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The Rönneholm Arrow

A Find of a Wooden Arrow-tip with Microliths in the Bog Rönneholms Mosse, Central Scania, Southern Sweden

BY LARS LARSSON, ARNE SJÖSTRÖM AND CARL HERON

Abstract

In Rönneholms Mosse, central Scania, southernmost Sweden, new excavations were initiated in the mid 1990s due to extraction of peat. Several bog sites and more than one hundred small campsites have been disclosed in layers of gyttja and peat.

One of the rarer finds is a wooden arrow made of hazel wood, with four microliths glued to the tip and a loose fifth microlith that probably also was attached. It is dated to the late Maglemose Culture. The arrow is one of the few examples in the world showing how narrow microliths were attached. A number of finds of archery in general and arrows specifically, mainly from Northern Europe, are also presented. A pure birch-bark tar adhesive was used to haft the arrow.

Introduction

During the last deglaciation a large number of shallow lakes were formed in southern Scandinavia. In the early postglacial a number of these lakes were transformed into bogs. The nutrient conditions with a variety of fish, birds, mammals and plants in or close by the lakes, in regrowing stages, made them attractive to Mesolithic hunter-gatherers. One of the largest bogs covering some 12 sq. km is situated in central Scania, southernmost Sweden. It is divided into two separate raised bogs, Ageröds Mosse and Rönneholms Mosse, separated by a river. Together they formed a former north-westerly arm of lake Ringsjön, which still remains today (Fig. 1).

These peat bogs show the extent of the ancient lake that was filled by organic material during the Atlantic and Subatlantic chronozones. During the Subboreal chronozone a raised bog was formed. A number of Mesolithic sites, dating to the Maglemose and Kongemose Cultures, were found during surveys and peat cutting in Ageröds Mosse before the 1960s (Althin 1954; Larsson 1978, 1983). Large-scale peat extraction has been going on in Rönneholms Mosse since the 1800s. In recent decades the extraction has been intensive and a total layer of more than 4 m of gyttja and peat has been removed.

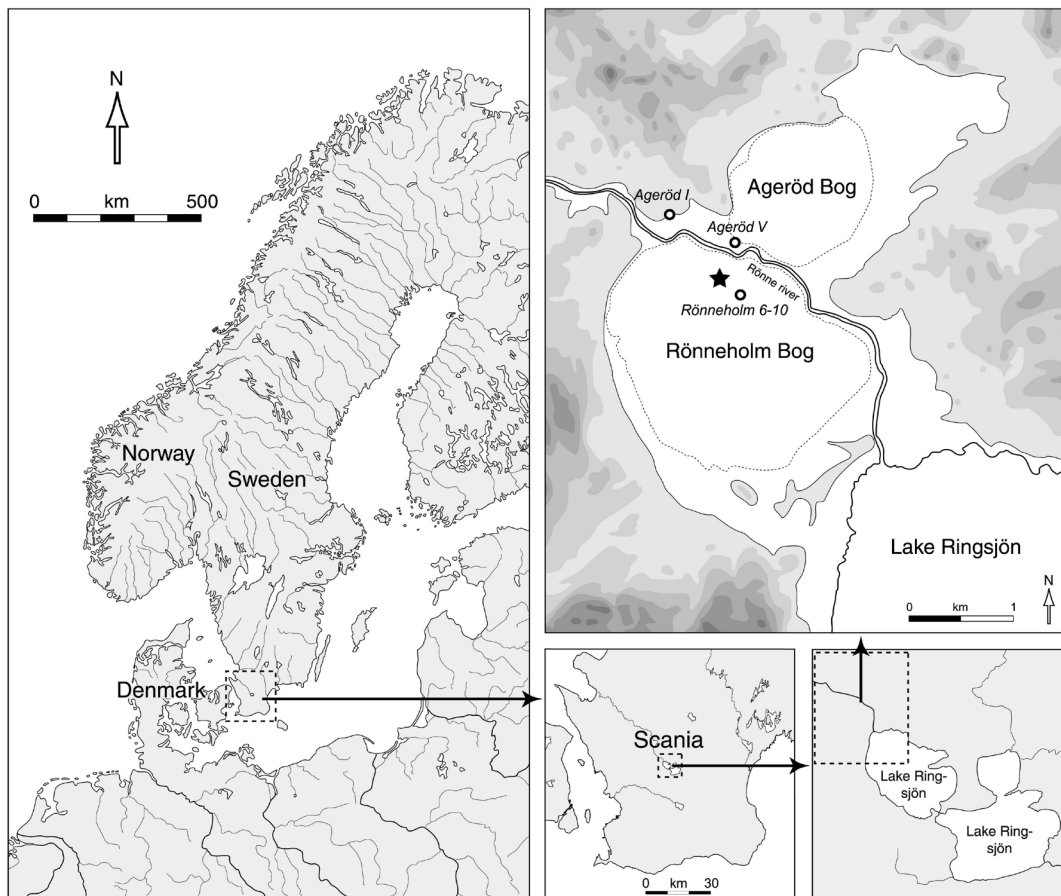


Fig. 1. Location of the bogs Ageröds Mosse and Rönneholms Mosse with the location of the arrow (star) and selected Mesolithic sites (circles). The white area north-west of lake Ringsjön on the enlarged map shows the maximum extent of the ancient lake before it was filled in. Topographic elevation on the enlarged map: 5 m. Drawing by Arne Sjöström.

The exploited area today is about 1.4 sq. km (Fig. 1). Thin layers of 10–15 mm are stripped mechanically about ten times every season. The production field is divided into long parcels by drainage ditches every 20 m, the longest of these measuring roughly 1.5 km. From an archaeological perspective this method of extraction is very good because it is possible to obtain an overview of the flat cutting surface, and the sites can easily be detected before too much damage has been done (Sjöström 2004). The bog has been surveyed annually and hundreds of stray finds of flint and bone tools have been

uncovered. Campsites with a size of 50 to 100 sq.m. have been identified on former peat islands. More than 100 very small sites of a few square metres in size have been recorded, in the layers of gyttja and sphagnum peat, often combined with a fireplace and a small number of flints and bones, indicating short stays (Hammarstrand Dehman & Sjöström 2009; Larsson & Sjöström 2011a, 2011b, 2013). The sites are dated by microliths and radiocarbon dates to the period from the late Maglemose Culture to the late Kongemose Culture (c. 7000–5500 cal BC).

The Rönneholm arrow was found in

connection with the annual investigations of Mesolithic remains uncovered by peat cutting at Rönneholms Mosse (Sjöström & Hammarstrand Dehman 2010, 27 ff.). The find spot is located in the former lake, about 670 m from the nearest solid ground on the former shore beside the Ageröd III settlement site. At this and the nearby settlement site area of Ageröd I there are several dwelling sites that can be dated to the late Maglemose period, which is more or less contemporary with the arrow (Fig. 1). The nearest contemporary larger bog campsite (R23:2) is about 300 m to the south-east, on an island of gyttja and peat. Apart from this the peat-cutting in Rönneholms Mosse has not revealed any larger bog campsite from the late Maglemose period. On the other hand, more than 100 small campsites have been found, usually consisting of no more than a simple hearth with a few artefacts scattered round about. Most of these can be dated to the late Maglemose Culture.

The arrow was discovered in the eastern part of a find-bearing area measuring over 12 × 5 m (site FP581) (Fig. 2). The area with finds was probably slightly bigger since it continued under the high peat bank to the north-east, where the railway to the peat factory runs. The south-western boundary of the layer could not be wholly ascertained either. When the find-bearing layer was being exposed, the algal gyttja that was dug up was removed by a shovel. It was during this rough work that the arrow was exposed, which meant that it was damaged and disturbed slightly from its original position. It was located very close to the peat-cutting surface and when discovered it had probably already been subjected to pressure damage from the heavy peat machines that had passed over the area several times. It has nevertheless been possible to reconstruct the preserved part of the arrow.

In the layer of algal gyttja there were finds of stone, flint and organic material. All the

finds were uncovered in a thin horizontal layer in the gyttja. Within the find-bearing area there was a concentration of gravel and small stones in the central part, interpreted as the remains of a hearth. A number of flint splinters and some seeds from yellow water lily were found in this. At the edge of the hearth there were some blade fragments and bones. Within the whole find-bearing area there were small stones which were probably used as net sinkers. West of the hearth a blade scraper was found, along with several flakes and also a small concentration of gravel and small stones. East of the hearth was an area with rich amounts of burnt wood, tar torches and charcoal. There were also some hazelnut

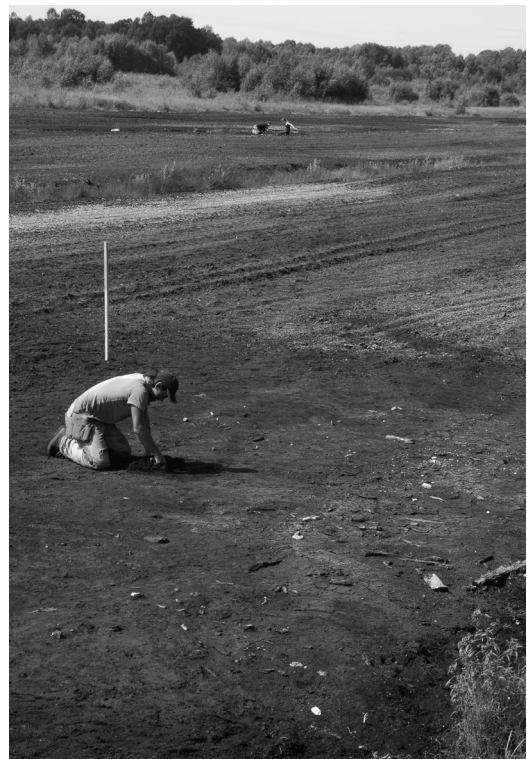


Fig. 2. Krister Käm Tayanin, who made the find, excavating at site FP581. In the layer of algae gyttja some finds of stone, wood, pine torches can be seen. The arrow marks the position of the arrow. Photo by Arne Sjöström.

shells and a blade core. It was in this eastern part of the layer that the arrow was located. Between the arrow and the hearth, a fragment of a narrow microlith was found as well.

The distribution of the finds in the layer is difficult to interpret, as it is probably a mixture of finds deposited over a considerable time, both above and below water. During a low-water period the more or less drained lake bottom may have been inhabited, resulting in a small activity area like the many other small campsites in the former lake. There is however a great deal to suggest that a large share of the finds on the site may have been deposited in open water, above all the stone sinkers and tar torches. In the northern part of the peat-cutting area there are several other spots with similar find-bearing layers, comprising thousands of square metres. It cannot be determined with certainty what kind of environment the arrow ended up in, or whether it had any connection to the smaller campsite at the hearth or if it ended up in the lake in connection with hunting or other activities.

The tip of an arrow

The arrow consists of a front part of an arrow shaft to which are attached four triangular microliths and a loose lancet (Figs. 3–4). The preserved part of the wooden shaft is fragmented in four parts which together constitute 102 mm of the point end. The tip of the shaft is slightly damaged, which makes the original form rather uncertain. Judging by the preserved part of the tip, however, it is clear that it was not longer in this part because clearly cut bevelled surfaces can be seen on the preserved side of the tip part. These show that the tip was not sharp but blunt, indicating that the lancet microlith may have been attached at the front in a lump of resin.

The arrow shaft is made of a one-year-old

branch of hazel and is partly oval in shape, probably due to pressure, measuring 8 × 6 mm (species identified by Hans Linderson, Lund University). The four triangular microliths were attached in a V-shaped furrow about 3.5 mm deep, on one side of the shaft (Fig. 5). The furrow extends along the whole length of the shaft without becoming shallower at either end. Like many flint-edged bone points with V-shaped furrows, the furrows on the arrow were probably made with the aid of a flint burin in the form of an unpolished or polished blade fragment, what is called a *ruler* (Sjöström & Nilsson 2009).

Judging by the character of the resin it may have been applied in successive long strings. The surface of the resin is bubbly in places, wavy and uneven in form, as if it had not been pressed or smoothed out after being applied, instead retaining the surface it had when it was applied in thin strings (Figs. 4 and 6). After one or two strings of resin had been put into the furrow, the microliths were pressed into place. Then a little resin was applied along the edges of the microliths. Parts of the resin beside some of the microliths have come loose and disappeared, while in other places the resin sticks up a millimetre or two above the edge of the furrow and reaches some way up the microliths.

The microliths are made of thin, narrow microblades which are 17.8–25.0 mm long, 5.0–5.7 mm wide and 1.1–2.4 mm thick (Table I, numbered from the tip as shown in Fig. 4). Microlith 2, with a visible length of 25 mm is somewhat longer since it is partly concealed by resin, but only 2 mm more at most. The triangles were obliquely fastened to the arrow at an angle of 20 degrees in such a way that they formed barbs. The loose lancet microlith may have been attached to the point. Unfortunately, because of the slight damage to the arrow shaft, it is difficult to ascertain whether this was the case. No residue of resin can be observed on the lancet microliths. The

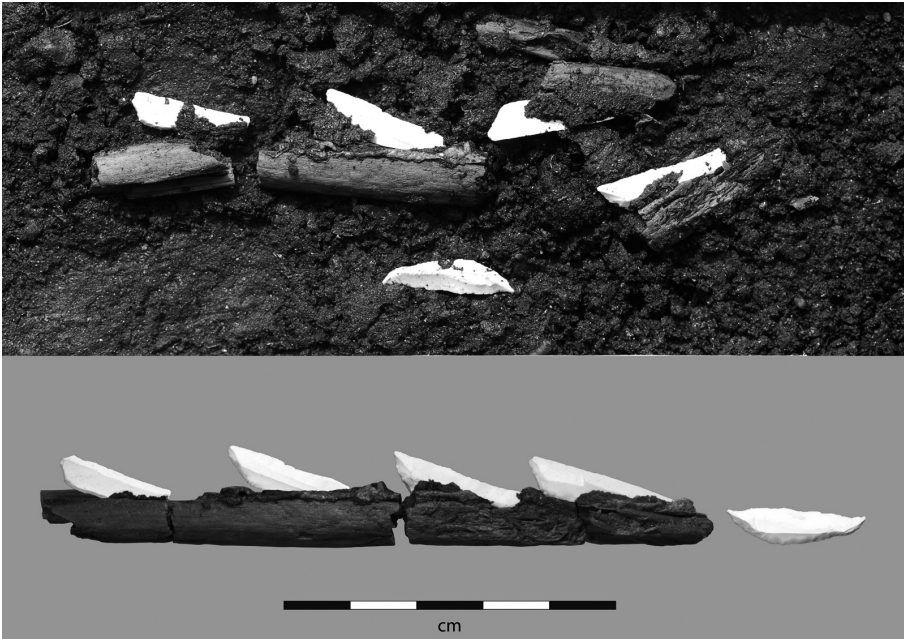


Fig. 3. The arrow *in situ* at the time of the discovery (top) and after the reconstruction (bottom). Scale 1:1. Photos by Arne Sjöström.

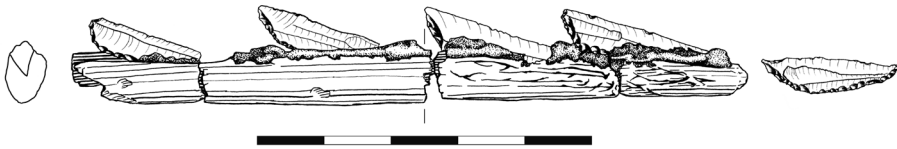


Fig. 4. The arrow after the reconstruction. Scale 1:1. Drawing by Krister Käm Tayanin.



Fig. 5. Cross-sections of the arrow shaft at different fractures. In the one on the left the resin-filled V-shaped furrow can be seen (the same cross-section as in figure 4). To the right microlith no. 3 firmly attached in the resin. Scale 5:1. Photo by Arne Sjöström.



Fig. 6. Close-up of the resin surface on microlith 2. Photo by Arne Sjöström.

Table I. Dimensions of the microliths (mm).
 Microlith no. 2 may be slightly longer since it is partly hidden by resin.

Microlith type	No.	Length	Width	Thickness
Lanceolate	1	20.2	5.3	1.6
Triangle	2	>25.0	5.7	2.4
Triangle	3	20.8	5.7	1.8
Triangle	4	20.6	5.3	1.1
Triangle	5	17.8	5.0	1.3

absence of resin on this is not an argument that it does not belong to the arrow, since no resin can be seen on the triangular microlith no. 4 either, which had come loose from the furrow. What speaks in favour of its belonging to the arrow is that it was found right beside the arrow shaft and the fact that no other flint finds appeared in the immediate vicinity of the shaft. Furthermore, the tip of the shaft is rather blunt, so it must have had some form of point in order to have functioned satisfactorily, and the fact that it differs in shape from the triangular microliths and thus must have had a different function from them. It is retouched along the whole side and slightly bent at the tips on the unretouched side (Fig. 7). The triangular microliths that have come loose and whose edges it has been possible to examine show that they are retouched only at the base and from there a few millimetres along the shorter of the long sides. It would have been of great interest if the microliths could have been analysed for traces of use wear. Unfortunately, this is not possible since they have all been affected by chemicals, causing the flint to be coloured white and partially dissolving the surface. As regards macro-traces, there is a fine retouch along the edges of the microliths that is probably a use/damage retouch. On the first (the lancelet) this is seen long the entire edge, while on the four triangles it is seen along roughly half the edge, where the protruding part of the edge is exposed.

As the arrow was broken just at the innermost microlith, there might have been even more microliths fastened in the furrow in the intact stage, but no other microliths or shaft remains were found in the neighbourhood.

The fact that the Rönneholm arrow was made of a small branch of hazel makes it different from other Mesolithic arrow finds, of which the majority of which are made of pine (Kloof 2015). In addition they are made of a splinted part of the inner part of a trunk. The reason might be that this kind of wood is hard and more resistant to humidity, keeping the arrow straight. A small branch is much more exposed to weather changes, especially in the kind of wetland environment where it was found.

One in a million

The find from the bog of Rönneholms Mosse is of special interest as we know of thousands, maybe millions, of microliths but very little about how they were fastened as they were so small that they rarely could be used in an unhafted way.



Fig. 7. Microliths no. 1 (left) and no. 4. Photo by Arne Sjöström.

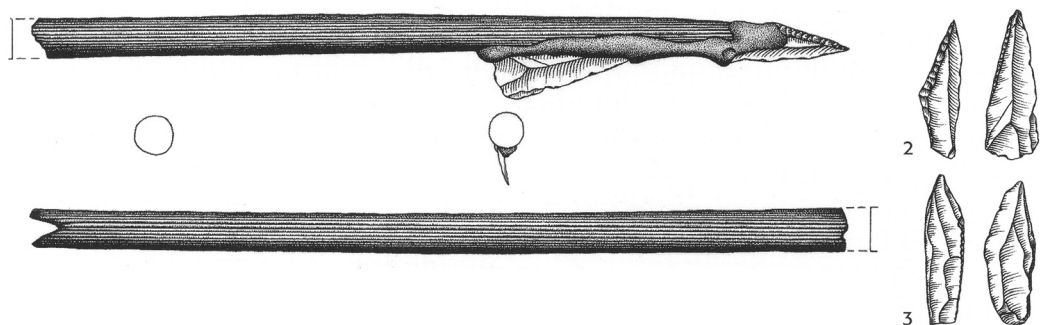


Fig. 8. The best-preserved arrow-tip from Loshult, southern Sweden, and the flints used for arrowheads. The microlith is depicted at top left, the others are microblades. Drawings by Björn Nilsson from Nilsson & Hanlon 2006.

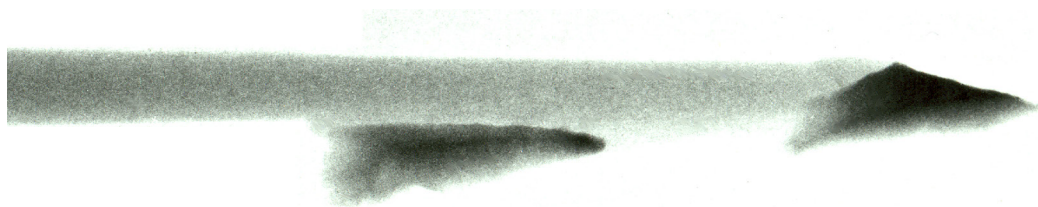


Fig. 9. An X-ray photo of the tip of the arrow from Loshult in Fig. 8.

A well-preserved example of an arrow tip with a hafted microlith is a find made in the bog Lilla Loshults Mosse in the northernmost part of the province of Scania, southern Sweden, in 1951 (Petersson 1951; Malmer 1969). The remains of two arrows were found in the course of peat cutting at a depth of about 2 m. Just one of the arrows from Loshult is preserved in its full length, which was 102 cm, with the thickest diameter 0.7 cm (Fig. 8). A notch was cut at the back to receive the string of the bow.

On one of the arrows the arrangement of flints with a point at the tip and another as a barb was still *in situ*. An X-ray photograph shows that only a lump of resin fastened the flint close to the tip without a groove (Fig. 9). The flints used for the other arrow were found as loose finds without the very tip of the

arrow so nothing is known about how they were fastened to the tip. Although the original report described the other flints illustrated in Fig. 8 as “microliths as arrowheads” (*Microlithen als Pfeilspitzen*), only one of them fitted as a barb is a true microlith, made by using the micro-burin technique. The remainder are microblades, with the bulb of percussion more or less preserved (Larsson 2009). This distinction between microliths and microblades is relevant for another composite tool, namely the slotted bone points that have been found in great numbers in Southern Scandinavia and the Baltic area (Verhart 1990, Fig. 7; Vankina 1999; Larsson 2005), where it appears that only microblades were used, although some scholars describe them as microliths.

Mesolithic arrows

Despite a number of Mesolithic sites with good preservation of wood, just a small number of arrows have been found. The arrow shaft most similar to those from Loshult and Rönneholm is a find from Vinkel in Jutland, Denmark (Troels-Smith 1962). It was found in a bog during peat digging and is dated to the Early Boreal chronozone. The shaft, cut from a pine stem, has a length of 102 cm and a diameter of about 0.7 cm. It is bevelled flat at the tip and a notch has been cut at the back to receive the string of the bow. Traces of lashing to fasten a feather are evident just above the notch.

Fragments of a number of arrows were found at the excavation of a site, Holmegaard IV, situated in a bog on southern Zealand, eastern Denmark and dated to a later part of the Maglemose Culture (Becker 1945). The longest fragment is 86 cm. Six fragments with a length of between 10 and 25 cm are preserved. They have cut furrows with a length of 7–11 cm and a width between 0.2 and 0.3 cm. The longest example has a furrow all the way up to the break, so it may have been longer. At the broken bases a couple

of fragments have a rectangular shape, the others are round or oval. Two fragments have been given transverse short strokes. One has opposite furrows while the rest show only a furrow that can be followed up to the point. Only one example has a hafted resin-like material still in the furrow together with a flint (Fig. 10). It is not possible to determine whether it is a fragment of a microlith or a microblade. The flint has been broken off after it was hafted, and no retouching can be seen on the bit that remains. The furrows at the tips have a length indicating that there was room for three or more microliths or microblades. Finds of base sections with a notch for the bowstring clearly show that they were used for archery. Besides this form of arrows, examples were also found at Holmegaard IV with the tip shaped like a lump.

A context of use for these arrows is indicated by a find from Prejlerup in northern Zealand, Denmark, where the intact skeleton of an aurochs was excavated, with 15 intact and fragmentary microliths and a small part of an arrow shaft (Aaris-Sørensen & Brinch Petersen 1986, 112 ff.). The flints included triangles, as well as lanceolates. Two triangles were found in a line at a distance of 3 cm and



Fig. 10. A: a tip off an arrow from Holmegaard IV, Zealand, Denmark and B: a close-up photo of the same tip.

could have belonged to the same arrow shaft. The arrow shaft fragment from Prejlerup was no more than 4 cm long, but a piece of resin was still fixed to the wooden shaft.

Wooden tips with a furrow for attaching flints in resin are not restricted to arrows. At a Middle Mesolithic settlement at Segebro, southern Sweden, a tip fragment the size of a spear was fashioned with such a furrow (Larsson 1982).

The number of arrows found in settlements with conditions to preserve wooden objects is very small. It is just close to settlements such as Rönneholm and Holmegaard that this type of arrow has been found. Somewhat more common are arrows with a thick wooden point, considered to have been used for hunting small animals with valuable skins. Arrows like the find of Loshult and Vinkel are single finds without connection to settlement sites. The situation at Loshult with the pieces of two arrows placed as a bundle, stabbed into the bottom, indicates that they were deliberately placed as a ritual deposition (Larsson 2009).

Beside the submerged settlement site of Ronæs Skov, Jutland, from the Ertebølle Culture a whole arrow was found, 89 cm long, made of a five-year-old branch of guelder-rose (Andersen 2009, 103 f.). A transverse arrowhead was set in a nick cut at the tip and at the back end was a notch for the bowstring. Dark material at the tip and at the other end was probably intended for hafting the arrowhead and the feathers. This is the first find of a whole arrow from the Ertebølle Culture. It should be borne in mind that the arrow from Ronæs Skov was found 40 metres from the excavation field, so it need not relate to this habitation and may just as well be lost during hunting in the neighbourhood of the settlement. On the settlement site a point was found of a probable club-shaped arrow. This can be compared with the ten finds of bows from the same spot. Two other Danish finds

comprise the front part of an arrow with the transverse arrowhead tied to the shaft (Madsen 1868, Pl. 22.19; Müller 1907, Fig. 1).

The arrow fragment from Rönneholm was made of a one-year-old branch of hazel. This differs from other finds from the Early Mesolithic which are made of split pine, with the exception of finds from Holmegaard IV, where birch and snowball were also used. In the Late Mesolithic pine disappeared as raw material, to be replaced by snowball, hazel, dogwood and alder (Kloöß 2015).

Especially the number of arrows is small in relation to the finds of bows. Bows have been found in sites with good preservation in central Scania, one at a site in the bog Rönneholms Mosse (Sjöström 2004) and two at the site Ageröd V in the bog Ageröds Mosse (Larsson 1983). Bows have also been found at a number of settlements in Denmark and northern Germany (Andersen 2013; Kloöß 2015). One should expect the number of arrows to be considerably larger than the finds of bows, which is not the case. This taphonomic discrepancy might relate to human behaviour. Either arrows that went out of use were given other functions or used as firewood. Another explanation could be that they were intentionally deposited at locations where they decayed or have not been found.

Dating

The Rönneholm arrow can be dated by the form of the microliths, which are typical of the late Maglemose Culture (Larsson 1978, Fig. 35). Radiocarbon dates of 7905±60 BP, 7002–6654 cal BC (1σ, LuS 8992) (Oxcal v. 4.1) were obtained for resin, and 7855±60 BP, 6805–6606 cal BC (1σ, LuS 8993) for wood (Table II). The date discrepancy between the samples is small and they fit very well with the Late Maglemose material culture.

Yet another find should be noted. A part

Table II. Radiocarbon dating of wood and resin from the arrow.

Lab. no.	¹⁴ C age BP	Cal. 1 σ	Cal. 2 σ	Site	Material
LuS 8993	7855 ± 60	6805–6606 BC	7002–6654 BC	FP581	Arrow shaft of hazel, <i>Corylus avellana</i>
LuS 8992	7905 ± 60	7029–6572 BC	7032–6644 BC	FP581	Resin from the furrow

of an arrow was found during peat-cutting in Vendsyssel, northern Jutland (Andersen 1979). Unfortunately it is broken at both ends. It was radiocarbon-dated to 8180±140 BP, 7374–7047 cal BC (K-1323)

The aurochs at Prejlerup with microliths has been dated to 8410±90 BP, 7595–7284 cal BC (K-4130). The Loshult arrows are dated to the middle part of the Maglemose Culture, close to the Early Boreal/Late Boreal (BO1/BO2) transition, with radiocarbon dates 8915±80 BP, 8279–7794 cal BC (Lu S 7195) and 8770±70 BP, 8004–7604 cal BC (Lu S 7217).

The invention of the combined bow and arrow was an important step in the development of hunting weapons. Based on use-wear coupled with opinions about the cognitive ability of modern humans, it has been suggested that the bow and arrow was introduced in southern Africa during the period called Howieson's Poort, which is dated between 70,000 and 50,000 years ago or possibly earlier (Lombard 2015; Coolidge *et al.* 2016; Lombard 2016).

The oldest find of a probable bow fragment from Mannheim-Vogelstang, south-western Germany, is dated to an early part of the Magdalénien with an age of about 18,000 years (Rosendahl *et al.* 2006). Different smaller forms of retouched stone tools older than the Magdalénien were used in composite tools, as is clear from the traces they show of hafting material, which usually consists of resin (Yaroshevich *et al.* 2010; 2013). But these objects may have been used in other tools such as spears or knives. A number of arrows and possible fragments of bows come from the Stellmoor site in northern Germany,

radiocarbon-dated to about 9500 cal. BC and belonging to the Ahrensburg Culture (Rust 1943; Fischer & Tauber 1987).

Analysis of the hafting adhesive used on the Rönneholms Mosse arrow

A sample of the hafting adhesive (approx. 20 mgs) was made available to establish its origin and to shed light on the technology of the Early Mesolithic find. The sample was suspended in a 1 ml mixture of dichloromethane/methanol (DCM/MeOH, 2:1 v/v) and ultrasonicated for 2 × 15 minutes. The solvent solubilized some of the sample as evidenced by the discolouration of the solvent to brown, although some of the sample remained as black particulates in the solvent. The solvent-soluble fraction was removed with a Pasteur pipette and blown to dryness under nitrogen. To promote chromatographic separation, silyl derivatives were produced through trimethylsilylation of the dried residue using 0.05 ml of *N,O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA) with 1% TMCS (60 °C, 1 hour). Excess reagent was removed by evaporation under nitrogen and the derivatized sample rediluted in DCM (0.1 ml) and transferred to a sample vial for analysis by gas chromatography-mass spectrometry (GC-MS).

GC-MS analysis

The analysis was carried out by combined gas chromatography-mass spectrometry using an Agilent 7890A GC system, fitted with a 30 m × 0.25 mm, 0.25 μm DB-5MS UI 5% phenyl

methyl siloxane phase fused silica column (Agilent), connected to a 5975C inert XL triple axis mass selective detector. The splitless injector and interface were maintained at 300 °C and 280 °C respectively and the carrier gas, helium, at constant flow. The temperature of the oven was programmed to rise from 50°C

(isothermal for 2 min) to 350°C (isothermal for 10 min) at a gradient of 10°C per minute. The column was directly inserted into the ion source where electron impact (EI) spectra were obtained at 70 eV with full scan from m/z 50 to 800 amu.

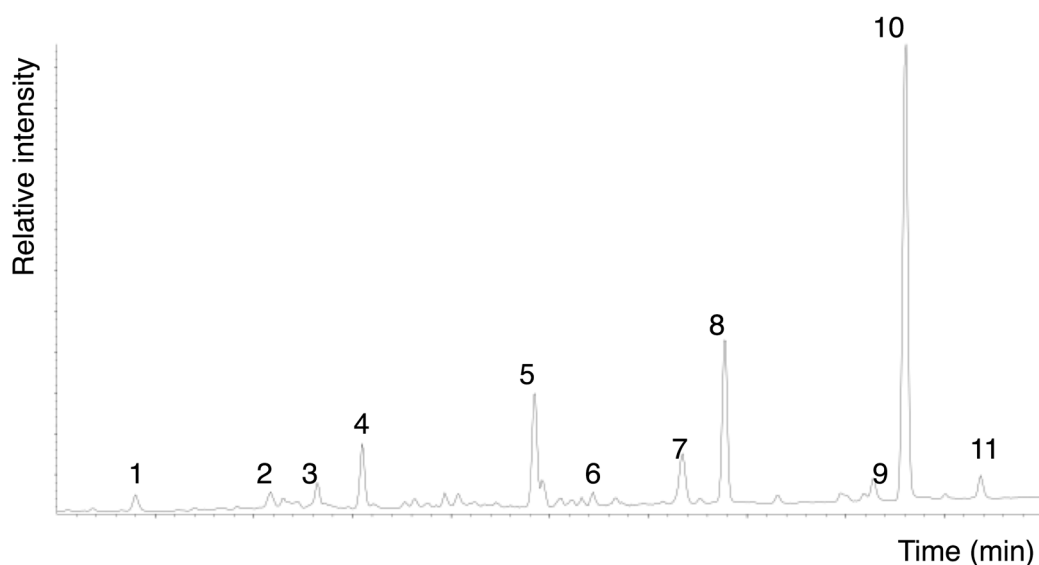


Fig. 11. Partial (25–32 min) TIC (total ion current) chromatogram of the hafting adhesive from the Rönneholms Mosse arrow. Peak identities are shown in Table III.

Table III. Characteristics of the major peaks found in the Rönneholm hafting adhesive.

Peak	Identity	Molecular ion (M^+)	Characteristic fragment ions, m/z (abundance)
1	Unassigned triterpenoid	408	365(100), 121(60), 229(20), 393(15), 323(10)
2	Unassigned triterpenoid	392(?)	189(100), 105(70), 229(50), 311(25), 377(30)
3	Lupa-2,20(29)-diene	408	189(100), 107(65), 203(30), 408(30), 297(25), 393(20)
4	Unassigned triterpenoid (TMS ether)	496	161(100), 121(90), 363(60), 453(60), 317(40), 481(10)
5	Lupa-2,20(29)-dien-28-ol (TMS ether)	496	393(100), 189(85), 406 (60), 203(35), 481(5)
6	Allobetul-2-ene	424	189(100), 134(90), 205(40), 353(30), 393(25), 409(10)
7	Unassigned triterpenoid (TMS ether)	482	189(100), 203(30), 279(20), 319(10), 467(5)
8	Lupeol (TMS ether)	498	189(100), 369(20), 279(15), 483(10), 393(10), 408(5)
9	Betulone (TMS ether)	512	409(100), 189(90), 203(60), 422(55), 483(10)
10	Betulin (<i>bis</i> -TMS ether)	586	73(100), 189(85), 203(80), 496 (50), 483 (40), 393(25)
11	Allobetulol (TMS ether)	514	189 (100), 385(55), 424(30), 203(20), 409(10)

Results

Fig. 11 shows the total ion current (TIC) chromatogram of the derivatized solvent extract. Table III provides the full molecular information on the major constituents. The molecules identified, a series of lup-20(29)-ene triterpenoids and their derivatives, are consistent with tar produced from birch bark (Orsini *et al.* 2015). Betulin is the major constituent of the sample comprising some 50% of the total triterpenoid fraction. In fresh birch bark, around 70% of the triterpenoid fraction is made up of betulin. During the manufacture of the tar, betulin is partly transformed into lupa-2,20(29)-dien-28-ol whereas lupeol leads to the formation of a triterpenoid hydrocarbon, probably lupa-2,20(29)-diene (Regert 2004). The unassigned peaks are likely to be trace constituents of birch bark or alteration products of original molecules, as evidenced by the base peak at *m/z* 189. No traces of any other substance such as fat, oil, beeswax or diterpenoid resin were identified.

Birch-bark tar has been identified at many prehistoric sites in Scandinavia (e.g. Aveling 1998; Aveling & Heron, 1999) and further afield (Aveling & Heron, 1998; Regert *et al.* 1998; Urem-Kotsou *et al.* 2002; Regert 2004) from the Middle Palaeolithic onwards (Grünberg 2002). In some circumstances birch-bark tar has been found mixed with substances such as beeswax and pine tar (Regert 2004). However, there is no evidence of this in the Rönneholm hafting adhesive.

These data confirm a pure birch-bark tar adhesive was used to haft the arrow from Rönneholms Mosse.

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