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COMPOSITE PROJECTILES IN THE HAMBURGIAN FACIES OF THE FINAL MAGDALENIAN – TECHNOLOGICAL, EXPERIMENTAL AND MACRO-WEAR STUDY OF THEIR FLINT, ANTLER, AND ADHESIVE COMPONENTS

Exactly 25 years ago, the so-called *Kerbnadeln* – double bevelled antler rods with a distal groove – of the Hamburgian were the object of an article in this journal (Lund 1993). It represented the point of departure for the present study, which further investigates the modalities of this artefact type serving as fore shaft in composite projectiles.

In his Ahrensburg tunnel valley (Kr. Stormarn/D) campaigns in the 1930s, Alfred Rust found a rich osseous industry belonging to the Hamburgian (Rust 1937; 1943). The assemblages consist almost exclusively of exploited reindeer (*Rangifer tarandus*) antlers. These regularly show the extraction of single elongated blanks by the groove and splinter procedure (Rust 1937; Clark 1938; Rust 1943; Clark/Thompson 1954). Especially in the final phase of the Magdalenian (c. 12.700-12.000 cal BC) – which is contemporaneous to its Hamburgian facies (Grimm/Weber 2008; Debout et al. 2012) – these blanks were almost exclusively used for the production of projectile elements (Averbouh 2000; Malgarini 2014; Langley 2015). Typical artefacts made of such blanks are Magdalenian *pointes de sagaie*, distally pointed objects with a single or double bevelled base (Delporte/Mons 1988). Solely one Hamburgian artefact bears a resemblance to these: it is a < 10 cm long, double bevelled point with a perfect circular cross-section (SH1932-4.49; Rust 1937) from Meiendorf (Kr. Stormarn/D). Except for this rather atypical *pointe de sagaie*, these projectiles are completely absent from the Hamburgian assemblages. Besides the uniquely decorated Poggenwisch rod (Kr. Stormarn/D; Bosinski 1978) and a possibly Hamburgian harpoon from Meiendorf (Tromnau 1999), the only other finished objects made of antler blanks in the Hamburgian are the so-called *Kerbnadeln* (»grooved needles«) (Rust 1943, 129 pl. 26, 1-2), which had been found at Stellmoor (Kr. Stormarn/D). These are long antler blanks with a characteristic, small, <1 cm long and 2-3 mm wide groove, which was deepened in a longitudinal direction into the distal part of the artefact (**fig. 1**). The proximal part of one, almost complete, tool shows a double bevelled base with oblique incisions (**fig. 1c**), which is usually seen as part of a hafting system (cf. Allain/Rigaud 1989). While A. Rust interpreted these artefacts as needles, the reading as awls or – of particular importance for this paper – simple points (Burdukiewicz 1986, 147-148 fig. 52; Veil 1988, 219) was added in the 1980s – probably because of the overall and particularly its basal shape most typical for osseous projectiles. The interpretation discussed in this paper finds its origin in actualistic experiments of the same decade.

Ulrich Stodiek and Harm Paulsen (Stodiek 1985), influenced by other archaeological finds, including the Mesolithic Lilla Loshult (Skåne län/S) arrow with an obliquely and frontally hafted triangular microlith (Petersson 1951), used 16 replicas of asymmetrical[1] lithic angle-backed points of the Final Magdalenian for shooting experiments. Three were hafted in an emphasised oblique fashion to move the lateral tip of the point to the central longitudinal axis of the projectile, whereas symmetrical points are usually hafted in symmetrical slots with a ligature.

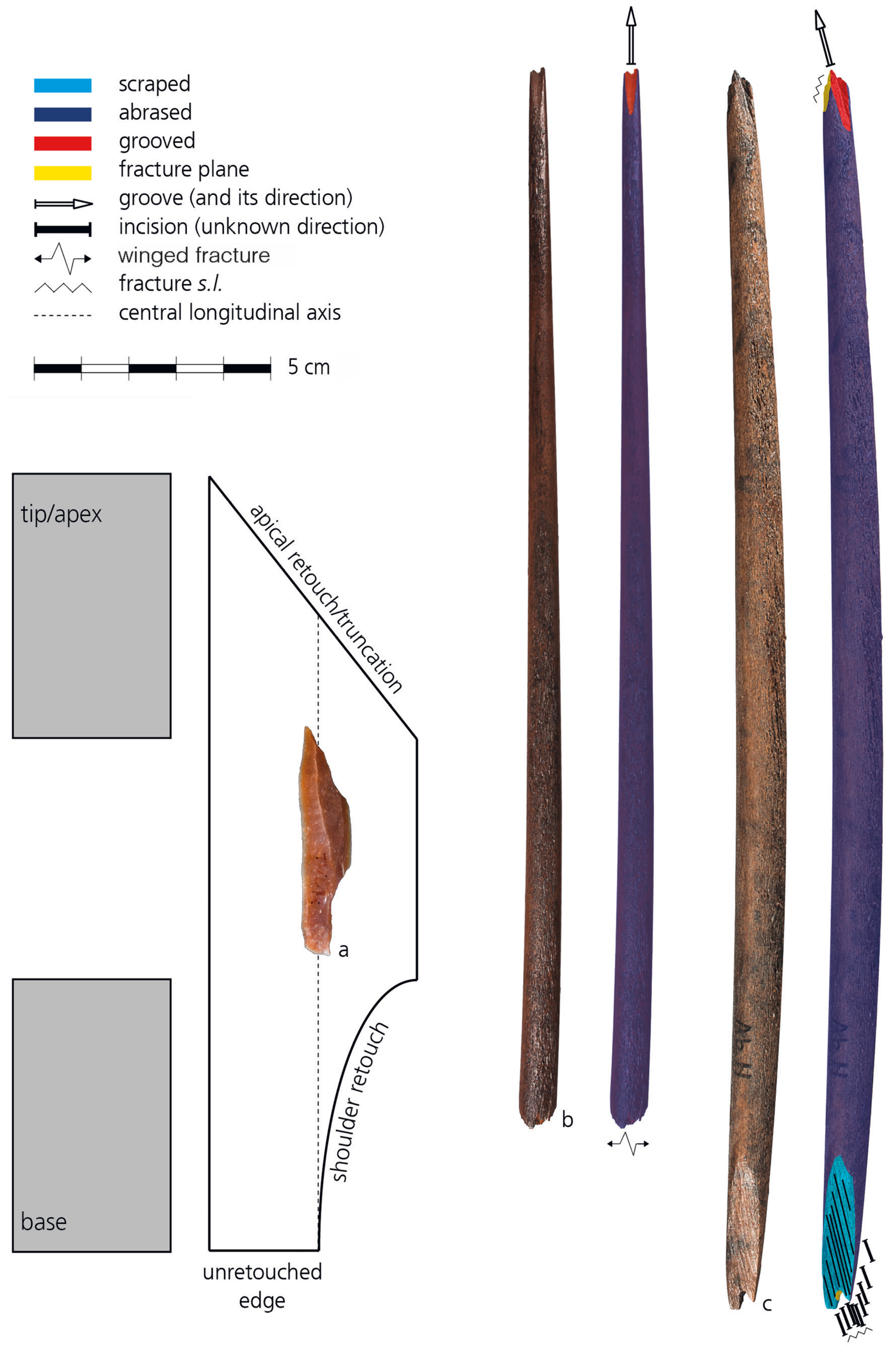


Fig. 1 **a** shouldered point from Teltwisch 1. – **b-c** possible fore shafts from the Hamburgian at Stellmoor (SH1935-5.217; SH1935-5.218) with their technological description. – Symbols for incision and groove by Groupement de Recherche Européen – Exploitation des Matières Osseuses dans l'Europe Préhistorique. – (Photos C. Janke, Stiftung Schleswig-Holsteinische Landesmuseen Schloss Gottorf; Illustration M. Wild).

Fig. 2 Experimental projectiles: **a** spear: shouldered point – sinew – antler fore shaft – bitumen covered sinew – wooden main shaft (15 mm diameter). – **b** arrow: shouldered point – birch bark tar – antler fore shaft – bitumen covered sinew – wooden main shaft (9.5 mm diameter). – (Photos M. Wild / M.-J. Weber).

In 1993 these ideas were combined and further developed by one of the authors of this paper (Lund 1993), who interpreted the function of the *Kerbnadeln* as fore shafts for Hamburgian shouldered points. His suggestion was to position the lithic points slightly oblique to their central longitudinal axis with the retouched part of the base below the shoulder inserted laterally in the distal grooves of the *Kerbnadeln* (**fig. 2**). In this way, the asymmetric outlines of the shouldered points and the distal grooves on the antler artefacts could be explained. As a result of the oblique positioning of the shouldered point, its sharp unretouched edge would be exposed to the target, enhancing the efficiency of the projectile (cf. Lund / Schürmann 1995; Pétillon et al. 2011). The fact that not only the straight apical truncation, but also the gently curved shoulder retouch, represents a consistent feature of Hamburgian shouldered points, suggests that it constitutes an indispensable element for the hafting of these implements. Its complementarity with the distal groove on the *Kerbnadeln* could argue in favour of Marquardt Lund's (1993) hypothesis, as the find context at Stellmoor with the two *Kerbnadeln* and four shouldered points (Rust 1943, pl. 22, 4-6; Fischer / Hansen / Rasmussen 1984, 36 fig. 23) in close association (Rust 1943, 126) also does.

FORE SHAFTS IN CONTEXT

Fore shafts are defined as an intermediate piece between the projectile's wooden main shaft and the actual point (Cattelain 1988). Typically, the raw material of the fore shaft (e. g. osseous material or hard wood) is both harder and heavier than the main shaft material (e. g. wood or cane). The application of fore shafts can be beneficial for a couple of reasons (Cattelain 1988; Ellis 1997; Junkmanns 2001; Fienup-Riordan 2007; Pfeifer 2012):

1. they balance the stresses between the main shaft and the point and provide a more robust socket for the hard point than a one-piece shaft would do, making the overall projectile more durable when thrust, thrown or shot into the target with great force;
2. they add mass to the projectile to increase its impact;
3. in case of damage only one part of the projectile has to be repaired / replaced and not the whole weapon;
4. in environmental contexts where wood is scarce, they help to accomplish a sufficient length of the projectile;
5. they can be used to standardise the masses and spines of projectiles in a set, and
6. removable fore shafts turn a projectile into a multi-purpose tool since they can be used as handles for knives and awls.

Ethnographic fore shafts

All those advantages in mind, it is not surprising that fore shafts of wood, bone, antler, ivory and horn as part of darts, spears, arrows, lances and harpoons are widespread in the global archaeological and ethnographic record – be it in Late Glacial Siberia and North America (Bradley 1995; Nikolskiy/Pitulko 2013), amongst different Palaeoindian and Palaeoeskimo cultures (Hare et al. 2004; Justice 2002; Potter et al. 2014; Grønnow 2017), Native Americans (Bohr 2014), historical Inuit societies (Kane 1856; Boas 1888; Murdoch 1892; Tuborg Sandell/Sandell 1991; Pfeifer in print), in Predynastic Egypt (Clark/Phillips/Staley 1974) and amongst traditional hunter-gatherer groups in Africa (Wiessner 1983; Bartram 1997; Bradfield 2012), Australia and Oceania (Ellis 1997).

Fore shafts in Late Glacial Europe

The wooden fore shafts encountered on the arrows from the famous Ahrensburgian Stellmoor site show that the fore shaft principle was well developed in the Late Palaeolithic on the North European Plain (Rust 1943). In the preceding Late Upper Palaeolithic, however, preserved fore shafts are a rare phenomenon (Pfeifer 2012). Although the leading tradition in Western and Central Europe, the Magdalenian (c. 18.500-12.000 cal BC), is characterised by an extraordinary assemblage of osseous projectile points (Stodiek 1993; Valoch 2001; Langley/Pétillon/Christensen 2016; Pétillon 2016; Pfeifer 2016), the only site where osseous fore shafts are found in substantial numbers is Isturitz cave (dép. Pyrénées-Atlantiques) in South-Western France (Pétillon 2006; 2008). Elsewhere, only single specimens have been recovered (see Pfeifer 2012).

THE EXPERIMENT

The general functionality of the combination of *Kerbnadeln* and Hamburgian shouldered points, as suggested by M. Lund (1993), has already been experimentally proven (Lund/Schürmann 1995). Their experimental setup showed arrow shafts with replicas of *Kerbnadeln* and Hamburgian shouldered points (**fig. 2**) that were shot with a Koldingen bow replica of the Holmegaard type (cf. Paulsen 1990) with a draw weight of 19 kg. The projectiles were firstly shot on a soft target from a distance of 8 m, and secondly into a pig's torso that was covered by reindeer fur at a »very short distance«.
The present study is beyond the scope of the former experimental series in that it varies the accelerators and compares the resulting macroscopic use-wear with that observed on Hamburgian artefacts in order to validate or reject the interpretation of *Kerbnadeln* as fore shafts.

Experimental setup

Since neither *Kerbnadeln* nor Hamburgian shouldered points have ever been found within a complete projectile, their way of hafting, the type of projectiles they belonged to, and the way they were accelerated are still a matter of discussion (e. g. Rust 1937, 126-127; Bosinski 1978; Burdukiewicz 1986, 160; Bratlund 1990, 9; Bokelmann 1991; Lund 1993; Riede 2010; Weber 2012). To include as many possibilities, conceivable in the Hamburgian context, as possible, six different experimental series were planned: one type of composite projectile (wooden main shaft with an antler fore shaft and a lithic projectile) was hafted in two

Fig. 3 H. Paulsen shoots the arrows with a bow (**a**), while the spears were accelerated by a spear thrower (**b**) and a controlled machine (**c**). The target is a red deer on a wooden rack. – (Photo M. Wild / M.-J. Weber).

different manners with birch bark tar and sinew, and was accelerated in three ways with a Holmegaard type bow (cf. Becker 1945; **fig. 3a**), an atlatl/spear thrower (**fig. 3b**), and a controlled machine (**fig. 3c**). For the bow, arrows were prepared (weight 49-73 g; length 98-109 cm; diameter 9.5 mm; pine; fletched), while the spear thrower and the machine accelerated spears (weight 212-241 g; length 216-223 cm; diameter 15 mm; pine; fletched).

H. Paulsen knapped blades for 23 shouldered points from good quality Baltic flint. In contrast to the Hamburgian examples from Teltwisch 1 and Poggenwisch (both Kr. Stormarn/D) in the Ahrensburg tunnel valley (Weber 2012, 141), the replicas were predominantly oriented with the base at the distal end of the blank and lateralised with the retouch on the left blank edge when placing the tip towards the top. The shoulder was exclusively formed by direct retouch. The extremity of the base consisted in two cases of the proximal end of the blank. This extremity showed in two cases direct retouch and was fractured or at least damaged in all but one other case. Further retouch on the edge opposite to the shoulder was only applied subsequently when the hafting necessitated it (see below). On nine specimens, a trihedral burin resulting from the use of the micro-burin technique was still visible at the apical extremity adjacent to the straight and direct apical retouch, in one further case, the presence of a trihedral burin was uncertain. The metrics of the points were comparable to the data given in Weber (2012) for the Hamburgian shouldered points from Poggenwisch and Teltwisch 1 (**tab. 1**). At the difference to these archaeological series, all chosen blanks or blank portions possessed a straight longitudinal profile.

shoulderd points			length (mm)	width (mm)	thickness (mm)	weight (g)	length (base) (mm)	thickness (shoulder) (mm)
replicas	H. Paulsen	min.	34.8	10.7	2.8	0.9	16.6	2.6
		max.	61.8	18.2	4.9	4.5	24.6	4.5
		mean	*42.4*	*13.1*	*3.6*	*1.8*	*17.7*	*3.3*
artefacts	Poggenwisch	min.	42.1	8.6	2.5	1.4	15.6	2.2
		max.	78.3	16.9	4.6	4.8	27.3	5.0
		mean	*53.5*	*12.6*	*3.4*	*2.1*	*21.1*	*3.3*
	Teltwisch 1	min.	34.2	9.1	2.2	1.0	15.1	2.0
		max.	67.6	19.2	5.0	6.1	24.8	5.2
		mean	*45.7*	*13*	*3.6*	*2.1*	*20.4*	*3.3*

Tab. 1 Hamburgian shouldered points produced by H. Paulsen (n = 23) and used in the experiments against the measurements taken by M.-J. Weber for the tunnel valley sites of Poggenwisch and Teltwisch 1 (both Kr. Stormarn / D; Weber 2012).

	length (mm)	width (mm)	compact bone (mm)	thickness (prox.) (mm)	thickness (mes.) (mm)	thickness (dist.) (mm)	weight (g)	length groove (mm)	width groove (mm)	length bevel (mm)
fore-shafts										
min.	220	9	4	7.1	7.8	2.2	17	9.9	2.6	20
max.	318	14	10	11.8	11.7	7.8	43	19.4	4.3	51
mean	*291*	*12*	*7*	*9.7*	*10*	*3.9*	*31*	*12.6*	*3.5*	*39*
Kerbnadeln										
SH1935-5.217	225+	9	7	8.1+	6.2	2.2	14+	11.5	2.1	–
SH1935-5.218	262	12	8	9.5	11.6	7	30	15.7	3.6	35
mean	*244+*	*11*	*8*	*8.8+*	*8.9*	*4.6*	*22+*	*13.6*	*2.9*	*35*

Tab. 2 Fore shafts produced by M. Lund, H. Paulsen, M.-J. Weber and M. Wild and used in the experiments against the measurements taken by M. Wild for the two secure *Kerbnadeln* from the Ahrensburg tunnel valley site Stellmoor (Kr. Stormarn / D).

For the production of fore shafts we oriented on the archaeological evidence, which is – although rather small – diverse: the only almost complete artefact (SH1935-5.218; **fig. 1c**) shows a double bevelled base and is spindle-shaped, while the other secure *Kerbnadel* (SH1935-5.217; **fig. 1b**) consists solely of the medial and distal part of the artefact. It tapers from the proximal bevelled fracture plane to the distal tip and is more delicate. Both artefacts are very long (**tab. 2**), showing a circular cross-section and a smooth surface. A third artefact (SH1935-5.333; Wild / Weber 2017, 29 fig. 5D) shares some of the *Kerbnadel*-characteristics (double bevelled base, length, circular cross-section, smoothness of the surface) but lacks its distal part with the possible groove because of taphonomical reasons.
The replicas were produced from c. five-year-old Norwegian reindeer antler. The non-soaked antler was worked by modern saws and files. In addition, six replicas that had been used in the 1990s experiments were utilised. These had been made from almost fresh reindeer antler from Finland and were straightened after becoming soaked and dried in a straight position (Lund / Schürmann 1995). Finally, the finished rough outs and the 1990s replicas were (re)straightened partly after heating by simple bending.
The 23 produced replicas of shouldered points were assigned to 20 fore shafts in order to find 18 combinations of fore shaft-point junctions (**tabs 1-2**) that adjusted the lateral tip of the shouldered points so that it stood approximately in the longitudinal axis of the fore shafts.

no. of foreshaft, point	weight of fore shaft	weight of shouldered point	weight of projectile	accelerator	hafting	macro use-wear on shouldered points						macro use-wear on foreshafts			
						pseudo-burin fracture	bending fracture with termination			cone fracture	flute-like fracture	crushing	mushrooming	bevelled break	specific fore shaft fracture
							snap	step	hinge						
29ª, 9	17	1.5	49	bow	tar	✓	–	–	–	–	–	✓	–	–	–
24ª, 19	21	1.3	222	machine	tar	–	–	–	–	–	–	–	–	–	–
27ª, ᵇ, 3	21	1.7	222	atlatl	tar	point not retrieved						✓	–	–	–
28ª, 18	22	2.4	53	bow	sinew	–	–	–	–	–	–	✓	–	–	–
26ª, ᵇ, ᶜ, 1	24	1.9	216	machine	sinew	–	✓	✓	–	–	–	–	–	–	✓
13, 11	27	2.2	212	atlatl	sinew	✓	–	–	–	–	–	–	–	–	–
18, 7	29	1.8	67	bow	tar	–	–	–	✓	–	–	–	–	✓	–
3ᶜ, 22	32	2.4	231	machine	tar	–	–	–	–	–	–	–	–	–	–
15ᵇ, 21	32	4.5	226	atlatl	tar	–	–	–	–	–	–	–	–	–	–
25ª, 12	32	1.9	65	bow	sinew	–	–	–	–	–	–	✓	–	–	–
4, 17	33	1.2	232	machine	sinew	–	–	–	–	–	✓	✓	–	–	–
16, 14	36	1.7	236	atlatl	sinew	–	–	–	–	–	–	–	✓	–	–
1, 20	37	1.6	70	bow	tar	–	–	–	–	–	–	–	–	–	–
17, 6	38	0.9	236	machine	tar	–	–	–	–	–	–	–	–	–	–
23, 8	39	1.2	241	atlatl	tar	✓✓	–	–	–	–	–	✓	–	✓	–
20, 10	40	1.5	73	bow	sinew	✓	–	–	–	–	–	✓	–	–	–
2, 4	42	1.3	219	machine	sinew	point not retrieved						✓	–	–	–
21, 16	43	1.1	232	atlatl	sinew	–	✓	–	–	✓	✓	–	–	✓	–

Tab. 3 Equal assignment of replicated projectiles to experimental series and hafting methods. – Weight in g. – ª already used in Lund/Schürmann 1995. – ᵇ hit the ground. – ᶜ shot twice. – mach = machine. – ✓ = observed once. – ✓✓ = observed twice. – Assignment by massiveness (≈ weight) of the fore shaft. – Use-wear patterns on lithic projectiles and fore shafts: Pseudo-burin, flute-like and step-terminating bending fractures are usually considered indicative of impact (red). Crushing and mushrooming taken as less important damage (yellow), bevelled breaks taken as dramatic damage (red) as it needed re-shaping of the tip/groove before a re-use. Colouring of accelerator and hafting should help to distinguish different experimental sets.

Afterwards, the fore shaft-point combinations were sorted by weight (≈ massiveness) of the fore shaft and were assigned alternating to the different experimental sets so that all accelerators, as well as arrows and spears, were armed with light-, medium- and heavy-weight projectiles (**tab. 3**). This led to three shots for each of the six experimental series.

The birch bark tar, produced in the double-pot procedure (Kurzweil/Todtenhaupt 1990) and extended by charcoal, was heated and c. 2-3 g of it was stuck around the fore shaft-point junction. The hafting with cervid sinew triggered a specific preparation of the lithic points: on the basal part, opposite to the shoulder, stump grooves were retouched into the shaft. This preparation should prevent a cutting of the sinew, which afterwards was wrapped around the shaft of the lithic projectile implement. Archaeologically, this kind of preparation has been observed on several examples (Rust 1958, pl. 5, 24-25. 28-30; Tromnau 1975, pl. 1, 10-11. 13). The junction between the main shaft and the fore shaft was wrapped with sinew and glued with bitumen (**fig. 2**).

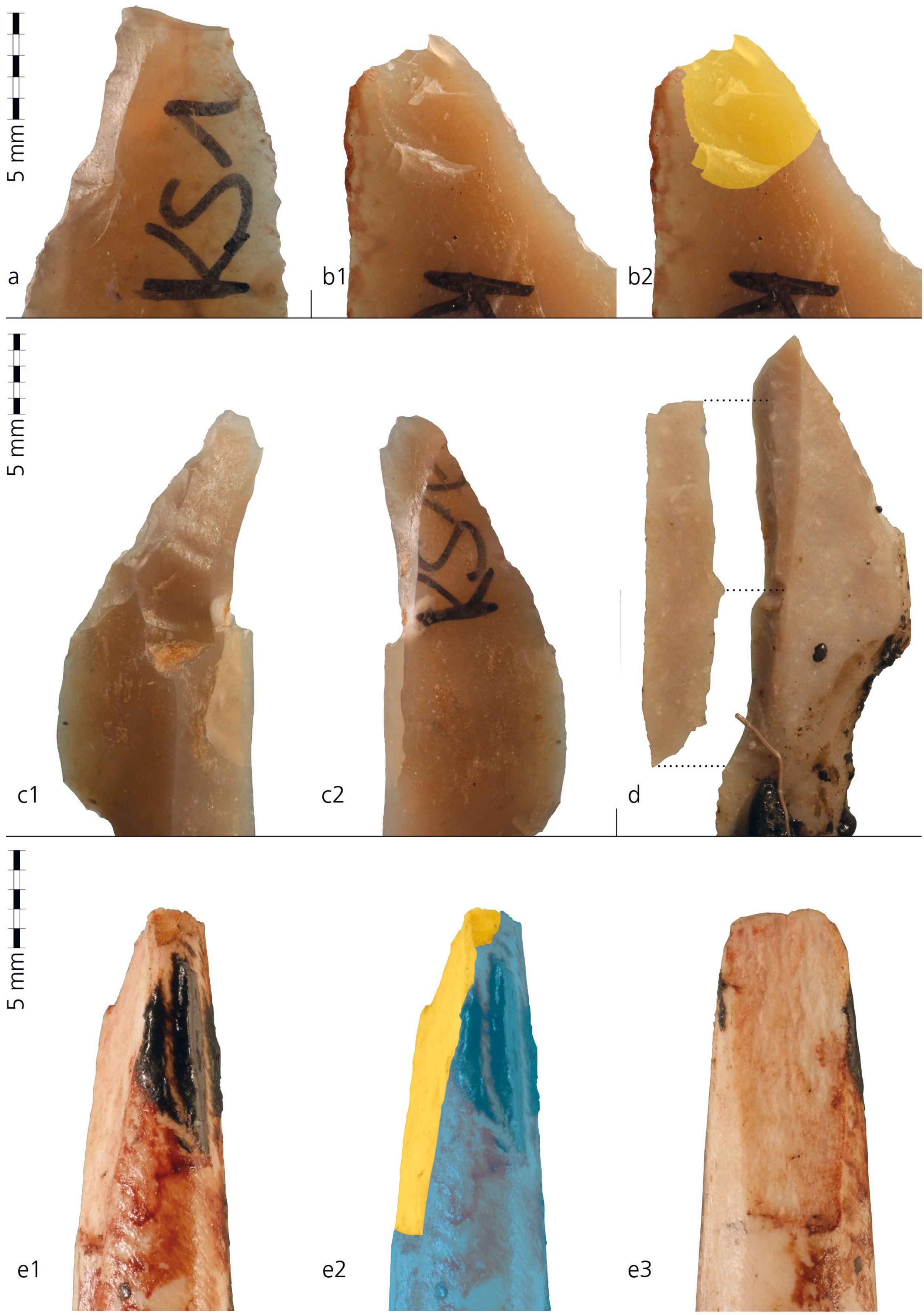
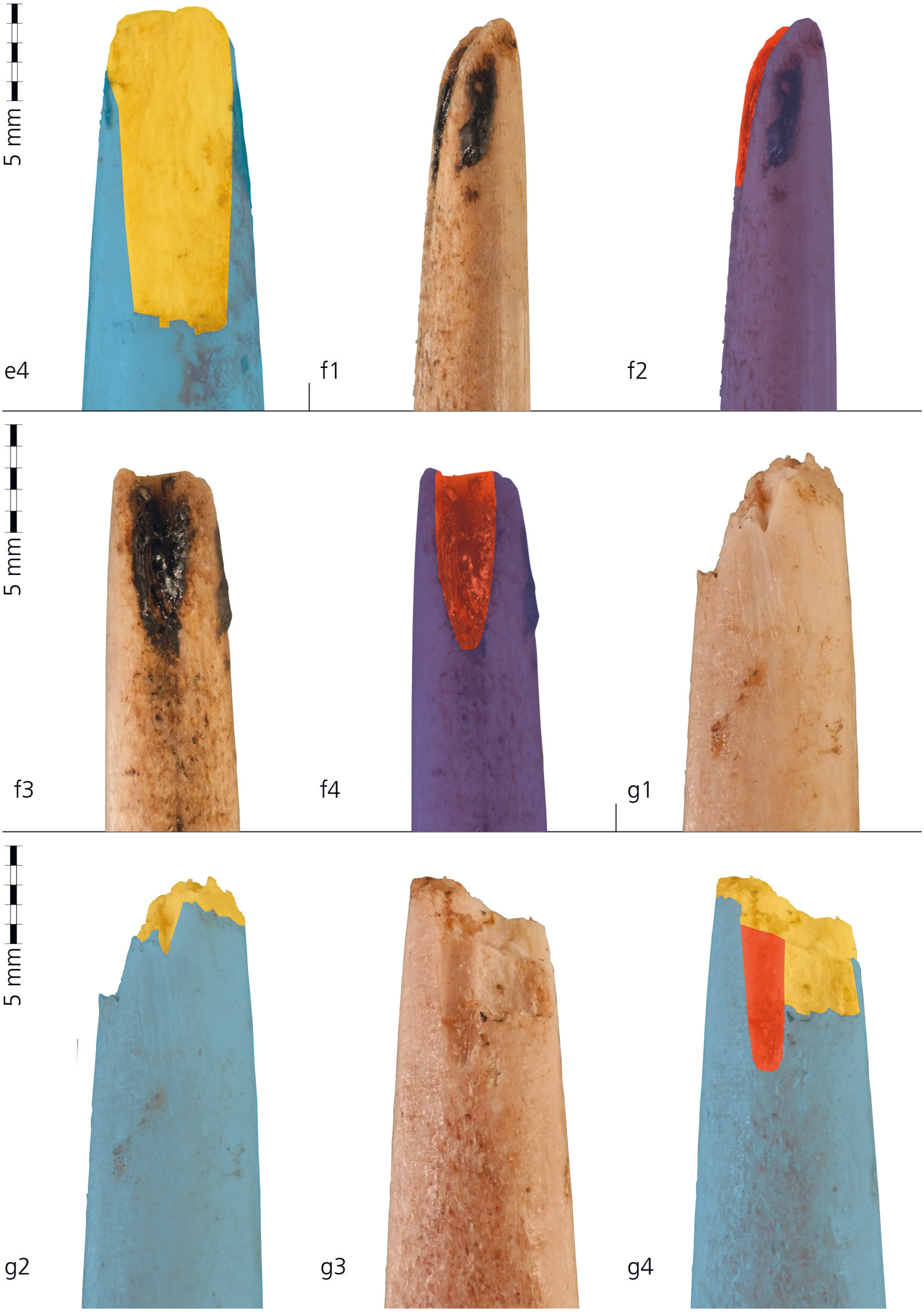


Fig. 4 Macro use-wear on flint points and antler fore shafts: **a** bending fracture with step termination on shouldered point no. 1 (ventral view). – **b** flute fracture on shouldered point no. 17 (ventral view). – **c** pseudo-burin fracture with remaining distal part of the pseudo-burin on shouldered point no. 11 (dorsal and ventral view). – **d** pseudo-burin fracture with pseudo-burin on shouldered point no. 9 (dorsal



view). – **e** bevelled break on fore shaft no. 23 (dorsal and right lateral view). – **f** crushing on fore shaft no. 27 (right lateral and ventral view). – **g** bevelled break with *dents de scie*-pattern on fore shaft no. 21 (right lateral and ventral view). – The colour code is given in **fig. 1**. – (Illustration M. Wild).

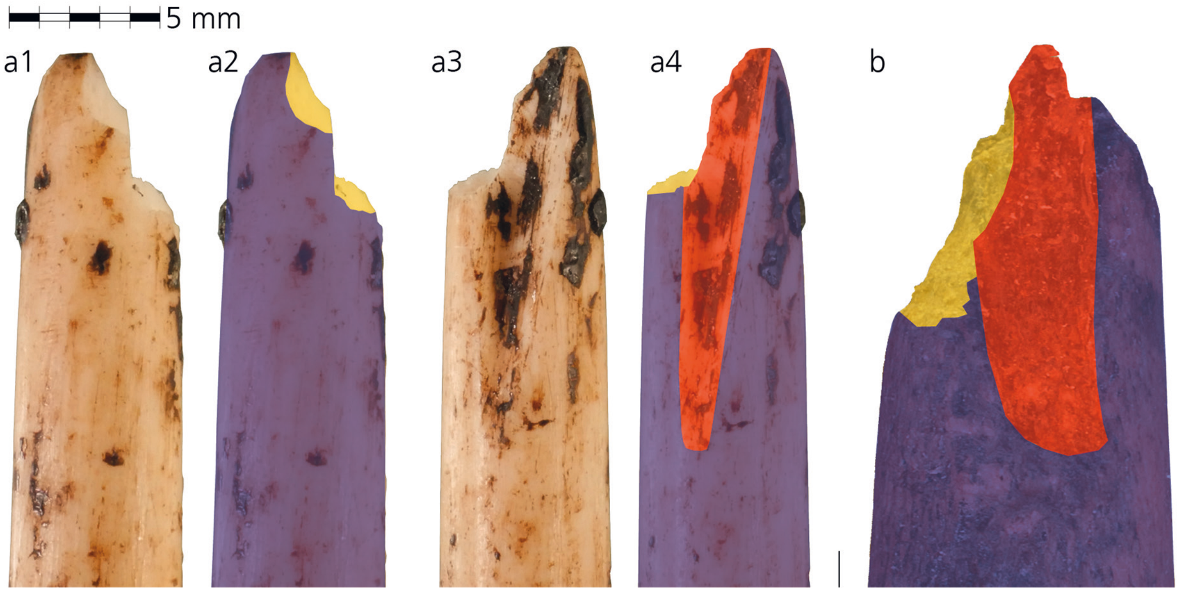


Fig. 5 Fore shaft specific macro-fracture: **a** experimental fore shaft no. 26 (**a1-a2** left lateral view of the distal fore shaft; **a3-a4** right lateral view of the distal fore shaft). – **b** ventral view of the distal artefact SH1935-5.218. – The colour code is given in **fig. 1**. – (Illustration M. Wild).

In February 2017 the experiments took place close to Schleswig (Kr. Schleswig-Flensburg/D). The weather was dry, the temperature around 2°C, and it was not windy. H. Paulsen – an experienced shooter – shot with the different accelerators (**fig. 3**) from a distance of 8m with a bow (7m distance between the tip of the arrow and the target), 8m with the atlatl (7.2m distance between the tip of the spear and the target), and 4m with the controlled machine (3.2m distance between the tip of the spear and the target). The draw weight for the bow ranged between 12 and 14kg and the expanders of the controlled machine were pulled with a force of 63kg, while the energy produced to accelerate the spears with the atlatl could not be measured. As a reindeer was not available, the target was an 80kg, female red deer (*Cervus elaphus*) of comparable size. It was eviscerated as it was supposed that the guts have almost no influence on the experiments (cf. Lund/Schürmann 1995). The target was hanging in an almost natural manner on a wooden rack (**fig. 1c**). The projectiles were meant to hit the target in an almost 90°-angle in those areas of the cervid body where Bodil Bratlund detected hunting lesions at the fauna from Meiendorf and Stellmoor, meaning the frontal half with rips, vertebrae and long bones (Bratlund 1994, 84 fig. 6). Additionally, aiming towards the centre of the target was meant to avoid missing shots.

Results

The use of antler fore shafts for spears and arrows worked with all different accelerators as the animal was penetrated deeply in all six series. 16 projectiles hit the target, one of which hit only the ground and was shot again. Two projectiles only hit the ground.

In one case, this led to the loss of the shouldered point (**tab. 3**, no. 3), as was the case of one projectile that hit the target (**tab. 3**, no. 4). Among the 16 remaining shouldered points, eight specimens do not show any fractures but, in one case, edge damage as a result of friction against a bone (**tab. 3**). The other half of the sample predominantly presents a single apical fracture (n=5; **tab. 3**, nos 7. 9-11. 17), in two cases one additional fracture at the base (**tab. 3**, no. 1) or at the shoulder (**tab. 3**, no. 8) and in one last case three fractures, situated at two apical positions and at the shoulder (**tab. 3**, no. 16). All eight fractured points are damaged in such a way that they would need to be re-sharpened or could not be used anymore. Seven of them exhibit at least one fracture, which corresponds to a fracture type considered significant of impact (Bergman/Newcomer 1983; Fischer/Hansen/Rasmussen 1984; Plisson/Geneste 1989; De Bie/Caspar 2000; Sano 2012), such as pseudo-burin, flute-like and step-terminating bending fractures, whereas one point (**tab. 3**, no. 7) presents a non-diagnostic apical bending fracture with hinge termination and a less than 2 mm long *languette*. Pseudo-burin fractures, which represent five of the twelve registered fractures, occur more often than any other fracture type.

On the double bevelled base of the antler rods no damage was detected, while several changes of the fore shafts' tip morphology were observed (terminology for crushing [**fig. 4f**], mushrooming and bevelled breaks [**fig. 4e. g**] after descriptions given for osseous projectile damages in Pétillon/Plisson/Cattelain 2016): distal crushing was detected on 9 of 18 pieces, mushrooming on one single fore shaft, while bevelled breaks were observed on three pieces, one of which with a perfect *en dents de scie*-pattern (**fig. 4 g**). However, one fore shaft showed damage atypical for osseous points: while the tip with the groove was almost completely preserved – some crushing was observed – the flank of the fore shaft showed a partial bevelled break (**fig. 5a**).

No difference in damage frequency or damage types was detected related to the use of different accelerators, hafting materials or weight of the projectiles (**tab. 3**).

Discussion

With regards to the macroscopic use-wear observed on the shouldered points, it should be noted that neither the type of hafting material nor the type of accelerator seems to have had an influence on the frequency or the morphology of fractures (**tab. 3**). Another factor, which can be ruled out in this respect is the weight of the projectile (cf. **tab. 3**). The undamaged state of eight points can be explained for some of them by the fact that they did not hit bone tissue or were detached from the fore shaft, whereas at least two of them seem to have been in contact with bones. The predominance of apical pseudo-burin fractures corresponds to the macroscopic use-wear patterns of the Hamburgian shouldered points from Poggenwisch and Teltwisch 1 where this fracture type is the most numerous one among the diagnostic impact fractures (Weber 2012, 152-154 tabs 16-18). However, in all three series, the number of fractures is too small to make statistically reliable statements. It is nevertheless noteworthy that a previous experiment with replicas of shouldered points, which were fixed by sinew to a wooden arrow shaft (Weber 2008; 2012, 149-151), yielded a higher proportion of fractures at or directly below the shoulder than the two archaeological samples and the present experimental one. This is potentially due to a more rigid fixation of the points at the previous experiment and may be interpreted in such a way that the way of hafting used here is more compatible with the prehistoric hafting of Hamburgian shouldered points.

As there exists no reference collection for fore shaft use-wear, the patterns will be compared with organic projectile use-wear. The observation of generally only light macroscopic damage on fore shafts despite frequent hits of bones and frozen soil is in concordance with many other experiments addressing osseous projectiles (Tyzzer 1936; Rozoy 1992; Knecht 1993; Pokines 1998; Bertrand 1999; Ikäheimo/Joona/Hietala 2004; Pétillon 2006; Buc 2011; Pétillon/Plisson/Cattelain 2016). This is due to the high elasticity and impact resistance of osseous materials (Albrecht 1977; Currey 1979; Currey et al. 2009; MacGregor/Currey 1983; Pfeifer 2016, 37-39). As in our experiment, distal crushing is the most frequent use-wear on experimental osseous points. Typically, the last few millimetres of the tip are crushed due to contact with bones or gravels in the soil (Tyzzer 1936; Arndt/Newcomer 1986; Bergman 1987; Stodiek 1993; Nuzhnyi 1998; Pétillon 2006; Bradfield/Lombard 2011; Pétillon et al. 2011; Pétillon/Plisson/Cattelain 2016). In contrast to the bevelled breaks, mushrooming is a very rare damage pattern observed in our experiment as well as in others (Arndt/Newcomer 1986; Bergman 1987; Stodiek 1993). Also the number of bevelled breaks can be compared with actualistic projectile experiments as this is one of the most frequent use-wear patterns (Tyzzer 1936; Rozoy 1992; Knecht 1993; Stodiek 1993; Pokines 1998; Bertrand 1999; Ikäheimo/Joona/Hietala 2004; Pétillon 2006; Bradfield/Lombard 2011; Buc 2011; Pétillon et al. 2011; Pétillon/Plisson/Cattelain 2016). Responsible are usually hits on bone or missing shots (Pétillon/Plisson/Cattelain 2016). Furthermore, the lack of basal use-wear can be explained by the general scarcity of this damage (Pétillon/Plisson/Cattelain 2016, 51; but see Lund/Schürmann 1995, 157 fig. 14). However, the small fracture on the bevel of SH1935-5.218 (**fig. 1c**) finds clear parallels in osseous projectiles from the Magdalenian of Southwestern France discussed by Michelle C. Langley (2015, 350 fig. 7).

Neither the use of recently produced or 25-year-old fore shafts nor the dimensions and massiveness of the fore shafts (≈ weight of the fore shaft) had an influence on the observed results[2]. However, when comparing experimental series with each other, one has to bear in mind that J.-M. Pétillon et al. (2016) point to the fact that there are lower numbers of damage and the degree of this damage on the experimental replicas compared to the archaeological evidence is also less. They explain this by higher weights of the archaeological projectiles (main shaft, possible fore shaft, and point) and, thus, a higher energy affecting the tip when hitting the target, frequently lower temperatures making osseous projectiles more brittle, higher frequencies of missed shots hitting gravelled or frozen soil and body movements of the prey. Whether this is also true for the *Kerbnadeln* cannot be answered due to the low number of archaeological artefacts.

Besides the solely quantitative approach of counting different fracture patterns, it was possible to strikingly copy the damage pattern of *Kerbnadel* SH1935-5.218 (**fig. 1c**). The groove builds the most distal part of the artefact and the replica. It is the area where a fore shaft first hits the target and, thus, has to absorb the highest energy. Nevertheless, one can observe bevelled breaks on the artefact's and the replica's (**tab. 3**, no. 26) lateral sides of the groove (**fig. 5**). This might be explained by the fact that the shouldered point shielded the grooves from direct impact or contact with hard tissues like bone or the ground, which is usually the reason for bevelled breaks (cf. above). This pattern is atypical for organic points (cf. above-mentioned literature) and can be described as specific fore shaft use-wear pattern.

Limitations

Although the possibility of the function of these artefacts as fore shafts was stressed, the experiments had some limitations. The functionality of the lithic points with a curved profile in combination with antler fore shafts remains open, as the replica shouldered points had only a straight longitudinal profile (cf. Weber 2012, 137-139). Furthermore, the angle on which the projectiles hit the target was almost always 90° to the longitudinal axis of the cervid, and to ensure an invasion into the cervid we aimed for the centre of the animal. This resulted in a bias towards thoracic hits with the presented major results, as also given as the main area of hits in the Hamburgian assemblages of Meiendorf and Stellmoor (Bratlund 1990). However, a single penetration of a projectile into the left humerus during the experiments resulted in the comminuting of the lithic point when it hit the more compact tissue. This would not have been counted as a hit in the analysis of B. Bratlund as she exclusively recorded inclusions of small lithic flakes in bones as hits and might have resulted in circular reasoning. Varying shooting angles and target areas of the animal might be worth testing. Finally, the small sample size (n = 18) leads to a statistically unreliable data set that in the future should be enlarged by further experiments.

CONCLUSIONS

Combining the gathered experiences from technological analysis, experiments and macro-wear observations this paper stressed the function of *Kerbnadeln* as fore shafts for Hamburgian shouldered points in a multi-faceted study that includes constraints from different areas of research (e. g. technological, experimental and macro-wear results from both lithic and organic materials as well as analysis of the material properties of the birch bark tar). In order to address these artefacts in different languages, we suggest the use of the term »(Hamburgian) fore shaft« in the future.

In this context, it might be worth considering the reasons why this technological particularity as a fore shaft is not a typical element of Magdalenian toolkits. On the other hand, we know of only two fore shafts from one single site and only one more osseous projectile from the Hamburgian facies. It might be one individual's special toolkit and not the common Hamburgian one that contained these artefacts. Another possible reason for the predominance of these projectiles in the Hamburgian assemblages might be found in the scarcity of wood, while reindeer antler was an abundant raw material. However, one has to consider the existence of highly similar, but slightly younger, antler artefacts from a comparable cultural context. In the more mountainous Peak District of Western England, the reindeer is solely represented by worked tools. Nevertheless, from Church Hole (Jacobi 2007, 100 fig. 7, 13) and Fox Hole (both Derbyshire / GB) (Bramwell 1977, 268 fig. 51, 5) we know of reindeer antler rods with longer grooves. Furthermore, the situation concerning wood scarcity seems to have been comparable for the mid-range mountain Magdalenian. Thus, despite (micro-)regional differences in climate, soil and, consequently, vegetation development no factors are discernible that could explain the technical innovation concerning fore shafts in the Hamburgian.

APPENDIX: MATERIAL PROPERTIES OF THE EXPERIMENTALLY USED BIRCH BARK TAR

Several grams of birch bark tar mixed with charcoal (see above) were sent to Jowat SE (Detmold) in order to analyse the material properties of the adhesive. Even though the amount of birch bark tar was not very big, the reliability of the results is assured.

The black birch bark tar had a high viscosity and during its melting, particles were observed.

First, the Shore-A-Hardness of the tar surface was tested under normed conditions (DIN 53505). It amounted to 17.2, which is comparable to rubber band material.

The birch bark tar is slightly tacky at room temperature, softens just above RT and melts (Kofler value) at 55-65 °C. Tack values using a Winopal Texture Analyzer (against a stainless steel ball probe) were determined as follows: 0.02 N (room temperature); 1.1 N (30 °C); 3.64 N (40 °C); 2.08 N (50 °C) and 0.75 N (60 °C). The latter values decrease because of the softening of the sample combined with a loss of cohesion.

After repeated thermal treatment the sample was more difficult to melt and process, which might indicate some curing/polymerization. The material then changes from thermoplastic properties towards a behaviour comparable to a duromer.

Adhesive strength (tensile shear strength) was 0.6-0.8 N / mm^2 between standardised beech wood and / or stainless steel or Acrylonitrile butadiene styrene (ABS), a thermoplastic polymer, test samples. Cohesive failure of the adhesive was often 100 %, meaning that breakage occurred in the birch bark tar bond line and that the adhesion forces towards the tested surfaces exceeded the material strength of the tar itself. In comparison with modern adhesives, the adhesive strength seems to be low but with an increasing surface the adhesive strength increases (e. g. 1 cm × 5 cm surface covered with birch bark tar results in an adhesive strength of 300-400 N / 30.6-40.8 kg). Thus, it can be sufficient for certain applications.

Further rheological measurements, using Anton Paar MCR 302, showed that frequency-dependent visco-elastic changes occurred. Under short-term stress (as during the impact of the projectiles) the tar breaks in splinters and performs rather like a solid material, while exposure to long-term stress leads to plastic deformation without breakage. The material also shows tendencies to extremely slow creep at room temperature (cold flow): Under normal conditions (low shear), the birch bark tar is not a solid but is still a liquid (even though it feels solid), as DMA measurements (temperature sweep) reveal that G' is always below G" without any crossover ($\tan\delta > 1$) between RT and 120 °C (cf. Mezger 2010, 149-151).

Thermogravimetric analysis with a Netzsch TG 209 F1 Libra showed that the organic / polymeric parts were degraded in two steps (maximum at 355 °C and 395 °C) with a combined mass loss of 81 % (estimated 10 % for the second step). The residual mass of 19 % (after 900 °C) derives from inorganic content. During long-term stability testing (8 h at 160 °C), a mass loss of 7.5 % was observed and the birch bark tar had not yet reached a constant mass level, meaning that the material is less stable than conventional adhesives (cf. Ehrenstein / Riedel / Trawiel 2003, 150-157).

Differential scanning calorimetry with a Netzsch DSC 204 F1 Phoenix revealed a glass transition temperature (Tg) of about –10 °C, meaning the material will be elastic above and rather brittle below that temperature. During first heating, some crystalline parts melted between 40 and 140 °C, while no crystallinity was observed during second heating, nor did cold crystallization occur. The crystallization speed of parts of the material is therefore very low (cf. Ehrenstein / Riedel / Trawiel 2003, 1-23).

As a conclusion of these examinations, we state that the ancient birch bark tar cannot compete with modern adhesives regarding its adhesive and cohesive strength. However, for the application as glue to fix points to projectile shafts, birch bark tar is fairly well suited, especially when taking into account that only a few real alternatives (e. g. sinew, bees wax [cf. Baales / Birker / Mucha 2017]) were available at these times. Without a deeper knowledge of synthesis and the influence of temperature and oxygen on final material properties, it must have been quite an achievement to produce birch bark tar batches with equal properties.

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Notes

1) As asymmetrical points, we regard lithic points with the tip located in the prolongation of the unretouched lateral edge and not on the central longitudinal axis (Beckhoff 1967).

2) FTIR-analysis (on a Thermo Scientific Nicolet 380 in combination with OMNIC™ Specta Software at the Leibniz-Labor für Altersbestimmung und Isotopenforschung, Kiel) of a fore shaft used

by Lund/Schürmann 1995 (no. 26) and one produced for the present experiment (no. 21) showed no differences in the composition and amount of the different organic fractions of the antler (in particular those responsible for the elasticity of the antler). Both can be described as green. Therefore, differences in the breakage types and frequencies between these two groups cannot be assigned to the condition of the raw material.

References

Albrecht 1977: G. Albrecht, Testing of materials as used for bone points of the Upper Palaeolithic. In: H. Camps-Fabrer (ed.), Méthodologie Appliquée à l'Industrie de l'Os Préhistorique. Deuxième Colloque International sur l'Industrie de l'Os dans la Préhistoire, Abbaye de Sénanque (Vaucluse), 9-12 juin 1976. Colloques Internationaux du Centre National de la Recherche Scientifique 568 (Paris 1977) 119-124.

Allain/Rigaud 1989: J. Allain / A. Rigaud, Colles et mastics au Magdalénien. In: M. Olive / Y. Taborin (eds), Nature et fonction des foyers préhistoriques. Actes du Colloque international de Nemours, 12-14 mai 1987. Mémoires du Musée de Préhistoire d'Ile-de-France 2 (Nemours 1989) 221-223.

Arndt/Newcomer 1986: S. Arndt / M. Newcomer, Breakage patterns on prehistoric bone points. In: D. A. Roe (ed.), Studies in the Upper Palaeolithic of Britain and Northwest Europe. BAR International Series 296 (Oxford 1986) 165-173.

Averbouh 2000: A. Averbouh, Technologie de la matière osseuse travaillée et implications palethnologiques: l'exemple des chaines d'exploitation du bois de cervidé chez les Magdaléniens des Pyrénées [unpubl. diss. Univ. Paris I 2000].

Baales/Birker/Mucha 2017: M. Baales / S. Birker / F. Mucha, Hafting with beeswax in the Final Palaeolithic: a barbed point from Bergkamen. Antiquity 91, 2017, 1155-1170.

Bartram 1997: L. Bartram, A Comparison of Kua (Botswana) and Hadza (Tanzania) Bow and Arrow Hunting. In: H. Knecht (ed.), Projectile Technology (London 1997) 321-344.

Becker 1945: C. J. Becker, En 8000-aarig Stenalderboplads i Holmegaards Mose. Foreløbig Meddelelse. Nationalmuseets Arbejdsmark 1945, 61-72.

Beckhoff 1967: K. Beckhoff, Zur jungpaläolithischen Kerbspitze. Die Kunde N.F. 18, 1967, 8-15.

Bergman 1987: C. A. Bergman, Hafting and use of bone and antler points from Ksar Akil, Lebanon. In: D. Stordeur (ed.), La main et l'outil. Manches et emmanchements préhistoriques. Table Ronde C.N.R.S. tenue à Lyon du 26 au 29 nov. 1984. Collection travaux de la Maison de l'Orient 15 (Paris 1987) 117-126.

Bergman/Newcomer 1983: C. A. Bergman / M. H. Newcomer, Flint arrowhead breakage: examples from Ksar Akil, Lebanon. Journal of Field Archaeology 10/2, 1983, 238-243.

Bertrand 1999: A. Bertrand, Les armatures de sagaies magdaléniennes en matière dure animale dans les Pyrénées. BAR International Series 773 (Oxford 1999).

Boas 1888: F. Boas, Die Tsimschian. Zeitschrift für Ethnologie 20, 1888, 231-247.

Bohr 2014: R. Bohr, Gifts from the Thunder Beings. Indigenous Archery and European Firearms in the Northern Plains and Central Subarctic, 1670-1870 (Lincoln 2014).

Bokelmann 1991: K. Bokelmann, Some new thoughts on old data on humans and reindeer in the Ahrensburgian tunnel valley in Schleswig-Holstein, Germany. In: N. Barton / A. J. Roberts / D. A. Roe (eds), The Late Glacial in Northwest Europe. Human adaptation and environmental change at the end of the Pleistocene. Council of British Archaeology, Research Report 77 (Oxford 1991) 72-81.

Bosinski 1978: G. Bosinski, Der Poggenwischstab. Bonner Jahrbücher 178, 1978, 83-92.

Bradfield 2012: J. Bradfield, Macrofractures on bone-tipped arrows: analysis of hunter-gatherer arrows in the Fourie collection from Namibia. Antiquity 86, 2012, 1179-1191.

Bradfield/Lombard 2011: J. Bradfield / M. Lombard, A macrofracture study of bone points used in experimental hunting with reference to the South African Middle Stone Age. South African Archaeological Bulletin 66, 2011, 67-76.

Bradley 1995: B. A. Bradley, Clovis ivory and bone rods. In: J. Hahn / M. Menu / Y. Taborin / P. Walter / F. Widemann (eds), Le travail et l'usage de l'ivoire au Paléolithique supérieur (Roma 1995). www.primtech.net/ivory/ivory.html (25.2.2018).

Bramwell 1977: D. Bramwell, Archaeology and palaeontology. In: T. D. Ford (ed.), Limestones and caves of the Peak District (Norwich 1977) 263-291.

Bratlund 1990: B. Bratlund, Rentierjagd im Spätglazial. Eine Untersuchung der Jagdfrakturen an Rentierknochen von Meiendorf und Stellmoor, Kreis Stormarn. Offa 47, 1990, 7-34.

1994: B. Bratlund, A survey of the subsistence and settlement pattern of the Hamburgian Culture in Schleswig-Holstein. Jahrbuch des RGZM 41, 1994, 59-93.

Buc 2011: N. Buc, Experimental series and use-wear in bone tools. Journal of Archaeological Science 38, 2011, 546-557.

Burdukiewicz 1986: J. M. Burdukiewicz, The late pleistocene shouldered point assemblages in Western Europe (Leiden 1986).

Cattelain 1988: P. Cattelain, Fiches typologiques de l'industrie osseuse préhistorique. II: Propulseurs (Aix-en-Provence 1988).

Clark 1938: J. G. D. Clark, The reindeer hunting tribes of northern Europe. Antiquity 12, 1938, 154-171.

Clark/Thompson 1954: J. G. D. Clark / M. W. Thompson, The Groove and Splinter Technique of working antler in Upper Palaeolithic and Mesolithic Europe. Proceedings of the Prehistoric Society 19, 1954, 148-160.

Clark/Phillips/Staley 1974: J. D. Clark / J. L. Phillips / P. S. Staley, Interpretations of Prehistoric Technology from Ancient Egyptian and Other Sources. Part 1: Ancient Egyptian Bows and Arrows and their Relevance for African Prehistory. Paléorient 2/2, 1974, 328-388.

Currey 1979: J. D. Currey, Mechanical properties of bone tissues with greatly differing functions. Journal of Biomechanics 12, 1979, 313-319.

Currey et al. 2009: J. D. Currey / T. Landete-Castillejos / J. Estevez / F. Ceacero / A. Olguin / A. Garcia / L. Gallego, The mechanical properties of red deer antler bone when used in fighting. Journal of Experimental Biology 212, 2009, 3985-3993.

De Bie / Caspar 2000: M. De Bie / J.-P. Caspar, Rekem – A Federmesser Camp on the Meuse River Bank. Archeologie in Vlaanderen: Monografie 3 = Acta Archaeologica Lovaniensia: Monographiae 10 (Leuven 2000).

Debout et al. 2012: G. Debout / M. Olive / O. Bignon / P. Bodu / L. Chehmana / B. Valentin, The Magdalenian in the Paris Basin: New results. Quaternary International 272/273, 2012, 176-190.

Delporte / Mons 1988: H. Delporte / L. Mons, Fiche sagaie à biseau double (bifacial). In: H. Camps-Fabrer (ed.), Fiches typologiques de l'industrie osseuse préhistorique. I: Sagaies (Aix-en-Provence 1988) 1-11.

Ehrenstein / Riedel / Trawiel 2003: G. W. Ehrenstein / G. Riedel / P. Trawiel, Praxis der thermischen Analyse von Kunststoffen (München ^{2}2003).

Ellis 1997: C. J. Ellis, Factors Influencing the Use of Stone Projectile Tips – An Ethnographic Perspective. In: H. Knecht (ed.), Projectile Technology (London 1997) 37-74.

Fienup-Riordan 2007: A. Fienup-Riordan, Yuungnaqpiallerput – The way we genuinely live. Masterworks of Yup'ik Science and Survival (Seattle, London 2007).

Fischer / Hansen / Rasmussen 1984: A. Fischer / P. V. Hansen / P. Rasmussen, Macro and micro wear traces on lithic projectile points: experimental results and prehistoric examples. Journal of Danish Archaeology 3, 1984, 19-46.

Grimm / Weber 2008: S. B. Grimm / M.-J. Weber, The chronological framework of the Hamburgian in the light of old and new ^{14}C dates. Quartär 55, 2008, 17-40.

Grønnow 2017: B. Grønnow, The frozen Saqqaq sites of Disko Bay, West Greenland. Qeqertasussuk and Qajaa (2400-900 BC). Studies of Saqqaq material culture in an Eastern Arctic perspective. Monographs on Greenland / Meddelelser om Grønland 356 = Man and Society 45 (København 2017).

Hare et al. 2004: P. G. Hare / S. Greer / R. Gotthardt / R. Farnell / V. Bowyer / C. Schwegler / D. Strand, Ethnographic and Archaeological Investigations of Alpine Ice Patches in Southwest Yukon, Canada. Arctic 57/3, 2004, 260-272.

Ikäheimo / Joona / Hietala 2004: J. P. Ikäheimo / J. P. Joona / M. Hietala, Wretchedly poor, but amazingly practical: Archaeological and experimental evidence on the bone arrowheads of the Fenni. Acta Borealia 21, 2004, 3-20.

Jacobi 2007: R. M. Jacobi, The Stone Age Archaeology of Church Hole, Creswell Crags, Nottinghamshire. In: P. Pettitt / P. Bahn / S. Ripoll (eds), Palaeolithic Cave Art at Creswell Crags in European Context (Oxford 2007) 71-111.

Junkmanns 2001: J. Junkmanns, Pfeil und Bogen – Herstellung und Gebrauch in der Jungsteinzeit (Biel 2001).

Justice 2002: N. D. Justice, Stone age spear and arrow points of the midcontinental and eastern United States: a modern survey and reference (Bloomington 2002).

Kane 1856: E. K. Kane, Arctic explorations in the years 1853, '54, '55, vol. 2 (Philadelphia 1856).

Knecht 1993: H. Knecht, Early Upper Palaeolithic approaches to bone and antler projectile technology. In: G. L. Peterkin / H. M. Bricker / P. Mellars (eds), Hunting and animal exploitation in the Later Palaeolithic and Mesolithic of Eurasia. Archeological Papers of the American Anthropological Association 4 (Washington, D.C. 1993) 33-47.

Kurzweil / Todtenhaupt 1990: A. Kurzweil / D. Todtenhaupt, Das Doppeltopf-Verfahren: Eine rekonstruierte mittelalterliche Methode der Holzteergewinnung. In: Experimentelle Archäologie in Deutschland [Ausstellungskat.]. Archäologische Mitteilungen aus Nordwestdeutschland Beiheft 4 (Oldenburg 1990) 472-479.

Langley 2015: M. C. Langley, Investigating maintenance and discard behaviours for osseous projectile points: A Middle to Late Magdalenian (c. 19,000-14,000 cal. BP) example. Journal of Anthropological Archaeology 40, 2015, 340-360.

Langley / Pétillon / Christensen 2016: M. C. Langley / J.-M. Pétillon / M. Christensen, Diversity and Evolution of Osseous Hunting Equipment During the Magdalenian (21,000-14,000 cal BP). In: M. Langley (ed.), Osseous Projectile Weaponry – Towards an Understanding of Pleistocene Cultural Variability (Dordrecht 2016) 143-159.

Lund 1993: M. Lund, Vorschäfte für Kerbspitzen der Hamburger Kultur. Archäologisches Korrespondenzblatt 23, 1993, 405-411.

Lund / Schürmann 1995: M. Lund / C. Schürmann, Schußversuche zur Wirkung und Schäftung einiger steinzeitlicher Projektilspitzen. In: M. Fansa (ed.), Experimentelle Archäologie Bilanz 1994. Symposium in Duisburg, August 1993. Archäologische Mitteilungen aus Nordwestdeutschland Beiheft 8 (Oldenburg 1995) 145-158.

MacGregor / Currey 1983: A. G. MacGregor / J. D. Currey, Mechanical properties as conditioning factors in the bone and antler industry of the 3rd to the 13th century AD. Journal of Archaeological Science 10, 1983, 71-77.

Malgarini 2014: R. Malgarini, Les gisements magdaléniens dans le Jura et les Alpes du Nord et leurs industries osseuses [unpubl. diss. Univ. de Franche-Comté 2014].

Mezger 2010: T. G. Mezger, Das Rheologie Handbuch für Anwedner von Rotations- und Oszillations-Rheometern (Hannover ^{3}2010).

Murdoch 1892: J. Murdoch, Ethnological results of the point barrow expedition (Washington, D.C. 1892).

Nikolskiy / Pitulko 2013: P. Nikolskiy / V. Pitulko, Evidence from the Yana Palaeolithic site, Arctic Siberia, yields clues to the riddle of mammoth hunting. Journal of Archaeological Science 40, 2013, 4189-4197.

Nuzhnyi 1998: D. Nuzhnyi, The preliminary results of experiments with Aurignacian split based points production, hafting and usage. Préhistoire Européenne 13, 1998, 117-132.

Paulsen 1990: H. Paulsen, Schussversuche mit einem Nachbau des Bogens von Koldingen, Lkr. Hannover. In: Experimentelle Archäologie in Deutschland [Ausstellungskat.]. Archäologische Mitteilungen aus Nordwestdeutschland Beiheft 4 (Oldenburg 1990) 73-80.

Petersson 1951: M. Petersson, Mikrolithen als Pfeilspitzen. Ein Fund aus dem Lilla Loshult-Moor, Ksp. Loshult, Skåne. Meddelanden Från Lunds Universitets Historiske Museum 1951 = Kungliga Humanistiska Vetenskapssamfundets i Lund Årsberättelse IV, 1950-1951 (1951), 1-16.

Pétillon 2006: J.-M. Pétillon, Des Magdaléniens en armes. Technologie des armatures de projectile en bois de cervidé du Magdalénien supérieur de la grotte d'Isturitz (Pyrénées-Atlantiques). Artefacts 10 (Treignes 2006).

2008: J.-M. Pétillon, First evidence of a whale-bone industry in the western European Upper Paleolithic: Magdalenian artifacts from Isturitz (Pyrenées-Atlantiques, France). Journal of Human Evolution 54, 2008, 720-726.

2016: J.-M. Pétillon, Technological evolution of hunting implements among Pleistocene hunter-gatherers: Osseous projectile points in the middle and upper Magdalenian (19-14 ka cal BP). Quaternary International 414, 2016, 108-134.

Pétillon / Plisson / Cattelain 2016: J.-M. Pétillon / H. Plisson / P. Cattelain, Thirty Years of Experimental Research on the Breakage Patterns of Stone Age Osseous Points. Overview, Methodological Problems and Current Perspectives. In: R. Iovita / K. Sano (eds), Multidisciplinary Approaches to the Study of Stone Age Weaponry (Dordrecht 2016) 47-63.

Pétillon et al. 2011: J.-M. Pétillon / O. Bignon / P. Bodu / P. Cattelain / G. Debout / M. Langlais / V. Laroulandie / H. Plisson / B. Valentin, Hard core and cutting edge: Experimental manufacture and use of Magdalenian composite projectile tips. Journal of Archaeological Science 38, 2011, 1266-1283.

Pfeifer 2012: S. J. Pfeifer, Überlegungen zum organischen Gerätetyp »Vorschaft« des europäischen Magdalénien. Ethnographisch-Archäologische Zeitschrift 53, 2012, 35-49.

2016: S. J. Pfeifer, Die Geweihfunde der magdalénienzeitlichen Station Petersfels, Lkr. Konstanz – eine archäologisch-taphonomische Studie. Forschungen und Berichte zur Archäologie in Baden-Württemberg 3 (Stuttgart 2016).

in print: S. J. Pfeifer, Archery technology of the Greenland Thule culture: An archaeological and ethnographic study (in print).

Plisson / Geneste 1989: H. Plisson / J.-M. Geneste, Analyse technologique des pointes à cran solutréennes du Placard (Charente), du Fourneau du Diable, du Pech de la Boissière et de Combe Saunière (Dordogne). Paléo 1, 1989, 65-106.

Pokines 1998: J. T. Pokines, Experimental replication and use of Cantabrian lower Magdalenian antler projectile points. Journal of Archaeological Science 25, 1998, 875-886.

Potter et al. 2014: B. A. Potter / J. D. Irish / J. D. Reuther / H. J. McKinney, New insights into Eastern Beringian mortuary behavior: A terminal Pleistocene double infant burial at Upward Sun River. Proceedings of the National Academy of Sciences 111, 2014, 17 060-17 065.

Riede 2010: F. Riede, Hamburgian weapon delivery technology: a quantitative comparative approach. Before Farming 1, 2010, 1-18.

Rozoy 1992: J.-G. Rozoy, Expérimentation de lancer de sagaies avec le propulseur. Bulletin de la Société royale belge d'études géologiques et archéologiques. Les chercheurs de la Wallonie 32, 1992, 169-184.

Rust 1937: A. Rust, Das altsteinzeitliche Rentierjägerlager Meiendorf (Neumünster 1937).

1943: A. Rust, Die alt- und mittelsteinzeitlichen Funde von Stellmoor (Neumünster 1943).

1958: A. Rust, Die jungpaläolithischen Zeltanlagen von Ahrensburg. Vor- und frühgeschichtliche Untersuchungen aus dem Schleswig-Holsteinischen Landesmuseum für Vor- und Frühgeschichte in Schleswig und dem Institut für Ur- und Frühgeschichte der Universität Kiel N. F. 15 (Neumünster 1958).

Sano 2012: K. Sano, Functional variability in the Late Upper Palaeolithic of north-western Europe: a traceological approach. Universitätsforschungen zur Prähistorischen Archäologie 219 (Bonn 2012).

Stodiek 1985: U. Stodiek, Fußgönheim. Zwei jungpaläolithische Fundplätze in der Vorderpfalz [M. A. thesis Univ. Köln 1985].

1993: U. Stodiek, Zur Technologie der jungpaläolithischen Speerschleuder. Eine Studie auf der Basis archäologischer, ethnologischer und experimenteller Erkenntnisse. Tübinger Monographien zur Urgeschichte 9 (Tübingen 1993).

Tromnau 1975: G. Tromnau, Neue Ausgrabungen im Ahrensburger Tunneltal. Ein Beitrag zur Erforschung des Jungpaläolithikums im nordwesteuropäischen Flachland. Offa-Bücher 33 (Neumünster 1975).

1999: G. Tromnau, Some remarks concerning the excavations at Meiendorf and Stellmoor in the Tunnelvalley of Ahrensburg by Alfred Rust. Folia Quaternaria 79, 1999, 147-155.

Tuborg Sandell / Sandell 1991: H. Tuborg Sandell / B. Sandell, Archaeology and environment in the Scoresby Sund fjord. Ethno-archaeological investigations of the last Thule culture of Northeast Greenland. Meddelelser om Grønland. Man and Society 15 (Copenhagen 1991).

Tyzzer 1936: E. E. Tyzzer, The »simple bone point« of the shell-heaps of the northeastern Algonkian area and its probable significance. American Anthropology 1, 1936, 261-279.

Valoch 2001: K. Valoch, Das Magdalénien in Mähren – 130 Jahre Forschung. Jahrbuch des RGZM 48, 2001, 103-159.

Veil 1988: S. Veil, Die jungpaläolithischen und mesolithischen Funde und Befunde aus der »Steinkirche« bei Scharzfeld, Lkr. Osterode am Harz. Die Kunde N. F. 39, 1988, 209-222.

Weber 2008: M.-J. Weber, Fabrication and use of Hamburgian shouldered points: new data from Poggenwisch and Teltwisch 1 (Ahrensburg Valley, Schleswig-Holstein, Germany). P@lethnologie 1, 2008 (2009), 99-132.

2012: M.-J. Weber, From technology to tradition – Re-evaluating the Hamburgian-Magdalenian relationship. Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum 5 (Neumünster 2012).

Wiessner 1983: P. Wiessner, Style and social information in Kalahari San projectile points. American Anthropology 48, 1983, 253-276.

Wild / Weber 2017: M. Wild / M.-J. Weber, Ein schräger Typ – eine Geweihspitze aus Lasbek und ihr Verhältnis zum europäischen Jung- und Spätpaläolithikum. In: B. V. Eriksen / A. Abegg-Wigg / R. Bleile / U. Ickerodt (eds), Interaktion ohne Grenzen. Beispiele archäologischer Forschungen am Beginn des 21. Jahrhunderts / Interaction without borders. Exemplary archaeological research at the beginning of the 21st century (Schleswig 2017) Vol. 1, 23-34.

Zusammenfassung / Summary / Résumé

Kompositprojektile in der Hamburger Fazies des Spätmagdaléniens – technologische, experimentelle und funktionale Untersuchung ihrer Feuerstein-, Geweih- und Schäftungsbestandteile

Der vorliegende Beitrag versteht sich als Fortführung von Studien zur Funktionalität von Kerbnadeln als Vorschäfte für Kerbspitzen. Spezifische Aspekte einer solchen Nutzung wurden beleuchtet sowie Daten generiert, anhand derer überprüft werden kann, ob die prähistorischen Artefakte tatsächlich Vorschäfte gewesen sind. Um diese Ziele zu erreichen, wurden Schussversuche mit 18 Vorschaft-Spitzen-Kombinationen durchgeführt. Dabei wurden verschiedene Projektilsysteme (Pfeil / Speer) und Schäftungen (Birkenpech / Sehne) genutzt, wie sie möglicherweise den hamburgerzeitlichen Jäger und Sammlern zur Verfügung standen.

Der Vergleich von Makro-Gebrauchsspuren an Repliken und archäologischen Stücken zeigt insgesamt vergleichbare Muster für die Kerbspitzen und die Vorschäfte. Zudem konnte die atypische Fraktur des Stellmoorer Vorschaftes SH1935-5.218 repliziert und gezeigt werden, dass sie vorschaftspezifisch ist. Schlussendlich kann die Hypothese, dass es sich bei den Geweihartefakten um Vorschäfte handelt, durch die vorliegenden Untersuchungen untermauert werden. Wir plädieren daher dafür, diese Artefakte als (Hamburger) Vorschäfte zu bezeichnen. Außerdem zeigt die Materialeigenschaftenanalyse des genutzten Birkenpechs, dass es gut geeignet für den Schäftungszweck, aber schwierig mit stabilen Eigenschaften herzustellen ist.

Composite Projectiles in the Hamburgian Facies of the Final Magdalenian – Technological, Experimental and Macro-wear Study of their Flint, Antler, and Adhesive Components

In continuation of former studies proving the functionality of *Kerbnadeln* as fore shafts for Hamburgian shouldered points, the presented work aims at elucidating specific aspects of this way of use and at providing data for testing whether the prehistoric artefacts could have served in this way. To reach these goals, a shooting experiment with 18 fore shaft-point combinations was carried out employing different projectile systems (arrows / spears) and hafting methods (birch bark tar / sinew) that may have been used by Hamburgian hunter-gatherers.

The comparison of the macro-wear traces appearing on the replicas with those observed on the archaeological finds shows comparable patterns for both the shouldered points and the fore shafts. More importantly, the atypical macro-wear on fore shaft SH1935-5.218 from Stellmoor was replicated. Arguments for interpreting this pattern as a fore shaft specific use-wear pattern are presented. In conclusion, the hypothesis that the antler artefacts in question were used as intermediate parts between points and main shafts is further supported by the new evidence and we therefore argue for calling them (Hamburgian) fore shafts. In addition, the analysis of the material properties of the used birch bark tar showed that it was well adapted to its hafting purpose but difficult to produce with constant properties.

Projectiles composites dans le faciès hambourgien du Magdalénien final – étude technologique, expérimentale et tracéologique de leurs composantes lithiques, osseuses et adhésives

En continuité avec des études précédentes démontrant la fonctionnalité de *Kerbnadeln* en tant que préhampes pour des pointes à cran hambourgiennes, cette étude a pour but d'éclaircir des aspects particuliers de cette manière d'utilisation et de fournir des données pour tester si les vestiges auraient pu être utilisés ainsi. Aussi, un essai de tir avec 18 combinaisons préhampe-pointe employant différents systèmes de projectile (flèche / sagaie) et de fixation (résine d'écorce de bouleau / tendon) qui auraient pu être utilisés au Hambourgien a été entrepris.

La comparaison des traces macroscopiques d'utilisation apparaissant sur les répliques avec celles sur les vestiges archéologiques montre des données comparables pour les pointes à cran et pour les préhampes. Toutefois, il est plus important que la fracture atypique d'utilisation de la préhampe SH1935-5.218 de Stellmoor a été reproduite. Des arguments pour interpréter cette fracture comme une fracture spécifique de préhampe sont présentés. En conclusion, l'hypothèse que les vestiges en question ont servi d'élément intermédiaire entre les pointes et les hampes est confortée et ces vestiges devraient ainsi être appelés préhampes (hambourgiennes). De plus, l'analyse des propriétés du matériel de la résine utilisée a montré qu'elle était bien adaptée à sa fonction de fixation mais difficile à produire avec des propriétés constantes.

Schlüsselwörter / Keywords / Mots clés

Nordwesteuropa / Paläolithikum / Jagd / Gebrauchsspurenanalyse / kontrollierte Experimente / Typologie
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