Palaeolithic bone and antler artefacts from Lateglacial and Early Holocene Denmark: technology and dating

Paläolithische Knochen- und Geweihartefakte des Spätglazials und Frühholozäns Dänemarks: Technologie und Datierung

Markus Wild[1,2,3,4*], Morten Fischer Mortensen[5], Niels H. Andreasen[6], Per Borup[7], Claudio Casati[8], Berit V. Eriksen[1], Lise Frost[9], Kristian M. Gregersen[10], Mogens Bo Henriksen[11], Marie Kanstrup[12], Jesper Olsen[12], Kristoffer Buck Pedersen[13], Peter V. Petersen[14], Conni Ramskov[15], Lasse Sørensen[12], Mikkel Sørensen[16] & Sidsel Wåhlin[17]

[1] Centre for Baltic and Scandinavian Archaeology (ZBSA), Foundation Schleswig-Holstein State Museums, Schloss Gottorf, 24837 Schleswig, Germany; ORCID: 0000-0003-0878-0403 [Wild], 0000-0002-6651-9249 [Eriksen]; email: mwild@roots.uni-kiel.de
[2] Collaborative Research Centre 1266, Subproject B2: Transitions of Specialized Foragers, University of Kiel, Germany
[3] Cluster of Excellence ROOTS, Subcluster Knowledge ROOTS, University of Kiel, Germany
[4] UMR 8068, TEMPS - Technologie et Ethnologie des Mondes PréhistoriqueS, Université Paris 1 & Université Paris 10, France
[5] The National Museum of Denmark, Environmental Archaeology and Material Sciences. I. C. Modewegsvej, 2800 Lyngby, Denmark; ORCID: 0000-0002-4167-8227
[6] Københavns Museum, Stormgade 20, 1550 København, Denmark
[7] Horsens Museum, Fussingsvej 8, 8700 Horsens, Denmark
[8] Museum Nordsjælland, Frederiksgade 9, 3400 Hillerød, Denmark
[9] Moesgård Museum, Moesgård Allé 15, 8270 Højbjerg, Denmark
[10] National History Museum of Denmark, Gothersgade 130, 1123 København K, Denmark
[11] Odense City Museums, Overgade 48, 5000 Odense C, Denmark
[12] Aarhus AMS Centre (AARAMS), Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus C, Denmark
[13] Museum Sydøstdanmark, Algade 97, 4760 Vordingborg, Denmark; ORCID: 0000-0003-4524-9400
[14] The National Museum of Denmark, Ancient Cultures of Denmark and the Mediterranean, Frederiksholms Kanal 12, 1220 København, Denmark
[15] Museum Kolding, Staldgården 1, 6000 Kolding, Denmark
[16] University of Copenhagen, the Saxo Institute, Karen Blixens Plads 8, 2300 Copenhagen S, Denmark
[17] Vendsyssel Historiske Museum, Museumsgade 13, 9800 Hjørring, Denmark

Abstract - The Danish Palaeolithic began during the Lateglacial (approximately 12,350 calBC) and lasted for about four thousand years. Only a handful of sites and organic stray finds have been precisely dated. And it is primarily on these that a preliminary chronological framework has been built. Similarly, numerous hypotheses on palaeohistory, typology, and settlement patterns have been proposed. However, due to the preservation of sediments that allow the preservation of organic materials and their exploitation during the past 170 years, abundant reindeer (*Rangifer tarandus*) and elk (*Alces alces*) remains have been uncovered. Many of these are worked and at least some of which can be assigned to the Palaeolithic. These remains have, so far, been only partly studied. Here, we present a study of the complete corpus. The Lateglacial faunal collections in 33 Danish museums were assessed, and 50 reindeer and elk objects are described in detail because they are worked or were mentioned in the literature as being worked. The Palaeolithic artefacts were AMS ^{14}C-dated and analysed together with existing datasets.

The results of the study create a more robust framework for hypotheses building. A reliance on reindeer for tool production throughout the Danish Palaeolithic is confirmed, as is the two-fold occupation of Denmark during the Hamburgian. Furthermore, the new results indicate a reduction of human occupation or even possible absence of humans during the first half of the Younger Dryas, followed by an intensive re-occupation of eastern Denmark during the Preboreal. Furthermore, the analysis of the worked bone and antler materials provides new insights into the manufacturing processes. The repeated occurrence of transversely segmented reindeer antler, documenting a continuous evolution of this technique from the Late Upper Palaeolithic to the Final Palaeolithic, speaks against a clear separation of the different cultural entities.

*corresponding author

Zusammenfassung - *Das dänische Paläolithikum beginnt während des Spätglazials (circa 12.350 calBC) und dauert ca. viertausend Jahre an. Nur wenige datierte Fundstellen und organische Streufunde bilden dabei das chronologische Gerüst. Auf dieser losen Grundlage wurden Hypothesen zur Paläohistorie, zur Typologie und zu Siedlungsmustern postuliert. Allerdings liegen viele Sedimente vor in denen sich organische Materialien gut erhalten und viele Knochen und Geweihe von Rentieren und Elchen wurden in den letzten 170 Jahren durch die Ausbeutung dieser Schichten entdeckt. Viele dieser sind bearbeitet und mindestens ein Teil ist dem Paläolithikum zuzuordnen. Während dieser Korpus bisher nur teilweise untersucht wurde, stellen wir hier eine Studie des kompletten Korpus vor. Neben der Begutachtung spätglazialer Knochensammlungen von 33 dänischen Museen werden 50 Rentier- und Elchobjekte im Detail beschrieben. Diese sind entweder bearbeitet oder wurden in der Vergangenheit als bearbeitet publiziert. Die paläolithischen Artefakte wurden AMS-^{14}C-datiert und zusammen mit bereits bestehenden Datensätzen analysiert.*

Insgesamt schaffen die Ergebnisse der Studie eine robustere Basis für die Hypothesenbildung. Eine Abhängigkeit vom Rentier für die Werkzeugherstellung während des gesamten dänischen Paläolithikums kann bestätigt werden, ebenso wie die zweigegliederte Besiedlung Dänemarks während der Hamburger Kultur. Zusätzlich deuten die neuen Datierungen auf eine mögliche Minderung oder gar ein Fehlen von Siedlungsaktivität während der ersten Hälfte der Jüngeren Dryas und eine intensive Wiederbesiedlung des östlichen Dänemarks im Präboreal hin. Des Weiteren erlaubten die Aufnahme der bearbeiteten Knochen und Geweihe neue Einsichten in die angewandten Herstellungsprozeduren. Das regelhafte Auftreten von transversal zerlegtem Rengeweih spricht dabei gegen eine deutliche Trennung der verschiedenen kulturellen Entitäten und für eine kontinuierliche Entwicklung der Technologie vom späten Jungpaläolithikum zum Spätpaläolithikum.

Keywords - Osseous technology, Radiocarbon dating, Lateglacial, Hamburgian, Brommean, Ahrensburgian, Reindeer
Knochentechnologie, Radiokarbondatierung, Spätglazial, Hamburger Kultur, Brommekultur, Ahrensburger Kultur, Rentier

Introduction

Over the last 170 years, thousands of prehistoric bone and antler artefacts have been found in Denmark. The majority has been unearthed during peat cutting and clay extraction, but drainage, tillage and dredging, as well as coastal surveys, have also contributed finds (Müller 1896; Mathiassen & Iversen 1937; Skaarup 1974; Fischer 1996). Most of this large bone and antler collection are stray finds and, only a tiny fraction can be directly associated with the Lateglacial period (Mathiassen 1938a, 1938b, 1941; Petersen & Johansen 1993; Fischer et al. 2013a). For this reason, absolute chronological evidence of the presence of humans in southern Scandinavia is scarce (e.g. Fischer 1996; Eriksen 2002; Grimm & Weber 2008; Mortensen et al. 2014a). This has been used as a loose basis for reconstructions of the past, such as modelling the dependence of cultures on specific animals (reindeer or elk hunters) (c.f. Hamer et al. 2019), the timing and frequency of human dispersals (Pedersen et al. 2018; Riede & Pedersen 2018), or the general synchronisation of environmental and archaeological changes (e.g. Mortensen et al. 2014b; Riede & Pedersen 2018).

The majority of Lateglacial bone and antler artefacts are stray finds from eastern Denmark. The waterlogged and often lime-rich sediments of the abundant kettle holes allow excellent preservation of organic substances. This contrasts with northern and western Denmark, where wetland areas are less frequent and the mineral- and lime-poor soil does not provide the same favourable conditions for the preservation of osseous remains (see above; Mortensen et al. 2014c).

Many of the possible Lateglacial finds have been assessed and published by archaeologists and zooarchaeologists during the 20th century (e.g. Hartz & Milthers 1902; Brøndsted 1938; Degerbøl & Krog 1959). However, it is mainly the finished objects, in particular barbed points and Lyngby-type antler tools (less neutrally called Lyngby axes), that have been addressed in more recent archaeological studies (Taute 1968; Petersen 1973; Andersen 1988; Fischer 1991; Eriksen 1996; Fischer 1996; Eriksen 1999; Johansen 2000; E. B. Petersen 2009; Fischer et al. 2013a). In contrast, raw material blocks, waste pieces and half-finished products of organic tool and projectile production have rarely been examined (Petersen & Johansen 1993; Fischer & Jensen 2018; Petersen 2018; Wild 2020). This is unfortunate since these products can provide diverse information, including data on seasonality, hunting activities and tool production that took place on and/or near the site. This stands in contrast to finished objects that might have been traded, transported and curated over long distances and periods. The lack of scientific engagement with raw material blocks and waste pieces is not related to them being stray finds and thereby bearing less information than excavated assemblages. This is especially indicated by the regular discussion of lithic stray finds (e.g. Mathiassen & Iversen 1937; Becker 1970; 1971; Holm & Rieck 1983; Burdukiewicz 1986; Fischer 1991; Henriksen 1996; Weber 2012; Pedersen et al. 2018). On the contrary, it seems that there is a fundamental problem when dealing with organic stray finds, particularly unfinished ones. The main reasons for a preference for finished over unfinished types may be problems in the identification of human modifications, the association of single waste

pieces with operational schemes and/or a general lack of knowledge of the differences in antler and bone-working among the different Palaeolithic cultures of Denmark.

In recent years, the Lateglacial and the Early Holocene in Denmark have attracted attention from researchers in both the natural sciences and archaeology. Several studies have focused on vegetation development and climate changes. These together have created a detailed reconstruction of the environment (Mortensen et al. 2011; Lemdahl et al. 2014; Mortensen et al. 2014b, 2014c; Jessen et al. 2015; Bennike & Mortensen 2018; Krüger & Damrath 2020). Furthermore, studies of the faunal remains have provided new insights regarding the presence of large game animals (Aaris-Sørensen et al. 2007; Aaris-Sørensen 2009, 2016). From an archaeological perspective, excavations and their recent publications have – alongside the above-mentioned studies of barbed points and Lyngby-type antler tools – shed further light on the presence of humans in Denmark during this period (e.g. Pedersen 2009; Fischer 2013; Mortensen et al. 2014a, 2014b, 2014c; Pedersen et al. 2016; Borup & Nielsen 2017; Madsen 2019; Riede et al. 2019; Sørensen et al. 2020; Wild 2020).

Here, we present a techno-typological assessment of known Palaeolithic stray finds made from bone and antler, including several 'previously unrecognised artefacts' (often waste pieces) that lay undiscovered in museum collections in Denmark (Appendix 1 [list of museums]). The large collection of reindeer bone and antler material from Slotseng is included in this study; however, a detailed description of the hundreds of osseous fragments is beyond the scope of this publication and we refer to Wild (2020) for more details. Likewise, the large faunal collection from the classical Bromme site is not included, with the exception of a ^{14}C-dated piece of reindeer antler. The remaining assemblage is highly fragmented and possibly intermixed with bone and antler from the Meso- and Neolithic periods.

The assessment is based on recent work on the technology of Palaeolithic cultures in northern Germany and southern Scandinavia (Wild 2017; Wild & Weber 2017; Wild et al. 2018; Wild 2020) and is supported by AMS ^{14}C analysis of human-modified pieces.

The main aims of this study are 1) to give an overview of known Palaeolithic bone and antler artefacts (worked raw material blocks, waste pieces, half-finished products/roughouts, and finished objects), 2) to provide a technological description of the artefacts and, if possible, relate it to a cultural period, 3) to improve the Lateglacial chronology by AMS ^{14}C analysis of worked osseous material, 4) to study the distribution of artefacts in time and space, 5) to correlate the spatial distribution in the different time slices to the known vegetation development and 6) if possible, to identify Lateglacial "hot-spots" for further surveying and/or re-assessment of old lithic collections.

Environmental stages

During the Lateglacial, some now-submerged areas were part of the North European Plain, and most of the Danish islands were still connected to the mainland (Fig. 1). The approximately four thousand years of the Danish Palaeolithic saw dynamic changes in the environment due to Lateglacial warming and isostatic elevations of large parts of Southern Scandinavia, as well as a rise in sea level. With the warming, colonisation by floral and faunal species began. Although the vegetation development is time-transgressive and the exact timing may vary slightly in different areas of Denmark, this development can be divided into four general vegetation stages:

Stage 1 includes the Bølling (12,750-12,100 BC) and Older Dryas periods (12,100-11,950 BC). The Bølling period is equivalent to the Meiendorf period in northern Germany (Krüger & Damrath 2020). During this period, the landscape was a tundra-/steppe-like environment dominated by pioneer vegetation and dwarf-shrub communities on dry land, while wetlands were dominated by various herbs (Mortensen et al. 2011). Reconstruction of the temperatures during this first part of the Lateglacial shows relatively warm summers (mean ~14 to 16 °C) and very cold winters (mean ~-3 to -20 °C) during the Bølling period (Lemdahl et al. 2014). In the following Older Dryas period, the climate became drier and colder; the mean summer temperatures dropped to ~9 to 13 °C (Lemdahl et al. 2014). Despite the changes in conditions, the effect on the dominant pioneer vegetation was relatively limited (Mortensen et al. 2011). This stage is in general marked by a return of larger mammals – in particular reindeer (Aaris-Sørensen et al. 2007) – while other large mammals seem to have been absent or appear at the very end of this stage (e.g. giant deer (*Megaloceros giganteus*); Aaris-Sørensen 2009).

Stage 2 marks the Allerød period (11,950-10,650 BC), which can be subdivided into three main vegetation periods: A) From 11,950 to 11,650 BC, the landscape was dominated by open grass and shrub vegetation. Summer and winter temperatures during this phase resemble the Bølling period (Lemdahl et al. 2014). B) Around 11,650 BC, an open birch woodland gradually formed in the eastern part of Denmark (Fig. 1), while the western and northern parts remained an open shrub-dominated landscape (Mortensen et al. 2014c) with summer temperatures around 11 to 13 °C (Coope et al. 1998). Eastern Denmark is, in the present paper, defined as the area covered by the Baltic Ice Advance during the Weichselian glaciation. These glaciers deposited calcareous and clayey sediments in the eastern part of Denmark, while the western and northern parts were covered

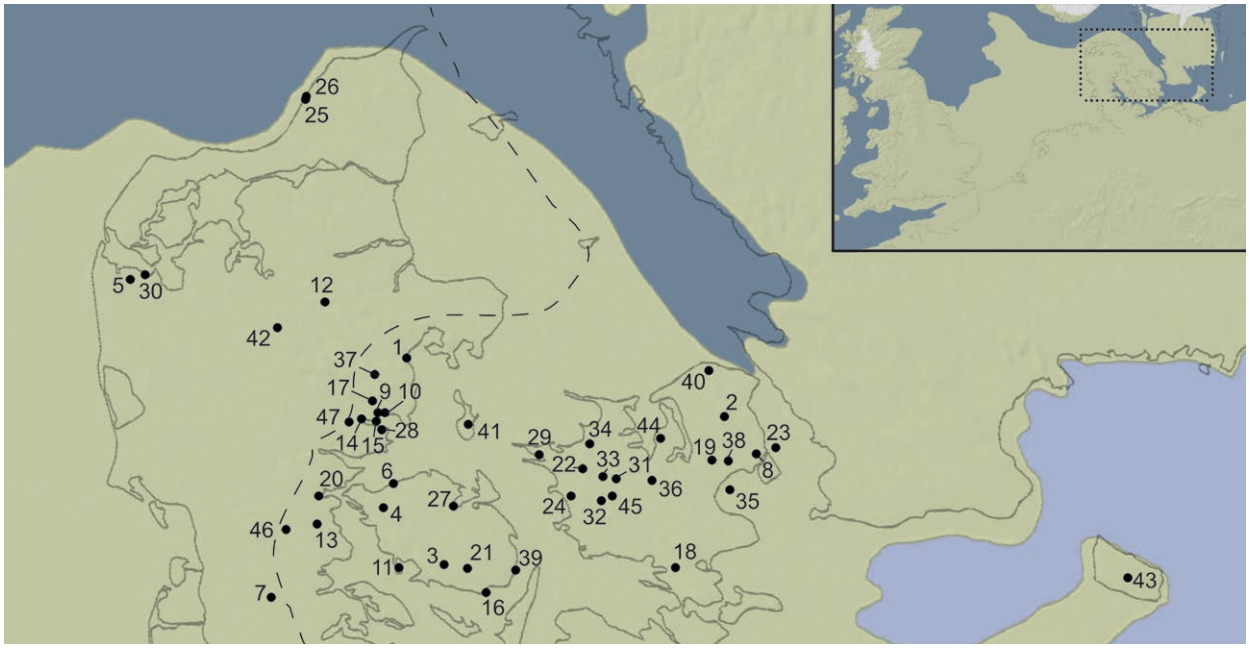

Fig. 1. Sites whose osseous remains have been assessed. In alphabetical order by site name: 1: Aarhus; 2: Allerød-Teglværk; 3: Arreskov; 4: Ejby Mose (not studied but mentioned in the text); 5: Faabjerg (not located); 6: Fogense Enge (not studied but mentioned in the text and catalogue; locality might be wrong and could be found in the Bred area (cf. catalogue); 7: Fogderup; 8: Fuglebakkevej 9: Glibinggård; 10: Havmarken; 11: Helnæs 12: Hjorthede; 13: Holbek near Christiansfeld; 14: Horsens Havn; 15: Horsens Fjord (not located); 16: Horseskov (Tåsinge); 17: Hovedgård; 18: Hundstrup Mose (not located); 19: Kallerup Mose; 20: Kolding Fjord; 21: Løgeskov; 22: Lille Aamose; 23: Middelgrund; 24: Mullerup Mose; 25: Nørre Lyngby; 26: Nørre Lyngby (1 km north of *locus classicus*); 27: Odense Kanal; 28: Overgård (not located); 29: Refnæs (Skambæk Mølle); 30: Rimmer Strand; 31: Sandlyng Mose; 32: Skaftelev; 33: Skellingsted Bro; 34: Skipinge Mark; 35: Solrød Strand; 36: Stestrup; 37: Stilling Mark; 38: Store Vejleå; 39: Storebælt; 40: Tammosegårds Mose; 41: Tranebjerg; 42: Ungstrup Mose; 43: Vallensgård Mose; 44: Vejleby. The following sites with important partly worked osseous remains are mentioned in the text: 45: Bromme; 46: Slotseng; 47: Tyrsted. Dotted line: Maximum extent of the Baltic Ice Advance indicating the border between eastern and western Denmark. Younger Dryas EPHA map (www.epha.zbsa.eu; CC BY 4.0; version 1.1.0; Mollweide projection; compiled by ZBSA after Björck 1995; Lemke et al. 2002; Weaver et al. 2003; Jakobsson et al. 2007; Patton et al. 2017).

Abb. 1. *Fundstellen deren Knochen- und Geweihartefakte bewertet wurden. In alphabetischer Reihenfolge der Fundstellennamen: 1: Aarhus; 2: Allerød-Teglværk; 3: Arreskov; 4: Ejby Mose (nicht aufgenommen aber im Text und Katalog erwähnt); 5: Faabjerg (nicht aufgefunden); 6: Fogense Enge (nicht aufgenommen aber im Text und Katalog erwähnt); 7: Fogderup; 8: Fuglebakkevej 9: Glibinggård; 10: Havmarken; 11: Helnæs 12: Hjorthede; 13: Holbek in der Nähe von Christiansfeld; 14: Horsens Havn; 15: Horsens Fjord (nicht aufgefunden); 16: Horseskov (Tåsinge); 17: Hovedgård; 18: Hundstrup Mose (nicht aufgefunden); 19: Kallerup Mose; 20: Kolding Fjord; 21: Løgeskov; 22: Lille Amose; 23: Middelgrund; 24: Mullerup Mose; 25: Nørre Lyngby; 26: Nørre Lyngby (1 km nördlich des Locus classicus); 27: Odense Kanal; 28: Overgård (nicht aufgefunden); 29: Refnæs (Skambæk Mølle); 30: Rimmer Strand; 31: Sandlyng Mose; 32: Skaftelev; 33: Skellingsted Bro; 34: Skipinge Mark; 35: Solrød Strand; 36: Stestrup; 37: Stilling Mark; 38: Store Vejleå; 39: Storebælt; 40: Tammosegårds Mose; 41: Tranebjerg; 42: Ungstrup Mose; 43: Vallensgård Mose; 44: Vejleby. Zusätzlich werden Fundstellen mit wichtigen, teilweise bearbeiteten Überresten aus Knochen und Geweih erwähnt: 45: Bromme; 46: Slotseng; 47: Tyrsted. Gestrichelte Linie: Maximale Ausbreitung der jüngeren skandinavischen Gletscher; zeigt die Grenze zwischen dem westlichen und östlichen Dänemark an. Jüngere Dryas-EPHA Karte (www.epha.zbsa.eu; CC BY 4.0; Version 1.1.0; Mollweide Projektion; zusammengestellt durch das ZBSA nach Björck 1995; Lemke et al. 2002; Weaver et al. 2003; Jakobsson et al. 2007; Patton et al. 2017.*

by sandier and less-calcareous sediments (Fig. 1). The Baltic Ice Advance furthermore formed vast areas with a dead-ice landscape, which later turned into wetland areas. During the Lateglacial and Early Holocene periods, thousands of water-filled kettle holes and wetlands were therefore scattered over eastern Denmark. These developments had a major effect on the flora and fauna available to Palaeolithic people (Mortensen et al. 2014c). C) With the transition into the cold GS-1 starting around 10,950 BC, the birch woodland gradually became more and more open. However, the Allerød environment persisted until approximately 10,650 BC before a vegetational shift is recorded in the pollen and macrofossil data (Mortensen et al. 2014b). It is possible that the average annual temperature dropped to 9 to 11 °C in this final stage (Coope et al. 1998).

The Allerød stage is marked by the return of another large cervid species, the elk, while reindeer were less dominant than during the preceding stage (Aaris-Sørensen 2009).

Stage 3 is the cold Younger Dryas period (10,650-9,550 BC), during which the landscape once again became treeless and dominated by pioneer vegetation and open dwarf-shrub communities. While the first part of the Younger Dryas was extremely cold and dry, with summer temperatures below 9 °C (Coope et al. 1998), the second part, starting around 10,200 BC, became more humid and possibly less cold (Bakke et al. 2009). During this less harsh period, crowberry (*Empetrum nigrum*) became more common due to the more oceanic conditions (Usinger 2004; Mortensen et al. 2014c). This period again seems to have been dominated by

reindeer, while the elk played a less dominant role (Aaris-Sørensen 2009).

Stage 4 is the Preboreal period (9,550-8,200 BC). From the ice core chronology, the onset of the Holocene warming is recorded to around 9,750 BC; however, the biological proxies are expected to have a delayed response time compared to the atmospheric chemistry (Rasmussen et al. 2006). In Denmark, the transition from the cold Younger Dryas into the warm Preboreal is not recorded in the pollen stratigraphy before 9,550 BC. The first 200 years are characterized by an open grassland before the first birch woodland started to spread around 9,350 BC, followed by pine (*Pinus* sp.) (Mortensen et al. 2011; Mortensen et al. 2014b). Some studies show an even longer response time in the vegetation (Jessen et al. 2015). The summer temperature is estimated to have been 15 to 17 °C (Coope et al. 1998). The Preboreal period is followed by the Boreal period, starting with the spreading of hazel (*Corylus avellana*) woodland around 8,200 BC (Odgaard 2010). While reindeer were still present during the Preboreal, other species, such as red deer (*Cervus elaphus*) and aurochs (*Bos primigenius*) appeared regularly in Denmark (Aaris-Sørensen 2009).

Material

In addition to references to worked osseous remains from excavated sites, such as Bromme (Mathiassen 1946), Tyrsted (Borup & Nielsen 2017) and Slotseng (Wild 2020), we found 46 faunal remains mentioned in the literature as being humanly modified and associated with the Palaeolithic. The chronological attribution to the Lateglacial most often derives from the species determination as reindeer. The majority of finds were mentioned by Degerbøl and Krog (1959) in their seminal publication on reindeer in Denmark; they had already been partly assessed in the early 20th century (Winge 1904). Furthermore, references to several, supposedly worked, artefacts can be found in different mid-20th century publications (Mathiassen & Iversen 1937; Brøndsted 1938; Mathiassen 1938a, 1938b, 1941; Brøndsted 1957). Precise information on these finds and references are given in the catalogue. In 2019, we contacted all the zoological and archaeological museums in Denmark (N = 34; Appendix 1) to locate the published artefacts and to ask for further potentially worked artefacts and collections of Lateglacial bone and antler.

Method

As we are not aware of any other such attempt to assess the entire body of recognised and unrecognised organic artefacts from a specific time period in a larger region, and given the restricted duration of the project, the tool set is partly restricted to methods that are not time consuming. As reindeer is assumed to have been the primary game during most of the Lateglacial period, the method used to locate old and new finds was based on inquiries. Every Danish archaeological and zoological museum curating Pleistocene and/or Palaeolithic faunal collections was asked for reindeer remains so that we could physically assess them. Another typical prey animal of Lateglacial hunter-gatherers was the elk. However, since this species lived well into the Holocene, Danish museums curate many elk remains dating to the Mesolithic. Within the current project, it was only possible to conduct a physical study on a small part of the elk material.

The method comprises four distinct steps. Steps 1 to 3 were applied to the original artefacts. For a handful of lost artefacts, we turned to published material.

1) Species and element identification.
2) Identification and description of past human modifications to the bone and antler as well as the integration of these artefacts into existing operational schemes (technological assessment) (Fig. 2, Tab. 1).
3) Sampling, pretreatment and radiocarbon dating of the identified Palaeolithic artefacts.
4) Modelling of new and existing radiocarbon data.

Species and element determination

Species and element determinations were based on several characteristics, such as shape, dimensions, cross-section, cross-section morphology, and surface structure (Fig. 3). The specific skeletal elements on which artefacts were made were identified through comparison with a reference collection from the zooarchaeological collection of the AZA (Archaeological Zoological Working Group) at the ZBSA, Schloss Gottorf, Schleswig (Germany).

Technological assessment

The identification and presentation of technological traces followed the methodology and terminology given in Wild (2020, 68-94, Figs. 2–3, Tab. 1). In short, results of the diagenesis of the specimen (weathering, trampling, root etching, etc.) were recorded, and primary stigmata as well as subfamilies of techniques deriving from possible anthropogenic modifications were described in detail. For the assessment, a low-power approach was used (cf. Odell & Odell-Vereecken 1980). Anthropogenic marks were identified by the naked eye and, where needed, further examined with a DinoLite AM7915MZTL USB-microscope with magnifications of 2x–40x.

When possible, the artefact's position in the operational schemes was deduced from the observed traces, the procedures used to modify the artefact and its location within the specific element. However, as the assessed finds are stray finds, most of the analogies with operational schemes derive from larger

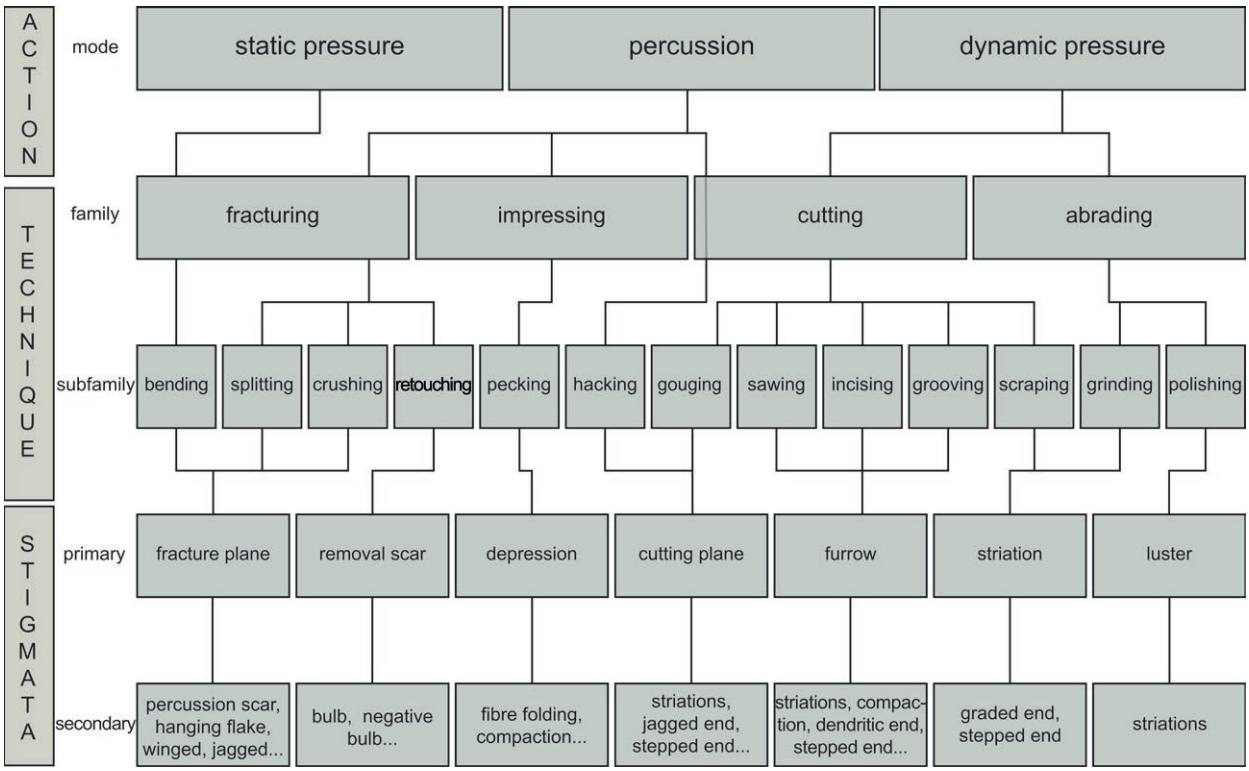

Fig. 2. Organisation of actions, techniques and stigmata that are associated with the working of osseous material. After Christensen 2015, Fig. 5-6. Combined, translated and modified (Wild 2020). For a description of the stigmata see Wild 2020.

Abb. 2. *Organisation von Aktionen, Techniken und Stigmata, die mit der Bearbeitung von Knochenmaterial in Verbindung stehen. Nach Christensen 2015, Abb. 5-6. Kombiniert, übersetzt und modifiziert (Wild 2020). Für eine Beschreibung der Stigmata siehe Wild 2020.*

action	static pressure	percussion					dynamic pressure						
technique	bending	splitting	crushing	retouching	pecking	hacking	gouging	sawing	incising	grooving	scraping	grinding	polishing
direction unknown													
direction known													
unidirectional													
back and forth													
changing													
primary stigmata	fracture plane			removal scar	depression	cutting plane		furrow			striation		luster

Tab. 1. Legend of symbols and colours for technical illustrations (www.wild2020.zbsa.eu). Illustrations show only the locations of primary stigmata and the subfamily of the technique applied.

Tab. 1. *Legende der Symbole und Farben für die technischen Darstellungen (www.wild2020.zbsa.eu). Die Darstellungen zeigen nur die Lage der primären Stigmata sowie die angewandte Technik-Subfamilie.*

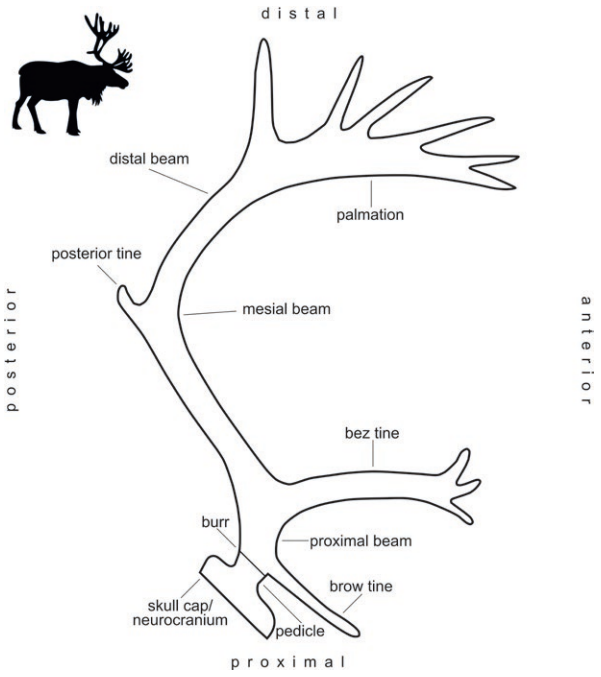

Fig. 3. Reindeer antler terminology.
Abb. 3. *Terminologie Rentiergeweih.*

assemblages from outside of Denmark (e.g. Rust 1943; Wild 2020). In this respect, it must be stressed that only well-known technological traces were used to identify past human handling of the specimens and it is, therefore, also possible that unremarkable antlers without clear traces of having been worked have been used as raw material blocks without further modification. The Final Palaeolithic assemblage from Tyrsted suggests such behaviour. At this small site, only the context allowed the identification of the agents who were responsible for the accumulation of five reindeer antlers without further unambiguous anthropogenic modifications as humans (Borup & Nielsen 2017; Eriksen et al. 2018). Comparable behaviour is attested for the Ahrensburgian complex from Stellmoor (Rust 1943). This highlights the possibility that more manuports are present in the collections. However, with no clear traces and context it is impossible to securely identify them.

Radiocarbon dating

Radiocarbon dating of all the assessed Palaeolithic artefacts that were undated was conducted by the Aarhus AMS Centre (AARAMS). The surface was cleaned and a surface sample separated before the dating samples were taken. Samples were taken - where possible - as solid blocks. As contamination from preservation chemicals was suspected, all samples were analysed by FTIR spectroscopy before pretreatment, and the extracted collagen of the dating samples was also analysed. Samples with inferred contamination from waxes were also analysed by FTIR spectroscopy after the contaminants were removed. FTIR spectroscopy was performed using an Agilent Technologies Cary 630 ATR-FTIR spectrometer. Scans were performed in the range from 4,000 to 650 cm^{-1} with a resolution of 2 cm^{-1}. Sample AAR-31845 showed FTIR peaks consistent with waxes. This sample was purified prior to collagen extraction using successive warm (45-50 °C for 15 minutes) and ultrasonic (15 minutes) baths of hexane, acetone, ethanol and finally ultrapure miliQ water (the last step was repeated twice). We followed a modified Longin procedure with ultrafiltration (Longin 1971; Brown et al. 1988; Brock et al. 2013). The bone pieces were dissolved in hydrochloric acid at 4 °C for several days to remove the inorganic apatite fraction. Subsequently, humic substances were removed using 0.2M NaOH at 4 °C, and the solution was replaced until it stayed clear. The samples were gelatinized in 0.01M HCl at 58 °C overnight, with an additional 3-day gelatinization afterwards. The extracted "collagen" was ultrafiltered in pre-cleaned Amicon Ultra Centrifugal Filters Ultracel – 30KDa. The collagen was then converted to CO_2 by combustion in sealed evacuated quartz tubes with 200 mg CuO. The CO_2 was reduced to graphite by the H_2 reduction method using an iron catalyst and $MgClO_4$ to remove the water (Vogel et al. 1984; Santos et al. 2007). The samples were ^{14}C dated using the HVE 1 MV tandetron accelerator AMS system at the Aarhus AMS Centre (Olsen et al. 2016). ^{14}C dates are reported as uncalibrated ^{14}C ages BP normalized to -25 ‰ according to international convention using online $^{13}C/^{12}C$ ratios (Stuiver & Polach 1977). Stable isotopes $\delta^{13}C$ and $\delta^{15}N$ were measured using a continuous-flow IsoPrime IRMS coupled to an Elementar PyroCube elemental analyser at the Aarhus AMS Centre (AARAMS), Aarhus University, Denmark. An in-house standard Gel-A was used as primary standard yielding ± 0.2 ‰ and ± 0.3 ‰ for carbon and nitrogen analysis respectively.

Additionally, some further dates that were previously unpublished derive from the AMS-laboratory at Uppsala. The pretreatment of samples followed the HCl method:

1) Mechanical cleaning of the surface by scraping and, in some cases, also by sandblasting; 2) ultrasonic cleaning in boiled distilled water (pH = 3); 3) grinding in the mortar; 4) adding 0.8M HCl and stirring at 10 °C for 30 minutes to remove the apatite; the soluble fraction at this point is named fraction A; 5) adding distilled water (pH = 3) to the insoluble fraction and stirring for 6-8 hours at 90 °C; at this point, the insoluble part is named fraction C and the soluble part is named fraction D; 6) burning the fraction to be ^{14}C dated and converting it to graphite using a Fe-catalyst reaction (K. Håkansson, pers. comm.).

Calibration and modelling of radiocarbon data

Calibration of all available dates on the Danish Palaeolithic was done using OxCal v. 4.4 (Bronk Ramsey 2009)

and the most recent calibration curve for the northern hemisphere IntCal20 (Reimer et al. 2020). Existing and new radiocarbon dates on osseous remains must fulfil standard acceptance criteria:

1. The date must derive from a bone or antler sample that can be associated with human presence
2. The obtained result must be in broad agreement with reliable stratigraphic, palaeoenvironmental and/or typological information

The radiocarbon dates of stray finds are calibrated, and the dates from the sites are used to create phase models to estimate the onset and termination of occupation at each site. Dates that do not agree well with the model are excluded and calibrated parallel to the model as they could indicate another visit on site.

Results

In the course of this study, more than 300 possible artefacts were assessed. As the project focused on worked remains and was limited to a short period, the many unworked bones and antlers – often highly fragmented – were only counted. Among the worked pieces, we found seven artefacts that had not yet been published or that had been published as unworked. Although we believe we have included all the material from Denmark, we cannot exclude the possibility of more unrecognised artefacts in museum collections. Among the studied objects, 45 were assessed in detail as they show anthropogenic modifications or were thought to have been modified. Several of the latter are good examples of pseudo-artefacts, e.g. due to animal gnawing, natural wear, taphonomy, or find circumstances (peat cutting by shovels, sand exploitation by mechanical diggers, etc.).

It was not possible to locate four of the (supposedly) worked artefacts (Faabjerg, Horsens Fjord, Hundstrup Mose, Overgård) and the Fogense Enge artefact is published elsewhere in detail (Petersen 2021). In addition to some possible elements deriving from elk or another large mammal (Ejby Mose, Fogense Enge, Tammosegårds Mose, Vallensgård Mose) and some artefacts for which species identification is uncertain (Helnæs, Sandlyng Mose (N = 2), Skellingsted Bro, Skipinge Mark), the majority of finds studied are reindeer antler.

Technology

After examination, the objects were organized into different categories: (1) unworked objects that have been published as worked; (2) worked objects that have been published as animal-gnawn; (3) previously published artefacts; (4) 'previously unrecognised artefacts'; and (5) new discoveries

(1) Unworked objects that have been published as worked

Several objects belong to the category of supposedly worked artefacts. The majority of them have been described as Lyngby-type antler tools (Faabjerg (Schacht 1979), Fogderup (Schwantes 1925) (Plate 21), Horsens (Mathiassen 1938a), Stestrup (Fig. 4, Plate 28), Store Vejleå (Mathiassen 1946) (Plate 30), Storebælt (Skaarup 1974) (Plate 31), and Vejleby (Mathiassen 1938a) (Fig. 5, Plate 32). In most cases, these reindeer antlers have their proximal (lower) to mesial (middle) parts preserved, while they show natural fractures (almost all of them), animal gnawing (e.g. Stestrup; Fig. 4, Plate 28) or, in most cases, deep hacking (direct percussion with a sharp working end) and scraping marks on one side (e.g. Vejleby; Fig. 5, Plate 32). The sharp edges of the marks derive from the mechanical diggers and/or spades and shovels that were used during unearthing. In some cases, it is possible to see different episodes in such traces, which are almost exclusively found on one side of the object and seem to derive from an attempt to cut through the object – perhaps the finders thought the object was a branch or root of a tree they needed to cut through.

Another Lyngby-type antler tool was reported from Tranebjerg on Samsø (Fig. 6, Plate 20). This antler shows no clear characteristics of this artefact type on its beam; however, the bez tine shows a transverse fracture with two winged (long and flat) fracture planes that could indicate the use of this antler as a striking or intermediate tool (cf. Jensen 2001). The fracture furthermore shows signs of fibre compression and a diffuse polish. Both point in the same direction as the winged fracture planes. Nonetheless, the discrete stigmata cannot be assigned to human action with any certainty and the ascription of the piece as artefactual remains dubious and needs further discussion (see below).

The last object in this category is the antler from Middelgrund (Plate 25), which had been published as a knife by Th. Mathiassen (1938a). A later ^{14}C analysis revealed that it belongs to historical times (Petersen & Johansen 1993). However, due to collagen preservation and dating problems, the ^{14}C date should be treated cautiously. Nonetheless, the recent character of possible smoothing of the object's lateral edge was confirmed by the new assessment.

(2) Worked objects that have been published as animal-gnawn

While animal-gnawn antlers have sometimes been interpreted as artefacts, the opposite holds true for a detached bez tine from Holbek near Christiansfeld (Winge 1904), which shows a series of hacked cutting planes on the medial side that create a typical 45° unilateral depression that acted as a predetermined breaking point that later caused a winged fracture plane on the opposite lateral side (Fig. 7, Plate 5).

(3) Previously published artefacts

The largest category of studied finds is that of confirmed artefacts that have already been published. Besides barbed points with shield-shaped bases (Ejby Mose (Plate 11A-B), Sandlyng Mose (A39773)

Fig. 4. Stestrup. Reindeer antler. The animal gnawing marks on the bez tine have been incorrectly attributed to humans. The object is listed as a Lyngby-type antler tool in several publications. a: medial side; b: medial detail of the bez tine with gnawing marks.

Abb. 4. *Stestrup. Reingeweih. Die tierischen Bissspuren auf der Eissprosse wurden fälschlicherweise als menschlich interpretiert. Das Objekt wurde in verschiedenen Publikationen als Geweihwerkzeug vom Lyngby-Typ geführt. a: mediale Seite; b: Detail der Eissprosse mit Bissspuren.*

(Plate 12C-D), Skaftelev (Plate 11), Skellingsted Bro (Plate 11E-F), Skipinge Mark (Fig. 12d, Plate 12K-L), Tammosegårds Mose (Plate 11G-H) (also called 'Gilleleje'), Vallensgård Mose (Plate 12G-H) and Lyngby-type antler tools (Arreskov (Fig. 13, Plate 13), Løgeskov (Plate 14), Nørre Lyngby (Fig. 11, Plate 15-16), Odense Kanal (Plate 17), a third group consists of waste pieces from the production of secondary raw material blocks and tools made from reindeer antler (Allerød-Teglværk (Plate 2), Fuglebakkevej (Fig. 8, Plate 3), Hjorthede (Plate 4), Mullerup Mose (Plate 7), Rimmer (Plate 9), Solrød Strand, Ungstrup Mose (Plate 10). Another find is one of the few decorated osseous artefacts from Palaeolithic Denmark: the reindeer antler from Kallerup Mose (Plate 19) shows intensive animal gnawing on its beam and brow tine and a finely incised helical furrow decorates the antler beam and the bez tine. Further published finds derive from Bromme and Slotseng.

(4) Previously unrecognised artefacts

Four artefacts belong to the category of 'previously unrecognised artefacts', i.e. humanly modified objects that have not been recognised as such or published to date. This category contains a reindeer antler beam with hacking and/or gouging (possibly the same tool as for hacking with a sharp working end, but the tool is pushed by direct pressure into the compact bone (≠ percussion) marks on a fracture on the distal beam from Aarhus (Fig. 9, Plate 1), a primary raw material block (an almost complete antler) from Kolding Fjord (Fig. 10, Plate 6) that shows a grooved furrow and a second,

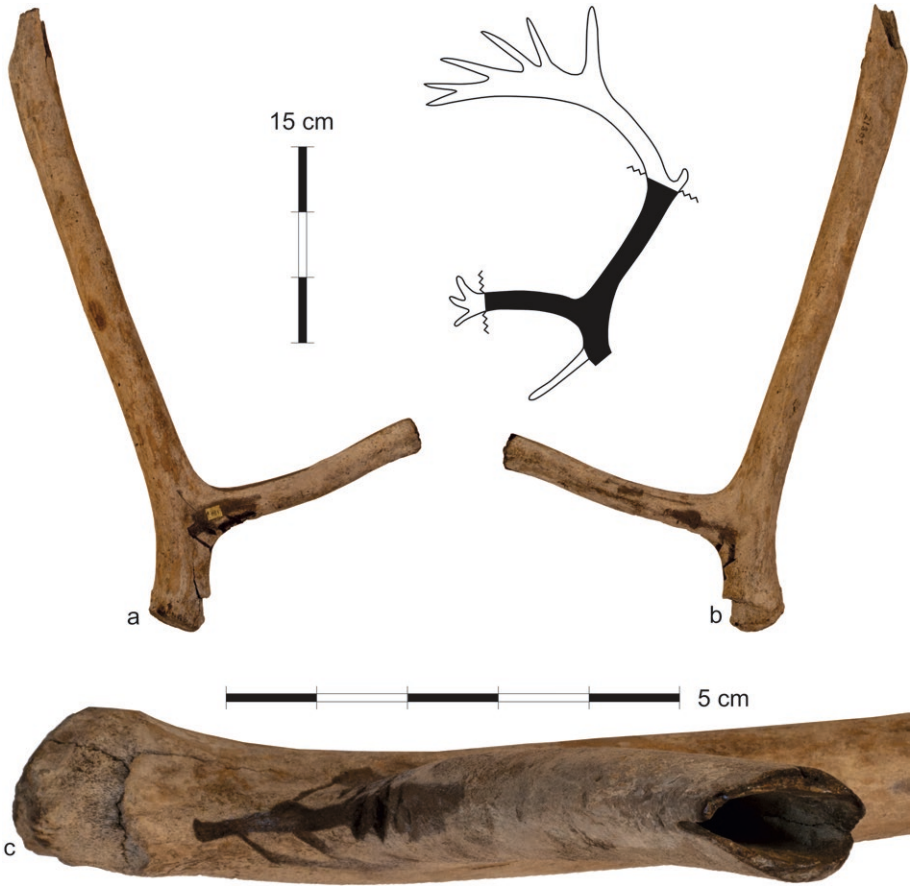

Fig. 5. Vejleby. Reindeer antler. The shape of the bez tine in connection with the wide cutting planes has been interpreted incorrectly as anthropogenic. The object is listed as a Lyngby-type antler tool in several publications. The antler most probably lay on its posterior side in the sediment as traces of a shovel or spade can only be found on the anterior side of the proximal antler. a: lateral side; b: medial side; c: anterior detail of the proximal antler and bez tine with stigmata left by a shovel/spade.

Abb. 5. *Vejleby. Rengeweih. Die Form der Eissprosse wurde in Verbindung mit den weiten Schnittflächen fälschlicherweise als menschlich modifiziert interpretiert. Das Geweih lag höchstwahrscheinlich in Rücklage im Sediment, da es nur auf der Vorderseite des proximalen Geweihs Spuren von Schaufel oder Spaten trägt. a: laterale Seite; b: mediale Seite; c: Detail des proximalen Geweihs und der Eissprosse mit Spuren von Kontakt mit Schaufel/Spaten. Vorderansicht.*

extensively water-rolled, Lyngby-type antler tool from the eponymous Nørre Lyngby (Fig. 11, Plate 16). Besides these finds, a proximal waste piece from the production of a secondary raw material block (a segmented primary raw material block) from Refnæs (Skambæk Mølle) is the only published artefact (Degerbøl & Krog 1959) in this category. However, it was not recognized as worked. This find shows a discrete remainder of a supposedly bilateral predetermined breaking point above the bez tine (Fig. 12, Plate 8).

(5) New discoveries

Three finds belong to the category of 'new discoveries'. One of them derives from the shore of Helnæs, and the others are from Lille Aamose (Fig. 13a, Plate 12A-B) and Sandlyng Mose (Fig. 13c, Plate 12E-F). All are biserially barbed points with shield-shaped bases. While the Helnæs point was discovered in 2020 on the beach at Helnæs, the Lille Aamose point was in private hands for decades and was only handed over to the Danish National Museum in 2009. The Sandlyng Mose point was presented to the Danish National Museum in 1943 but has not been published adequately. Additional reindeer antlers were found in Tyrsted near Horsens in connection with Final Palaeolithic lithic artefacts. However, as mentioned none of these bear unambiguous traces of working (see above).

^{14}C dating

Of the assessed artefacts that have not been dated so far, 14 were given to AARAMS for ^{14}C dating. Including the direct dates previously assigned to other finds, the only non-dated Palaeolithic osseous finds from Denmark are the Ejby Mose and Helnæs points, since only non-destructive analyses were allowed (Tab. 2).

For the Ua-dates, the radiocarbon laboratory cannot provide further supplementary information for quality control. However, as the soluble part D was dated (K. Hakånsson, pers. communication),

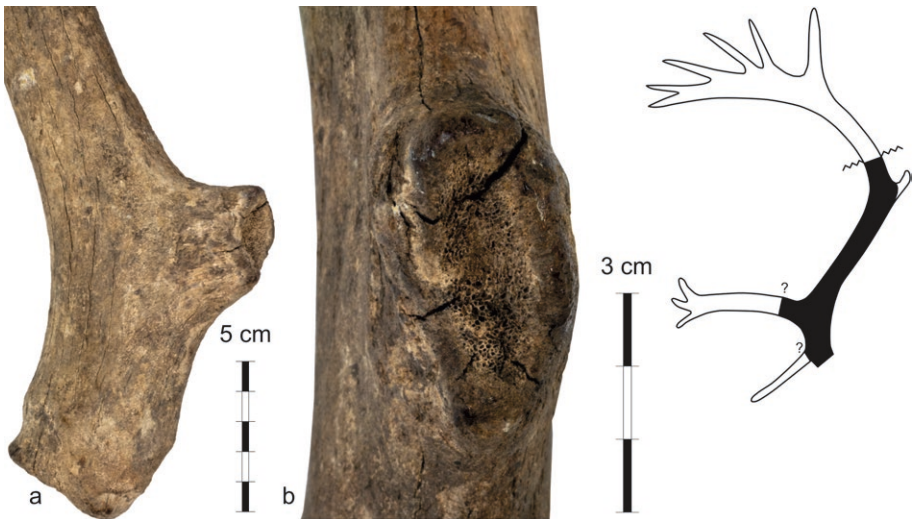

Fig. 6. Tranebjerg. Reindeer antler. The fibre compression, small fissures and small winged fracture planes on the bez tine could derive from human action. However, none of the stigmata are unambiguous. a: lateral side of the proximal antler; b: anterior side of the bez tine.

Abb. 6. *Tranebjerg. Rengeweih. Die Stauchung der Fasern, kleine Fissuren und kleine en languette-Bruchflächen könnten von menschlichen Handlungen stammen. Nichtsdestotrotz ist keines der Stigmata eindeutig. a: laterale Seite des proximalen Geweihs; b: Aufsicht auf Eissprosse.*

the collagen preservation should be sufficient. The radiocarbon dates obtained from Aarhus were checked for possible contaminants and sufficient collagen content. The collagen FTIR spectra indicate clean samples (Fig. 14–15). The C:N ratios of all samples fall within the expected range from 2.9 to 3.6 (DeNiro 1985) as well as fulfilling the quality guidelines provided by G. J. Van Klinken

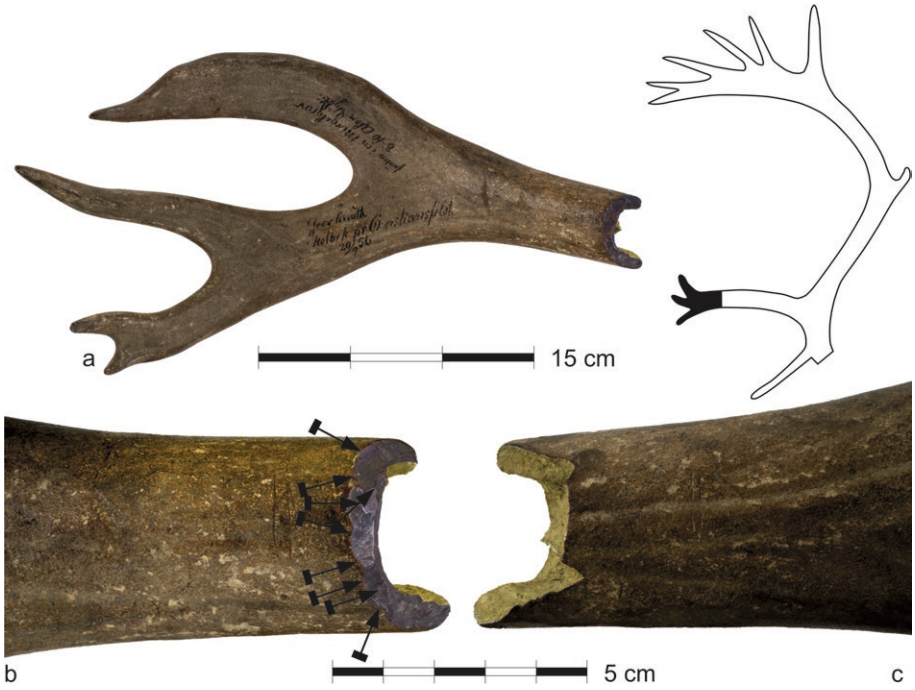

Fig. 7. Holbek. Reindeer antler. The distal end of a bez tine was detached at a predetermined breaking point. Several well-preserved cutting planes were hacked into the medial compact bone. a: medial side; b: detail of the medial side with a predetermined breaking point and hacked cutting planes; c: detail of the lateral side with a fracture plane.

Abb. 7. *Holbek. Rengeweih. Das distale Ende der Eissprosse wurde durch eine Sollbruchstelle entfernt. Einige gut erhaltene Schnittflächen wurden in den medialen Kompaktabereich gehackt. a: mediale Seite; b: Detail der medialen Seite mit Sollbruchstelle und gehackten Schnittflächen; c: Detail der lateralen Seite mit Bruchfläche.*

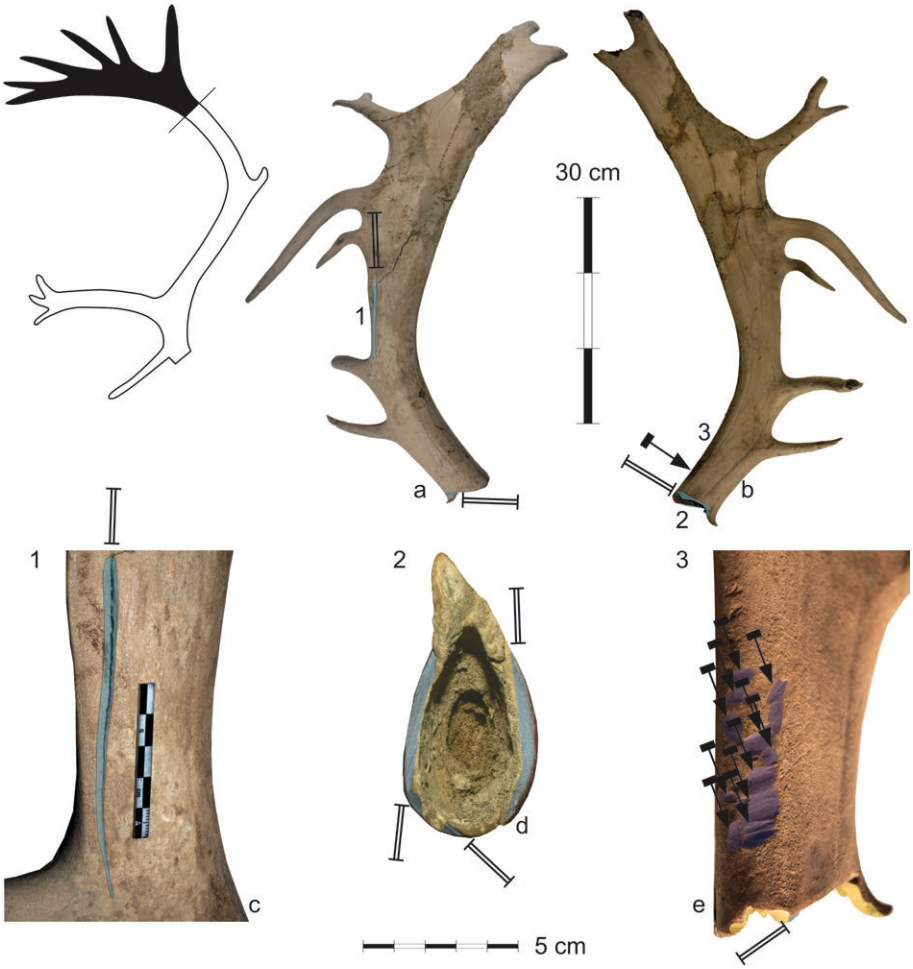

Fig. 8. Fuglebakkevej. Reindeer antler. Right distal reindeer antler with grooved trilateral predetermined breaking point, hacking marks and a grooved furrow on the palmation. a: lateral side with grooved furrow; b: medial side with hacking marks on the anterior side; c: detail of the grooved furrow; d: top view of the trilateral predetermined breaking point; e: hacking marks on the anterior side of the antler above the predetermined breaking point.

Abb. 8. *Fugglebakkevej. Rengeweih. Rechtes distales Geweih mit dreiseitig gerillter Sollbruchstelle, Schnittflächen und einer gerillten Furche auf der Palme. a: laterale Seite mit gerillter Furche; b: mediale Seite mit Hackspuren auf der Vorderseite; c: Detail der gefurchten Rille; d: Aufsicht auf dreiseitige Sollbruchstelle; e: Hackspuren auf der Vorderseite des Geweihs oberhalb der Sollbruchstelle.*

(1999), i.e. carbon content <25 %, nitrogen content <10 %, collagen yield <1 % (for ultrafiltered samples, collagen yields as low as 0.1 % are considered valid). However, the samples from Rimmer Strand (AAR-31846) and Nørre Lyngby (AAR-31845) were clearly assigned a date that was too young. For Nørre Lyngby, this might be explained by the same consolidation problems that caused the young dating of the first identified Lyngby-type antler tool from the eponymous site (cf. Fischer et al. 2013a). No additional data is available for the Fuglebakkevej antler; however, its date is in accordance with the biostratigraphy of the find layer, placing the find in the late Bølling/Older Dryas Period (Degerbøl & Krog 1959).

Modelling of ^{14}C data

The simple phase model used estimates the onset (13,015-12,339 BC; 95.4 % confidence interval) and the end (8,598-8,160 BC; 95.4 % confidence interval) of the use of Palaeolithic bone and antler artefacts (Fig. 15). Furthermore, the overall activity in the use of Palaeolithic-type bone and antler artefacts was estimated using a kernel density estimate (KDE) (Fig. 16, KDE summary; Bronk Ramsey 2017). For the Slotseng and Tyrsted localities, several ^{14}C samples were taken from each site and a simple phase model was used to estimate the onset and termination of each site (Fig. 16). From the Slotseng phase model, AAR-906, -8159, and -8161 were calibrated separately due to low agreement. The Slotseng location indicates a very short usage period with an onset at 12,329-12,118 BC (95.4 % confidence interval) and termination at 12,196-12,020 BC (95.4 % confidence interval), whereas the Tyrsted location suggests a much longer usage period from 11,062-10,056 BC (95.4 % confidence interval) to 9,978-9,104 BC (95.4 % confidence interval) (Fig. 16).

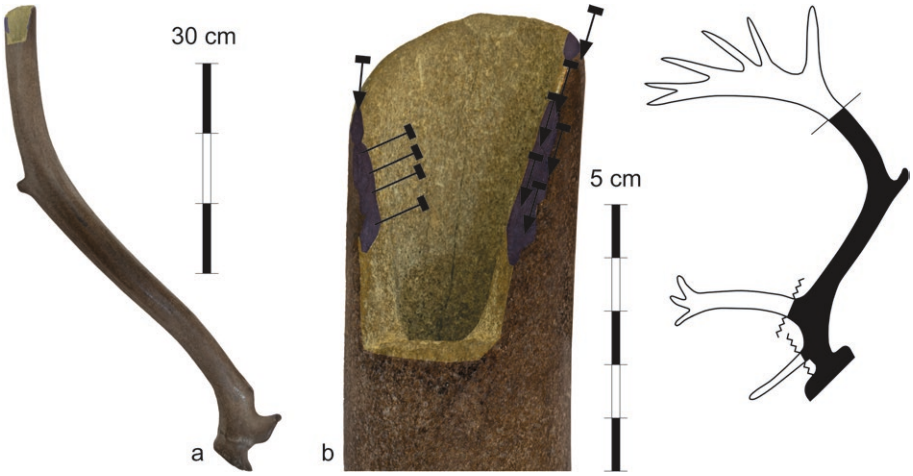

Fig. 9. Aarhus. Reindeer antler. The proximo-mesial antler shows the stepped end of a winged fracture plane and several hacked cutting planes on the distal end. a: lateral side; b: detail of the lateral side with cutting planes.

Abb. 9. *Aarhus. Rengeweih. Das proximo-mesiale Geweih zeigt ein stufiges Ende an einer en languette-Bruchfläche und einige gehackte Schnittflächen am Distalende. a: laterale Seite; b: Detail der lateralen Seite mit Schnittflächen.*

Discussion

This paper presents and discusses Lateglacial organic artefacts from a chrono-spatial perspective. Starting from a strictly chronological perspective, the new results suggest the regular presence of humans in Denmark throughout the Lateglacial with only a possible gap of a few centuries during the Younger Dryas cold period (Fig. 16, cf. KDE summary with Slotseng and Tyrsted removed; Tab. 3). No new data

Fig. 10. Kolding Fjord. Reindeer antler. The almost-fully preserved antler shows a grooved furrow on its latero-anterior side. a: lateral side; b: detail of lateral side of the mesial beam.

Abb.10. *Kolding Fjord. Rengeweih. Das fast vollständig erhaltene Geweih zeigt eine gerillte Furche auf der latero-anterior Seite.*

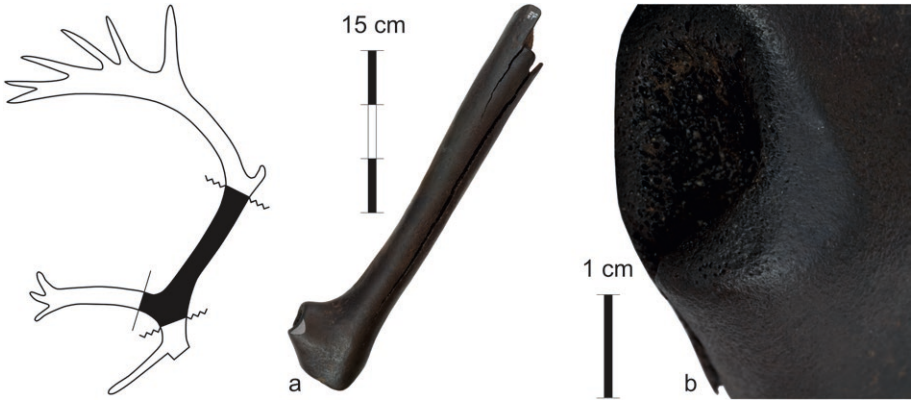

Fig. 11. Nørre Lyngby. Reindeer antler. The artefact shows a bevel on the medial side of the bez tine that indicates its nature as a Lyngby-type antler tool. a: medial side with the bevel on the bez tine indicated by a white area; b: detail of the bevel.

Abb. 11. *Nørre Lyngby. Rengeweih. Das Artefakt zeigt eine Anschrägung der medialen Eissprossenseite. Das deutet darauf hin, dass es sich um ein Geweihwerkzeug des Lyngby-Typs handelt. a: mediale Seite mit der Anschrägung der Eissprosse. Angedeutet durch weiße Fläche; b: Detail der Anschrägung.*

can be added regarding the seasons during which hunter-gatherers were present in Denmark during the Lateglacial, as most of the worked reindeer artefacts were made from the fully grown antlers of bulls and are therefore biased towards the autumn.

Interestingly, the results of the study indicate a change in discard behaviour during the Palaeolithic. While the majority of finds derive from former bodies of water, the type and nature of the objects change through time. The earliest finished osseous objects from Denmark are the Fogense Enge rod and the Odense Kanal- and Arreskov-Lyngby-type antler tools, which all date to the late Allerød period. All other humanly modified objects identified before this period are waste products or discarded/stored raw material blocks. This trend changes within the Younger Dryas and the Preboreal phase, from which most of the finds are finished objects – Lyngby-type antler tools and biserially barbed points with shield-shaped bases – while no production waste or raw material blocks with the first signs of being worked were identified. Both types of behaviour are mirrored in the northern German Ahrensburg tunnel valley. For the early Lateglacial Hamburgian, abundant evidence of production waste was confirmed, with only rare evidence of finished objects (Wild 2020), while most of the antlers deriving from the late Lateglacial complex are unworked or unfinished objects (Rust 1943). This change in discard-behaviour could relate to changes of group or camp size, of the duration of stays, or to repeated stays at the same site and a related preparation of the camps. In addition, a change in hunting behaviour towards chasing swimming terrestrial and aquatic mammals may also be the reason why some

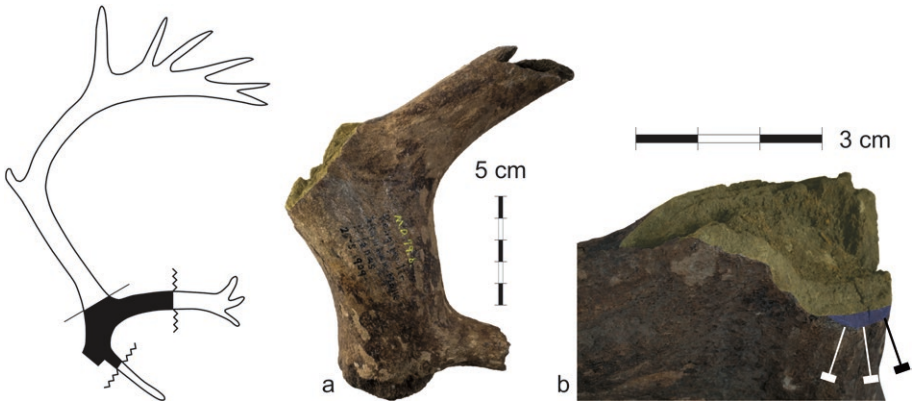

Fig. 12. Refnæs (Skambæk Mølle). Reindeer antler. Proximal waste piece showing at least a unilateral predetermined breaking point on the beam above the bez tine. The large fracture plane has a partly jagged appearance that may be due to the removal of the second half of a bilateral predetermined breaking point. a: medial side; b: detail of the lateral side with hacking stigmata.

Abb. 12. *Refnæs (Skambæk Mølle). Rengeweih. Proximales Geweihstück, das mindestens eine einseitige Sollbruchstelle an der Stange oberhalb der Eissprosse zeigt. Die große Bruchfläche hat teilweise eine w-gezähnte Form und könnte den gegenüberliegenden Teil einer zweiseitigen Sollbruchstelle entfernt haben. a: mediale Seite; b: Detail der lateralen Seite mit Hackspuren.*

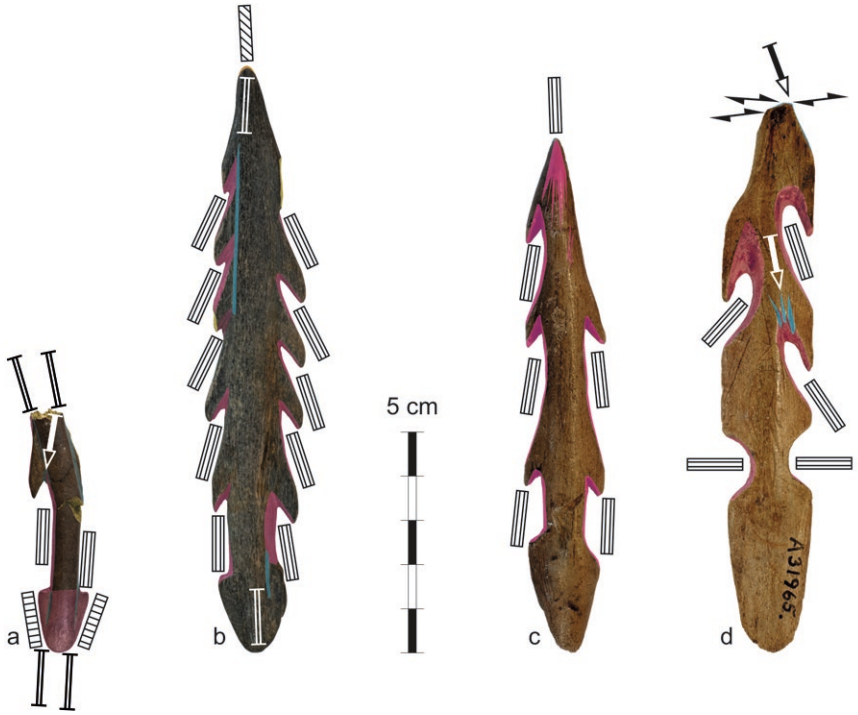

Fig. 13. As-yet unpublished biserially barbed points with shield-shaped bases as well as the previously published point from Skipinge Mark. Unknown raw material. a: dorsal side of the Lille Aamose point; b: ventral side of the Helnæs point; c: dorsal side of the Sandlyng Mose-point (A39782); d: dorsal side of the Skipinge Mark point.

Abb. 13. *Bisher unpubizierte, zweireihige Widerhakenspitzen mit wappenschildförmiger Basis sowie die bereits publizierte Spitze von Skipinge Mark. Unbekanntes Rohmaterial. a: dorsale Seite der Lille Aamose-Spitze; b: ventrale Seite der Helnæs-Spitze; c: dorsale Seite der Sandlyng-Mose-Spitze (A39782); d: dorsale Seite der Skipinge Mark-Spitze.*

of the osseous tools were found in former lakes, as has been proposed for Lyngby-type antler tools (Tromnau 1981, 1987), or large barbed points from the Palaeolithic and Early Mesolithic (see Cziesla 2007b; P. V. Petersen 2009; Cziesla 2018). Finally, a change in ritual behaviour is also a possible explanation for the observed changes.

After these more general points, we now deal with four time-slices and their respective temporal and spatial results. In addition to the Bølling/Older Dryas phase, the Allerød phase, the Younger Dryas, and the Preboreal phase will be highlighted (Fig. 17a–d; see above: environmental stages).

Bølling/Older Dryas (12,750-11,950 BC)

The results for the earliest occupation of Denmark during the Bølling and Older Dryas (Fig. 17b) indicate the presence of hunter-gatherers between Jels (Holm & Rieck 1983; Holm et al. 1987), Slotseng, and the Kolding Fjord, which is located approximately 25 km northeast of Slotseng. The width, angle and location of the grooved furrow on the Kolding Fjord antler (Fig. 10, Plate 6) is comparable to those observed at the Havelte group site of Slotseng and at the Classic Hamburgian sites in northern Germany (Wild 2020). Nonetheless, the Kolding Fjord antler is, to date, the only Hamburgian antler outside of the Ahrensburg tunnel valley that shows signs of grooving on a primary raw material block. The antlers from the tunnel valley have recently been interpreted as indicating a strategic early autumn camp where migrating reindeer were hunted; their unshed antlers were processed immediately at a location nearby (Wild 2020). This type of spatio-temporal scheme stands in contrast to later autumn camps, where reindeer antler – often shed or showing the first signs of shedding (osteoclasts) – were transversally segmented and the resulting secondary raw material block was exploited (Wild 2020, Fig. 126). The Kolding Fjord antler stands between the two schemes as it is a shed antler with signs of grooving.

Another early find from this area is the distal bez tine from Holbek (Fig. 7, Plate 5), which displays a technique that resembles the Hamburgian practice. The site is located approximately 20 km east of Jels, 17 km south of Kolding Fjord, and 15 km from Slotseng. Accordingly, this could be another corner mark of a settlement pocket that is indicated by several lithic stray finds (Pedersen et al. 2018, Fig. 8B). However, the dates from Kolding Fjord and Holbek have a low agreement when combined and seemingly do not reflect a contemporaneous presence. On the contrary, the young Holbek date speaks for a longer presence of Late Upper

Site	Catalogue-ID	ID	Lab-ID	Collagen Yield	^{14}C age (^{14}C yrs BP)	d^{13}C (‰ VPDB)	d15N (‰ AIR)	C:N (atomic)	Material	Comment	Literature
Slotseng	-	-	AAR-906	-	12,520 ± 190	-19.98	-	-	bone/antler	-	Holm 1991
Slotseng	-	-	AAR-8159	-	12,410 ± 70	-19.62	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Kolding Fjord	6	O.3514	AAR-31844	5.0 %	12,379 ± 42	-18.9	1.8	3.3	bone/antler	-	this paper
Slotseng	-	-	AAR-8165	-	12,290 ± 75	-19.39	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Slotseng	-	-	AAR-8160	-	12,240 ± 50	-18.99	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Solrød Strand	32	"1947 M.D. 65e"	AAR-18733	-	12,238 ± 46	-19.7	-	-	bone/antler	-	Fischer/Jensen 2018
Slotseng	-	-	AAR-8162	-	12,220 ± 100	-	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Slotseng	-	-	AAR-8163	-	12,205 ± 65	-19.51	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Slotseng	-	-	AAR-8164	-	12,205 ± 50	-18.6	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Slotseng	-	-	AAR-8157	-	12,190 ± 100	-19.06	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Slotseng	-	-	AAR-8158	-	12,170 ± 55	-19.01	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Solrød Strand	10	Z.M.K. 32/1948; P63/2013	AAR-18732	-	12,170 ± 45	-18.5	-	-	bone/antler	-	Fischer/Jensen 2018
Solrød Strand	11	Z.M.K. 12/1947; M.D. 65e	AAR-1036	-	12,140 ± 110	-19.3	-	-	bone/antler	-	Petersen/Johansen 1991 Petersen/Johansen 1991
Slotseng	-	-	AAR-8161	-	12,065 ± 80	-	-	-	bone/antler	-	Aaris-Sørensen et al. 2007
Fuglebakkevej	3	ZMK45/1949 - P141/2017KMG	LuS-12652	-	12,050 ± 90	-	-	-	bone/antler	-	this paper
Holbæk near Christiansfeld	5	ZMK8/1856 - P220/2019KMG	AAR-31842	7.1 %	11,843 ± 56	-19.4	0.3	3.2	bone/antler	-	this paper
Mullerup Mose	7	A 37621	AAR-30763	10.8 %	11,721 ± 62	-19.4	1.9	3.3	bone/antler	-	this paper
Ungstrup Mose	12	ZMK 3/1877 - P222/2019KMG	AAR-31839	6.6 %	11,505 ± 61	-19.3	0.9	3.3	bone/antler	-	this paper
Tranebjerg	33	FHM6118X1	AAR-31848	1.1 %	11,222 ± 63	-18.3	0.3	3.2	bone/antler	-	this paper
Allerød-Teglværk	2	ZMK 118/2000 - P218/2019KMG	AAR-31838	6.6 %	11,217 ± 60	-18.7	1.9	3.3	bone/antler	-	this paper
Hjorthede	4	ZMK 198/0000 - P219/2019KMG	AAR-31841	5.7 %	10,928 ± 54	-18.2	1	3.3	bone/antler	-	this paper
Odense Kanal	21	A16679	AAR-9298	-	10,815 ± 65	-	-	-	bone/antler	-	Stensager 2006
Fogense Enge	15	A53507	AAR-15025	-	10,726 ± 27	-	-	-	bone/antler	-	Petersen 2019
Bromme	-	-	AAR-4539	-	10,720 ± 90	-	-	-	bone/antler	-	Heinemeier/Rud 2000
Aarhus	1	A52666	AAR-31847	5.9 %	10,629 ± 52	-18.7	2.7	3.2	bone/antler	-	this paper

Tab. 2. ^{14}C data for osseous finds (artefacts and manuports) from Palaeolithic Denmark.

Tab. 2. ^{14}C-Daten von paläolithischen Knochen- und Geweihfunden Dänemarks (Artefakte und manuports).

Site	Catalogue-ID	ID	Lab-ID	Collagen Yield	^{14}C age (^{14}C yrs BP)	d^{13}C (‰ VPDB)	d15N (‰ AIR)	C:N (atomic)	Material	Comment	Literature
Arreskøv	13	A51070	OxA-3173/ACQ-293	-	10,600 ± 100	-	-	-	bone/antler	-	Fischer 1996
Refnæs	8	ZMK 21/1909 - P221/2019KMG	AAR-31840	5.5 %	10,575 ± 61	-19	2.5	3.3	bone/antler	-	this paper
Tyrsted	-	X179	AAR-27584	-	10,445 ± 49	-	-	-	bone/antler	-	
Tyrsted	-	X180	AAR-27585	-	10,356 ± 42	-	-	-	bone/antler	same artefact as KIA-53528	
Tyrsted	-	X181	AAR-27586	-	10,321 ± 46	-	-	-	bone/antler	same artefact as KIA-53529	
Tyrsted	-	X181	KIA-53529	-	10,315 ± 45	-	-	-	bone/antler	same artefact as AAR-27586	
Tyrsted	-	X180	KIA53528	-	10,270 ± 45	-	-	-	bone/antler	same artefact as AAR-27585	
Tyrsted	-	X182	KIA-53530	-	10,235 ± 45	-	-	-	bone/antler	same artefact as AAR-27587	
Tyrsted	-	X182	AAR-27587	-	10,205 ± 47	-	-	-	bone/antler	same artefact as KIA-53530	
Løgeskov	18	OBM /FS 8765	AAR-31864	10.5 %	10,161 ± 62	-19.9	1.6	3.3	bone/antler	-	this paper
Tyrsted	-	X183	AAR-27588	-	10,102 ± 39	-	-	-	bone/antler	-	
Lille Aamose	17	A54643	AAR-15007	3.6 %	9,919 ± 26	-	-	-	bone/antler	-	Zagorska et al. 2019
Sandlyng Mose	21	A39733	AAR-9296	-	9,905 ± 65	-	-	-	bone/antler	-	this paper
Skellingsted Bro	25	A42895	Ua-54134	-	9,835 ± 37	-	-	-	bone/antler	-	this paper
Tammosegårds Mose	27	GIM 991x1	AAR-30764	4.5 %	9,813 ± 55	-21.8	2.1	3.4	bone/antler	-	this paper
Kallerup Mose	31	A36118	AAR-31843	4.0 %	9,738 ± 55	-18.1	1.2	3.4	bone/antler	-	this paper
Skipinge mark	26	A31965	Ua-54135	-	9,735 ± 36	-	-	-	bone/antler	-	this paper
Vallensgård Mose	28	A22394	AAR-9404	-	9,585 ± 55	-	-	-	bone/antler	-	P. V. Petersen 2009
Sandlyng Mose	22	A39782	Ua-54132	-	9,533 ± 35	-	-	-	bone/antler	-	this paper
Skaftelev	24	A38715	Ua-54133	-	9,218 ± 35	-	-	-	bone/antler	-	this paper
Nørre Lyngby	19	A16678	AAR-8919	2.7 %	9,110 ± 65	-19.1	-	-	bone/antler	-	Stensager 2004
Nørre Lyngby	19	A16678	AAR-16622,4	2.1 %	8,815 ± 47	-19.7	-	-	bone/antler	too young	Fischer et al. 2013
Nørre Lyngby	19	A16678	AAR-16622,2	2.1 %	8,710 ± 41	-19.4	-	-	bone/antler	too young	Fischer et al. 2013
Nørre Lyngby	19	A16678	AAR-16622,3	2.0 %	6,687 ± 35	-17.7	-	-	bone/antler	too young	Fischer et al. 2013
Nørre Lyngby	19	A16678	AAR-16622,1	2.0 %	6,573 ± 30	-18.2	-	-	bone/antler	too young	Fischer et al. 2013
Rimmer	9	A37020	AAR-31846	7.5 %	6,073 ± 35	-23.4	4.2	3.2	bone/antler	too young	this paper
Nørre Lyngby	20	1975/0073	AAR-31845	3.7 %	4,380 ± 51	-21.6	5.1	3.5	bone/antler	too young	this paper

Tab. 2. ^{14}C data for osseous finds (artefacts and manuports) from Palaeolithic Denmark. (continued)

Tab. 2. *^{14}C-Daten von paläolithischen Knochen- und Geweihfunden Dänemarks (Artefakte und manuports). (Fortsetzung)*

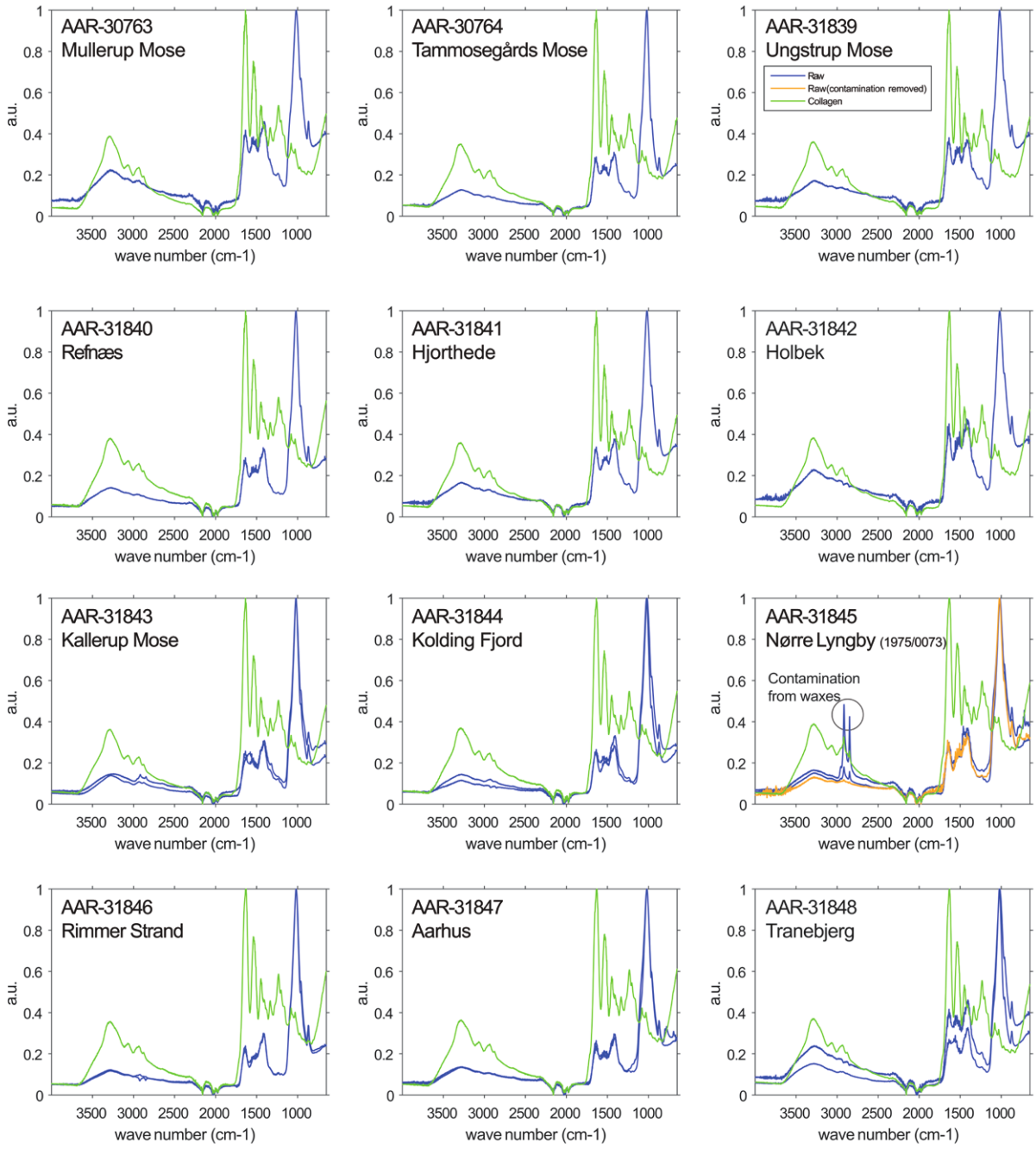

Fig. 14. FTIR spectra of ^{14}C samples dated within the project at AARAMS. FTIR spectroscopy was applied to raw bone material prior to any pretreatment to scan for possible contaminants. Sample AAR-31845 showed FTIR peaks that can be associated with preservation using waxes. Also shown are the FTIR spectra of all the samples after collagen extraction. The collagen fractions are all consistent with normal collagen spectra (see Fig. 17).

Abb. 14. *FTIR-Spektren von ^{14}C-Proben, die im Rahmen des Projekts im AARAMS datiert wurden. FTIR-Spektren wurden an "rohem" Knochenmaterial vor der weiteren Verarbeitung genommen um mögliche Konservierungsmittel zu ermitteln. Probe AAR-31845 zeigte FTIR-Spitzen, die mit einer Behandlung mit Wachsen in Verbindung stehen. Zusätzlich werden FTIR-Spektren aller Proben nach der Kollagen-Extraktion gezeigt. Die Kollagenfraktionen sind alle konsistent mit normalen Kollagenspektren (s. Fig. 17).*

Palaeolithic Hamburgian hunter-gatherers up to the end of the Older Dryas or an early Final Palaeolithic (Federmesser/Bromme?) occupation in this area (see below for a discussion of the finds from the second time slice).

While the Kolding Fjord antler, along with the finds from Slotseng and Holbek, could indicate an early presence of hunter-gatherers on the present-day island of Funen, no Hamburgian organic or lithic finds have been made on this large former part of the Danish mainland. The only other worked osseous finds from this time derive from eastern Zealand, in particular from the bottom of the Baltic Sea off Solrød Strand. These stray finds – in particular

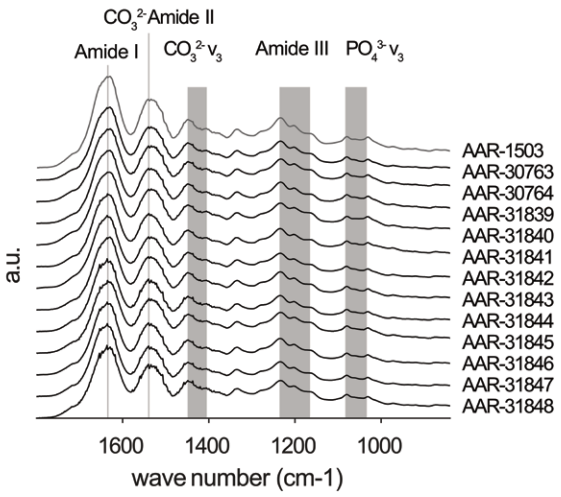

Fig. 15. Collagen FTIR data for samples dated within the project at AARAMS compared with the normal ^{14}C background sample (AAR-1503).

Abb. 15. *Kollagen-FTIR-Daten von Proben, die im Rahmen des Projekts in AARAMS datiert wurden, im Vergleich mit einer normalen ^{14}C-Referenzhintergrundprobe (AAR-1503).*

the proximal waste piece with its bilateral predetermined breaking point, which is connected with the production of secondary raw material blocks – have clear parallels in the Late Upper Palaeolithic assemblages from the Ahrensburg tunnel valley and Slotseng (Wild 2020). While Hamburgian-type lithics are almost absent from Zealand – only two possible finds from Tranegilde Tofter have been reported (Pedersen et al. 2018, Fig. 6) – the only other find of a proximal antler waste piece of the Solrød-type (proximal antler waste piece with bilateral predetermined breaking point) was found at Refnæs in northwestern Zealand (Fig. 12, Plate 8). However, the latter artefact dates to the end of the Allerød and an association with the Hamburgian can only be deduced if we accept that the dating failed or that the technical tradition survived throughout the Allerød. Unfortunately, there is no further evidence for either hypothesis. The lithic finds from Tranegilde Tofter, however, were found between the finds from the Baltic Sea at Solrød Strand and the Fuglebakkevej antler, and could therefore speak for another Hamburgian settlement pocket in this area (Fig. 17b). The Fuglebakkevej antler (Fig. 8, Plate 3) is a massive distal reindeer antler piece that shows a trilateral grooved predetermined breaking point and a grooved furrow of unknown function on the flat palmation. While grooving predetermined breaking points is not typical of the more south-western Hamburgian, the location of the predetermined breaking point is, and to date, the grooving of antler is during the Lateglacial almost exclusively observed in the Hamburgian (but see Rust 1943, pl. 66; Terberger 1996 for two exceptions). The four early dates from Zealand (cf. Tab. 2) show good agreement and speak for a Hamburgian settlement pulse during the Havelte phase in Zealand. Overall, this early evidence from Denmark, together with the two sites of Sølbjerg and Krogsbølle on Lolland (Petersen & Johansen 1993; Riede et al. 2019), make the hypothesis of a two-fold settlement of Denmark by the use of possible main routes of migrating reindeer (a western route via Jutland and an eastern route via eastern Germany and Lolland) most likely (see Fig. 17b; Petersen & Johansen 1993, 1996).

Allerød 11,950-10,650 BC

During the Allerød, we see a relatively even distribution of finds over most of Eastern Denmark (Fig. 17c). The finds from Hjorthede, Ungstrup Mose, and Aarhus underline the importance of the northern and western parts of Jutland, as has already been indicated by the artefacts and dated reindeer finds from Nørre Lyngby (Aaris-Sørensen 1995; Fischer et al. 2013a). Except for the Fogense Enge rod, all the artefacts whose dates fall into the Allerød were made from reindeer remains. Despite the generally small numbers of dated artefacts and the lack of context for the reindeer antler waste pieces, their dominance is quite interesting as the evidence from Bromme (Mathiassen 1946), Fogense Enge (Petersen 2021), as well as Klein Nordende (Bokelmann et al. 1983) and Endingen (Street 1996; Terberger 1996) in northern Germany indicates an industry based on more boreal species, such as elk and giant deer. In particular, the production of long blanks from metapodial bones of elk and probably also giant deer seem to play an important role (e.g. Fogense Enge). Furthermore, two amber pendants resembling elk were found on Zealand. They resemble amber figurines from more southern areas and are typologically dated to the Allerød period (Mortensen et al. 2014d; Petersen 2021). A possible explanation for the lack of Lateglacial elk artefacts in Denmark is that the Allerød artefact types are not specific enough to identify them as Palaeolithic and they were overlooked and are still seen as Mesolithic finds in the large collections of Danish museums (see above). However, regular transverse segmentation of reindeer antler for tool or secondary raw material block production can be observed throughout the Allerød period. Interestingly, finds such as those from Allerød-Teglværk (proximal waste piece) (Plate 2) or Hjorthede (distal waste piece) (Plate 4) resemble the remains of the secondary raw material block production sequences in the preceding Hamburgian and Magdalenian, while the procedures differ slightly (e.g. circumferential vs. bilateral predetermined breaking points (Wild 2020). In contrast, the Mullerup Mose (Plate 7) and Ungstrup Mose (Plate 10) antlers (distal waste pieces) morphologically resemble what we might expect in waste pieces from Lyngby-type antler tool production. These tools – most often linked to the Brommean and Ahrensburgian – date to as early as the mid-Allerød in northern Germany (Clausen 2003; 2004) and the eastern Baltic (Girininkas et al. 2016; Philippsen et al.

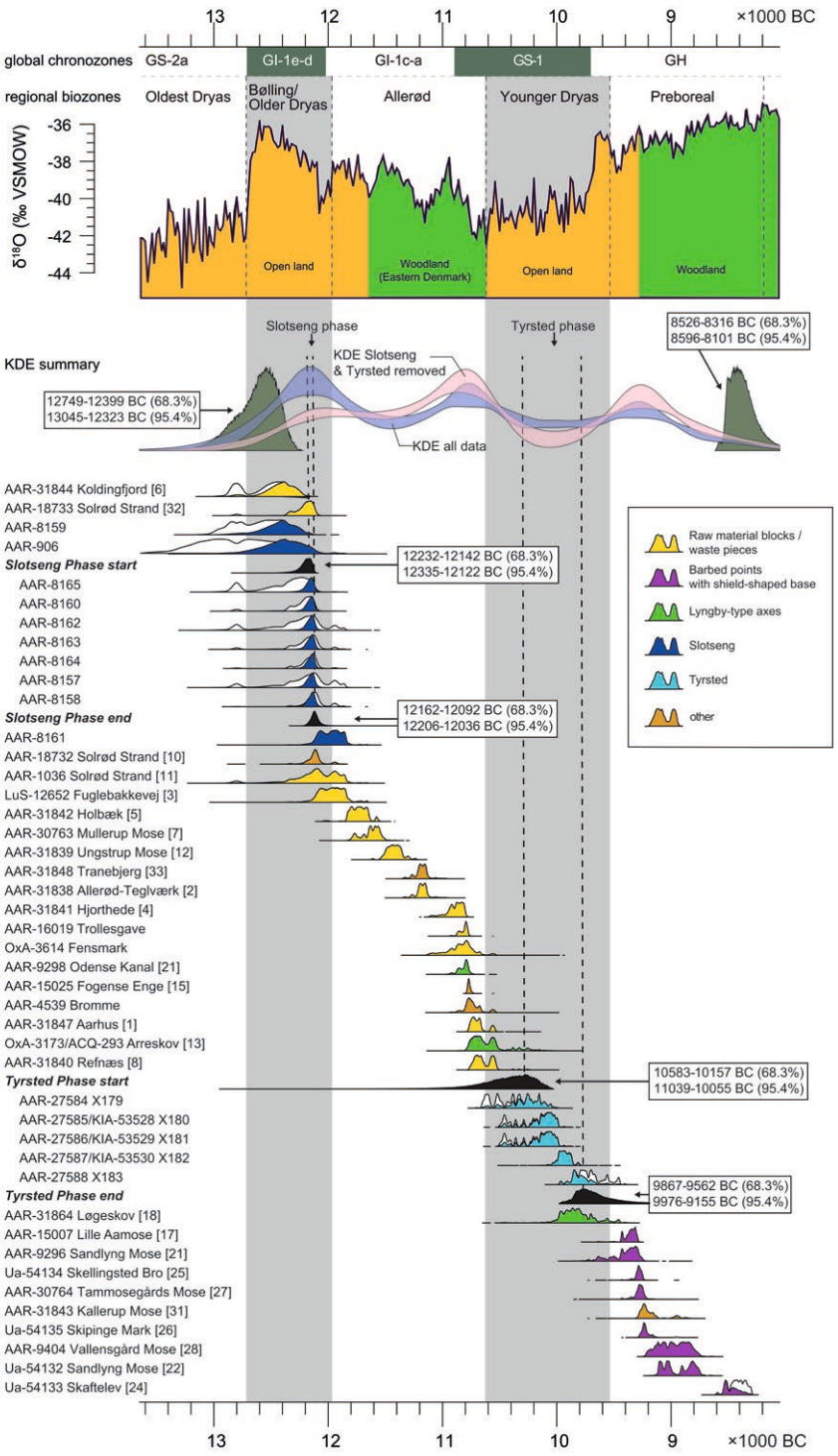

Fig. 16. Multi-plot of ^{14}C dates from Palaeolithic Denmark. Contextualized by NGRIP ^{18}O isotope values together with global climate chronozones and regional biozones. Activity was estimated using a KDE model of all ^{14}C samples from the dataset together with the onset and termination estimated by a simple phase model using all ^{14}C samples. Lower panel: calibrated probability distributions of all ^{14}C samples presented in this study. For Slotseng and Tyrsted, which had several ^{14}C samples per site, an onset and end for each locality were estimated using a simple phase model. Vertical stippled lines indicate the onset and termination. Catalogue numbers are given in squared brackets (script in appendix 2).

Abb. 16. *Darstellung der ^{14}C-Daten des dänischen Paläolithikums. Kontextualisiert durch NGRIP-^{18}O-Isotopenwerte, globale Klima-Chronozonen und regionale Biozonen. Aktivitätsschätzung durch KDE-Model aller ^{14}C-Daten des Datensatzes zusammen mit Beginn und Ende geschätzt durch ein simples Phasenmodel aller ^{14}C-Daten. Im unteren Bereich: Kalibrierte Wahscheinlichkeitsverteilungen aller ^{14}C-Daten dieser Studie. Für Slotseng und Tyrsted – mit mehreren ^{14}C-Daten – wurde der Beginn und das Ende jeder Lokalität durch ein einfaches Phasenmodel geschätzt. Die vertikalen gestrichelten Linien weisen auf den Beginn und das Ende hin. Katalognummern sind in eckigen Klammern angegeben. Das Skript liegt als Appendix 2 vor.*

Lab-ID	^{14}C Age ^{14}C years BP	Calibrated age (BC) 68.2 % confidence interval(s)	Calibrated age (BC) 95.4 % confidence interval(s)	Model agreement	Calibrated age (BC, modelled) 68.2 % confidence interval(s)	Calibrated age (BC, modelled) 95.4 % confidence interval(s)
Phase start					12,748-12,397 [68.3 %]	13,044-12,321 [95.4 %]
AAR-31844 Koldingfjord [6]	12,379 ± 42	12,857-12,761 [18.6 %] 12,569-12,334 [49.6 %]	12,892-12,721 [25.7 %] 12,670-12,233 [69.7 %]	103.40 %	12,507-12,281 [68.3 %]	12,829-12,754 [3.0 %] 12,637-12,208 [92.4 %]
AAR-18733 Solrød Strand [32]	12,238 ± 46	12,250-12,120 [68.3 %]	12,817-12,792 [1.4 %] 12,375-12,094 [94.1 %]	103.10 %	12,246-12,121 [68.3 %]	12,361-12,104 [95.4 %]
AAR-8159	12,410 ± 70	12,882-12,732 [21.1 %] 12,660-12,363 [47.1 %]	12,987-12,240 [95.4 %]	99.90 %	12,541-12,266 [68.3 %]	12,771-12,169 [95.4 %]
AAR-906	12,520 ± 190	13,160-12,825 [31.3 %] 12,789-12,378 [37.0 %]	13,413-12,118 [95.4 %]	88.60 %	12,552-12,187 [68.3 %]	12,858-12,840 [0.3 %] 12,834-12,065 [94.8 %] 11,961-11,939 [0.4 %]
Slotseng Phase start					12,231-12,140 [68.3 %]	12,333-12,121 [95.4 %]
AAR-8165	12,290 ± 75	12,837-12,777 [9.1 %] 12,394-12,128 [59.2 %]	12,879-12,736 [15.0 %] 12,625-12,098 [80.4 %]	117.70 %	12,195-12,126 [68.3 %]	12,260-12,105 [95.4 %]
AAR-8160	12,240 ± 50	12,264-12,118 [68.3 %]	12,831-12,779 [3.2 %] 12,380-12,091 [92.3 %]	131.40 %	12,191-12,126 [68.3 %]	12,242-12,106 [95.4 %]
AAR-8162	12,220 ± 100	12,829-12,784 [4.6 %] 12,381-12,069 [62.9 %] 11,952-11,943 [0.8 %]	12,870-12,745 [9.2 %] 12,595-11,857 [86.2 %]	163.10 %	12,192-12,122 [68.3 %]	12,255-12,090 [95.4 %]
AAR-8163	12,205 ± 65	12,259-12,087 [68.3 %]	12,844-12,768 [3.2 %] 12,391-12,040 [88.2 %] 11,985-11,911 [4.0 %]	144.00 %	12,188-12,122 [68.3 %]	12,240-12,095 [95.4 %]
AAR-8164	12,205 ± 50	12,217-12,101 [68.3 %]	12,369-12,064 [94.8 %] 11,954-11,938 [0.6 %]	12.98 %	12,185-12,122 [68.3 %]	12,230-12,100 [95.4 %]
AAR-8157	12,190 ± 100	12,353-12,057 [60.9 %] 11,975-11,922 [7.3 %]	12,858-12,757 [6.0 %] 12,541-11,849 [89.5 %]	161.50 %	12,191-12,120 [68.3 %]	12,250-12,087 [95.4 %]
AAR-8158	12,170 ± 55	12,204-12,073 [68.3 %]	12,357-12,315 [2.2 %] 12,288-12,028 [82.1 %] 11,991-11,904 [10.8 %] 11,875-11,865 [0.4 %]	117.40 %	12,182-12,117 [68.3 %]	12,225-12,091 [95.4 %]
Slotseng Phase end					12,160-12,091 [68.3 %]	12,205-12,035 [95.4 %]
AAR-8161	12,065 ± 80	12,095-12,040 [19.3 %] 11,997-11,859 [49.0 %]	12,162-11,829 [95.4 %]	100.10 %	12,096-12,037 [20.7 %] 11,998-11,894 [37.6 %] 11,889-11,859 [10.0 %]	12,161-11,830 [95.4 %]
AAR-18732 Solrød Strand [10]	12,170 ± 45	12,174-12,080 [68.3 %]	12,350-12,331 [0.8 %] 12,250-12,041 [87.4 %] 11,982-11,915 [7.2 %]	100.40 %	12,173-12,080 [68.3 %]	12,350-12,331 [0.8 %] 12,249-12,040 [87.5 %] 11,982-11,915 [7.2 %]
AAR-1036 Solrød Strand [11]	12,140 ± 110	12,215-12,030 [41.0 %] 12,000-11,858 [27.3 %]	12,850-12,765 [3.1 %] 12,498-11,818 [92.3 %]	104.40 %	12,210-12,034 [41.6 %] 11,998-11,897 [21.7 %] 11,890-11,861 [5.0 %]	12,453-12,441 [0.3 %] 12,432-12,427 [0.1 %] 12,420-11,817 [95.1 %]
LuS-12652 Frederiksberg [3]	12,050 ± 90	12,085-12,031 [17.6 %] 12,006-11,856 [50.7 %]	12,199-11,801 [94.9 %] 11,725-11,716 [0.3 %] 11,675-11,666 [0.3 %]	100.10 %	12,085-12,034 [16.7 %] 12,010-11,857 [51.6 %]	12,196-11,801 [95.2 %] 11,722-11,718 [0.1 %] 11,672-11,667 [0.2 %]

Tab. 3. Calibrated and modelled dates as well as model agreement (cf. Fig. 16) of osseous finds (artefacts and manuports) from Palaeolithic Denmark.

Tab. 3. Kalibrierte und modellierte Datierungen sowie Modell-Übereinstimmung (cf. Abb. 16) paläolithischer Knochen- und Geweihfunde Dänemarks (Artefakte und manuports).

Lab-ID	^{14}C Age ^{14}C years BP	Calibrated age (BC) 68.2 % confidence interval(s)	Calibrated age (BC) 95.4 % confidence interval(s)	Model agreement	Calibrated age (BC, modelled) 68.2 % confidence interval(s)	Calibrated age (BC, modelled) 95.4 % confidence interval(s)
AAR-31842 Holbæk [5]	11,843 ± 56	11,816-11,782 [16.9 %] 11,766-11,658 [51.4 %]	11,848-11,637 [92.1 %] 11,594-11,569 [3.3 %]	99.90 %	11,815-11,782 [16.7 %] 11,766-11,696 [35.8 %] 11,690-11,658 [15.7 %]	11,848-11,637 [92.1 %] 11,595-11,569 [3.3 %]
AAR-30763 Mullerup Mose [7]	11,721 ± 62	11,782-11,766 [5.1 %] 11,694-11,689 [1.3 %] 11,657-11,542 [61.9 %]	11,801-11,516 [95.4 %]	99.80 %	11,783-11,765 [5.3 %] 11,694-11,690 [1.2 %] 11,658-11,541 [61.7 %]	11,802-11,517 [95.4 %]
AAR-31839 Ungstrup Mose [12]	11,505 ± 61	11,491-11,370 [68.3 %]	11,545-11,337 [90.9 %] 11,329-11,291 [4.5 %]	99.90 %	11,491-11,370 [68.3 %]	11,545-11,338 [90.9 %] 11,329-11,291 [4.5 %]
AAR-31848 Tranebjerg [33]	11,222 ± 63	11,220-11,143 [68.3 %]	11,347-11,316 [2.2 %] 11,301-11,106 [91.8 %] 11,076-11,051 [1.4 %]	99.70 %	11,220-11,143 [68.3 %]	11,347-11,315 [2.2 %] 11,301-11,105 [91.8 %] 11,077-11,051 [1.5 %]
AAR-31838 Allerød-Teglværk [2]	11,217 ± 60	11,215-11,145 [68.3 %]	11,343-11,323 [1.1 %] 11,296-11,105 [92.8 %] 11,077-11,051 [1.5 %]	99.80 %	11,215-11,145 [68.3 %]	11,343-11,323 [1.1 %] 11,296-11,105 [92.9 %] 11,077-11,051 [1.5 %]
AAR-31841 Hjorthede [4]	10,928 ± 54	10,940-10,910 [15.5 %] 10,896-10,810 [52.8 %]	11,045-10,795 [95.4 %]	99.90 %	10,939-10,910 [15.3 %] 10,896-10,811 [53.0 %]	11,045-10,795 [95.4 %]
AAR-16019	10,826 ± 49	10,868-10,850 [12.2 %] 10,821-10,780 [56.0 %]	10,886-10,771 [95.4 %]	99.70 %	10,867-10,850 [11.4 %] 10,822-10,780 [56.8 %]	10,887-10,771 [95.4 %]
OxA-3614	10,810 ± 120	10,943-10,906 [8.3 %] 10,899-10,736 [60.0 %]	11,119-10,665 [94.6 %] 10,573-10,559 [0.8 %]	99.90 %	10,943-10,906 [8.3 %] 10,899-10,736 [59.9 %]	11,119-10,665 [94.6 %] 10,573-10,558 [0.8 %]
AAR-9298 Odense Kanal [21]	10,815 ± 65	10,872-10,846 [15.1 %] 10,830-10,775 [53.2 %]	10,939-10,910 [3.6 %] 10,896-10,748 [91.9 %]	99.90 %	10,871-10,845 [15.1 %] 10,830-10,775 [53.2 %]	10,939-10,910 [3.6 %] 10,896-10,749 [91.8 %]
AAR-15025 Fogense Enge [15]	10,726 ± 27	10,787-10,764 [68.3 %]	10,796-10,747 [95.4 %]	99.30 %	10,787-10,764 [68.3 %]	10,796-10,747 [95.4 %]
AAR-4539 Bromme	10,720 ± 90	10,806-10,714 [60.6 %] 10,693-10,673 [7.7 %]	10,883-10,648 [88.2 %] 10,592-10,539 [7.2 %]	99.90 %	10,806-10,714 [60.7 %] 10,693-10,674 [7.5 %]	10,884-10,648 [88.2 %] 10,593-10,539 [7.3 %]
AAR-31847 Aarhus [1]	10,629 ± 52	10,761-10,671 [68.3 %]	10,780-10,657 [82.0 %] 10,588-10,543 [13.4 %]	99.90 %	10,761-10,671 [68.3 %]	10,780-10,656 [82.1 %] 10,588-10,543 [13.3 %]
OxA-3173/ACQ-293 Arreskov [13]	10,600 ± 100	10,773-10,640 [48.8 %] 10,595-10,537 [19.5 %]	10,804-10,480 [85.0 %] 10,445-10,371 [3.4 %] 10,360-10,300 [3.3 %] 10,288-10,221 [3.4 %] 10,167-10,154 [0.4 %]	99.90 %	10,772-10,640 [48.8 %] 10,595-10,538 [19.4 %]	10,804-10,480 [85.2 %] 10,445-10,371 [3.2 %] 10,360-10,298 [3.3 %] 10,288-10,221 [3.4 %] 10,167-10,154 [0.4 %]
AAR-31840 Refnæs [8]	10,575 ± 61	10,736-10,655 [43.8 %] 10,589-10,543 [24.4 %]	10,768-10,528 [95.4 %]	99.90 %	10,735-10,655 [44.1 %] 10,589-10,543 [24.1 %]	10,768-10,528 [95.4 %]
Tyrsted Phase start					10,581-10,156 [68.3 %]	11,037-10,054 [95.4 %]
AAR-27584 X179	10,445 ± 49	10,655-10,589 [19.4 %] 10,543-10,493 [13.6 %] 10,405-10,374 [8.8 %] 10,356-10,303 [14.2 %] 10,283-10,241 [11.9 %] 10,231-10,229 [0.4 %]	10,666-10,575 [21.3 %] 10,557-10,467 [17.4 %] 10,460-10,146 [56.0 %] 10,132-10,126 [0.3 %] 10,119-10,110 [0.5 %]	79.00 %	10,399-10,377 [4.6 %] 10,353-10,302 [13.1 %] 10,287-10,146 [43.6 %] 10,134-10,099 [6.9 %]	10,641-10,591 [3.4 %] 10,544-10,478 [5.8 %] 10,449-10,045 [86.2 %]

Tab. 3. Calibrated and modelled dates as well as model agreement (cf. Fig. 16) of osseous finds (artefacts and manuports) from Palaeolithic Denmark. (continued)

Tab. 3. *Kalibrierte und modellierte Datierungen sowie Modell-Übereinstimmung (cf. Abb. 16) paläolithischer Knochen- und Geweihfunde Dänemarks (Artefakte und manuports). (Fortsetzung)*

Lab-ID	^{14}C Age ^{14}C years BP	Calibrated age (BC) 68.2 % confidence interval(s)	Calibrated age (BC) 95.4 % confidence interval(s)	Model agreement	Calibrated age (BC, modelled) 68.2 % confidence interval(s)	Calibrated age (BC, modelled) 95.4 % confidence interval(s)
AAR-27588 X183	10,102 ± 39	9,865-9,735 [46.0 %] 9,723-9,666 [19.1 %] 9,571-9,559 [3.2 %]	9,881-9,515 [89.3 %] 9,499-9,451 [6.1 %]	100.70 %	9,875-9,739 [65.0 %] 9,716-9,703 [3.2 %]	9,986-9,945 [4.8 %] 9,939-9,652 [88.6 %] 9,600-9,591 [0.4 %] 9,580-9,553 [1.6 %]
Tyrsted Phase end					9865-9561 [68.3 %]	9975-9153 [95.4 %]
AAR-31864 Løgeskov [18]	10,161 ± 62	9,985-9,775 [62.9 %] 9,769-9,755 [3.0 %] 9,712-9,702 [2.4 %]	10,049-9,648 [86.8 %] 9,632-9,524 [6.2 %] 9,493-9,452 [2.4 %]	100.00 %	9,985-9,773 [63.9 %] 9,765-9,755 [2.1 %] 9,712-9,702 [2.2 %]	10,049-9,647 [86.8 %] 9,632-9,524 [6.2 %] 9,494-9,452 [2.4 %]
AAR-15007 Lille Aamose [17]	9,919 ± 26	9,439-9,429 [7.0 %] 9,377-9,307 [61.3 %]	9,446-9,294 [95.4 %]	99.80 %	9,439-9,429 [6.3 %] 9,378-9,307 [62.0 %]	9,446-9,295 [95.4 %]
AAR-9296 Sandlyng Mose [21]	9,905 ± 65	9,450-9,278 [68.3 %]	9,733-9,724 [0.5 %] 9,665-9,572 [10.2 %] 9,558-9,250 [84.7 %]	99.80 %	9,450-9,277 [68.3 %]	9,732-9,724 [0.5 %] 9,665-9,571 [10.3 %] 9,558-9,251 [84.7 %]
Ua-54134 Skellingsted Bro [25]	9,835 ± 37	9,306-9,260 [68.3 %]	9,365-9,243 [95.4 %]	100.00 %	9,306-9,260 [68.3 %]	9,364-9,242 [95.4 %]
AAR-30764 Tammosegårds Mose [27]	9,813 ± 55	9,308-9,244 [68.3 %]	9,443-9,425 [1.6 %] 9,396-9,203 [93.9 %]	99.80 %	9,308-9,244 [68.3 %]	9,442-9,425 [1.5 %] 9,395-9,205 [94.0 %]
AAR-31843 Kallerup Mose [31]	9,738 ± 55	9,285-9,190 [62.1 %] 9,178-9,162 [6.1 %]	9,306-9,120 [84.2 %] 8,999-8,921 [9.9 %] 8,891-8,866 [1.4 %]	100.20 %	9,285-9,190 [62.4 %] 9,178-9,163 [5.8 %]	9,306-9,120 [84.4 %] 8,998-8,921 [9.7 %] 8,890-8,865 [1.4 %]
Ua-54135 Skipinge Mark [26]	9,735 ± 36	9,274-9,210 [68.3 %]	9,290-9,146 [94.1 %] 8,965-8,950 [1.4 %]	99.80 %	9,274-9,210 [68.3 %]	9,291-9,145 [94.2 %] 8,965-8,952 [1.2 %]
AAR-9404 Vallensgård Mose [28]	9,585 ± 55	9,140-9,106 [7.9 %] 9,100-9,045 [13.7 %] 9,024-8,965 [14.9 %] 8,948-8,824 [31.8 %]	9,214-8,784 [95.4 %]	100.00 %	9,136-9,106 [7.3 %] 9,099-9,046 [13.8 %] 9,024-8,964 [15.3 %] 8,945-8,824 [31.9 %]	9,213-8,783 [95.4 %]
Ua-54132 Sandlyng Mose [22]	9,533 ± 35	9,117-9,076 [16.5 %] 9,057-9,010 [19.2 %] 8,916-8,902 [4.2 %] 8,850-8,774 [28.3 %]	9,125-8,974 [45.9 %] 8,930-8,744 [49.5 %]	99.70 %	9,117-9,076 [16.4 %] 9,058-9,010 [19.6 %] 8,916-8,903 [3.9 %] 8,850-8,774 [28.4 %]	9,125-8,975 [46.0 %] 8,930-8,745 [49.5 %]
Ua-54133 Skaftelev [24]	9,218 ± 35	8,535-8,514 [9.8 %] 8,471-8,383 [43.2 %] 8,375-8,343 [15.3 %]	8,548-8,501 [16.7 %] 8,493-8,302 [78.7 %]	93.00 %	8,551-8,503 [35.9 %] 8,489-8,415 [32.3 %]	8,610-8,589 [2.9 %] 8,561-8,334 [92.6 %]
Phase end					8,525-8,314 [68.3 %]	8,594-8,565 [1.1 %] 8,560-8,099 [94.4 %]

Tab. 3. Calibrated and modelled dates as well as model agreement (cf. Fig. 16) of osseous finds (artefacts and manuports) from Palaeolithic Denmark. (continued)

Tab. 3. *Kalibrierte und modellierte Datierungen sowie Modell-Übereinstimmung (cf. Abb. 16) paläolithischer Knochen- und Geweihfunde Dänemarks (Artefakte und manuports). (Fortsetzung)*

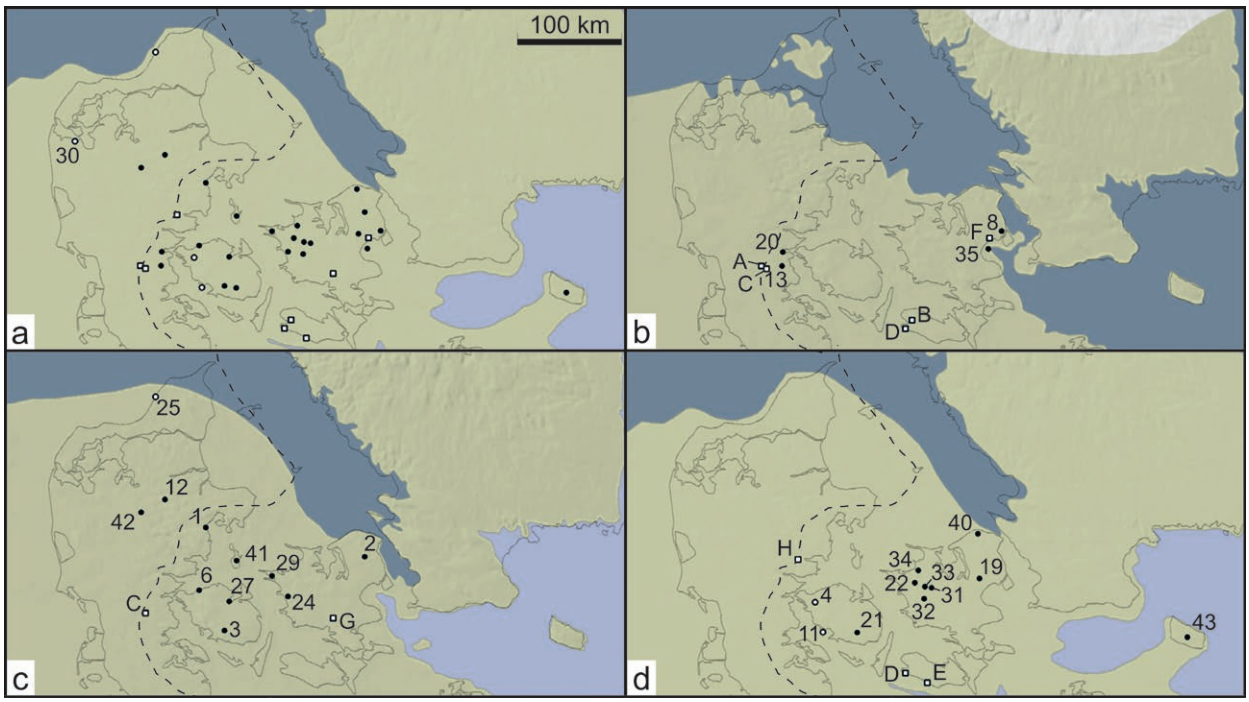

Fig. 17. Dated osseous stray finds from Palaeolithic Denmark in the different biozones. IDs after Fig. 1. a: overall distribution of assessed finds (cf. Fig. 1); b: Bølling–Older Dryas; c: Allerød; d: Younger Dryas–Preboreal (combined). In alphabetical order by site name: 1: Aarhus; 2: Allerød-Teglværk; 3: Arreskov; 4: Ejby; 6: Fogense Enge (not studied but mentioned in the text); 8: Fuglebakkevej; 11: Helnæs; 12: Hjorthede; 13: Holbek near Christiansfeld; 19: Kallerup Mose; 20: Kolding Fjord; 21: Løgeskov; 22: Lille Aamose; 24: Mullerup Mose; 25: Nørre Lyngby (N = 2); 27: Odense Kanal; 29: Refnæs (Skambæk Mølle); 30: Rimmer Strand; 31: Sandlyng Mose (N = 2); 32: Skaftelev; 33: Skellingsted Bro; 34: Skipinge Mark; 35: Solrød Strand; 40: Tammosegårds Mose; 41: Tranebjerg (not unambiguously worked, cf. with text and catalogue); 42: Ungstrup Mose; 43: Vallensgård Mose. Further sites/finds mentioned in context: A: Jels; B: Krogsbølle; C: Slotseng; D: Sølbjerg; E: Sylthom; F: Tranegilde Tofter; G: Trollesgave; H: Tyrsted. Open circle: dating failed/no date available but thought to belong to a certain time slice. Dotted line: Maximum extent of the Baltic Ice Advance indicating the border between eastern and western Denmark. Background: Preboreal (a&d), GI-1e (b), and GI-1c–a (c) EPHA-maps (www.epha.zbsa.eu; CC BY 4.0; version 1.1.0; Mollweide projection; compiled by ZBSA after Lagerlund & Houmark-Nielsen 1993; Björck 1995; Lemke et al. 2002; Weaver et al. 2003; Jakobsson et al. 2007; Edwards & Brooks 2008; Brooks et al. 2011; Vassiljev & Saarse 2013; Hughes et al. 2016; Stroeven et al. 2016; Harff et al. 2017; Patton et al. 2017).

Abb. 17. *Datierte Knochen- und Geweihartefakte des Paläolithikums Dänemarks in den verschiedenen Biozonen. IDs nach Abb. 1. a: allgemeine Verteilung der aufgenommenen Funde (vgl. Abb. 1); b: Bølling-Ältere Dryas; c: Allerød; d: Jüngere Dryas-Präboreal. In alphabetischer Reihenfolge der Fundstellennamen: 1: Aarhus; 2: Allerød-Teglværk; 3: Arreskov; 4: Ejby; 6: Fogense Enge (nicht aufgenommen aber im Text und Katalog erwähnt); 7: Fuglebakkevey; 11: Helnæs; 12: Hjorthede; 13: Holbek bei Christiansfeld; 19: Kallerup Mose; 20: Kolding Fjord; 21: Løgeskov; 22: Lille Aamose; 24: Mullerup Mose; 25: Nørre Lyngby; 27: Odense Kanal; 29: Refnæs (Skambæk Mølle); 30: Rimmer Strand; 31: Sandlyng Mose; 32: Skaftelev; 33: Skellingsted Bro; 34: Skipinge Mark; 35: Solrød Strand; 40: Tammosegårds Mose; 41: Tranebjerg (nicht eindeutig bearbeitet; vgl. mit Text und Katalog); 42: Ungstrup Mose; 43: Vallensgård Mose. Weitere Fundstellen, die im Text erwähnt werden: A: Jels; B: Krogsbølle; C: Slotseng; D: Sølbjerg; E: Sylthom; F: Tranegilde Tofter; G: Trollesgave; H: Tyrsted. Offener Kreis: Datierung fehlerhaft/kein Datum verfügbar, aber Zugehörigkeit zu der Zeitscheibe wird vermutet. Gestrichelte Linie: Maximale Ausbreitung der jüngeren skandinavischen Gletscher, zeigt die Grenze zwischen dem westlichen und östlichen Dänemark an. Hintergrund: Präboreal (a&d), GI-1e (b), und GI-1c–a (c) EPHA-Karten (www.epha.zbsa.eu; CC BY 4.0; Version 1.1.0; Mollweide Projektion; zusammengestellt durch das ZBSA nach Lagerlund & Houmark-Nielsen 1993; Björck 1995; Lemke et al. 2002; Weaver et al. 2003; Jakobsson et al. 2007; Edwards & Brooks 2008; Brooks et al. 2011; Vassiljev & Saarse 2013; Hughes et al. 2016; Stroeven et al. 2016; Harff et al. 2017; Patton et al. 2017).*

2019) and most probably to slightly later at Nørre Lyngby (Aaris-Sørensen 1995; Fischer et al. 2013a; this work) and Arreskov (Fischer 1996). No circumferential predetermined breaking points, as observed on the two pieces from Mullerup (Plate 7) and Ungstrup Mose (Plate 10), have been observed on the Lyngby-type antler tools from southern Scandinavia and northern Germany. Only the Klappholz artefact features a predetermined breaking point that covers a third of the circumference of the beam and was similarly hacked into the compact bone (Clausen 2003, Fig. 8-1; 2004, Fig. 6-1). This leaves the question of the possible traces left on a detached part when a predetermined breaking point was deepened into the compact bone. For the Hamburgian, it has been shown that predetermined breaking points leave traces on both products; however, the younger technology could be different. Furthermore, it could also be possible that the Mullerup and Ungstrup Mose antlers derive from the production of secondary raw material blocks for tool, and especially projectile, production. Such secondary raw material blocks might have been used to produce antler projectiles, such as the reindeer antler point from Lasbek in northern Germany (Wild & Weber 2017) or the related spindle-shaped points from the southern Baltic (Gramsch 2003). However, the cultural affiliation of these finds remains uncertain.

The presence of Lyngby-type antler tools in the second half of the Allerød period is quite interesting as it links the Brommean (after the find of the eponymous antler tool and a lithic Bromme point from Nørre Lyngby (Müller 1896) with the slightly younger Ahrensburgian, which in Denmark began during the second half of the Younger Dryas. No clear differences exist between the four Danish Lyngby-type antler tools from Arreskov (Plate 13), Nørre Lyngby (Fig. 12, Plate 15-16), and Odense Kanal (Plate 17) that might be chronologically assigned to the Brommean and the Løgeskov (Plate 14) Lyngby-type antler tool, which might represent the Ahrensburgian. The Tranebjerg specimen is not mentioned here as it is not possible to unambiguously assign it to an anthropogenic action. Interestingly, the examples from the eastern Baltic are usually associated with the Swiderian (or even the Federmessergruppen) (Girininkas et al. 2016; Philippsen et al. 2019; see also Zagorska et al. 2019 for an insecure Lyngby-type antler tool from Mellupīte in Latvia), indicating a widespread, long-term and cross-cultural phenomenon. Nonetheless, only the finds from Stellmoor have been connected with an unambiguous cultural assemblage (Ahrensburgian), while the connection of the other possible Lyngby-type antler tools – a thorough modern techno-typological assessment of the majority of the finds is still needed – to other cultural entities, despite the early dates of some, remains vague.

The Allerød period in Denmark is furthermore marked by the first appearance of decorations on osseous artefacts. Besides complex patterns on the Fogense Enge rod (Petersen 2021), the first Nørre Lyngby antler tool shows a comparable zig-zag pattern. While this find is not directly dated, it most probably derives from a mid-Lateglacial layer in the Nørre Lyngby cliff (Fischer et al. 2013a). Furthermore, such patterns can also be observed on the already-mentioned amber figurines from Denmark that have recently been typologically assessed as Lateglacial (Mortensen et al. 2014d; Petersen 2021). Finally, two younger artefacts that date to the Younger Dryas and the Preboreal show modifications that can be interpreted as decorations. On the Lyngby-type antler tool from Løgeskov (Plate 14), some unusual grooving of a blood vessel imprint is crossed by several transverse incised furrows on the shaft, and the Kallerup Mose antler has a helical incised furrow that covers the entire shaft and bez tine of the artefact (Plate 19).

Younger Dryas 10,650-9,550 BC

The lack of finds from the first part of the Younger Dryas (Tab. 2, Fig. 16) indicates a gap of a few hundred years in the presence of humans in Denmark after the very beginning of the environmental deterioration there around 10,600 BC (Mortensen et al. 2014c). The absence of favourable conditions during the early Younger Dryas might have forced people to move to more southern refugia. New finds from Tyrsted would then be the oldest dates of the youngest Palaeolithic phase. This possible recolonisation of Denmark might be related to the milder conditions that started after 10,200 BC (Mortensen et al. 2014b).

The only stray find from this later phase of the Younger Dryas is the youngest of the five Danish Lyngby-type antler tools, which was found in southern Funen at Løgeskov. Interestingly, none of the Lyngby-type antler tools have been dated to the Preboreal, as is indicated for more southern and eastern regions (Rust 1943; Philippsen et al. 2019).

Preboreal 9,550-8,200 BC

At Ahrensburgian Stellmoor, Lyngby-type antler tools have been found alongside uni- and biserially barbed points with shield-shaped bases in the same layers (Rust 1943) in a Younger Dryas to Preboreal context (Weber et al. 2011; Wild & Weber 2017; Rivals et al. 2020). In contrast, all dated barbed points with shield-shaped bases from Denmark date to the Preboreal (Tab. 2). They are therefore younger than all the Danish Lyngby-type antler tools. Nevertheless, due to the low number of finds, this picture should not be overemphasized. However, it is striking that the barbed points seem to be a younger phenomenon of the Preboreal in Denmark and might indicate an increasing role of mammal hunting in lakes (P. V. Petersen 2009) or fishing and sea mammal hunting (cf. Cziesla 2007b, 2018) at the beginning of the Preboreal. Such a change in subsistence and/or hunting behaviour might have taken place earlier in the southeast, where barbed points of this type are dated to the mid-Younger Dryas (Cziesla & Pettitt 2003; Winkler 2019). This possible increase of new faunal sources is not only indicated by this new artefact type but also by the raw materials that have been used for the production of osseous tools. At least, the Vallensgård Mose and Ejby Mose points are thought to have been produced not from reindeer antler but from elk antler and bone (Andersen 1974; Andersen & Petersen 2009). Additionally, the Skipinge Mark point is made from bone and further species determination by ZooMS analysis of this and the other barbed points may lead to surprising raw materials and new insights into the adaptation patterns of Palaeolithic hunter-gatherers during the initial Holocene warming. This is even more important as abundant new ^{14}C dates of Mesolithic barbed points (Jensen et al. 2020) indicate a temporal overlap of Palaeolithic and Mesolithic traditions on Zealand (Fischer 1996; Hansen et al. 2004; Casati 2019; Sørensen et al. 2020). While this assumption is tempting, we need to keep in mind that none of the barbed points with shield-shaped bases found in Denmark were associated with lithic artefacts, and therefore no association with the Palaeolithic Ahrensburgian has been proven for Denmark or for two comparable finds of barbed points with shield-shaped bases from Sweden (Montelius 1917, Fig. 57-58).

The same holds true for the Kallerup Mose antler, an animal-gnawn reindeer antler with a thin helical furrow that decorates the beam and bez tine (see above). This find is unique to this period and cannot be attributed to the Palaeolithic or the Mesolithic. A hint pointing towards a Palaeolithic origin of the antler could be that current data on the Preboreal Mesolithic of Zealand suggests that none of the existing artefacts of Mesolithic typology had been made from reindeer remains (Hansen et al. 2004; Jensen et al. 2020); therefore, the simultaneous presence of Palaeolithic and Mesolithic hunter-gatherers could only be due to low chronological resolution or dating errors.

Conclusion

Overall, the current study underlines the potential of old and previously unrecognised finds present in our collections. The study adds significantly to the number of radiocarbon dates from the Danish Palaeolithic. This new and nearly complete dataset supports the hypothesis of a two-fold Hamburgian occupation in western and in eastern Denmark, the regular presence of hunter-gatherers during the Allerød and their possible absence during the first phase of the Younger Dryas biozone.

Although most of the studied artefacts lack a reliable context, the combined analysis based on the technology, palaeoenvironmental observations and radiocarbon dating allows the majority of radiocarbon dates to be accepted and at least some artefacts to be assigned to a Lateglacial culture. The latter took place on a chrono-typological basis (e.g. the Fuglebakkevej or Kolding Fjord antler). However, for most of the artefacts, this was still not possible. Among these were the waste pieces that show signs of a transverse segmentation (e.g. the Mullerup and Ungstrup antlers), the Lyngby-type antler tools (and the barbed points with shield-shaped bases (see above)). However, the new radiocarbon data, together with the detailed technological description, create an improved framework for future research.

Furthermore, regardless of the major changes in the environment (open land vs. woodland) during the Lateglacial, reindeer antler still seems to be the preferred raw material for tool production, even though it seems to play a minor role in the general subsistence strategy of some environmental stages. Taking these general environmental developments into consideration and using them as proxies, a rough dependence of humans on this species is nevertheless visible. Without arguing eco-deterministically, and taking the study bias into account, the presence of reindeer in Denmark was essential for the presence of humans throughout the Lateglacial as it was only during the Allerød and the beginning of the Preboreal that the regular use of other raw materials for Palaeolithic-type tool production can be observed, while reindeer antler was always a dominant raw material. Thus, the study underlines the strong reliance of Palaeolithic hunter-gatherers on almost-guaranteed and clearly predictable success in hunting this source of food, antler, skin and sinew (e.g. Burch 1972; Wild 2020).

Finally, the study sheds further light on many important questions concerning the Danish Palaeolithic (e.g. the possible two-fold settling of Denmark during the Hamburgian, the technological knowledge of the people that lived during the Allerød, the possible impact of the Younger Dryas cold period, and the survival of Palaeolithic traditions into the Holocene), and it will help future investigations and analyses. Even more importantly, this new investigation allows to address further research questions, such as those concerning the exact nature of the Palaeolithic-Mesolithic transition in Denmark.

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Contributor roles:
Conceptualization: Markus Wild, Morten Fischer Mortensen
Data curation: Markus Wild
Formal analysis: Markus Wild, Morten Fischer Mortensen, Jesper Olsen
Funding acquisition: Morten Fischer Mortensen, Berit V. Eriksen, Mikkel Sørensen, Kristoffer Buck Pedersen
Investigation: Markus Wild, Morten Fischer Mortensen
Methodology: Markus Wild, Morten Fischer Mortensen, Marie Kanstrup, Jesper Olsen
Project administration: Morten Fischer Mortensen, Markus Wild, Berit V. Eriksen
Resources: Niels H. Andreasen, Per Borup, Claudio Casati, Lise Frost, Kristian M. Gregersen, Mogens Bo Henriksen, Kristoffer Buck Pedersen, Peter V. Petersen, Conni Ramskov, Lasse Sørensen, Sidsel Wåhlin
Visualization: Markus Wild, Morten Fischer Mortensen, Jesper Olsen
Writing – original draft: Markus Wild, Morten Fischer Mortensen
Writing – review & editing: Markus Wild, Morten Fischer Mortensen, Niels H. Andreasen, Per Borup, Claudio Casati, Berit V. Eriksen, Lise Frost, Kristian M. Gregersen, Mogens Bo Henriksen, Marie Kanstrup, Jesper Olsen, Kristoffer Buck Pedersen, Peter V. Petersen, Conni Ramskov, Lasse Sørensen, Mikkel Sørensen, Sidsel Wåhlin

1. Arkvest
2. Arkæologi Sydfyn
3. Bornholms Museum
4. Copenhagen Museum
5. Holstebro Museum
6. Kroppedal Museum
7. Langelands Museum
8. Moesgaard Museum
9. Museum für Archäologie Schloss Gottorf
10. Museum Horsens
11. Museum Lolland-Falster
12. Museum Kolding
13. Museum Midtjylland
14. Museum Nordsjælland
15. Museum Salling
16. Museum Skanderborg
17. Museum Sydøstdanmark
18. Museum Sønderjylland
19. Museum Thy
20. Museum Vestsjælland
21. Museum Østjylland
22. National History Museum of Denmark
23. National Museum of Denmark
24. Naturama
25. Naturhistorisk Museum
26. Nordjyllands Historiske Museum
27. Odense City Museums
28. Roskilde Museum
29. Silkeborg Museum
30. Sydvestjyske Museer
31. VejleMuseerne
32. Vendsyssel Historiske Museum
33. Vesthimmerlands Museum
34. Viborg Museum

Appendix 1. List of Museums.
Appendix 1. *Liste der Museen.*

Model 1

KDE model using all available data. A_{model} = 109.6%.

```
KDE_Model()
  {
   R_Date("AAR-31844 Koldingfjord [6]", 12379, 42);
   R_Date("AAR-18733 Solrød Strand [32]", 12238, 46);
   R_Date("AAR-8159", 12410, 70);
   R_Date("AAR-906", 12520, 190);
   //SLOTSENG DATA -->
   R_Date("AAR-8165", 12290, 75);
   R_Date("AAR-8160", 12240, 50);
   R_Date("AAR-8162", 12220, 100);
   R_Date("AAR-8163", 12205, 65);
   R_Date("AAR-8164", 12205, 50);
   R_Date("AAR-8157", 12190, 100);
   R_Date("AAR-8158", 12170, 55);
   //<--
   R_Date("AAR-8161", 12065, 80);
   R_Date("AAR-18732 Solrød Strand [10]", 12170, 45);
   R_Date("AAR-1036 Solrød Strand [11]", 12140, 110);
   R_Date("LuS-12652 Frederiksberg [3]", 12050, 90);
   R_Date("AAR-31842 Holbæk [5]", 11843, 56);
   R_Date("AAR-30763 Mullerup Mose [7]", 11721, 62);
   R_Date("AAR-31839 Ungstrup Mose [12]", 11505, 61);
   R_Date("AAR-31848 Tranebjerg [33]", 11222, 63);
   R_Date("AAR-31838 Allerød-Teglværk [2]", 11217, 60);
   R_Date("AAR-31841 Hjorthede [4]", 10928, 54);
   R_Date("AAR-16019",10826,49);
   R_Date("OxA-3614",10810,120);
   R_Date("AAR-9298 Odense Kanal [21]", 10815, 65);
   R_Date("AAR-15025 Fogense Enge [15]", 10726, 27);
   R_Date("AAR-4539 Bromme", 10720, 90);
   R_Date("AAR-31847 Aarhus [1]", 10629, 52);
   R_Date("OxA-3173/ACQ-293 Arreskov [13]", 10600, 100);
   R_Date("AAR-31840 Refnæs [8]", 10575, 61);
   //TYRSTED DATA -->
   R_Date("AAR-27584 X179", 10445, 49);
   R_Combine("X180")
   {
    R_Date("KIA-53528",10270,45);
    R_Date("AAR-27585",10356,42);
   };
   R_Combine("X181")
   {
    R_Date("KIA-53528",10315,45);
    R_Date("AAR-27586",10321,46);
   };
   R_Combine("X182")
   {
    R_Date("KIA-53528",10235,45);
    R_Date("AAR-27587",10205,47);
   };
   R_Date("AAR-27588 X183", 10102, 39);
   //<--
   R_Date("AAR-31864 Løgeskov [18]", 10161, 62);
   R_Date("AAR-15007 Lille Aamose [17]", 9919, 26);
   R_Date("AAR-9296 Sandlyng Mose [21]", 9905, 65);
   R_Date("Ua-54134 Skellingsted Bro [25]", 9835, 37);
   R_Date("AAR-30764 Tammosegårds Mose [27]", 9813, 55);
   R_Date("AAR-31843 Kallerup Mose [31]", 9738, 55);
   R_Date("Ua-54135 Skipinge Mark [26]", 9735, 36);
   R_Date("AAR-9404 Vallensgård Mose [28]", 9585, 55);
   R_Date("Ua-54132 Sandlyng Mose [22]", 9533, 35);
   R_Date("Ua-54133 Skaftelev [24]", 9218, 35);
  };
```

Model 2

KDE model where the Slotseng and Tyrsted data are removed.. A_{model} = 102.1%.

```
KDE_Model()
  {
   R_Date("AAR-31844 Koldingfjord [6]", 12379, 42);
   R_Date("AAR-18733 Solrød Strand [32]", 12238, 46);
   R_Date("AAR-18732 Solrød Strand [10]", 12170, 45);
   R_Date("AAR-1036 Solrød Strand [11]", 12140, 110);
   R_Date("LuS-12652 Frederiksberg [3]", 12050, 90);
   R_Date("AAR-31842 Holbæk [5]", 11843, 56);
   R_Date("AAR-30763 Mullerup Mose [7]", 11721, 62);
   R_Date("AAR-31839 Ungstrup Mose [12]", 11505, 61);
   R_Date("AAR-31848 Tranebjerg [33]", 11222, 63);
   R_Date("AAR-31838 Allerød-Teglværk [2]", 11217, 60);
   R_Date("AAR-31841 Hjorthede [4]", 10928, 54);
   R_Date("AAR-16019 Trollesgave",10826,49);
   R_Date("OxA-3614 Fensmark",10810,120);
   R_Date("AAR-9298 Odense Kanal [21]", 10815, 65);
   R_Date("AAR-15025 Fogense Enge [15]", 10726, 27);
   R_Date("AAR-4539 Bromme", 10720, 90);
   R_Date("AAR-31847 Aarhus [1]", 10629, 52);
   R_Date("OxA-3173/ACQ-293 Arreskov [13]", 10600, 100);
   R_Date("AAR-31840 Refnæs [8]", 10575, 61);
   R_Date("AAR-31864 Løgeskov [18]", 10161, 62);
   R_Date("AAR-15007 Lille Aamose [17]", 9919, 26);
   R_Date("AAR-9296 Sandlyng Mose [21]", 9905, 65);
   R_Date("Ua-54134 Skellingsted Bro [25]", 9835, 37);
   R_Date("AAR-30764 Tammosegårds Mose [27]", 9813, 55);
   R_Date("AAR-31843 Kallerup Mose [31]", 9738, 55);
   R_Date("Ua-54135 Skipinge Mark [26]", 9735, 36);
   R_Date("AAR-9404 Vallensgård Mose [28]", 9585, 55);
   R_Date("Ua-54132 Sandlyng Mose [22]", 9533, 35);
   R_Date("Ua-54133 Skaftelev [24]", 9218, 35);
  };
```

Appendix 2. OxCal scripts.

Appendix 2. *OxCal Skripte.*

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Catalogue

Abbreviations:
cbtpbp = compact bone thickness at the predetermined breaking point
dcb = distal circumference of the burr
l = length
lob = length of base
pcb = proximal circumference of the burr
pbp = predetermined breaking point
w = width
wob = width of base

Waste pieces and raw material blocks

1 Aarhus NM A52666
Cultural attribution: -
Category: Secondary raw material block/waste piece (proximal to distal antler)
Localisation: Aarhus, Århus Amt (150000)
Lat/long (WGS84) [estimated for mapping, etc.]: 56.149722/10.224167
Raw material: Reindeer antler
Dimensions: l: 710 mm; w: 158 mm; pcb: 151.0 mm; dcb: 131.5 mm
Description: Right unshed antler that shows a fracture plane below the palmation. The brow and bez tine show signs of water rolling. The fracture of the distal beam left a winged fracture plane with a jagged end on the lateral side. On both sides of the fractured compact bone of this plane, 15 small facets with striations can be found. They measure max. 10.5 mm in length and 6 mm in width and are longitudinal to the main axis. On the most distal part of the antler, another single transverse facet with the same striations is located (Plate 1).
Date: AAR-31847: 10,629 ± 52 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: -
Placed at: National Museum of Denmark, Copenhagen
Literature: -

2 Allerød-Teglværk ZMK 118/2000 - P218/2019KMG
Cultural attribution: -
Category: Waste piece (proximal antler)
Localisation: Allerød-Teglværk, Blovstrød Sogn, Lynge-Kronborg Herred, Frederiksborg Amt (010403)
Lat/long (WGS84): 55.868611/12.344167
Raw material: Reindeer antler
Dimensions: l: 402 mm; w: 147 mm; cbtpbp: 7 mm; pcb: 125.1 mm; dcb: 118.8 mm
Description: Left proximal antler with bez tine. An almost circumferential predetermined breaking point was pecked into the beam above the bez tine. The ~10-mm-wide predetermined breaking point of 30° consists of stump pecking marks. Two lens-shaped to circular single marks on the medial side of the antler in the area of the bez tine as well as on the bez tine may derive from the deepening of the predetermined breaking point or the final break (Plate 2).
Date: AAR-31838: 11,217 ± 60 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Given to N. Hartz by workers from the brickyard. It was found at a depth of 4-6 m in blue clay that underlies a succession of yellow sandy clay and black sandy clay and that is covered by peat.
Placed at: Natural History Museum of Denmark
Literature: Hartz & Milthers 1902, Fig. 1-2; Degerbøl & Krog 1959

3 Fuglebakkevej ZMK 45/1949 - P141/2017KMG
Cultural attribution: Hamburgian?
Category: Waste piece (distal antler)
Localisation: Fuglebakkevej, Københavns Sogn, Sokkelund Herred, Københavns Amt (020306-873)
Lat/long (WGS84): 55.692187/12.527825
Raw material: Reindeer antler
Dimensions: l: 675 mm; w: 357 mm; cbt at pbp: 4 mm
Description: Right distal antler with palmation. Three furrow planes (grooving/sawing) on the lateral, medial and anterior sides of the antler build an almost circumferential pbp at a 90° angle. Additionally, a seemingly non-functional groove was deepened into the lateral side of the palmation (Plate 3).
Date: LuS-12652: 12,050 ± 90 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found during factory building at Nordre Fasanvej 215, Frederiksberg (formerly Fuglebakkevej). Pollen analysis of the stratigraphy places the find in the late Bølling/Older Dryas bio-zone.
Placed at: Copenhagen Museum (on short-term loan from the Natural History Museum of Denmark)
Literature: Degerbøl & Krog 1959, 11, 128, Fig. 4

4 Hjorthede ZMK 198/0000 - P219/2019KMG
Cultural attribution: -
Category: Waste piece (distal antler)
Localisation: Hjorthede, Hjorthede Sogn, Middelsom Herred, Viborg Amt (130706)
Lat/long (WGS84): 56.4176/9.706186
Raw material: Reindeer antler
Dimensions: l: 580 mm; w: 460 mm; cbt at pbp: 6 mm
Description: Left distal antler with palmation. A circumferential pbp at an angle of 35-40° is deepened into the antler below the palmation. It is up to 8 mm wide. On the lateral side, many parallel and sharp-edged stigmata indicate hacking, while the medial site shows more stump impacts that indicate pecking. On the medio-anterior side of the palmation four almost parallel pecking-depressions are located. They measure 8/5, 8/3, 3/2 and 15 mm/2 mm in length and

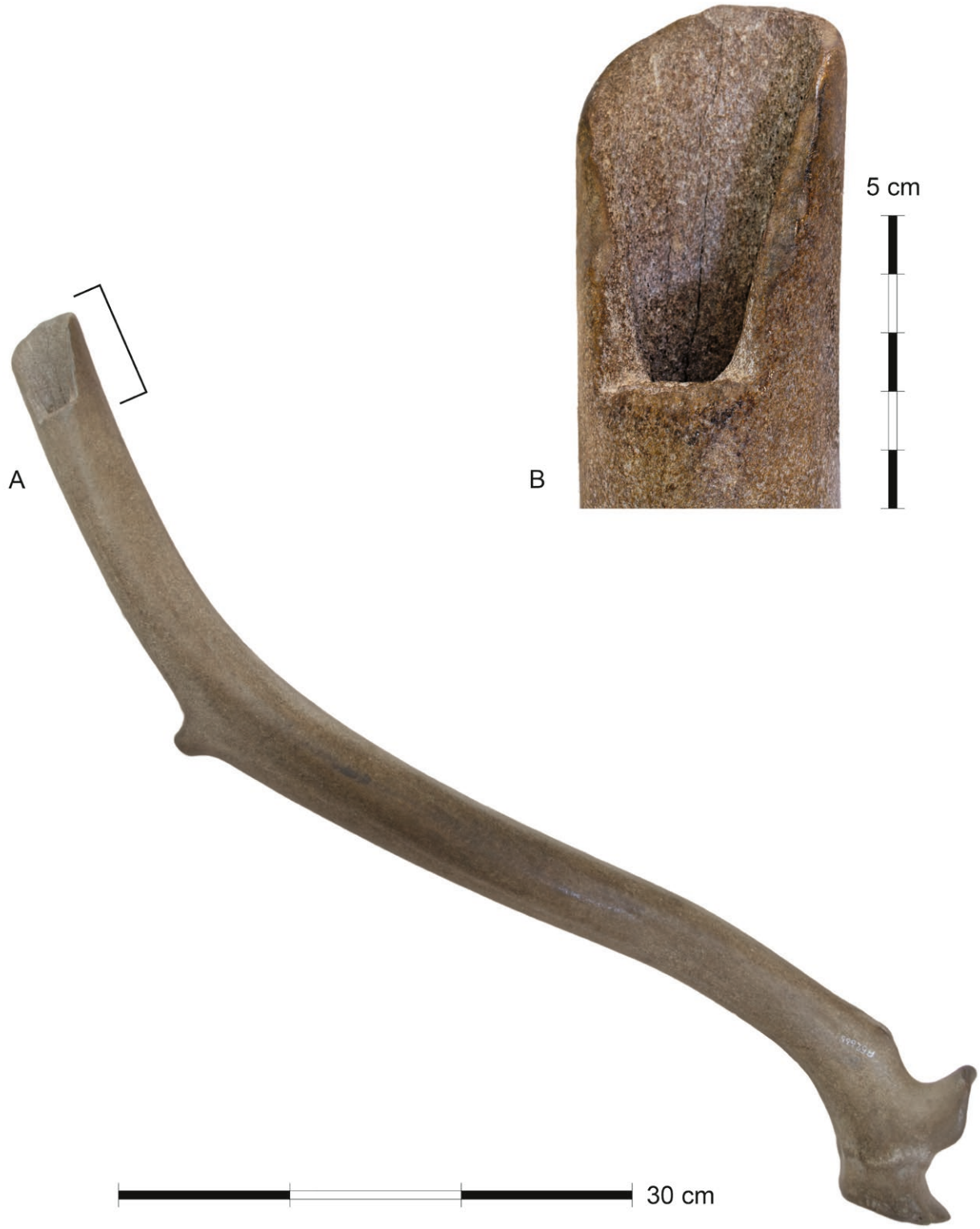

Plate 1. Aarhus A52666. A: lateral side; B: detail of lateral side (rotated by 45 degrees).
Tafel 1. *Aarhus A52666. A: laterale Seite; B: Detail der lateralen Seite (gedreht um 45 Grad).*

Plate 2. Allerød-Teglværk ZMK 118/2000 – P218/2019KMG. A: medial side; B: lateral side; C: detail of lateral side.
Tafel 2. *Allerød-Teglværk ZMK 118/2000 – P218/2019KMG. A: mediale Seite; B: laterale Seite; C: Detail der lateralen Seite.*

Plate 3. Fuglebakkevej ZMK 45/1949 – P141/2017KMG. A: lateral side; B: medial side; C: detail of lateral side (rotated by 30 degrees); D: detail of predetermined breaking point; E: detail of anterior side.

Tafel 3. *Fuglebakkevej ZMK 45/1949 – P141/2017KMG. A: laterale Seite; B: mediale Seite; C: Detail der lateralen Seite (gedreht um 90 Grad); D: Detail der Sollbruchstelle; E: Detail der Vorderseite.*

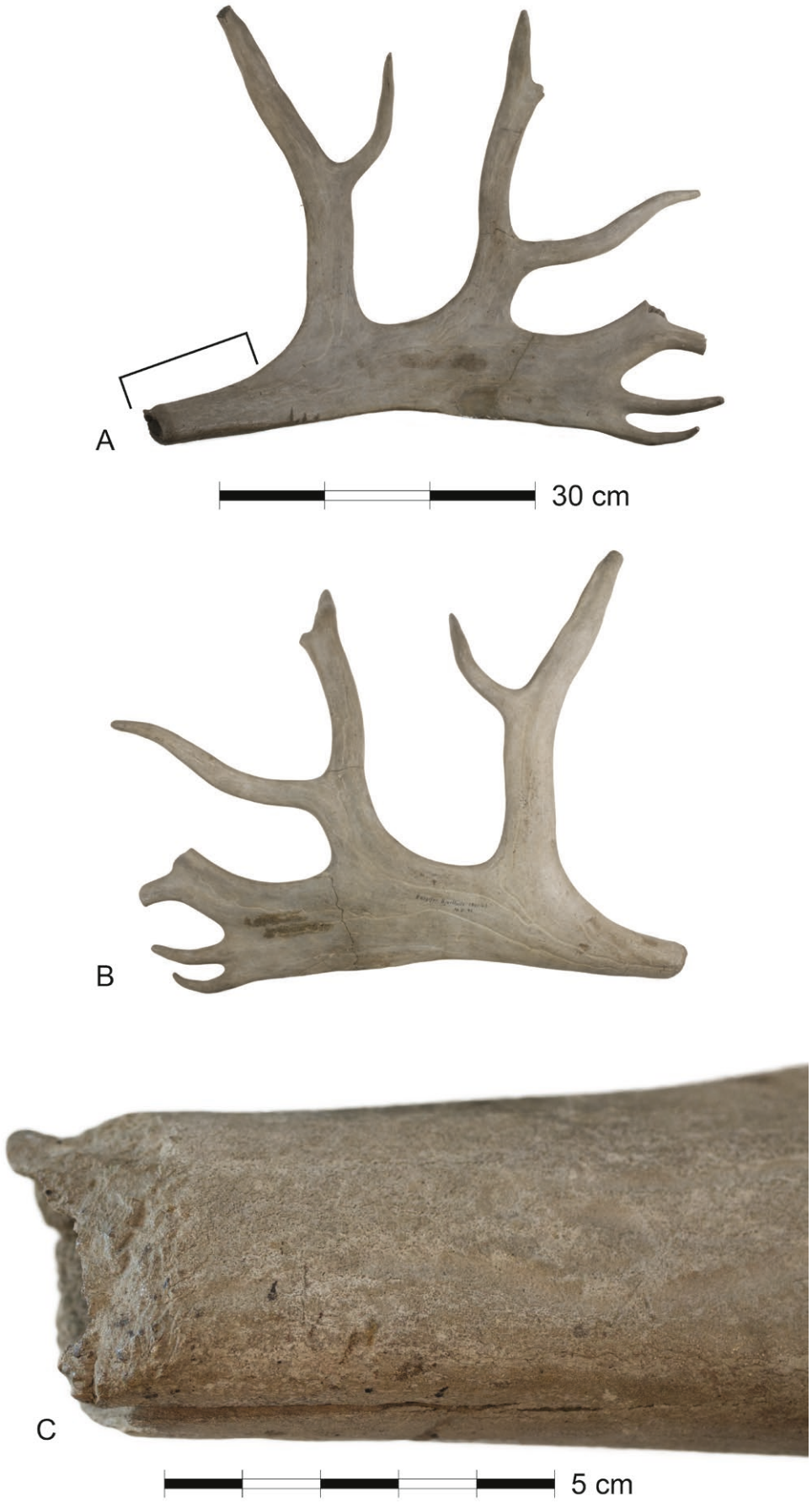

Plate 4. Hjorthede ZMK 198/0000 – P219/2019KMG. A: medial side; B: lateral side; C: detail of medial side.
Tafel 4. *Hjorthede ZMK 198/0000 – P219/2019KMG. A: mediale Seite; B: laterale Seite; C: Detail der medialen Seite.*

width (from the most proximal to the most distal) and could derive from the breaking of the beam (Plate 4).
Date: AAR-31841: 10,928 ± 54 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: '1861–1864' and 'A. Feddersen' are mentioned on a label at the Natural History Museum of Denmark. It was found in a marl pit; a pollen sample from the artefact contained *Juniperus*, *Empetrum*, and *Dryopteris linnaeana* as well as a low *Betula* percentage, indicating a late Younger Dryas age.
Placed at: Natural History Museum of Denmark
Literature: Winge 1904, 279, 286, plate 11,4; Nordmann 1936, 47-48, Fig. 35; Degerbøl & Krog 1959, 17, 135.

5 Holbek near Christiansfeld ZMK 8/1856 - P220/2019KMG
Cultural attribution: -
Category: Waste piece (distal bez tine)
Localisation: Holbek, Tyrstrup Sogn, Tyrstrup Herred, Haderslev Amt (200503)
Lat/long (WGS84): 55.356653/9.486305
Raw material: Reindeer antler
Dimensions: l: 311 mm; w: 149 mm
Description: Right distal bez tine. A hacked pbp at 45° is visible on the medial side of the tine. It is 33 mm long and c. 4 mm wide. At least four single small and flat depressions with micro-striations identify the hacking. The stigmata indicate that the working end of the hacking tool was directed in a longitudinal direction to the tines axis (Plate 5).
Date: AAR-31842: 11,843 ± 56 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Presented by Count Conrad Ditlev Knuth-Conradsborg via Theodor Schiøtz on 20.9.1856 to the Zoological Museum, University of Copenhagen. It was found 5-6.25 m deep in a marl pit that was dug in boulder clay.
Placed at: Natural History Museum of Denmark
Literature: Winge 1904, 279; Degerbøl & Krog 1959, 8, 126.

6 Kolding Fjord MKH O.3514
Cultural attribution: Hamburgian
Category: Primary raw material block
Localisation: Kolding Fjord, Vejle Amt (marine district 401514-30)
Lat/long (WGS84): 55.491304/9.518280
Raw material: Reindeer antler
Dimensions: l: 650 mm; w: 406 mm; pcb: 138.0 mm; dcb: 128.0 mm
Description: Left antler with a fracture of the proximal brow tine, distal bez tine and distal beam below the palmation. On the latero-anterior side below the back tine a furrow 97 mm long, up to 8 mm wide and 5 mm deep was deepened into the antler. It has an angle of 90° (lateral) and 45° (medial) and perfect parallel striations. The groove tapers proximally, which indicates that it was deepened from the distal end towards the proximal end. The distal fracture shows no anthropogenic modifications, while two 12-mm-long and 3-mm-wide hacking marks are located on the medial and medio-anterior sides. Comparable marks on the bez tine are recent (Plate 6).
Date: AAR-31844: 12,379 ± 42 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was supposedly found in 1896 during the clearing out of silt in the Kolding Fjord.
Placed at: Museum Kolding
Literature: -

7 Mullerup Mose NM A37621
Cultural attribution: -
Category: Waste piece (medio-distal beam)
Localisation: Western edge of Mullerup Mose, Drøsselbjerg Sogn, Løve Herred, Holbæk Amt (030203-26)
Lat/long (WGS84): 55.488726/11.228285
Raw material: Reindeer antler
Dimensions: l: 548 mm; w: 451 mm; cbt at pbp: 4 mm
Description: Right medio-distal antler beam with palmation. An almost circumferential predetermined breaking point was deepened into the beam below the back tine. The ~10-mm-wide predetermined breaking point of 40° angle consists of transversely oriented sharp hacking marks. The shape of these stigmata differs in the anterior and posterior aspects. This indicates at least two different working angles or different tools. The first palmation tine shows characteristics of a jagged and winged fracture plane, while the fourth palmation tine shows a unilateral predetermined breaking point at a 45° angle on its medial aspect. The tine was removed (Plate 7).
Date: AAR-30763: 11,721 ± 62 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found with two other bone points (one of them a fine barbed point of Mesolithic type) 1 m deep in a gravel pit at the edge of the bog.
Placed at: National Museum of Denmark, Copenhagen
Literature: Mathiassen 1938a, 175; Degerbøl & Krog 1959, 7, 125

8 Refnæs (Skambæk Mølle) ZMK 21/1909 - P221/2019KMG
Cultural attribution: Hamburgian(?)
Category: Waste piece (proximal antler)
Localisation: Skambæk Mølle, Raklev Sogn, Ars Herred, Holbæk Amt (030103)
Lat/long (WGS84): 55.688224/11.046172
Raw material: Reindeer antler
Dimensions: l: 140 mm; w: 144 mm; cbt at pbp: 10 mm; pcb in mm: 134.9 mm; dcb in mm: 133.9 mm
Description: Left shed proximal antler with fracture planes on the brow tine, bez tine and beam. On the

Plate 5. Holbek near Christiansfeld ZMK 8/1856 – P220/2019KMG. A: medial side; B: lateral side; C: detail of medial side; D: detail of lateral side.

Tafel 5. *Holbek bei Christiansfeld ZMK 8/1856 – P220/2019KMG. A: mediale Seite; B: laterale Seite; C: Detail der medialen Seite; D: Detail der lateralen Seite.*

Plate 6. Kolding Fjord MKH O.3514. A: lateral side; B: detail of lateral side (rotated by 70 degrees).
Tafel 6. *Kolding Fjord MKH O.3514. A: laterale Seite; B: Detail der lateralen Seite (gedreht um 70 Grad).*

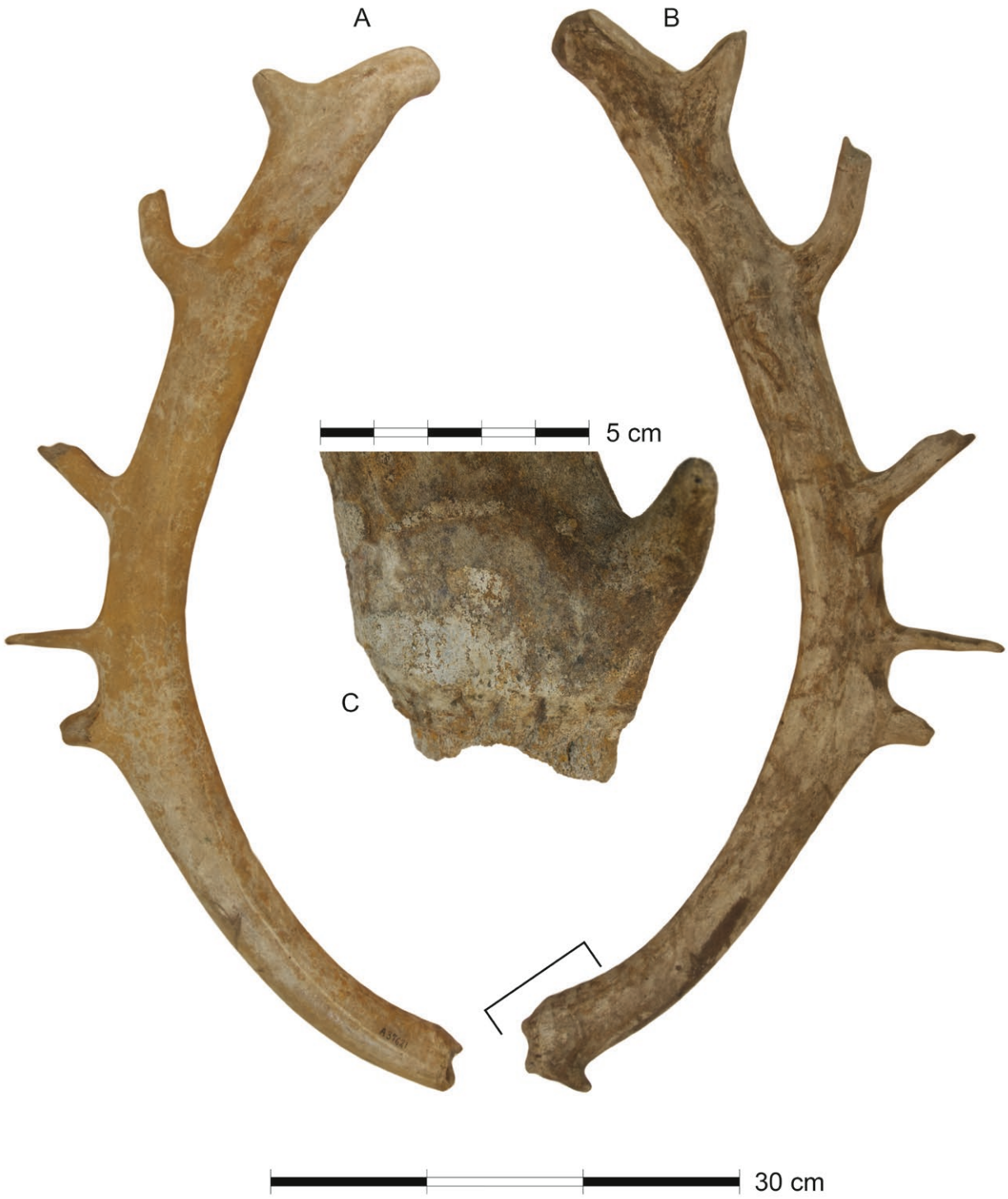

Plate 7. Mullerup Mose A37621. A: lateral side; B: medial side; C: detail of medial side (rotated by 90 degrees).
Tafel 7. *Mullerup Mose A37621. A: laterale Seite; B: mediale Seite; C: Detail der medialen Seite (gedreht um 90 Grad).*

Plate 8. Refnæs (Skambæk Mølle) ZMK 21/1909 – P221/2019KMG. A: medial side; B: lateral side; C: detail of lateral side (rotated by 90 degrees).
Tafel 8. *Refnæs (Skambæk Mølle) ZMK 21/1909 – P221/2019KMG. A: mediale Seite; B: laterale Seite; C: Detail der lateralen Seite (gedreht um 90 Grad).*

lateral side below the jagged fracture plan of the beam the rest of a small pbp at a 45° angle can be identified. No primary stigmata preserved. The preserved part of the bevel is 17 mm long and 2 mm wide (Plate 8).
Date: AAR-31840: 10,575 ± 61 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was given to the Zoological Museum, University of Copenhagen, by Søren Christiansen on the 26.5.1909.
Placed at: Natural History Museum of Denmark
Literature: Degerbøl & Krog 1959

9 Rimmer Strand NM A37020
Cultural attribution: -
Category: Waste piece (distal bez tine)
Localisation: Rimmer Strand, Gudum Sogn, Skodborg Herred, Ringkøbing Amt (180704-234)
Lat/long (WGS84): 56.550116/8.489513
Raw material: Reindeer antler
Dimensions: l: 313 mm; w: 79 mm; cbt at pbp: 4 mm
Description: Left bez tine with proximal pbp. No primary stigmata visible on the 35-40° angled pbp that continues for 33 mm around the proximal tine and is disturbed by a huge winged fracture plane on the medial side of the tine. The pbp has a max. width of 10 mm and might have been circumferential (Plate 9).
Date: AAR-31846: 6,073 ± 35 ^{14}C BP [problem with consolidants?]
Locality, find circumstances & geo- and palynological observations: -
Placed at: Zoological Museum Copenhagen
Literature: Mathiassen & Iversen 1937, pl. 12; Brøndsted 1938 Fig. 6e; Degerbøl & Krog 1959, 54

10 (Off) Solrød Strand 1947 ZMK 32/1948; P63/2013
Cultural attribution: Hamburgian?
Category: Waste piece (proximal antler)
Localisation: Couple of km off Solrød Strand, marine, Øresund (401377)
Lat/long (WGS84): 55.519691/12.310867
Raw material: Reindeer antler
Dimensions: l: 155 mm; w: 151 mm; pcb: 111.8 mm; dcb: 110.9 mm; cbt at pbp: 5 mm
Description: Left shed antler with a bilateral pbp at 30° above the bez tine. The medial part of the pbp measures 39 mm in length and 10 mm in width; the lateral part measures 40 mm in length and 8 mm in width. The brow tine is not developed, the bez tine is not broken archaeologically.
Date: AAR-18732: 12,170 ± 45 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found in 1948 by G. Olasson during sand pumping in the Køge Bugt. It was found in the same area as further reindeer bones and some more Holocene elements. It is suggested that the finds were located close to a former bog.
Placed at: Natural History Museum of Denmark
Literature: Degerbøl & Krog 1959; Petersen & Johansen 1993; Fischer & Jensen 2018; Wild 2020

11 (Off) Solrød Strand ZMK 12/1947; M.D. 65e
Cultural attribution: Hamburgian?
Category: Raw material block with modifications
Localisation: couple of km off Solrød Strand, marine, Øresund (401377)
Lat/long (WGS84): 55.519691/12.310867
Raw material: Reindeer antler
Dimensions: l: 131 mm; w: 74 mm; pcb: 105.0 mm; dcb: 97.2 mm; cbt at distal fracture: 7 mm.
Description: Left shed proximal antler. Fracture of beam and tines without human traces. The brow tine nevertheless shows a winged fracture plane. On the latero-posterior side a 64-mm groove was deepened into the antler. The groove starts at the medaillon and ends before the fracture plane of the beam. A second wide groove-like depression on the medio-posterior side shows no clear anthropogenic traces and might be the result of taphonomy or taphonomic widening of a former grooved furrow.
Date: AAR-1036: 12,140 ± 110 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found in 1947 by G. Olasson during sand pumping in the Køge Bugt. It was found in the same area as further reindeer bones and some more Holocene elements. It is suggested that the finds were located close to a former bog.
Placed at: Natural History Museum of Denmark
Literature: Degerbøl & Krog 1959; Petersen & Johansen 1993; Wild 2020

12 Ungstrup Mose ZMK 3/1877 - P222/2019KMG; M.D. 134
Cultural attribution: -
Category: Waste piece (mesio-distal antler)
Localisation: Ungstrup Mose, Torning Sogn, Lysgård Herred, Viborg Amt (130612)
Lat/long (WGS84): 56.293895/9.360113
Raw material: Reindeer antler
Dimensions: l: 560 mm; w: 264 mm; cbt at pbp: 8 mm
Description: Proxi-mesial antler of medium size. The area between the pbp and the back tine speaks for a left antler, the part between the back tine and the distal end speaks for a right antler. Several areas of hacking marks can be found on the proximal fracture plane. Although these areas are partly disturbed by the later fracture plane, they together build a circumferential pbp up to 12 mm wide. The angle of the pbp ranges between 22.5° and almost 90°. Four single hacking marks are located on the medial side below the first palmation tine. All of them are comparable in size (l: 15 mm; w: 5 mm) and lens-shape (Plate 10).
Date: AAR-31839: 11,505 ± 61 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Presented by Prof. Arthur Frederik Feddersen in 1877.
Placed at: Natural History Museum of Denmark
Literature: Winge 1904; Degerbøl & Krog 1959

Plate 9. Rimmer Strand A37020. A: medial side; B: lateral side; C: detail of lateral side (rotated by 60 degrees).
Tafel 9. *Rimmer Strand A37020. A: mediale Seite; B: laterale Seite; C: Detail der lateralen Seite (gedreht um 60 Grad).*

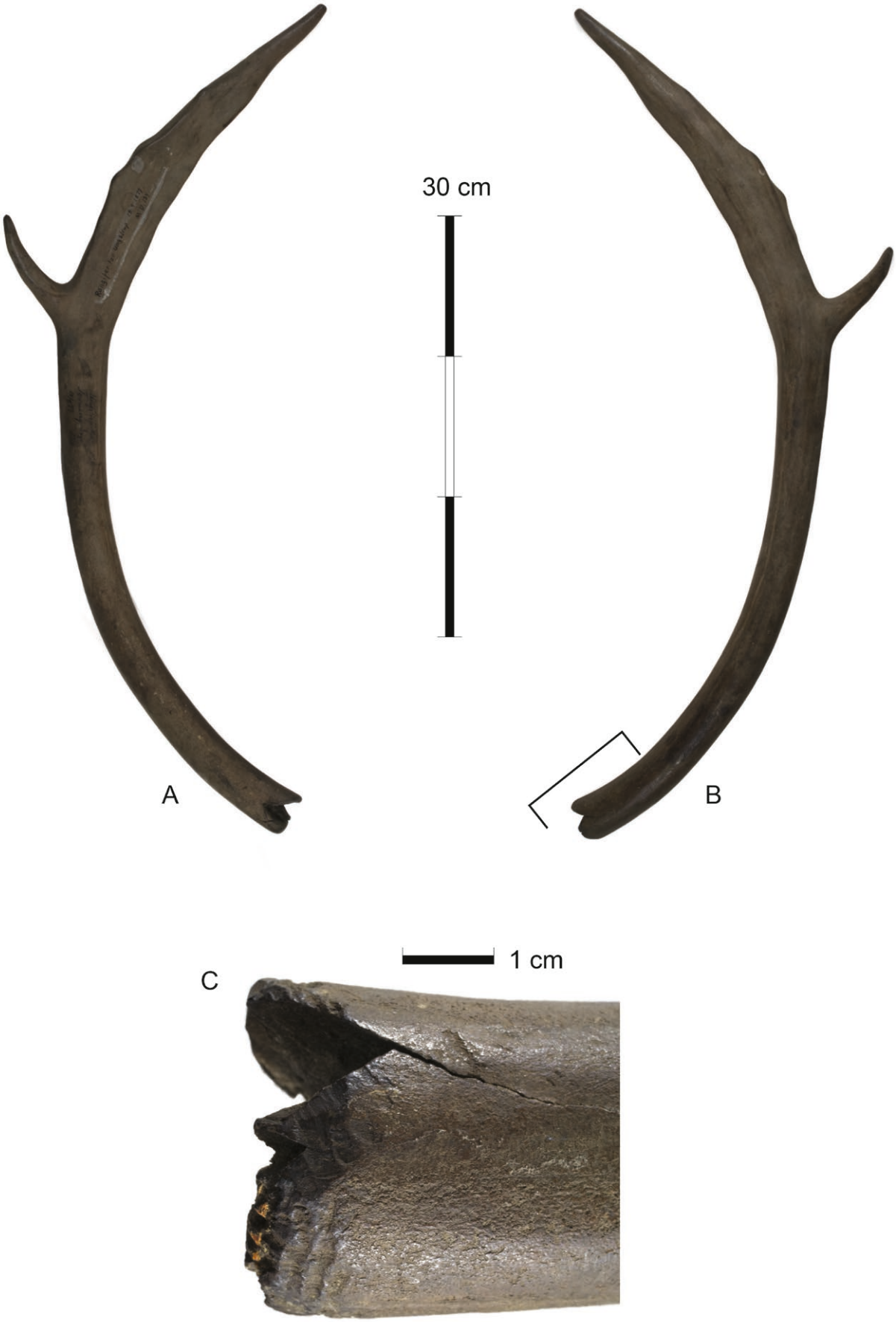

Plate 10. Ungstrup Mose ZMK 3/1877 – P222/2019KMG. A: side a; B: side b; C: detail of side b (rotated by 45 degrees).
Tafel 10. *Ungstrup Mose ZMK 3/1877 – P222/2019KMG. A: Seite a; B: Seite b; C: Detail der Seite b (gedreht um 45 Grad).*

Finished objects

13 (Sebbelung,) Arreskov (Sø) NM A51070 (OBM 3211x1)
Cultural attribution: Brommean/Ahrensburgian
Category: Lyngby-type antler tool
Localisation: Arreskov Sø (Sebbelung), Øster Hæsinge Sogn, Sallinge Herred, Svendborg Amt (090428-37)
Lat/long (WGS84): 55.164028/10.315278
Raw material: Reindeer antler
Dimensions: l: 540 mm; w: 205 mm; dcb: 116.0 mm
Description: Right shed antler. The bez tine is sharpened into a cutting edge (on the peripheral half of the tine) that is not well preserved but shows the typical round shape. The proximal part of the cutting edge shows longitudinal scraping marks and on the opposite side pits and grooves from use. No use-wear is present on the neck opposing the bez tine and the base of the antler. A series of ~10 half-moon shaped hacking marks of c. 10 mm width alongside the fracture plane of the back tine indicates the preparation of a unilateral pbp. The distal beam was detached after the preparation of a 15-mm-wide circumferential pbp of 35° angle that was hacked into the antler (Plate 13).
Date: OxA-3173/Bradford ACQ293: 10,600 ± 100 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Found in 1981 during drainage work in a reclaimed branch of Lake Arreskov. Found in Lateglacial lake deposits.
Placed at: Odense City Museums
Literature: Fischer 1996

14 Ejby Mose FS7901 (OBM 3556)
Cultural attribution: Ahrensburgian(?)
Category: Uniserially barbed point with shield-shaped base
Localisation: Ejby Mose, Ejby Sogn, Vends Herred, Odense Amt (080704-46)
Lat/long (WGS84): 55.433981/9.948850
Raw material: Large mammal (elk/aurochs) metapodium(?)
Dimensions: l: 248 mm; w: 21 mm; w(itdh)o(f)s(haft): 12 mm; lob: 24 mm; wob: 16 mm
Description: Long bone – most probably metapodium – of elk (according to Ulrik Møhl in Andersen 1974). Complete barbed point with three left-sided barbs. The proximal base shows a small fracture; the distal end shows another small fracture plane. The cross-section of the barbed point is drop-shaped and follows the natural shape of the bone. The barbs were made of the thinner part of the bone and were cut and scraped off it. The shaft shows longitudinal facet-like cutting planes from scraping. A grooved furrow is located on the dorsal side of the artefact. It is oriented longitudinally, begins at the base and continues along the barbs. While many incision-like marks can be observed on the artefact, no traces of grinding can be observed (Plate 11A-B).
Date: -
Locality, find circumstances & geo- and palynological observations: It was found during peat cutting in the northern part of Ejby Mose. Only one meter away a fine barbed point of Mesolithic type was found (FS7902).
Placed at: Odense City Museums
Literature: Andersen 1974; Andersen & Petersen 2009, 21

15 (Bred area?; formerly published as) Fogense Enge NM A53507 (OBM 8795x1)
Cultural attribution: Federmessergruppen/ Brommean/Ahrensburgian(?)
Category: Decorated rod
Localisation: The rod was handed over to the Odense City Museums in 2007 by the deceased finder's relative, but it was found more than 60 years earlier. It was reportedly found in Fogense Enge, Northern Funen, though without documentation from the finder. A detailed analysis of the geology in the area revealed that there are no Lateglacial sediments at all. The finder's relative was contacted and said that Fogense Enge was just a suggestion from the family. Moreover, he reported that the finder had lived in the village Bred, Western Funen, where he did drainage work for a contractor. The dead-ice landscape around Bred is well-known for its many bogs and kettle holes containing Lateglacial sediments. Therefore it is more likely that the rod was found in the Bred area, Vissenbjerg Sogn, Odense Herred, Odense Amt (080415-0 A).
Lat/long (WGS84): 55.551244/10.037256 (Fogense Enge)
Raw material: Elk metapodium
Dimensions: l: 331 mm; w: 12 mm; cbt: 11 mm
Description: Bone rod with stump ends. Decoration on the ventral and dorsal side. Cross-section almost isosceles triangle-shaped with rounded edges. The surface shows signs of grinding. The dorsal side of the rod is decorated with a so-called viper pattern consisting of incised zigzag lines. The ventral side is decorated with six columns of numerous parallel incised zigzag lines.
Date: AAR-15025: 10,726 ± 27 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: -
Placed at: Odense City Museums
Literature: Petersen 2021; Henriksen 2021

16 Helnæs (Skaghorn Syd) NM A54714 (OBM 4341x1)
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with shield-shaped base
Localisation: Skaghorn Syd, Helnæs Sogn, Båg Herred, Odense Amt (080207-70)
Lat/long (WGS84): 55.150378/10.007605
Raw material: Most probably bone; no absolute determination possible. Only in the area of the right lower barb is the cancellous bone visible.

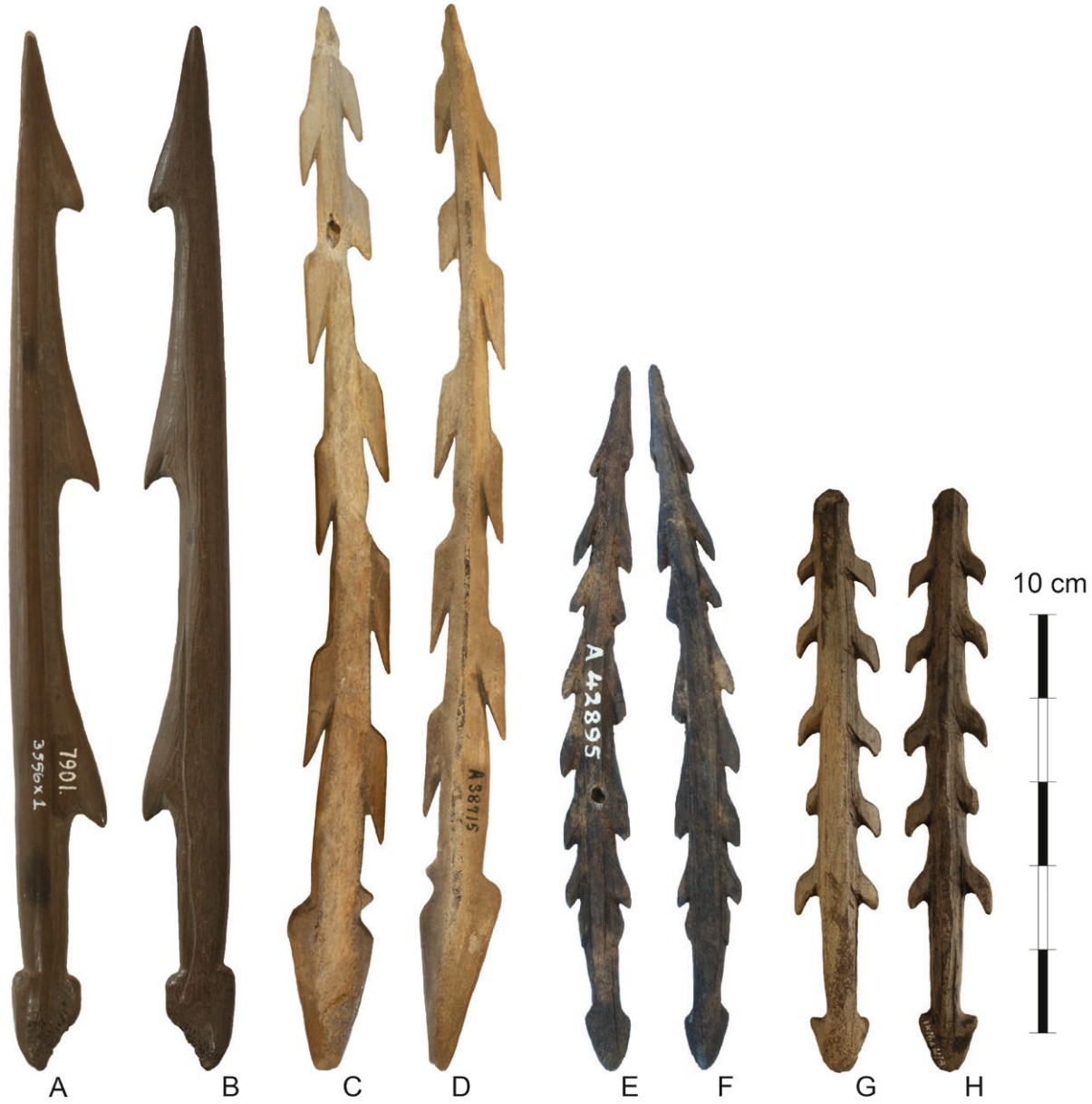

Plate 11. Barbed points. A–B: Ejby Mose FS7901; C–D: Skaftelev A38715; E–F: Skellingsted Bro A42895; G–H: Tammosegårds Mose GIM 991x1.
Tafel 11. *Widerhakenspitzen. A–B: Ejby Mose FS7901; C–D: Skaftelev A38715; E–F: Skellingsted Bro A42895; G–H: Tammosegårds Mose GIM 991x1.*

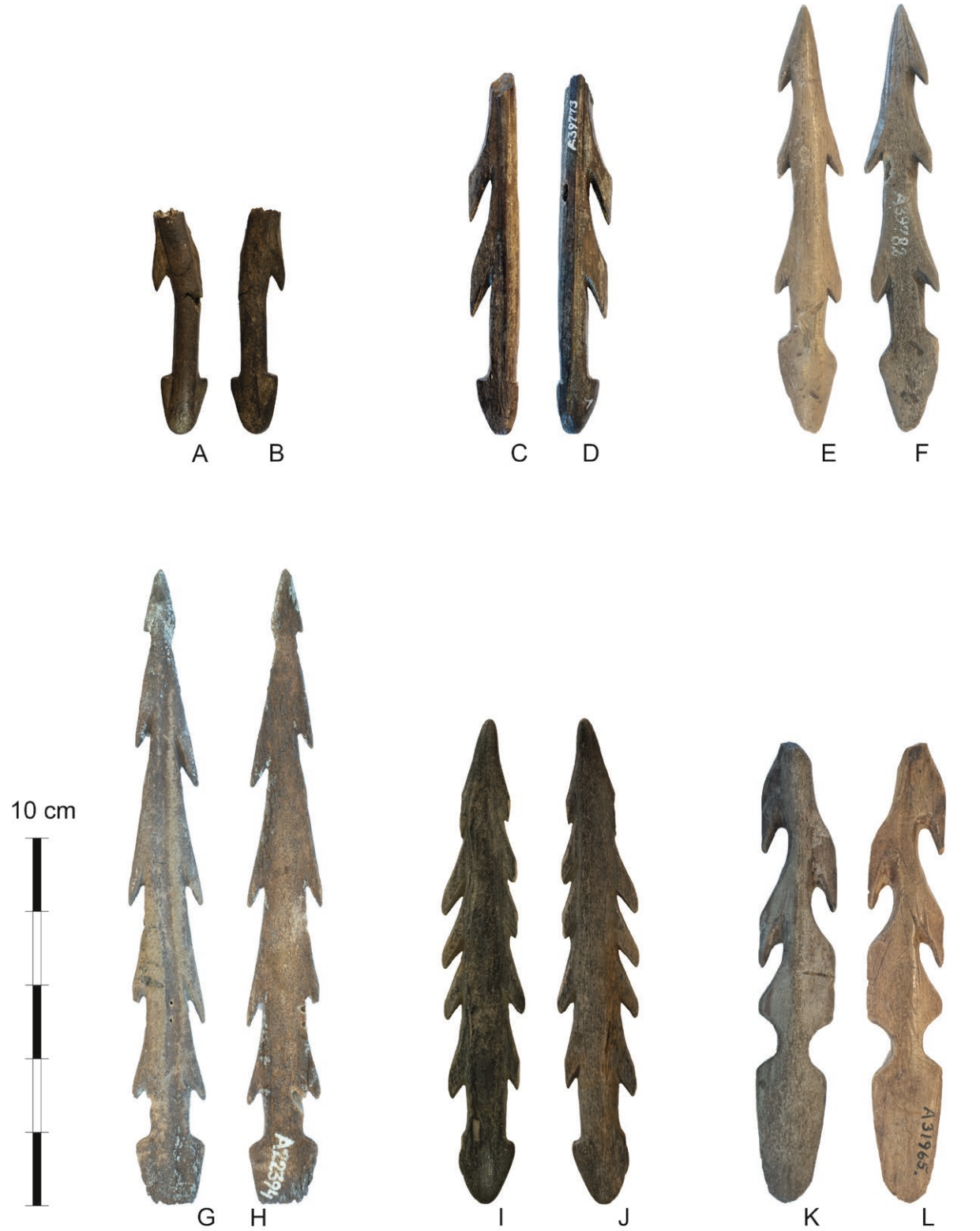

Plate 12. Barbed points. A–B: Lille Aamose A54643; C–D: Sandlyng Mose A39773; E–F: Sandlyng Mose A39782; G–H: Vallensgård Mose A22394; I–J: Helnæs A54714; K–L: Skipinge Mark A31965.

Tafel 12. *Widerhakenspitzen. A–B: Lille Aamose A54643; C–D: Sandlyng Mose A39773; E–F: Sandlyng Mose A39782; G–H: Vallensgård Mose A22394; I–J: Helnæs A54714; K–L: Skipinge Mark A31965.*

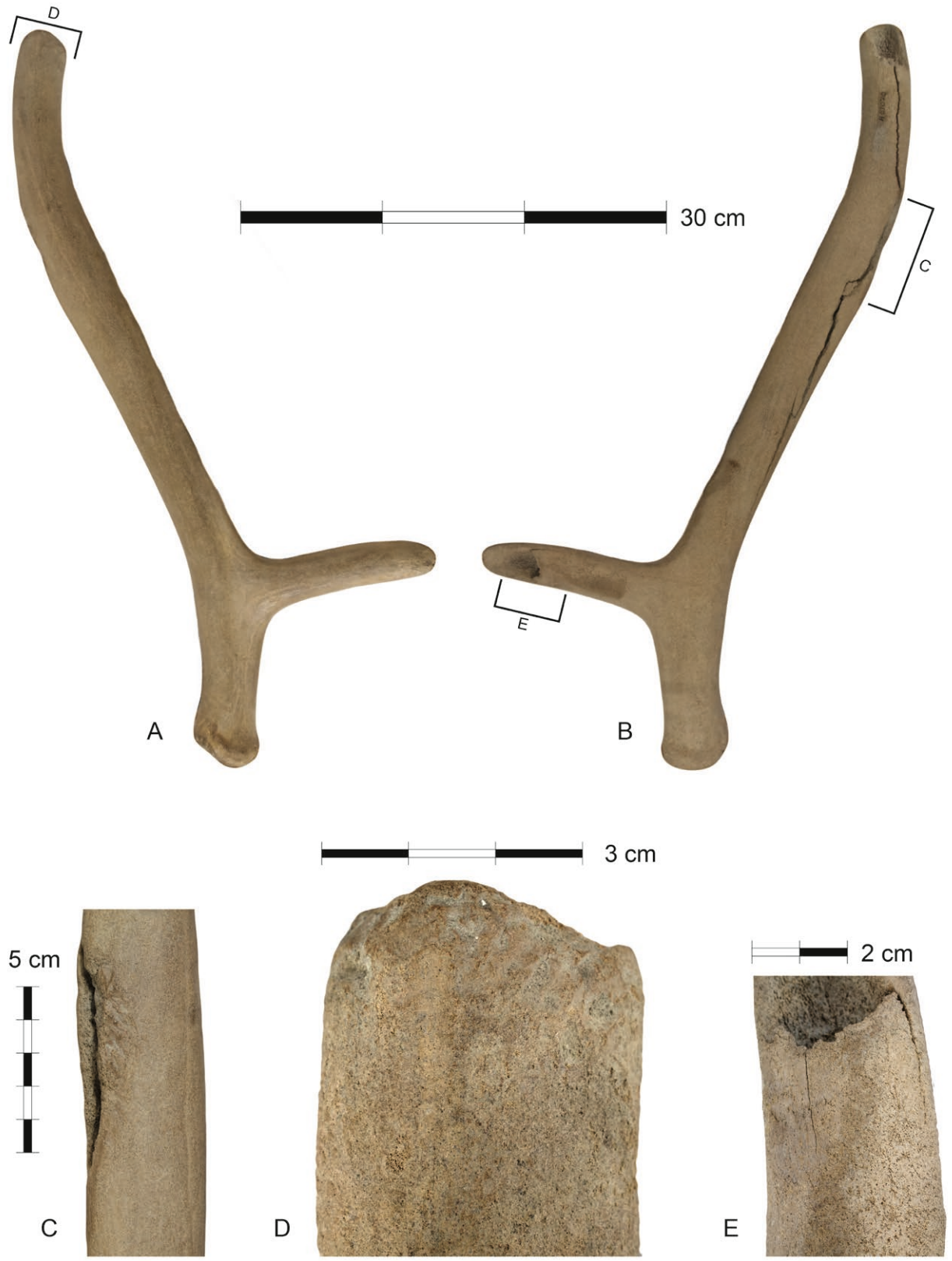

Plate 13. Arreskov A51070. A: lateral side; B: medial side; C: detail of posterior side (rotated by 20 degrees); D: detail of lateral side; E: detail of bez tine (rotated by 90 degrees).

Tafel 13. *Arreskov A51070. A: laterale Seite; B: mediale Seite; C: Detail der Rückseite (gedreht um 20 Grad); D: Detail der lateralen Seite; E: Detail der Eissprosse (gedreht um 90 Grad).*

Dimensions: l: 128 mm; w: 21 mm; cbt: 6 mm; lob: 16 mm; wob (slightly fragmented): 15 mm
Description: Complete with five partly alternating barbs on each side. The point's tip is slightly displaced, indicating reworking after a fracture. The cross-section shows the shaft and the bilaterally thinned-down barbs. The barbs have been cut and scraped off. Due to the preservation no possible signs of grinding or scraping of the overall surface are visible (Plate 12I-J).
Date: -
Locality, find circumstances & geo- and palynological observations: Found on top of a beach ridge in 2020. The sea cliff behind the beach ridge consists of moraine sand, thus the point was washed out from a submarine context - most probably organic sediments in one of the kettle-holes of the area.
Placed at: The National Museum, Copenhagen
Literature: Henriksen 2021

17 Lille Aamose NM A54643
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with shield-shaped base
Localisation: Lille Aamose, Buerup Sogn, Løve Herred, Holbæk Amt (030202-48)
Lat/long (WGS84): 55.619444/11.330278
Raw material: Reindeer antler
Dimensions: l: 58 mm; w: 13 mm; cbt: 7 mm; lob: 16 mm; wob: 12 mm
Description: Proximal fragment with two barbs. It is bent towards the right side, which led to a fissure below the barbed area. Partly lens-shaped section; the barbs and base have been made thinner than the shaft. No macro-wear is visible on the distal fracture. The right barb is almost completely fractured; only a small part is preserved. It could have been parallel to the preserved barb on the left side. Two narrow grooved furrows run along the lateral edges of the shaft from the middle of the base to the distal fracture. The left barb shows signs of incising. Longitudinally oriented, parallel micro-striations derive from grinding of the surface (Plate 12A-B).
Date: AAR-15007: 9,916 ± 26 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: -
Placed at: National Museum of Denmark, Copenhagen
Literature: Zagorska et al. 2019

18 Løgeskov FS 8765 (OBM 3203)
Cultural attribution: Ahrensburgian
Category: Lyngby-type antler tool
Localisation: Løgeskov, Stenstrup Sogn, Sunds Herred, Svendborg Amt (090511-8)
Lat/long (WGS84): 55.146755/10.467247
Raw material: Reindeer antler
Dimensions: l: 422 mm; w: 124 mm; dcb: 110.5 mm
Description: Right shed antler. The 75-mm-long preserved bez tine is sharpened to a cutting edge (on the central half). The cutting edge shows signs of scraping, intensive use-marks and polish as well as a transverse fracture plane on the distal active part. The cancellous bone in this area is not preserved. The proximal antler shows many diffuse impacts (pecking?). This substantially changed the shape of the burr, including the area where the brow tine is located. The fracture plane of the distal beam shows no signs of anthropogenic modification. On the lateral side of the antler some incisions and impacts can be observed as well as two rows of parallel incisions oriented transverse to the longitudinal axis below the back tine. The medial side of the antler is covered by stigmata. Below the back tine hacking marks; at least 25 fine incisions (l: 5-10 mm; w: ~1 mm); a shallow grooved furrow oriented longitudinally to the main axis in a naturally occurring furrow; and lens-shaped pecking marks on the medio-posterior side. Furthermore the distal parts of the artefact show darker areas. These areas coincide with more polished surfaces of the area and might derive from oily substances (sweat, dirt etc.) and might indicate intensive handling of the tool. Found in dug-out material in 1947 by a son of Hans Christian Jensen at Løgeskov (catastral number 119) in Stenstrup (Plate 14).
Date: AAR-31864: 10,161 ± 62 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Analysis of sediments from the implement was carried out at the National Museum of Denmark with no results.
Placed at: Odense City Museums
Literature: Albrectsen 1951

19 Nørre Lyngby NM A16678
Cultural attribution: Brommean/Ahrensburgian
Category: Lyngby-type antler tool
Localisation: Nørre Lyngby, Rubjerg Sogn, Vennebjerg Herred, Hjørring Amt (100610-20); Løkken, (Saltum - Nr. Lyngby) marine district (401108-3)
Lat/long (WGS84): 57.408906/9.742813
Raw material: Reindeer antler
Dimensions: l: 457; w: 97 mm
Description: Left antler. Signs of water-rolling. Winged fracture planes on the medallion (medial and anterior side) and the edge of the bez tine (medial side). An area 40 mm long and 19 mm wide on the lateral side of the antler below the bez tine is covered by half-moon-shaped pecking marks. The remnant of a small bevel at a 30° angle can be observed below the fracture of the bez tine. It is preserved for a length of 15.6 mm and a width of 6.7 mm. Three lines of a zigzag decoration cover an area of the antler shaft 6 mm in width and 12 cm in length (Plate 15).
Date: AAR-8919 & AAR-16622,1–4. Too young.
Locality, find circumstances & geo- and palynological observations: It was found in 1889 on the beach in front of the steep coastal cliff. Most probably it can be associated with the blue clay that dates to the Allerød period.
Placed at: National Museum of Denmark, Copenhagen

Literature: Müller 1896; Stensager 2006; Fischer et al. 2013a

20 Nørre Lyngby VHM 1975/0073
Cultural attribution: Brommean/Ahrensburgian
Category: Lyngby-type antler tool
Localisation: Nørre Lyngby, Lyngby Sogn, Børglum Herred, Hjørring Amt (100107-); Løkken (Saltum - Nr. Lyngby) marine district 401108-15
Lat/long (WGS84): 57.408906/9.742813
Raw material: Reindeer antler
Dimensions: l: 388 mm; w: 74 mm.
Description: Right antler without base. Highly water-rolled. Beam preserved from between the brow and the bez tine to below the back tine. Longitudinal fissures due to weathering. The bez tine shows an oblique fracture plane that is accompanied on the medial side by a small bevelled area that, due to the water-rolling, does not show further anthropogenic stigmata (Plate 16).
Date: AAR-31845. Too young.
Locality, find circumstances & geo- and palynological observations: It was collected in front of the steep coastal cliff. Most probably it can be associated with the blue clay that dates to the Allerød period.
Placed at: Vendsyssels Historiske Museum
Literature: -

21 Odense Kanal NM A16679 (OBM 5748)
Cultural attribution: Brommean/Ahrensburgian
Category: Lyngby-type antler axe
Localisation: Odense Kanal (Odense Harbour), Odense Sogn, Odense Herred, Odense Amt. (Marine district 401290-21)
Lat/long (WGS84): 55.442234/10.421562
Raw material: Reindeer antler
Dimensions: l: 468 mm; w: 95 mm
Description: Right shed antler. The bez tine is sharpened to a cutting edge (on the peripheral half). The cutting edge shows signs of scraping, intensive use-polish and damage to the distal active part. On the neck opposing the bez tine and the base of the antler, the surface is highly modified by stump pecking marks (length of this field of modifications: 12 cm). On the latero-posterior side the proximal antler shows two large winged fracture planes that are the result of heavy use of the tool. Two natural blood channels have been slightly deepened by cutting with a lithic tool on a length of 19 cm. On the edge of the distal beam, a circumferential pbp was pecked into the antler. Around the shaft of the tool an area 11 cm long is modified by pecking and hacking marks of c. 3 mm length and width. This area ends 8 cm before the distal fracture. This area differs from the proximal area with impacts and is not interpreted as use-wear (Plate 17).
Date: AAR-9298: 10,815 ± 65 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Found in 1890 during construction of a new harbor basin in Odense. This part of the harbour is dug out in the reclaimed lake Næsbyhoved Sø. It was handed over by the Odense City Museums to the National Museum in 1896.
Placed at: National Museum of Denmark, Copenhagen
Literature: Müller 1896; Stensager 2006

22 Sandlyng Mose NM A39782
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with shield-shaped base
Localisation: Assentorp, Stenmagle Sogn, Alsted Herred, Sorø Amt (040112-39)
Lat/long (WGS84): 55.573406/11.549349
Raw material: bone(?)
Dimensions: l: 114 mm; w: 18 mm; th: 6 mm; lob: 28 mm; wob: 17 mm
Description: Complete recycled point. Segment-shaped section. Five barbs are located in parallel, except for the most distal one on the left, which is solitary. The barbs were shaped by incising and overworked by scraping. Intensive surface modifications (grinding) appear only on the ventral side (Plate 12E-F).
Date: Ua-54132: 9,533 ± 35 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Found during peat cutting in Sandlyng Mose. No further investigation. The piece was handed over to the National Museum in 1943.
Placed at: National Museum of Denmark, Copenhagen
Literature: -

23 Sandlyng Mose NM A39773
Cultural attribution: Ahrensburgian
Category: Uniserially barbed point with shield-shaped base
Localisation: Assentorp, Stenmagle Sogn, Alsted Herred, Sorø Amt (040112)
Lat/long (WGS84): 55.573406/11.549349
Raw material: Antler
Dimensions: l: 95; w: 13 mm; th: 7 mm; lob: 16 mm; wob: 11 mm
Description: Proximal fragment with two barbs on the right side and remains of cancellous bone along the ventral side. Drop-shaped cross-section. The barbs are shaped by incising and sawing and overworked by scraping. A longitudinal grooved furrow c. 1 mm wide lies on the dorsal side at the bases of the barbs. Fine parallel striations on all sides of the artefact indicate the final abrasion of the surface. The fracture plane is non-indicative of its use (Plate 12C-D).
Date: AAR-9296: 9,905 ± 65 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Found during peat cutting in Sandlyng Mose, Assentorp catastral number 7, among a series of Mesolithic appearing leister prongs.
Placed at: National Museum of Denmark, Copenhagen
Literature: Andersen & Petersen 2009

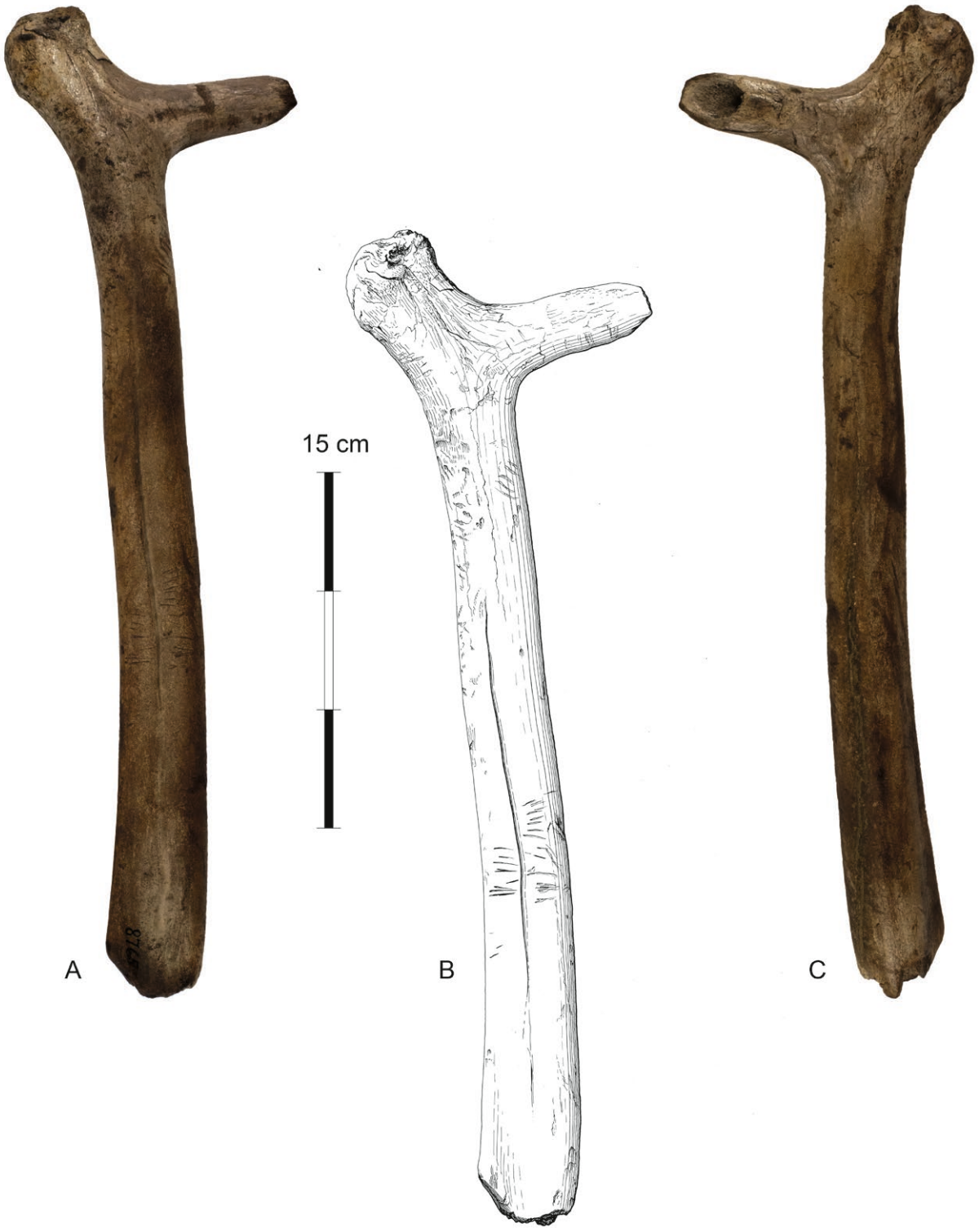

Plate 14. Løgeskov FS 8765. A: lateral side; B: drawing of medial side. Drawing: Orla Svendsen after Søren H. Andersen.; C: medial side.
Tafel 14. *Løgeskov FS 8765. A: laterale Seite; B: Zeichnung der medialen Seite. Zeichnung: Orla Svendsen nach Søren H. Andersen.; C: mediale Seite.*

Plate 15. Nørre Lyngby A16678. A: lateral side; B: medial side.
Tafel 15. *Nørre Lyngby A16678. A: laterale Seite; B: mediale Seite.*

Plate 16. Nørre Lyngby VHM 1975/0073. A: medial side; B: lateral side.
Tafel 16. *Nørre Lyngby VHM 1975/0073. A: mediale Seite; B: laterale Seite.*

Plate 17. Odense Kanal A16679. A: medial side; B: lateral side.
Tafel 17. *Odense Kanal A16679. A: mediale Seite; B: laterale Seite.*

24 Skaftelev NM A38715
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with shield-shaped base
Localisation: Skaftelev, Nordrupvester Sogn, Slagelse Herred, Sorø Amt (040310-8)
Lat/long (WGS84): 55.466667/11.433333
Raw material: Reindeer antler
Dimensions: l: 246 mm; w: 20 mm; th: 5 mm; lob: 45 mm; wob: 20 mm
Description: The barbed point is fully preserved and tapers slightly from the base to the tip. The tip indicates recycling of the point. The alternating barbs were incised, sawn off and then scraped to regulate the shape. Overall only a few production stigmata are visible due to ventral grinding of the artefact (Plate 11C-D).
Date: Ua-54133: 9,218 ± 35 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found by H. W. Thornsen during draining of a bog in 1941 and was subsequently given to the Nationalmuseet. It was found in sediment that was dug out of a depth of approximately 3 m. The barbed point lay in a dark stratum surrounded by two layers of white gyttja.
Placed at: National Museum of Denmark, Copenhagen
Literature: Mathiassen 1941; Taute 1968; Cziesla 2007a

25 Skellingsted Bro NM A42895
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with shield-shaped base
Localisation: Skellingsted, Skamstrup Sogn, Tuse Herred, Holbæk Amt (030710-27)
Lat/long (WGS84): 55.582857/11.460714
Raw material: -
Dimensions: l: 166 mm; w: 11 mm; th: 7 mm; lob: 15 mm; wob: 11 mm
Description: Complete point with a blunt tip and 12 barbs. Partly lens-shaped section; barbs thinner than the shaft. On the proximal part the pairs of barbs are parallel, but they start to alternate and then return to a more parallel pairing on the distal part. Below the most proximal pair of barbs two small bulges indicate another pair of barbs. No stigmata of shaping can be observed on the surface of the point (Plate 11E-F).
Date: Ua-54134: 9,835 ± 37 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: The point was found in the Skellingsted Mose, north of the Åmose, 250 m North of the Skelingsted-bridge. It was found during peat cutting above sandy soil.
Placed at: National Museum of Denmark, Copenhagen
Literature: Taute 1968, 206, 310, Pl. 162,3

26 Skipinge Mark A31965
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with shield-shaped base
Localisation: Skipinge Mark, Vallekilde Sogn, Ods Herred, Holbæk Amt (030411)
Lat/long (WGS84): 55.740139/11.399947
Raw material: -
Dimensions: l: 116 mm; w: 20 mm; th: 6 mm; lob: 37 mm; wob: 18 mm
Description: Proximo-mesial fragment with signs of recycling and three barbs. Lens-shaped section. The base is separated from the shaft by two cut half-moon-shaped hollows. The surface of these modifications was polished and no stigmata are left. The barbs are located alternately with two barbs on one side and one on the other side. The tip is blunt with several sawn or incised facets that all show parallel micro-striations. The different facets' micro-striations are oriented in different directions. Several incisions and scraping marks are oriented chaotically on the surface of the point (Plate 12K-L).
Date: Ua-54135: 9,735 ± 36 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was given to the National Museum of Denmark, Copenhagen by Dr. E. Tulinius, a citizen scientist from Snertinge. It was found 65 cm deep in organic mud.
Placed at: National Museum of Denmark, Copenhagen
Literature: Mathiassen 1938b

27 Tammosegårds Mose GIM 991x1
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with spade-shaped base
Localisation: Tammosegårds Mose, Græsted Sogn, Holbo Herred; Frederiksborg Amt (010105-70)
Lat/long (WGS84): 56.090829/12.286282
Raw material: Metapodium of large mammal
Dimensions: l: 135 mm; w: 19 mm; th: 7 mm; lob: 14 mm; wob: 13 mm
Description: Proximo-mesial fragment with a bevelled break from its use at the distal end. The section of the point is lens shaped with the barbs being thinned down distally. The base of the point was thinned down by scraping as were the barbs and the shaft. The 10 barbs – five on each side - are located slightly asymmetrically (Plate 11G-H).
Date: AAR-30764: 9,813 ± 55 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found by a girl and was given to H. C. Terslin – head of the local school and museum – who finally gave it to the Gilleleje Museum (Museum Nordsjælland). It was stuck in a turve of peat that was cut out during peat cutting.
Placed at: Museum Nordsjælland
Literature: Freundt 1949

28 Vallensgård Mose NM A22394
Cultural attribution: Ahrensburgian
Category: Biserially barbed point with spade-shaped base

Localisation: Vallensgård Mose, Åker Sogn, Bornholms Sønder Herred, Bornholms Amt (060205-173)
Lat/long (WGS84): 55.099849/14.910719
Raw material: Elk antler(?)
Dimensions: l: 166 mm; w: 20 mm; th: 5 mm; wob: 18 mm
Description: Almost complete recycled point with a small transverse fracture of the proximal base and nine barbs. Rectangular, slightly rounded section. The three lower pairs of barbs are parallel, while the distal pair alternates. The point and the barbs taper towards the distal end of the point. The tip was recycled. Almost no stigmata are visible. Small grooved furrows are visible at the shoulders of the barbs (Plate 12G-H).
Date: AAR-9404: 9,585 ± 55 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found with two other bone points (one of them is a fine barbed Mesolithic type) 100 cm deep in calcareous mud.
Placed at: National Museum of Denmark, Copenhagen
Literature: Brøndsted 1938; Mathiassen 1938b; Becker 1951, Fig. 33: 3; Andersen & Petersen 2009; P. V. Petersen 2009

Further finds

29 Hundstrup Mose ZMK 53/1945
Cultural attribution: -
Localisation: Hundstrup Mose, Hammer Sogn, Hammer Herred, Præstø Amt (050401)
Lat/long (WGS84): 55.16330/11.87206
Raw material: Reindeer antler
Dimensions: l: 720 mm
Description: Right shed antler broken between back tine and palm. Brow tine broken 13 cm away from the beam; bez tine broken 22 cm from beam; back tine thought to be broken artificially (after Degerbøl & Krog 1959).
Date: -
Locality, find circumstances & geo- and palynological observations: It was registered in the Herlufsholms museum in 1945.
Placed at: unknown
Literature: Degerbøl & Krog 1959

30 Horseskov (Tåsinge) NM A50427 (SOM 27338)
Cultural attribution: Unclear
Category: worked?
Localisation: Horseskov, Bregninge Sogn, Sunds Herred, Svendborg Amt (090502-28)
Lat/long (WGS84): 55.031023/10.577259
Raw material: Reindeer antler
Dimensions: l: 377 mm; w: 126 mm; dcb: 121.5 mm
Description: Right shed antler. Recent fracture of the lateral, anterior and medial part of the burr including the brow tine. Bez tine and distal beam fractured recently. The antler shows some minor incision-like grooves and a few half-moon shaped impacts. Their anthropogenic origin cannot be verified. The beam shows longitudinally oriented facets with fine, almost parallel transverse incision-like grooves. An anthropogenic origin can again not be verified (Plate 18).
Date: -
Locality, find circumstances & geo- and palynological observations: Found at the beach and presumably washed ashore.
Placed at: Svendborg Museum
Literature: Rieck 1977

31 Kallerup Mose NM A36118
Cultural attribution: Unclear
Category: Decorated piece
Localisation: Kallerup Mose, Tåstrup Nykirke Sogn, Smørum Herred, København Amt (020214)
Lat/long (WGS84): 55.661734/12.218423
Raw material: Reindeer antler
Dimensions: l: 433 mm; w: 283 mm; dcb: 111.5 mm
Description: Left proxi-mesial shed antler. The brow tine and the distal part of the beam directly above the back tine are animal gnawed, while the distal bez tine shows a recent fracture plane. On the proximal lateral side, a series of several small hacking or cut marks are oriented transverse to the main axis of the antler. A continuous fine incision can be observed on the beam. It turns helically around the beam at least 13 times and crosses the distal gnawing marks (Plate 19).
Date: AAR-31843: 9,738 ± 55 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: Was given by a citizen scientist (the teacher Martin Hansen of Hedehusene) to the Nationalmuseet in the 1930s. Found 4.5 m deep in sand below peat.
Placed at: National Museum of Denmark, Copenhagen
Literature: Mathiassen 1938a; Degerbøl & Krog 1959

32 (Off) Solrød Strand 1947 M.D. 65e
Cultural attribution: Hamburgian?
Category: Marrow-split bone
Localisation: couple of km off Solrød Strand, marine, Øresund (401377)
Lat/long (WGS84): 55.519691/12.310867
Raw material: Reindeer metacarpus
Dimensions: -
Description: Metacarpus with longitudinal fracture plane, interpreted as being marrow fractured. No impacts are visible.
Date: AAR-18733: 12,238 ± 46 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: It was found during sand pumping in the Køge Bugt. It was found in the same area as further reindeer bones and some more Holocene elements. It has been suggested that the finds were located close to a former bog.
Placed at: Natural History Museum of Denmark
Literature: Degerbøl & Krog 1959; Petersen & Johansen 1993; Fischer & Jensen 2018

Plate 18. Horseskov A50427. A: lateral side; B: medial side.
Tafel 18. *Horseskov A50427. A: laterale Seite; B: mediale Seite.*

Plate 19. Kallerup Mose A36118. A: lateral side; B: medial side; C: latero-anterior side of mesial beam.
Tafel 19. *Kallerup Mose A36118. A: laterale Seite; B: mediale Seite; C: Detail der lateralen Seite und der Vorderseite der mesialen Stange.*

33 Tranebjerg FHM 6118x1
Cultural attribution: Brommean/Ahrensburgian?
Category: Possibly a Lyngby-type antler tool
Localisation: Tranebjerg, Onsbjerg Parish, Samsø Herred, Holbæk Amt (030504-117)
Lat/long (WGS84): 55.832614/10.58941
Raw material: Reindeer antler
Dimensions: l: 504 mm; w: 92 mm; pcb: 128.0 mm; dcb: 126.5 mm
Description: Right shed antler with fractures at the brow tine, the bez tine and the beam between the back tine and the palmation. The bez tine shows some rounding and the fracture has a bevel-like appearance. On the medial side, two winged fracture planes (l: 15/7 mm; w: 20/11 mm) are longitudinally oriented from the fracture plane to the beam (Plate 20).
Date: AAR-31848: 11,222 ± 63 ^{14}C BP
Locality, find circumstances & geo- and palynological observations: -
Placed at: Moesgaard Museum
Literature: Nordmann 1936, Fig. 33c; Mathiassen 1938a; Degerbøl & Krog 1959
Not worked

34 Faabjerg ID unknown
Localisation: Faabjerg, Faabjerg Parish, Skodborg Herred, Ringkøbing Amt (180702)
Lat/long (WGS84): 56.525642/8.38287
Raw material: Reindeer antler
Dimensions: -
Description: Right proximal antler with signs of high weathering. While the fracture planes on distal beam and bez tine seem to have been made without anthropogenic influence, the brow tine appears to have been broken artificially. However, the antler (mentioned as a Lyngby-type antler tool in Schacht 1979) could not be localised and the published photo in Degerbøl & Krog 1959 does not indicate an archaeological origin of the brow tine fracture.
Locality, find circumstances & geo- and palynological observations: It was found in a sandy clay gyttja; a pollen sample from the artefact showed high *Empetrum* and low *Betula* values.
Placed at: unknown
Literature: Degerbøl & Krog 1959, 17, 135, Fig. 9; Schacht 1979

35 Fogderup (formerly Fauderup) KS11209
Localisation: Fogderup, Ravsted Sogn, Slogs Herred, Tønder Amt (210405-33)
Lat/long (WGS84): 55.009196/9.126182
Raw material: Reindeer antler
Dimensions: l: 582 mm; w: 199 mm; pcb: 135.0 mm; dcb: 106.5 mm
Description: Left shed antler with a fracture of the distal beam and the brow tine. The bez tine was not built. Long and narrow planes with perfectly parallel micro-striations including a slight polish on the edge of the fractures speak to a metal tool. The morphology of the distal beam speaks to it, too. The brow tine shows a jagged fracture plane that without the recent traces could speak to an archaeological fracture. G. Schwantes furthermore described an intended hollowing-out of the distal antler. This cannot be confirmed but may be explained by taphonomy (Plate 21).
Locality, find circumstances & geo- and palynological observations: The antler was found in 1902 by Andreas Nissen at a depth of approximately 3 m in a marl pit. In the distal fracture plane a yellowish-grey sediment was observed (clay or antler powder?). **Placed at**: Museum für Archäologie, Schleswig (Germany)
Literature: Schwantes 1925

36 Glibinggård ZMK 2/1867; M.D.129
Localisation: Glibinggård, Søvind Sogn, Voer Herred, Skanderborg Amt (160508)
Lat/long (WGS84): 55.889317/10.032517
Raw material: Reindeer antler
Dimensions: -
Description: Left mesial antler beam with signs of recent damage (Plate 22).
Locality, find circumstances & geo- and palynological observations: -
Placed at: Natural History Museum of Denmark
Literature: Winge 1904; Degerbøl & Krog 1959

37 Havmarken HOM 531x45
Localisation: Havmarken, Søvind Sogn, Voer Herred, Skanderborg Amt (160508-152)
Lat/long (WGS84): 55.883008/9.999617
Raw material: Reindeer antler
Dimensions: -
Description: Left shed antler with longitudinal fractures and large parts reconstructed. Parts of the proximal beam with the bez tine preserved. Beam fractured in the area of the bez tine. No modifications visible (Plate 23).
Locality, find circumstances & geo- and palynological observations: -
Placed at: Horsens Museum
Literature: -

38 Horsens Havn HOM 10xA0280
Localisation: Horsens Havn, Horsens Fjord, Voer Herred, Skanderborg Amt (401284)
Lat/long (WGS84): 55.856817/9.868813
Raw material: Reindeer antler
Dimensions: l: 235 mm; w: l: 260 mm; cbt at fracture plane above the bez tine: 3 mm; dcb: 129.5 mm
Description: Left shed antler without brow tine, with fracture plane at the proximal beam above the bez tine. No modifications visible (Plate 24).
Locality, find circumstances & geo- and palynological observations: -
Placed at: Horsens Museum
Literature: Mathiassen 1938a?

Plate 20. Tranebjerg FHM 6118x1. A: medial side; B: lateral side; C: detail of medial side (rotated by 50 degrees).
Tafel 20. *Tranebjerg FHM 6118x1. A: mediale Seite; B: laterale Seite; C: Detail der medialen Seite (gedreht um 50 Grad).*

Plate 21. Fogderup KS11209. A: medial side; B: lateral side.
Tafel 21. *Fogderup KS11209. A: medial side; B: lateral side.*

Plate 22. Glibinggård ZMK 2/1867. A: medial side; B: lateral side; C: detail of medial side (rotated by 90 degrees).
Tafel 22. *Glibinggård ZMK 2/1867. A: mediale Seite; B: laterale Seite; C: Detail der medialen Seite (gedreht um 90 Grad).*

Plate 23. Havmarken HOM 531x45. A: medial side; B: lateral side.
Tafel 23. *Havmarken HOM 531x45. A: mediale Seite; B: laterale Seite.*

Plate 24. Horsens Havn HOM 10xA0280. A: medial side; B: lateral side.
Tafel 24. *Horsens Havn HOM 10xA0280. A: mediale Seite; B: laterale Seite.*

39 Horsensfjord noID
Localisation: Horsens Fjord, Horsens Fjord, Voer Herred, Skanderborg Amt (401284)
Lat/long (WGS84): 55.845253/9.964600
Raw material: Reindeer antler
Dimensions: l: 250 mm
Description: Antler beam with bez tine. Highly weathered. Bez tine preserved over 18 cm. Supposed Lyngby-type antler tool.
Locality, find circumstances & geo- and palynological observations: Thought to derive from Horsens Fjord but also mentioned as from Horsensegnen (region Horsens).
Placed at: unknown
Literature: Brøndsted 1938; Degerbøl & Krog 1959; Skaarup 1974

40 Hovedgård HOM 531x47
Localisation: Hovedgård, Ørridslev, Sogn, Voer Herred, Skanderborg Amt (160514)
Lat/long (WGS84): 55.938129/9.937544
Raw material: Reindeer antler
Dimensions: l: 135 mm; w: 165 mm; cbt at fracture plane: 2 mm
Description: Distal end of brow or bez tine palmation. No signs of modification.
Locality, find circumstances & geo- and palynological observations: Thought to have been found in a context related to drainage near Ørridslev.
Placed at: Horsens Museum
Literature: -

41 Middelgrund NM A37765
Localisation: Middelgrund, Middelgrunden bank, marine (401353)
Lat/long (WGS84):
Raw material: Reindeer antler
Dimensions: l: 402; w: 147 mm; cbt at proximal fracture: 7 mm
Description: Distal bez tine. Proximally and distally the antler shows recent fracture planes. The sharp edge that is thought to be a cutting edge shows no signs of working or use (Plate 25).
Date: This object was radiocarbon dated by the Uppsala radiocarbon laboratory in 1987. The radiocarbon ages of Ua347 and Ua348 were 180 ± 112 and 10 ± 10 ^{14}C years BP respectively. The Uppsala radiocarbon laboratory reported difficulties in extracting collagen and therefore the ^{14}C results are likely uncertain.
Locality, find circumstances & geo- and palynological observations: It was given by C. E. Jespersen to the Denmark Geological Survey, which gave it to the Nationalmuset in the 1930s. It was found 4.5 m deep in gravel that covered the limestone bottom, 12.5 m below sea level. Pollen-flora indicates arctic vegetation.
Placed at: National Museum of Denmark, Copenhagen
Literature: Mathiassen 1938a; Degerbøl & Krog 1959; Petersen & Johansen 1993

42 Nørre Lyngby ZMK 17/1993; 41.5-41.2/16
Localisation: Nørre Lyngby, Lyngby Sogn, Børglum Herred, Hjørring Amt (100107-17)
Lat/long (WGS84): 57.408906/9.742813
Raw material: Reindeer rib
Dimensions: -
Description: Rib with a longitudinal furrow covered by incrustations. An anthropogenic origin cannot be unambiguously verified as the combination of cross-section, location, intra-furrow striations etc. speak against it being intentionally and human-made (Plate 26).
Locality, find circumstances & geo- and palynological observations: It was found by staff from the Zoological Museum, University of Copenhagen, during systematic investigations at the locus classicus in 1993–1994.
Placed at: Natural History Museum of Denmark
Literature: Aaris-Sørensen 1995; Fischer et al. 2013a

43 Nørre Lyngby M.D. 44d
Localisation: Nørre Lyngby, Lyngby sogn, Børglum herred, Hjørring amt (100107-17)
Lat/long (WGS84): 57.408906/9.742813
Raw material: Reindeer mandible
Dimensions: -
Description: The mandible shows no "cut[ting] off" (cf. Degerbøl & Krog 1959, 19).
Locality, find circumstances & geo- and palynological observations: -
Placed at: Natural History Museum of Denmark
Literature: Degerbøl & Krog 1959

44 Nørre Lyngby (1 km north of locus classicus) VHM 14382
Localisation: Nørre Lyngby, Rubjerg Sogn,Vennebjerg Herred, Hjørring Amt (100610-52)
Lat/long (WGS84): 57.396237/9.732170
Raw material: Reindeer antler
Dimensions: l: 231 mm; w: 75 mm; cbt at fracture plane above the bez tine: 5 mm; pcb: 149.0 mm; dcb: 128.5 mm
Description: Right unshed antler that shows fracture planes at the proximal brow, the bez tine and the beam above the bez tine. The fracture plane of the beam is obliquely oriented and has an irregular surface. This indicates a break in a non-fresh state. The fracture plane is accompanied on the lateral and posterior sides of the beam by four impacts/depressions c. 15 mm long and c. 2-3 mm wide. Their appearance indicates a recent origin (Plate 27).
Locality, find circumstances & geo- and palynological observations: Found in situ at the beach, c. 1 km North of the locus classicus Nørre Lyngby and given to the Zoological Museum, University of Copenhagen, in 1981.
Placed at: Vendsyssels Historiske Museum
Literature: -

Plate 25. Middelgrund A37765. A: side a; B: side b; C: detail of side b (rotated by 20 degrees).
Tafel 25. *Middelgrund A37765. A: Seite a; B: Seite b; C: Detail der Seite b (gedreht um 20 Grad).*

Plate 26. Nørre Lyngby ZMK 17/1993. A: side a; B: detail of side a.
Tafel 26. *Nørre Lyngby ZMK 17/1993. A: Seite a; B: Detail der Seite a.*

Plate 27. Nørre Lyngby VHM 14382. A: medial side; B: lateral side.
Tafel 27. *Nørre Lyngby VHM 14382. A: mediale Seite; B: laterale Seite.*

45 Overgård ZMK 7/1943
Localisation: Overgård, As Sogn, Bjerre Herred, Vejle Amt (170101)
Lat/long (WGS84): 55.807641/9.998522
Raw material: Reindeer antler
Dimensions: -
Description: Left proxi-mesial shed antler with signs of animal gnawing on the bez tine.
Locality, find circumstances & geo- and palynological observations: The find was made in 1943 together with further bones and antler. Degerbøl & Krog 1959, 134: "The following information concerning the find is available: At the top was found approximately two metres of fat peat soil, under which was 2 to 2 1/2 m of marl. The antler and various other bones were found just beneath this stratum. Next followed alternating thin strata of moss and marl, and below these about 25 cm of compressed mud, an approximately 2 m thick layer of marl, and, finally, black quicksand. A sample of clay gyttja from the antler was examined by Dr. Iversen immediately on the appearance of the find. The spectrum [...] may be ascribed to zone III, among other things because of a rather low *Betula* percentage, some *Empertrum*, and a single *Dryopteris linnaeana* spore. This dating is further made probable by the recorded sequence of strate, in which the compressed mud can reasonably be assumed to be Allerød gyttja."
Placed at: unknown
Literature: Degerbøl & Krog 1959, 16, 134, Fig. 6; Schacht 1979.

46 Stestrup NM A40861
Localisation: Stestrup, Kirke Eskildstrup Sogn, Merløse Herred, Holbæk Amt (030304)
Lat/long (WGS84): 55.565767/11.793399
Raw material: Reindeer antler
Dimensions: l: 570 mm; w: 185 mm; pcb: 148.5 mm; dcb: 122.0 mm
Description: Right shed antler. Brow tine not built, bez tine shows signs of animal gnawing (cf. bez tine of the Kallerup Mose antler). The fracture of the distal beam shows no anthropogenic traces but does show signs of heavy weathering. On the medial side, there are more than 20 parallel impressions of a tool with straight and sharp working end (a modern shovel/spade?) (Plate 28).
Locality, find circumstances & geo- and palynological observations: -
Placed at: National Museum of Denmark, Copenhagen
Literature: Mathiassen 1946, 175; Degerbøl & Krog 1959, 20; Schacht 1979, Fig. 2; Girininkas et al. 2016, Fig. 3

47 Stilling Mark SBM 1 (N9.1)
Localisation: Stilling Sogn, Hjelmslev Herred, Skanderborg Amt (160209)
Lat/long (WGS84): 56.070377/9.993807
Raw material: Reindeer antler
Dimensions: l: 570 mm; w: 263 mm; pcb: 79.0 mm; dcb: 101.0 mm
Description: Left shed antler with distal fractures of brow tine, bez tine and distal beam below the palmation. No modification visible. Furrow-like modification on the medial mesial beam shows no stigmata and cannot be determined as archaeological (Plate 29).
Locality, find circumstances & geo- and palynological observations: The antler originates from lawyer H.C. Arent's private collection which was given to Skanderborg Museum in 1913. No further information available.
Placed at: Skanderborg Museum
Literature: -

48 Store Vejleå NM A52667
Localisation: Store Vejleå, Tåstrup Nykirke Sogn, Smørum Herred, København Amt (020214)
Lat/long (WGS84): 55.656878/12.326897
Raw material: Reindeer antler
Dimensions: l: 636 mm; w: 130 mm
Description: Right shed antler. The fracture of the distal beam below the palmation is recent. Several fields of shard incisions and hacking marks are located on the medial side of the antler. The shape, morphology and organisation speak to a modern tool (spade/shovel etc.) causing modifications when the antler was found (Plate 30).
Locality, find circumstances & geo- and palynological observations: It was given to the National Museum of Denmark, Copenhagen, by Jelstrup in 1858.
Placed at: National Museum of Denmark, Copenhagen
Literature: Mathiassen 1946; Degerbøl & Krog 1959

49 Storebælt LMR 8439:25
Localisation: Off Lundeborg, Hesselager Sogn, Gudme Herred, Svendborg Amt (Marine district 401424-20)
Lat/long (WGS84): 55.138855/10.792179
Raw material: Reindeer antler
Dimensions: l: 410 mm
Description: Antler beam, lacking the proximal part, with fractures of the bez tine and the distal beam. Signs of intensive water-rolling and cover by *Balanidae*. No modifications visible (Plate 31).
Locality, find circumstances & geo- and palynological observations: Jørgen Borne found it during diving in the Storebælt, North of Lundeborg in 1.75 m deep water, 170 m away from the present coastline, in the autumn 1971.
Placed at: Langelands Museum
Literature: Skaarup 1974

50 Vejleby NM A21808
Localisation: Vejleby, Ferslev Sogn, Horns Herred, Frederiksborg Amt (010202)

Plate 28. Stestrup A40861. A: lateral side; B: medial side.
Tafel 28. *Stestrup A40861. A: laterale Seite; B: mediale Seite.*

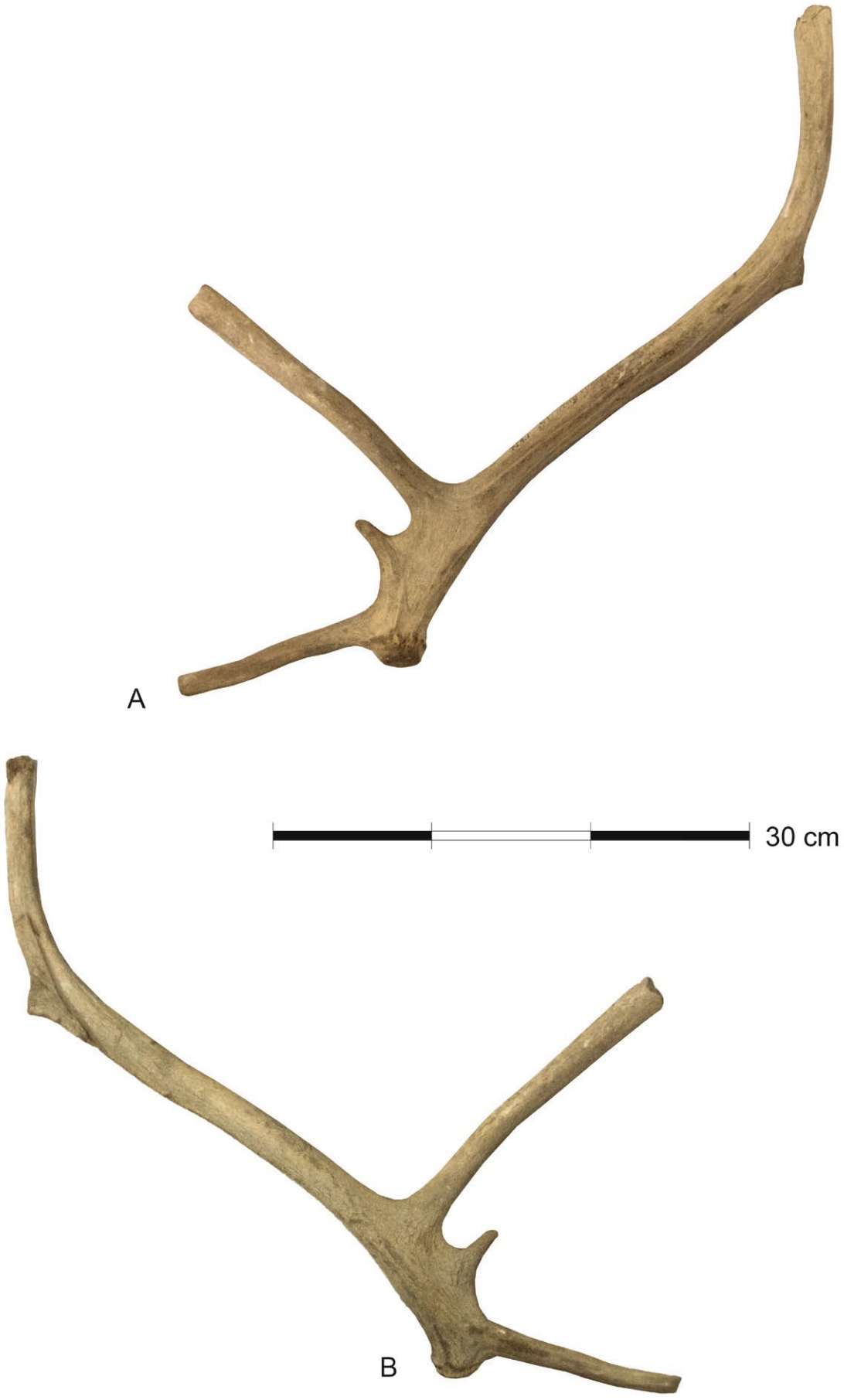

Plate 29. Stilling Mark SBM 1. A: lateral side; B: medial side.
Tafel 29. *Stilling Mark SBM 1. A: laterale Seite; B: mediale Seite.*

Plate 30. Store Vejleå A52667. A: anterior side; B: medial side.
Tafel 30. *Store Vejleå A52667. A: Vorderseite; B: mediale Seite.*

Plate 31. Storebælt LMR 8439:25. A: side a; B: side b.
Tafel 31. *Storebælt LMR 8439:25. A: Seite a; B: Seite b.*

Plate 32. Vejleby A21808. A: lateral side; B: medial side.
Tafel 32. *Vejleby A21808. A: laterale Seite a; B: mediale Seite.*

Lat/long (WGS84): 55.763386/11.88818
Raw material: Reindeer antler
Dimensions: l: 467 mm; w: 222 mm; pcb: 119.5 mm; dcb: 107.5 mm
Description: Right shed antler. Brow tine not preserved, bez tine and distal beam fractured. The center of the proximal side of the bez tine shows signs of recent damage. This modification covers the proximal tine and the beam between the bez tine and the brow tine. Most probably this resulted in the brow tine breaking off (Plate 32).

Locality, find circumstances & geo- and palynological observations: It was given to the National Museum of Denmark, Copenhagen in 1864. The cancellous bone was filled with clay.
Placed at: National Museum of Denmark, Copenhagen
Literature: Sarauw 1903, 303; Brøndsted 1938, Fig. 6a; Degerbøl & Krog 1959

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