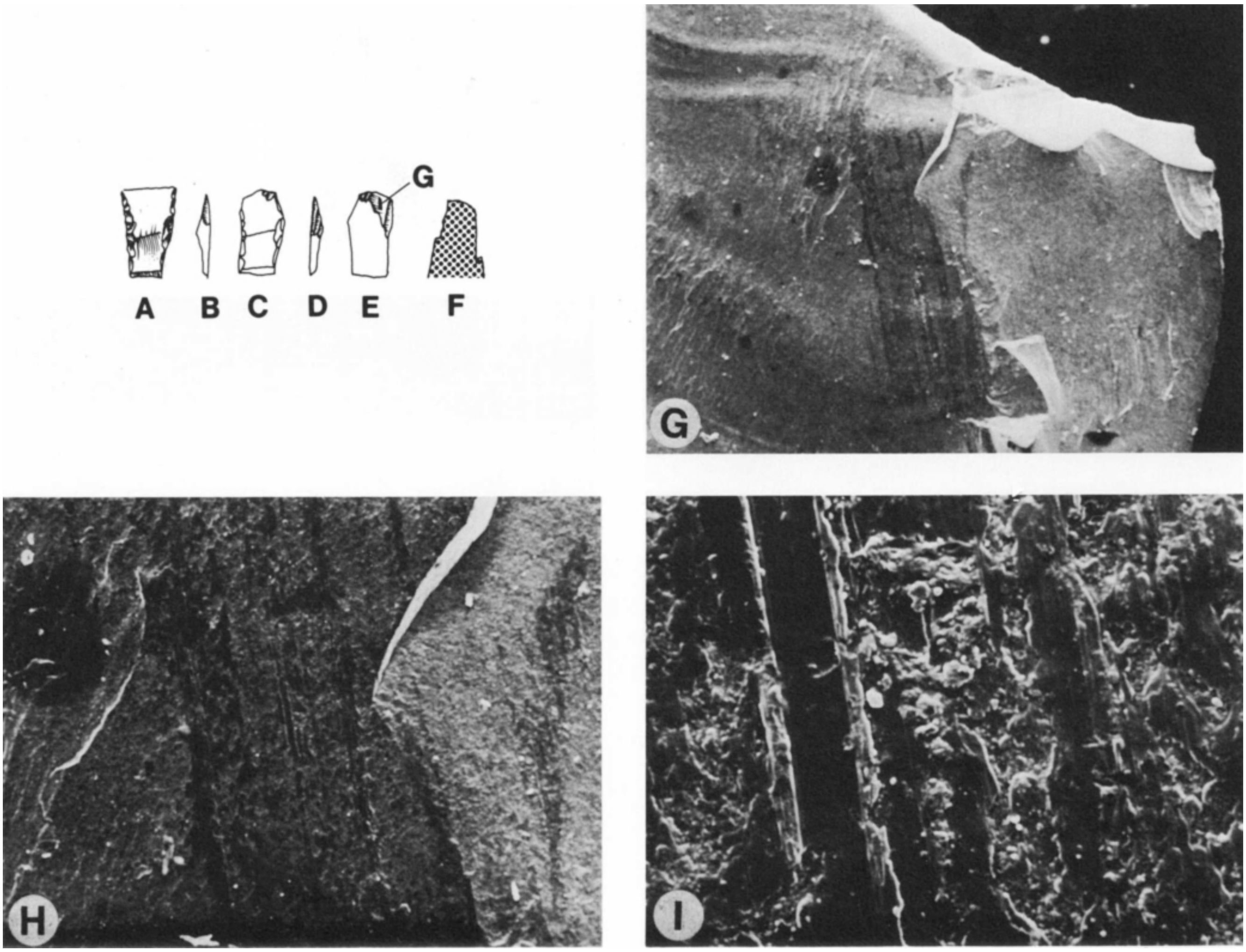
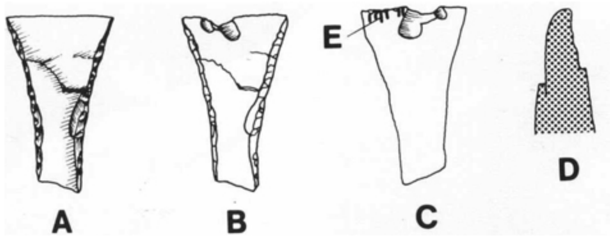


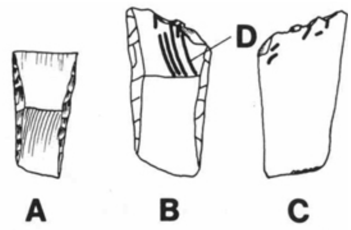
Fig. 14. Experimental transverse arrowhead shot through the chest of a sheep. – A: Prior to use. 2:3. – B – E: After use. The edge is heavily damaged. The fractures consist of several bending fractures and spin-offs. – F: Cross section of the edge at a place where a step terminating bending fracture is the basis of a spin-off. – G: SEM-photo of wear traces which are seen as long, dark lines oriented approximately perpendicular to the edge. 1:40. – H: Section of G. A very distinct striation is seen at the arrow. 1:110. – I: Section of H. To the right, at the arrow, polish of the originally uneven surface is seen. To the left are several striations of which one in particular is cut very deeply down into the surface of the flint. 1:1100.

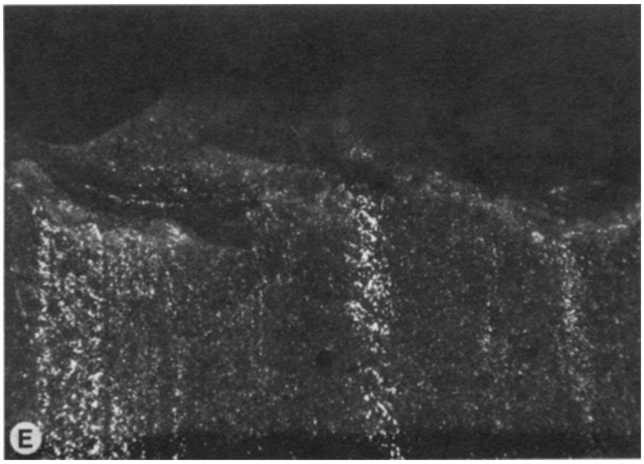
ment will be oriented more or less perpendicular to the longitudinal axis of the flint specimen and the micro wear traces will accordingly not run parallel with the longitudinal axis. If used as a knife, characteristic surface covering polishes will be created which are clearly connected to the edge (Fig. 20 and 21). In the absence of definite proof, it seems reasonable to presume that linear polishes and striations occur only on flint points used as projectiles. In the following these wear traces are therefore considered diagnostic for the projectile function.

Micro wear traces vs. hunting object

The experiments show that it is impossible to establish what the projectile point hit. As appears from table 3, the projectile diagnosticating wear traces occur when an arrow is shot into animals, willow branches, birch trunks as well as soil (Fig. 11). The only exception being fish where a socalled fish polish may occur on the point (9) (Fig. 22).







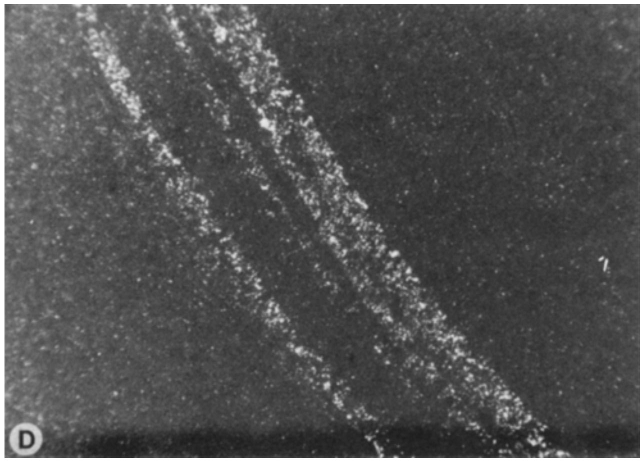


Fig. 15. Experimental transverse arrowhead shot at a right angle against the chest of a sheep where it first splintered a rib and then made a cut in the lower part of the spine. – A: Prior to use. 2:3. – B + C: After use. The whole edge shows macro fractures, i.e. small cone fractures and a large step terminating bending fracture (C) from which several spin-offs, up to 3 mm long, initiate on the dorsal side. – D: Cross section of the edge with a step terminating bending fracture, from which a (step terminating) cone fracture initiate. – E: Photomicrograph of linear polishes and striations initiating from the edge and running parallel with the length over the blade. 1:42.

Fig. 16. Experimental transverse arrowhead shot into a sheep where it hit a rib. – A: Prior to use. 2:3. – B + C: After use. There are macro fractures along almost the entire edge. A snap terminating bending fracture is seen on the ventral side. From this, two spin-offs initiate on the dorsal side of which the longest is approx. 2 mm. The proximal end shows a snap terminating bending fracture and several small cone fractures. – D: Photomicrograph of wear traces. The linear polishes and striations are turning, probably because the point changed its course on collision with the rib. 1:42.

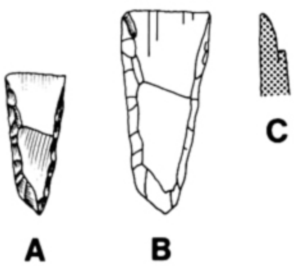


Fig. 17. Experimental transverse arrowhead shot into a sheep where it produced a cut in a rib on each side of the chest. – A: Prior to use. 2:3. – B: After use. A small step terminating bending fracture initiates from the left side of the edge. The dorsal side shows micro wear traces oriented parallel with the length. They are so faintly developed that it would hardly be possible to see them on a prehistoric specimen. Therefore, they are considered non-diagnostic. – C: Cross section of the step terminating bending fracture.

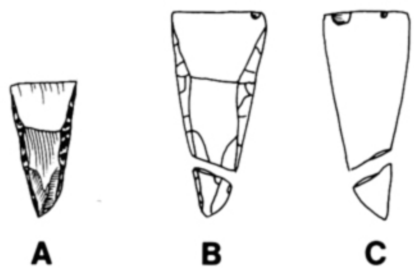


Fig. 18. Experimental transverse arrowhead shot through the chest of a sheep. – A: Prior to use. 2:3. – B + C: After use. The edge shows several very small cone fractures and two small, non-step terminating bending fractures. Micro wear traces oriented parallel with the length are seen on the dorsal and the ventral side. They are faintly developed and are consequently considered non-diagnostic.

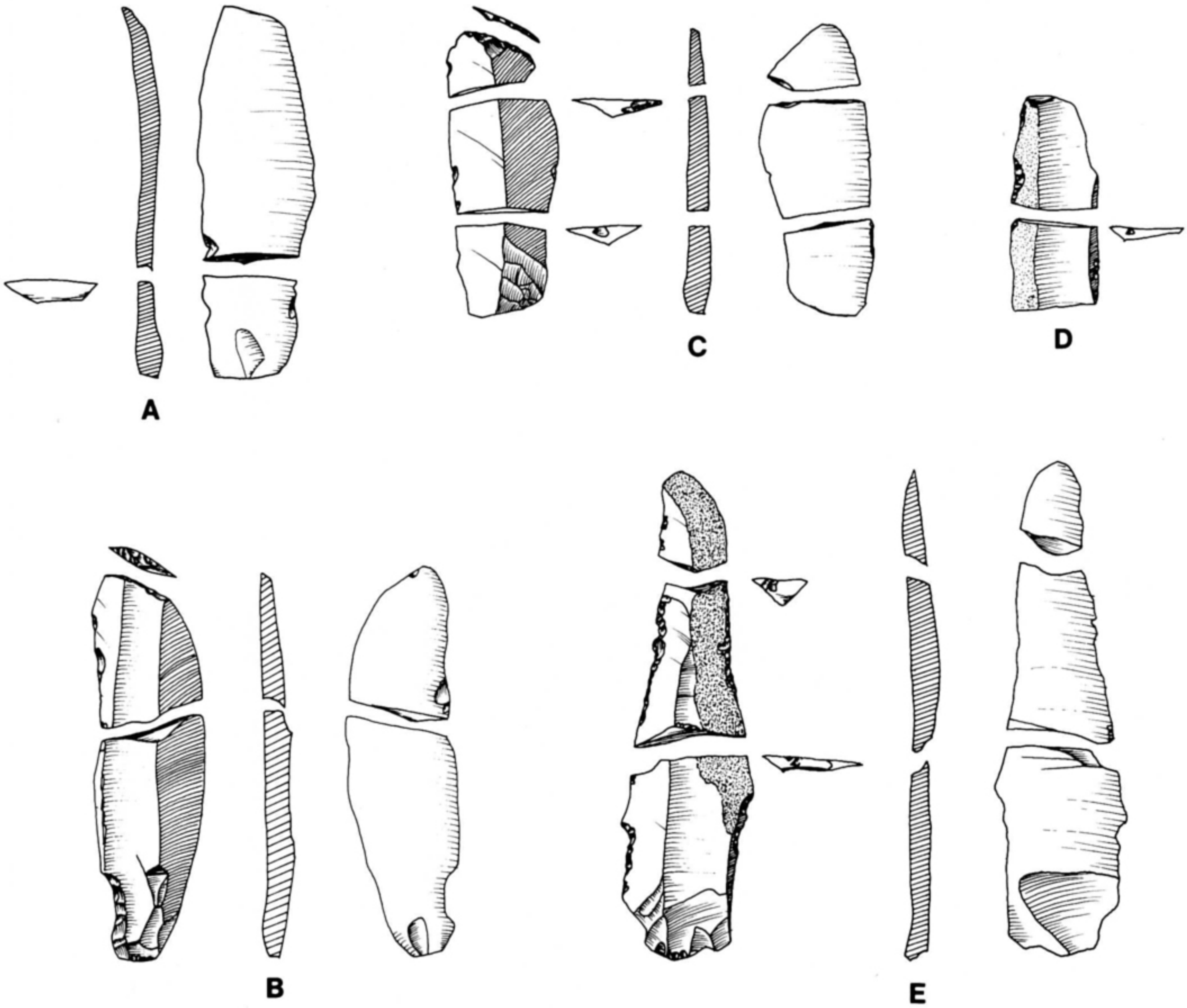


Fig. 19. Examples of bending and cone fractures produced by "accidental" processes. The fractures on A, B and D are the results of dropping of hammer-stones on a heap of flakes, and on C and E of walking on a heap of flakes. The bending fractures are generally of the snap type and very often there are secondary cone fractures on top of them (e.g. B, C and E). E represents one of the few accidentally produced bending fractures from which spin-offs initiate. They are unifacial and relatively small related to the size of the flake. 2:3.

The frequency of micro wear traces vs. hunting object

On arrows shot into simulated hunting objects, such as whole boar, shoulders of pork and whole sheep, micro wear traces are observed having roughly the same frequencies, i.e. 61%, 66% and 66% respectively (see table 3). This means that the chances of micro wear traces on projectile points shot into life-like hunting objects are roughly 60%.

Two of the arrows shot into the boar clearly illustrate that micro wear traces are not always seen on projectiles shot into hunting objects. We know for certain that the two arrows would have been fatal. The one arrow went into the boar immediately in front of the right hind leg, passed the abdominal cavity and cut a hole, approx. 2 cm long, in the lower vena cava. The other arrow went into the animal behind the right foreleg, went through the anterior wall of the right ventricle at an oblique

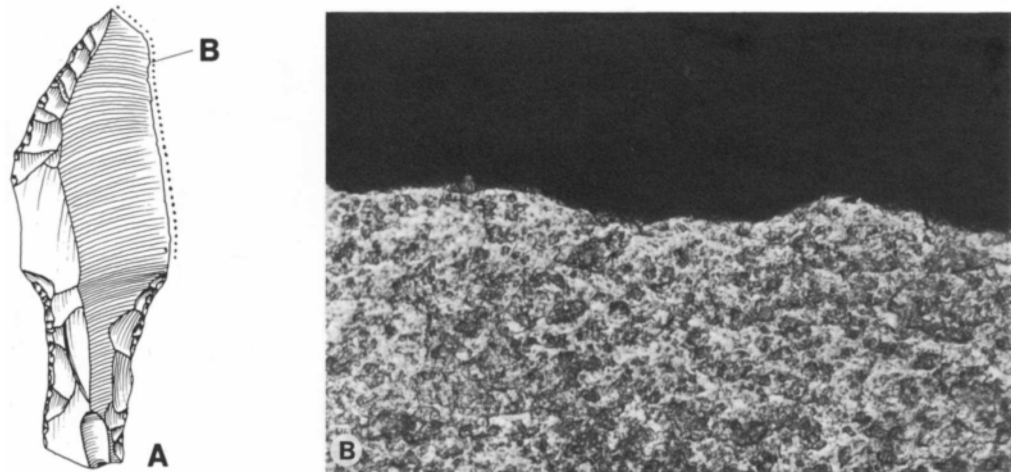


Fig. 20. Brommian point used for approx. 45 min. as knife for skinning a boar. A well-developed meat polish is seen along the edge. The polish is dull and the contrast to the unpolished surface of the flint is relatively insignificant. The polish follows the small elevations and depressions of the original flint surface so the surface is very granulated and uneven. Drawing 2:3, microphoto 1:333.

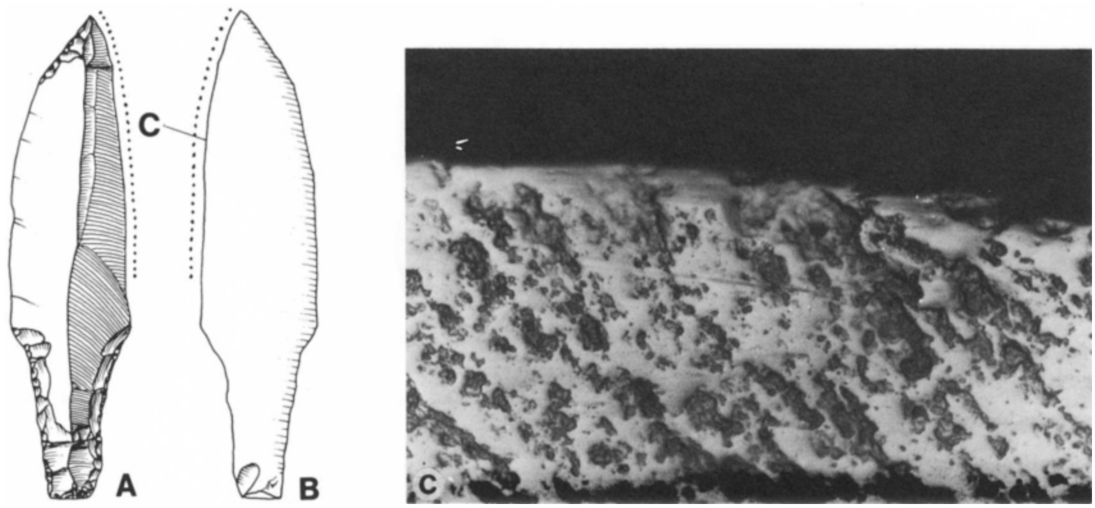


Fig. 21. Brommian point used for 15 min. as knife for cutting grass. A plant polish is seen along the edge. The polish is shining, even and smooth and covers a relatively wide belt along the working edge. Striations oriented parallel with the edge are seen in the polish. Drawing 2:3, microphoto 1:333.

angle and into the left thoracic cavity. The point hitting the heart shows diagnostic micro and macro wear (Fig. 12), while the one hitting the vena cava shows no wear traces at all. So, the two arrows clearly illustrate the framework within which we must work when moving from experiments to the study of prehistoric projectile points: On the one hand, it is possible – on the basis of the presence of wear traces – to establish for certain that a point was used. On the other hand, absence of wear traces does not necessarily mean that a point was not used, since the above example shows that even a fatal shot can result in the point being intact without any wear traces at all.

The frequency of micro wear traces vs. point morphology

If we consider the 23 Brommian points and the 27 transverse arrowheads shot into largish life-like hunting objects, the frequency of projectile diagnosticating

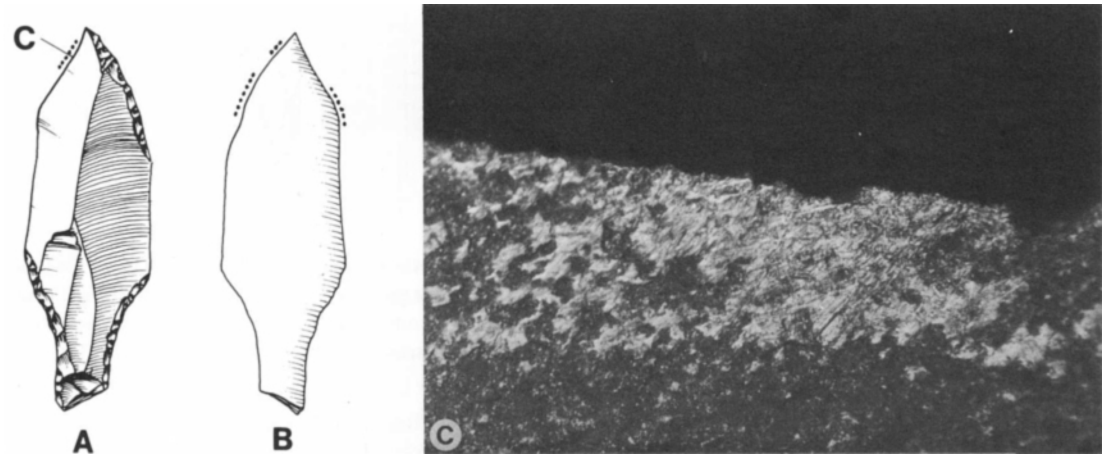


Fig. 22. Brommian point shot into a pike. The tip shows areas with fish polish. The polish is relatively bright and the contrast to the unpolished surfaces of the flint is significant. Superficially striations oriented in all directions are seen in the polish. 1:167.

micro wear traces is roughly similar, i.e. 61% and 66% respectively.

The points must be considered representatives of the whole range of edge morphologies of arrow tips (cf. page 25). We therefore assume that the frequency of diagnostic micro wear traces on points shot into animals is approx. 60%, irrespective of the morphology of the points.

MACRO AND MICRO WEAR TRACES ON PREHISTORIC FLINT POINTS

For the purpose of testing the applicability of the projectile diagnosticating macro and micro wear traces described in the preceding passages, we have analysed a selection of prehistoric flint points. The analysis included a number of points from different sites pur-

EXPERIMENTS		Number of examened points	Number of points with diagnostic micro wear traces	Number of points with non-diagnostic micro wear traces	Number of undamaged points	Frequency of points with diagnostic micro wear traces
Point type	Shot into					
Brommian point	Whole boar	23	14	2	7	57%
	Boned leg of boar	5	1	2	2	20%
	Pork with shoulder-blade	12	8	0	4	66%
	Fish	4	3	0	1	75%
	Reed growth	4	0	0	4	0%
	Grass and soil	5	1	0	2	20%
	Willow bush	3	1	0	2	33%
	Birch trunk	2	2	0	0	100%
Transverse arrowhead	Whole sheep	27	18	8	1	66%

Table 3. The combination of micro wear traces and experimental shootings. (8).

posively chosen so that the analysed material included a large number of Brommian points and transverse arrowheads as well as all Danish finds of animal skeletons with attached flint points referable to a morphological type. The purpose of the analysis was to obtain answers to the following questions:

1) Are the above defined projectile point diagnosticating characteristics found on prehistoric flint points?

2) Are hunting object and point morphology influencing the frequency of projectile diagnosticating wear traces?

Before we present a conclusive reply to these questions, we shall give a description of the prehistoric points and the circumstances of their discovery. The individual sites are mentioned chronologically.

Stellmoor – Lower Layer

Water-deposited layer from the Hamburgian culture, excavated north-east of Hamburg (Rust 1943). The layer is dated to pollen zone I, ex. Iversen, and most likely to the middle part of said zone, the Bølling period (Usinger 1975: 123 and 136). A C-14 analysis (W-261) established its age to 10500 ± 200 b.c. The find contains 5 *Kerbspitzen*. Among the 4 which could be subjected to a thorough macro fracture analysis, 2 show projectile diagnosticating bending fractures (Fig. 23). The fifth is shot into the vertebra of a reindeer and its tip is not visible. An X-ray (10) has shown that there is at least one bending fracture perpendicular to the length on that part of the point which is hidden in the bone. The visible part of the object shows a non-diagnostic bending fracture. None of the points were examined for micro wear traces.

Ommelshoved

Site of the Brommian culture, situated on the beach of the north-eastern part of Ærø. The material comprises 111 more or less fragmented Brommian points and a handful of unretouched blades of the same age, all found within an area of approx. 25 times 5 m. No other late paleolithic objects were found, so the excavator interprets the place as a "kill site" (Holm 1973: 11).

Of the 110 points examined, 12 show projectile diagnosticating macro fractures. The number of these fractures may originally have been a little larger, since later damage, such as water wear blurred the original shape of several of the points. The existing diagnostic fractures include 7 step terminating bending fractures (Fig. 24 B and E), 3 unifacial spin-offs more than 6 mm long (Fig. 24 C) and 2 spin-offs extending over both broad sides (Fig. 24 E).

All point surfaces show varying degrees of physical or chemical disintegration because of water wear, solifluction, decalcification etc. The least damaged specimens were analysed for micro wear traces, and one of these showed linear polish which may – subject to reservations – be called projectile point diagnosticating. Another showed clear diagnostic wear traces at the bottom of a large macro fracture (Fig. 24 F).

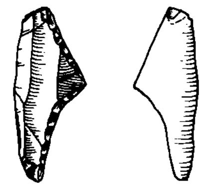


Fig. 23. Hamburgian point ("Kerbspitze") from the lower layer at Stellmoor. The tip shows a hinge terminating bending fracture initiating from the distal retouch and running a little down the opposite edge. From this fracture, spin-offs initiate on both broad sides. 1:1,5.

Bromme

Excavated settlement in the south-west of Zealand (Mathiassen 1947), dated to pollen zone II, the Allerød period (Iversen 1947).

The material comprises 65 Brommian points of which 1 must be considered unfinished, whereas 8 were re-worked into burins or scrapers. Only 3 of the points show projectile point diagnosticating macro fractures. But the number may originally have been larger since 9 of the points had been exposed to so heavy, secondary damage that the wear traces may have disappeared. The existing diagnostic macro fractures include two cases of step terminating bending fractures and two spin-offs of a length of more than 6 mm (Fig. 24A).

The surfaces of all points are worn as a result of periglacial soil movements. Moreover, several of them are made of such light flint that they are unsuitable for the observance of micro wear traces.

Stellmoor – Upper Layer

Water-deposited layer from the Ahrensburgian culture (Rust 1943). By means of pollen analysis, the sediment is dated to the Younger Dryas period, pollen zone III (Schütrumpf 1943).

The abundant material included among other things the oldest known bows and arrowshafts in the world. In two of the arrowshafts, broken proximal ends of tanged points were found (11). A third arrowshaft was found in the immediate vicinity of a tanged point (Fig. 25B) in the abdomen of the skeleton of a reindeer. The circumstances of the discovery indicate that the flint point was originally mounted on the arrowshaft and shot into the reindeer (Rust 1943: 191). Moreover, a number of shoulder blades with holes in them indicate that the numerous reindeer discovered were shot with flint points mounted on arrowshafts (Rust 1943: 186–187). This is further supported by two reindeer vertebrae with embedded fragments of flint points (Rust 1943: Tafel 87 and Möller 1975). Of the 45 points examined in detail, 19 showed projectile diagnosticating macro fractures (18 tanged points and 1 Zonhoven point). There were 11 step terminating bending fractures (Fig. 25 A and D), 4 spin-offs over two broad sides

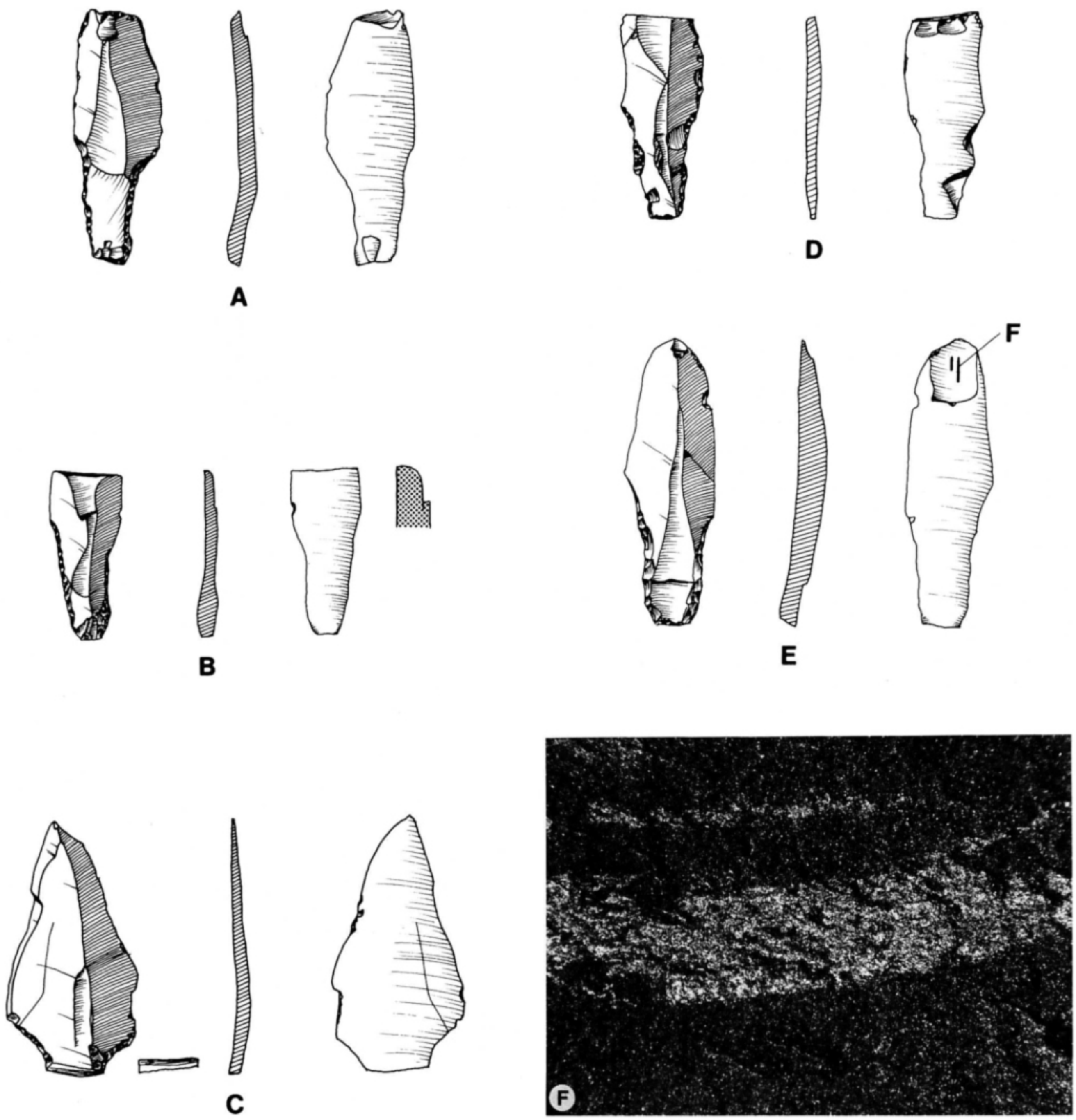


Fig. 24. Examples of Brommian points with wear traces. A is from Bromme (*locus classicus*) and B – E from Ommelshoved. 2:3. – A: The distal part shows a step terminating bending fracture from which unifacial spin-offs, more than 6 mm long, initiate. – B: The distal part shows a step terminating bending fracture. – C: The proximal part shows a bending fracture from which a spin-off, more than 6 mm long, initiate. – D: The edges are heavily water worn. The tip shows a snap fracture from which unifacial spin-offs, less than 6 mm long, initiate. The wear traces are non-diagnostic. – E: The tip shows a step terminating bending fracture from which bifacial spin-offs initiate. There are linear polishes at the bottom of the bending fracture. Both the macro and micro wear traces on this point are fine examples of diagnostic wear. – F: Photomicrograph of linear polish, oriented parallel to the longitudinal axis of the point. 1:42.

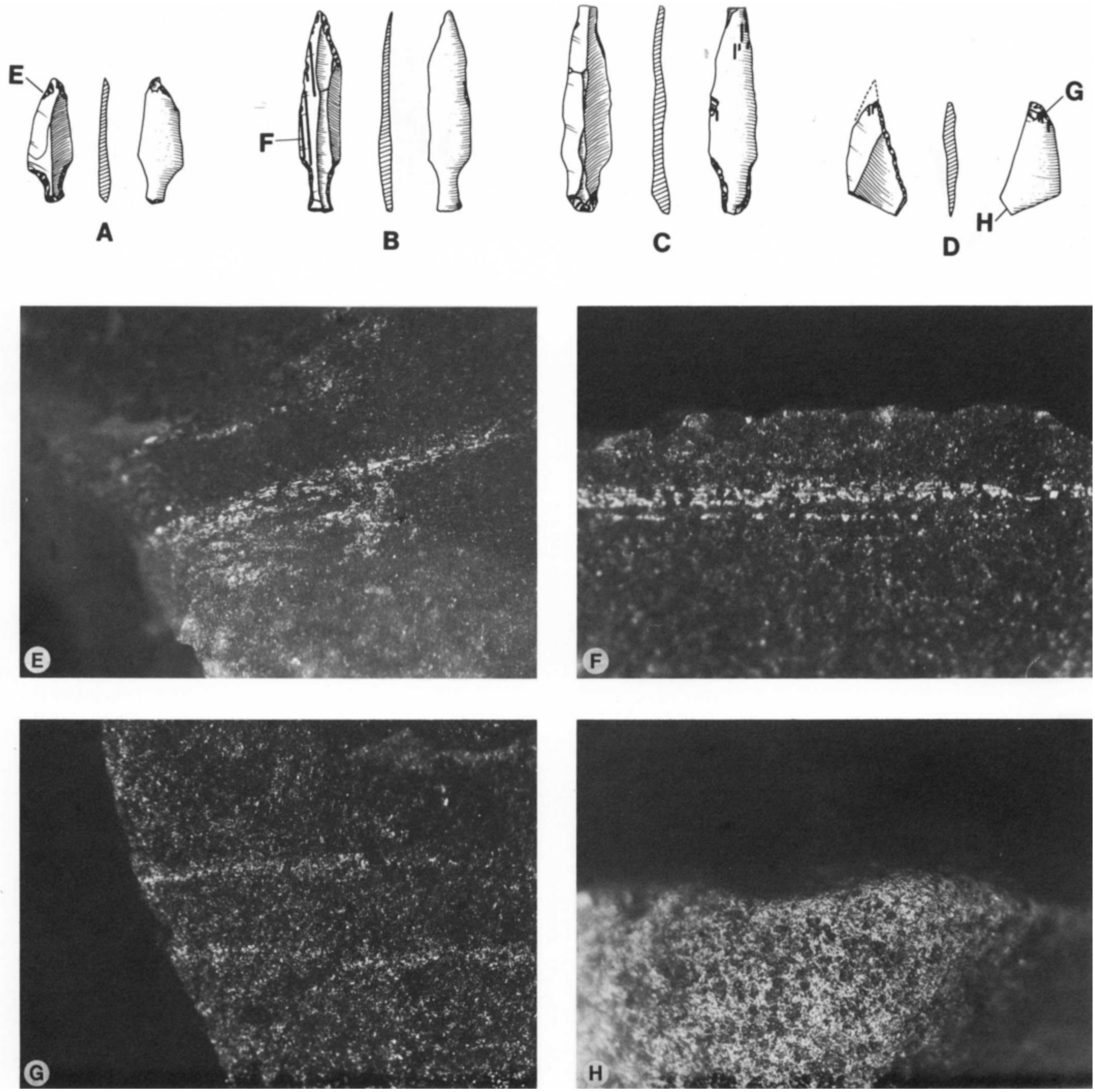


Fig. 25. Examples of flint points from the upper layer at Stellmoor, with indications of macro and micro wear traces. A–C: tanged points, D : Zonhoven point. 2:3. – A: The dorsal side of the tip shows a small step terminating bending fracture from which several unifacial spin-offs initiate on the ventral side. Along the distal part of the edges are several cone fractures. – B: Several cone fractures are seen along the edges. – C: The tip shows a snap fracture from which several unifacial spin-offs initiate. One of these is 13 mm long and runs along the edge, resembling a burin blow. Along the edges, several cone fractures are seen. – D: The tip shows two step terminating bending fractures. From these, a unifacial spin-off, less than 1 mm long, initiates on the dorsal side. A small cone fracture is seen on the dorsal side of the base. – E: Photomicrograph of linear polish with striations at the bottom of a small fracture. The micro wear is oriented parallel to the longitudinal axis of the point (cf. A). 1:83. – F: Photomicrograph of linear polish with striations running along the edge of the point (cf. B). 1:83. – G: Photomicrograph of linear polish at the tip of the Zonhoven point (cf. D). 1:83. – H: Photomicrograph of an abrasion at the proximal end of the Zonhoven point. This abrasion may be a result of friction between the point and the shaft (cf. D). 1:167.

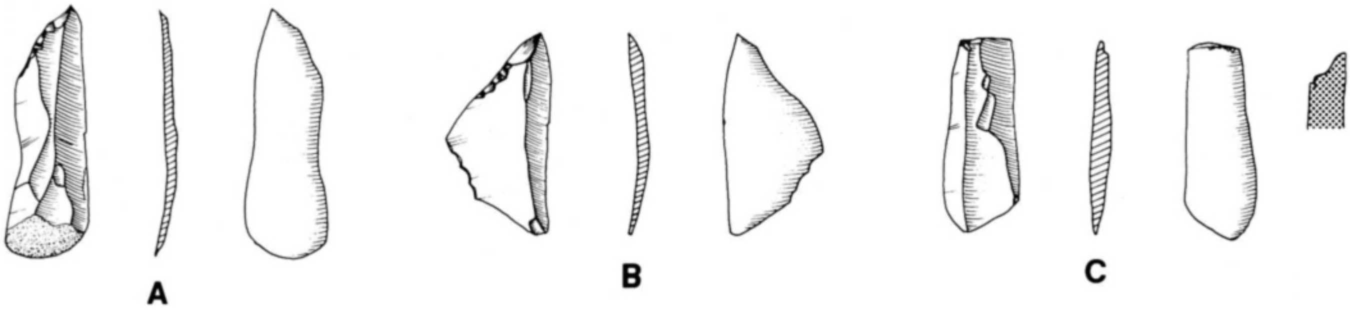


Fig. 26. The three microliths from the aurochs from Vig. 2:3. – A: No wear traces are seen. – B: The proximal end shows several small snap fractures. – C: The tip shows a bending fracture which, in places, is step terminating. From this fracture several spin-offs, less than 1 mm long, initiate on the ventral side.

and 12 unifacial spin-offs of a length of more than 1 mm (Fig. 25 A, C and D). (As the points are relatively small, spin-offs with a length of more than 1 mm are considered diagnostic).

23 of the points were examined for micro wear traces. Of these, 13 showed no wear traces. 4 had wear traces which could – subject to reservations – be considered projectile diagnosticating, and 8 (6 tanged points and 2 Zonhoven points) showed clear, projectile diagnosticating micro wear traces (Fig. 25).

The frequency of diagnostic macro and micro wear traces is relatively high in this assemblage. Moreover, all discovered points show non-diagnostic fractures and wear traces which may well have arisen from their use as projectile tips. Therefore, it is likely that all flint points from the upper layer at Stellmoor represent used arrowheads.

The Aurochs from Vig

A complete and well-preserved skeleton of an aurochs found during peat digging in a small bog at Vig in the north-west of Zealand (Hartz & Winge 1906). The animal was dated to pollen zone IV, the preboreal period (Degerbøl & Fredskild 1970: 188–189).

Two ribs on the right side of the aurochs show lesions with embedded flint chips. The one lesion was healed, but the other was completely fresh at the death of the animal (Hartz & Winge 1906: 232–233). Holes through both shoulder blades may also be attributable to hunting weapons (Noe-Nygaard 1973 and 1974, see however Møhl 1980).

During excavation of the skeleton, three flint points which must have been shot into the animal were found around the chest. They are all lancet microliths with oblique retouch at the tips (Fig. 26). One of them shows projectile diagnosticating macro fractures (Fig. 26 C), i.e. a step terminating bending fracture perpendicular to the length. From this unifacial spin-offs, less than 1 mm in length, initiate.

The calcareous gyttja, in which the flint points were embedded, decalcified their surfaces so they are unsuitable for micro wear trace analysis.

The Aurochs from Prejlerup

A whole and well-preserved skeleton of an aurochs, excavated in a small bog at Prejlerup in the north-west of Zealand (Aaris-Sørensen 1984). It was dated by C-14 analysis to 6460 ± 90 b.c. (K-3130), and by pollen analysis to the boreal period, pollen zone V.

During the careful excavation, 12 more or less fragmented lancet microliths, 3 triangular microliths and 1 fragment of a presumed arrowshaft were found directly in connection with the skeleton. Projectile diagnosticating macro fractures are seen on 6 of the points (all lancets). But it has not been possible to demonstrate micro wear traces, which must be attributed to the fact that the surfaces of most of the points were more or less

Fig. 27. Oblique arrowhead embedded in the proximal epiphysis of the left humerus of a red deer, found at Kongemose (*locus classicus*). Photo: Nanna Noe-Nygaard.

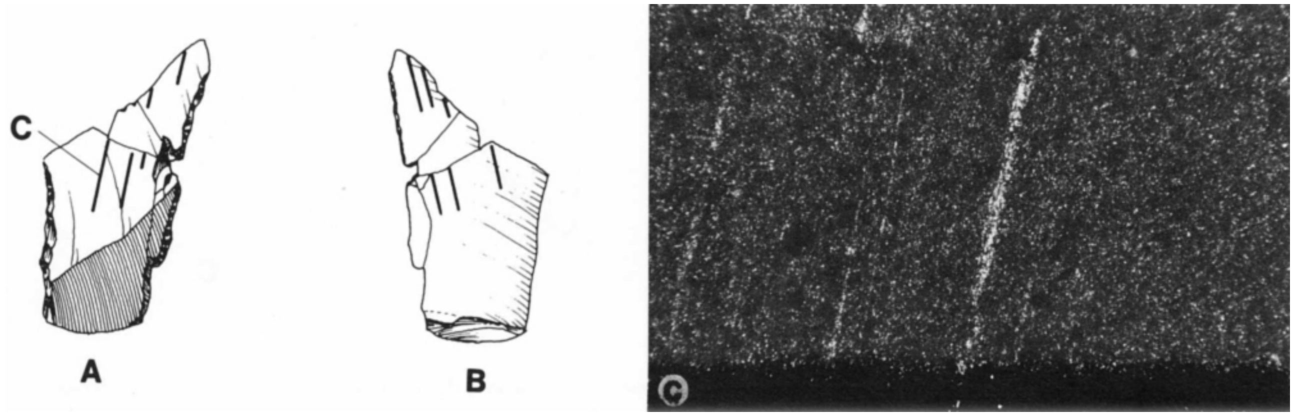


Fig. 28. The same arrowhead as shown on fig. 27 with indications of macro and micro wear traces (redrawn after Noe-Nygaard 1974). – A + B: The arrowhead consists of 6 fragments, showing several step terminating bending fractures at its tip and base. From one of the bending fractures of the tip, spin-offs initiate, running down one of the retouched sides. 1:1,3. – C: Photomicrograph of linear polish with striations. 1:42.

decalcified by the calcareous sediments. The diagnostic macro fractures include 6 step terminating bending fractures, 3 unifacial spin-offs with a length of more than 1 mm and 1 bifacial spin-off (Fischer 1984).

Red Deer Bone with an Embedded Oblique Arrowhead from the Kongemose Settlement

Limb bone of red deer with an oblique arrowhead embedded in an unhealed lesion (Fig. 27), found at the Kongemose settlement in western Zealand (Noe-Nygaard 1974: 224–225). C-14 analyses date the settlement to approx. 5600 to 5350 b.c. (Tauber 1971: 127 and 131), and by pollen analysis it is referred to the early atlantic period, pollen zone VI (Jørgensen 1956: 37, 1961: 445).

On collision with the bone, the flint point was heavily damaged (Fig. 28 A-B). The tip end shows two step terminating bending fractures from which spin-offs of up to approx. 1 cm initiate. The proximal end is missing. It was broken off by a step terminating bending fracture perpendicular to the length. Apart from these macro fractures, there are a number of well-developed projectile diagnosticating micro wear traces (Fig. 28 C).

Vejlebro, Layers 8 and 9

Settlement from the Ertebølle culture, excavated in the northeast of Zealand (Malmros 1975). Both layers are, on the basis of a series of C-14 analyses, dated to approx. 3525 b.c. (Malmros 1975: 113).

The flint inventory of both layers includes transverse arrowheads in all stages of production. If the undisputably unfinished specimens are excluded, there are 24 more or less successful arrowheads from layer 8 and 42 from layer 9. Of these, 5 and 2 respectively show projectile diagnosticating macro fractures. The material has not been examined for micro wear traces.

Præstelyng

Excavated settlement from the final part of the Ertebølle culture, situated in the Åmose in western Zealand. By means of C-14 analyses the settlement is dated to approx. 3200 b.c., and by pollen analyses it is referred to the late part of pollen zone VII (Troels-Smith 1981: 110, note 4, Noe-Nygaard 1971: 18–19 and 1981: 110–111).

The existing material comprises 57 finished and usable transverse arrowheads, a considerable number of pre-forms and, moreover, quite a few specimens which were in principle finished by the flint knapper but the retouch was so unsuccessful that they must be considered failures. Projectile diagnostic macro or micro wear traces have not been observed on the unfinished or unsuccessful specimens. Of the usable transverse arrowheads, 8 show projectile diagnosticating macro fractures. There are 7 step terminating bending fractures perpendicular to the length, 2 unifacial spin-offs longer than 1 mm and 1 bifacial spin-off.

Four of the finished and usable transverse arrowheads proved unsuitable for micro analyses because of decalcification and crazing by fire. Of the remaining 53 specimens, 2 show diagnostic micro wear traces.

Red Deer Bone with Embedded Transverse Arrowhead from Maglelyng

Red deer rib with a transverse arrowhead embedded in a healed lesion, found in the Maglelyng complex of the Åmose in western Zealand (Noe-Nygaard 1974: 227–229). Detailed information about the original context of the bone is not available. But, on the basis of a pollen analysis, it is dated to the subboreal period, pollen zone VIII.

Through collision with the rib, several cone fractures occurred on the edge of the arrowhead, and the longest are more than 3 mm long. Moreover, the entire proximal end was broken off – partly by a hinge terminating bending fracture and partly by a series of cone fractures.

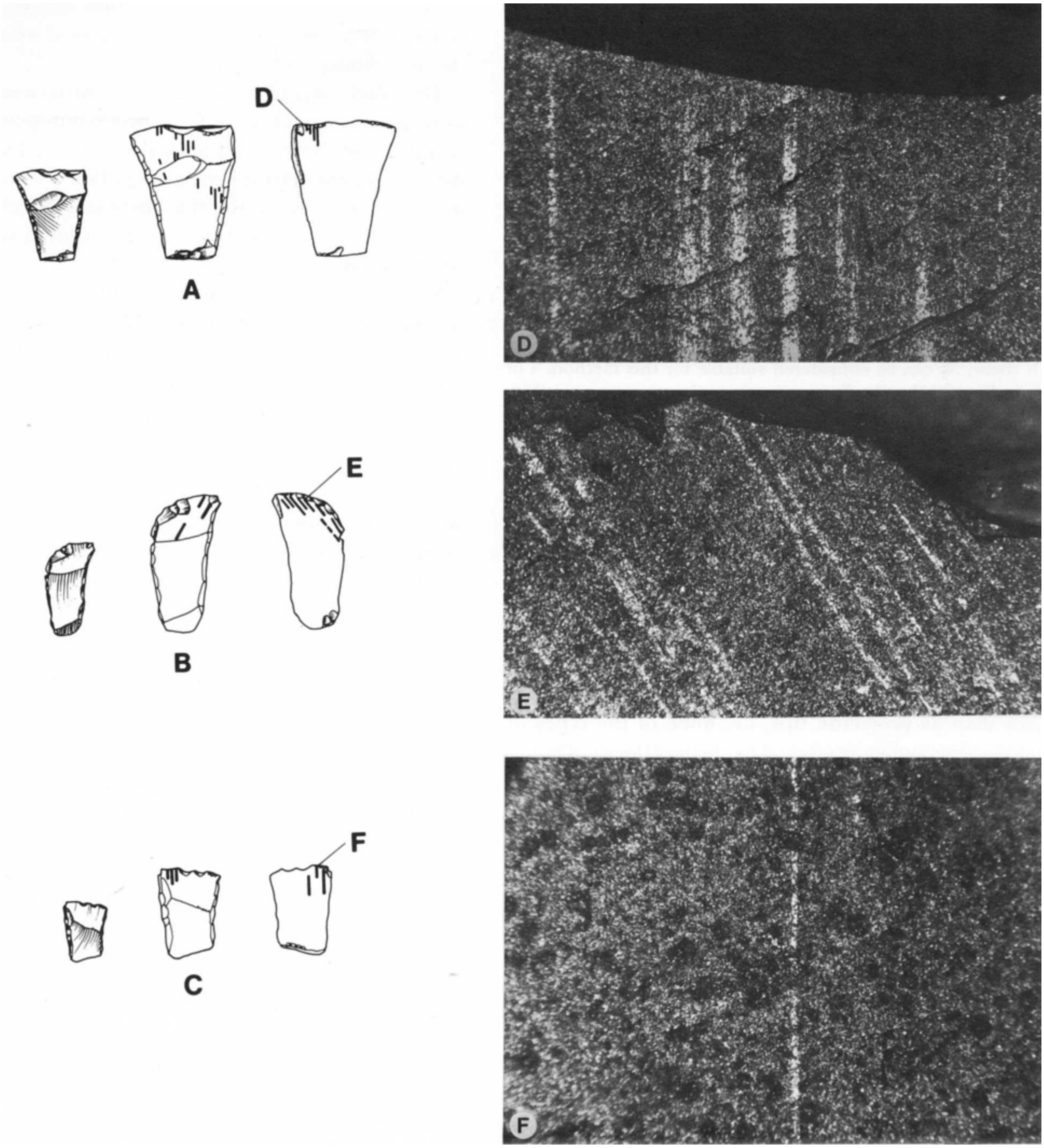


Fig. 29. Three transverse arrowheads from the Muldbjerg site with macro and micro wear traces, each specimen shown first on scale 2:3 and then twice on scale. 1:1. – A: The edge shows several small cone fractures and two small bending fractures. From the bending fractures, several spin-offs initiate along the ventral as well as the dorsal side. A spin-off, 8 mm long, runs – like a burin blow – along one of the retouched sides. The proximal end shows a step terminating bending fracture from which bifacial spin-offs initiate. – B: The edge shows several bending fractures on the ventral side and on one of the retouched sides. From these, spin-offs along the dorsal side initiate, their maximum length being 3 mm. The ventral side of the proximal end shows several small cone fractures. – C: The edge shows several small cone and bending fractures – none of which are diagnostic. The proximal end shows a snap fracture from which unifacial spin-offs, less than 1 mm long, initiate. – D: Photomicrograph of linear polishes, oriented at right angles to the edge. 1:42. – E: Photomicrograph of linear polishes oriented at acute angles to the edge. This orientation indicates that the point was forced in another direction than the original (cf. Fig. 16). 1:42. – F: Photomicrograph of linear polish oriented at a right angle to the edge. 1:42.

Muldbjerg
Excavated settlement from the early Funnel Beaker Culture, situated in the Åmose in western Zealand. The settlement is dated to approx. 2800 b.c., pollen zone VIII (Troels-Smith 1954, 1960 a, 1960 b and 1967).

The material comprises 34 transverse arrowheads. Of these, 30 can be characterized as finished and usable, whereas 4 seem to have been failures and hardly usable as arrowheads.

Even though a few of the transverse arrowheads were damaged by fire, they are all usable for macro analysis. An examination of them showed that 9 have projectile diagnosticating macro fractures. There are 13 step terminating bending fractures, 6 unifacial spin-offs with a length of more than 1 mm and 3 bifacial spin-offs (Fig. 29).

Micro wear analysis was made of 34 transverse arrowheads. Of these, 30 can be considered suitable for this method. 4 of them have projectile diagnosticating micro wear traces (Fig. 29).

The analysis of 397 flint points of different age and morphology shows that the defined macroscopic and microscopic characteristics of the projectile point function are present on the prehistoric material. This not only applies to the two point types with which we primarily experimented (Brommian points and transverse arrowheads), but also to the other point types. Moreover, none of the points show traces from other uses than as projectile tips, i.e. none of the types of microscopic polish produced by the treatment of meat, hide, bones, plants or wood were demonstrated. Further, we can demonstrate that several of the prehistoric points with projectile diagnostic macro and/or micro wear traces were used as projectile tips. The analyses shows that the characteristics of projectile points, isolated on the basis of experiments, are very numerous on Stone Age flint points and that these characteristics are connected with the very projectile point function.

The frequency of projectile point diagnosticating wear traces on the analysed, prehistoric points are summed up in table 4. It appears from the table that the frequency of diagnostic macrofractures is almost the same for all points shot into largish animals. The 18 points of which we know for certain that they were shot into aurochses are – taken as a whole – showing a frequency of 39%. Moreover, the 45 points which were in all probability shot into reindeer show a frequency of 42%. The examination of the prehistoric finds has not yielded any results which contradict the assumption: that the chance of the occurrence of diagnostic macro fractures on projectile points shot into largish animals is about 40%, irrespective of the species of animal and the morphology of the points.

The conditions of preservation for micro wear traces were generally poor in the finds where flint points were found in connection with animal skeletons. Therefore, the existing material affords no possibility of evaluating the advanced assumption that there is a 60% chance of diagnostic micro wear traces if the point is shot into largish animals.

Several of the sites enumerated in table 4 must be considered proper settlements. This applies to Bromme, Vejlebro, layers 8 & 9, Præstelyng and Muldbjerg. These sites all contain a comprehensive artefact inventory, comprising among other things large amounts of flint waste and "constructions" such as fireplaces. This does not apply to Ommelshoved which is more likely a "special activity site". The two water-deposited find layers at Stellmoor cannot be grouped with any of these categories. More likely, Stellmoor was a refuse area and a storage place for meat and raw materials for the tool production.

On the basis of the settlements and the special activity site enumerated in table 4, it appears that the corrected frequencies of diagnostic macro and micro wear traces are between 4% and 30%. These frequencies are considerably lower than the approx. 40% and 60% respectively which, according to the experiments, occur through shooting into largish animals. They are in most cases even lower than what may be expected from arrows which missed the target by accident (cf. tables 2 and 3). On the basis of the above, we can conclude that a considerable part of the points found at the settlements and special activity site were hardly used for hunting largish animals. They must have been used for other purposes or not at all. As previously mentioned (pages 19 and 42), there is no positive evidence for any other functions of these point types than as projectile points. Therefore, it seems most likely that relatively many of the finished and apparently usable points in the examined inventories were never used. If we assume that in a population of used projectile points the frequency of diagnostic macro and micro wear traces will be 40% and 60% respectively, then approx. 25% to 90% of the points of the examined settlements and special activity site must be considered unused. This situation calls for an explanation. It is worth noticing that an arrowhead can be made within a few minutes while the

NAME OF SITE	SCIENTIFIC DATING: Pollen zone	SCIENTIFIC DATING: C-14 age b.c.	Number of available points	RESULT OF MACRO ANALYSIS: Number of analysed points	Number of points unsuitable for macro analysis	Number of points with projectile diagnostic macro fractures	Frequency of points with projectile diagnostic macro fractures	Corrected frequency of points with projectile diagnostic macro fractures	RESULT OF MICRO ANALYSIS: Number of analysed points	Number of points unsuitable for micro analysis	Number of points with projectile diagnostic micro fractures	Frequency of points with projectile diagnostic micro fractures	Corrected frequency of points with projectile diagnostic micro fractures
Stellmoor, lower level	I	10,500	4	4	0	2	50%	50%					
Ommelshoved			110	110	22	11	10%	13%	15	14	1		
Bromme	II		65	65	18	3	5%	6%	61	61			
Stellmoor, upper level	III		45	45	0	19	42%	42%	23	0	8	35%	35%
Vig, aurochs	IV		3	3	0	1	33%	33%	3	3			
Prejlerup, aurochs	V	6,500	15	15	0	6	40%	40%	15	8	0	0%	0%
Kongemose, oblique point in a bone	VI	5,500	1	1	0	1	100%	100%	1	0	1	100%	100%
Vejlebro, level 8		3,525	24	24	0	5	21%	21%					
Vejlebro, level 9		3,525	42	42	0	2	5%	5%					
Præstelyng	VII	3,200	57	57	1	8	14%	14%	57	4	2	4%	4%
Maglelyng, transverse arrowhead in a bone	VIII		1	1	0	0	0%	0%	1	1			
Muldbjerg	VIII	2,800	30	30	0	9	30%	30%	30	5	4	13%	16%
Σ			397	397	41				206	96			

Table 4. The results of the application of the macro and micro methods on prehistoric points. The various sites are mentioned chronologically. The frequency of projectile diagnosticating wear are stated partly in relation to the total number of analysed points and partly in relation to the points, the condition of preservation which makes them suitable for the analysis method in question.

production of an arrowshaft demands much more time. An obvious explanation may thus be that Stone Age flint knappers generally produced series of points to make sure always to have some on stock from which the hunters could pick out the ones most suited for the shafts at hand and the hunt ahead.

SUMMARY AND CONCLUSION

By means of practical experiments, we have demonstrated and defined two types of wear traces which are diagnostic for the projectile point function. The one type can be studied with the naked eye (the macro method), the other type requires a microscope (the micro method). Both types are found on all types of projectile points used in the experiments. They have furthermore been found on a large number of prehistoric flint points of very different age, size and shape. We therefore expect that the defined macro- and microscopic characteristics of the projectile function are universal for points of flint and related stone – irrespective of the morphology and mounting method of the points.

Diagnostic macro and micro wear traces were observed on approx. 40% and 60% respectively of the fired points. Similar frequencies of macro and micro wear traces were observed on prehistoric flint points which were for certain or in all probability shot into aurochses, red deer and reindeer. We have consequently put forth the assumption that these percentages are universal for points shot into largish animals.

A total of 85 of the projectile points used in the experiments were analysed by means of the macro and the micro method. In each case, distinction was made between diagnostic and non-diagnostic wear traces and no wear traces at all.

The result of the two analyses is that the macro method diagnosticated the projectile function on 36% of the fired points (12), whereas the micro method reached a total of 53%. However, the micro method does not make the macro method superfluous. By using both methods, it is possible to diagnosticate as much as 61% of all cases – and this increase is obtained by a relatively modest extra effort: the time used for each object is very limited in the case of the macro method, whereas it is rather time-consuming to examine a flint object for micro wear traces. Moreover, the macro methods requires no special equipment and is far more tolerant to the texture, colour and surface disintegration of the flint.

So, we must conclude that the macro and micro methods can be used independently, that their strength is found in different fields, and that, especially in combination, they are efficient means of establishing whether a flint object served as a projectile tip.

The results presented here are based on examinations of 448 flint objects used in the experiments and 397 prehistoric flint points. Had we made more experiments, and had we included even more prehistoric objects in our analyses, we would undoubtedly have been able to present considerably more exact statements than now. Nevertheless, we expect that the methods developed will be helpful in the numerous attempts at functional and behavioural interpretations of lithic assemblages which are increasingly occupying archaeologists all over the world.

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NOTES

1. A piece of flint resembling a transverse arrowhead and found embedded in a swan bone at Bøgebakken in Vedbæk (Møhl 1979: 68–69) has turned out to have been made in more recent times and cannot therefore be regarded as evidence for interpretations of the function of prehistoric transverse arrowheads.
2. The points were made of socalled senonian flint from the island of Falster (Hansen og Madsen 1983: 48) and were manufactured in accordance with the size, weight and general morphology of the prehistoric ones.
3. We would like to thank Harm Paulsen, Schleswig-Holsteinisches Landesmuseum für Vor- und Frühgeschichte, and Søren Moses, Søllerød Museum, for informations about their work in connection with reconstructions of prehistoric bows.
4. It is to be expected that tools used for chopping and stabbing will be exposed to forces similar to those of the projectile points – i.e. parallel to the length. Therefore, other flint tools, such as axes, may show related fractures.
5. The proximal end of many Brommian points show bending fractures of the types defined as diagnostic in this article. Whether these fractures occurred in the moment of detachment or later during use of the finished points is usually easy to ascertain from the order in which the retouching of the tang and the fractures have occurred.
6. The micro wear analysis was done by Peter Rasmussen.
7. We would like to thank Nanna Noe-Nygård, Institute of Historical Geology and Palaeontology, Univ. of Copenhagen, for her help with the SEM photographs. These were taken by Stig Hansen, Institute of Geology, Univ. of Copenhagen.
8. As to the terms diagnostic and non-diagnostic the wear traces named diagnostic are so clear and well-developed that to all appearances similar traces can be found on prehistoric projectile points. The wear traces called non-diagnostic are so faintly developed that it is douptful whether they could be seen on prehistoric points. Obviously, this division of wear traces is purely subjective, but it enables us to present a more realistic picture of the experiments in relation to the archaeological material.
9. The work in connection with the experimental points with fish polishes gavè rise to important observation because it turned out that it is possible to remove the polish by cleaning the flint in HCl.
10. The examination was carried out on a X-ray monitor plant at the *Schleswig-Holsteinisches Landesmuseum für Vor- und Frühgeschichte*. We are indebted to Hans-Otto Nielsen for making the examination.
11. According to the *Schleswig-Holsteinisches Landesmuseum für Vor- und Frühgeschichte*, the bows and arrows from Stellmoor were lost during

a fire in 1944. The same seems to apply to the two proximal ends of tanged points.

12. The macro analysis included a total of 148 experimental projectile points shot into different materials, excl. water. The method diagnosticated the projectile point function in 41% of these cases.

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