SONJA B. GRIMM · BERIT VALENTIN ERIKSEN · SASCHA KRÜGER
TOBIAS REUTER · MARKUS WILD · MARA-JULIA WEBER

LATE GLACIAL OCCUPATION OF NORTHERN GERMANY AND ADJACENT AREAS. REVISITING THE ARCHIVES

Abstract

This contribution presents the status quo of research on the Final Palaeolithic occupation of Schleswig-Holstein. Over the last two decades new insights became possible based on isotopic, genetic, biostratigraphic, tephrochronologic, and archaeological analyses. Some of these projects and studies are still on-going. The material on which these analyses were performed was mainly uncovered during the 20th century. We particularly focus on the chronology and the different challenges associated with the Late Glacial record. To do so, we review the radiocarbon dating record of Schleswig-Holstein and adjacent areas, especially Denmark, including 11 new radiocarbon dates from the sites of Stellmoor and Meiendorf. At present, in particular, the period of the Federmessergruppen (i. e., curve-backed point industries) appears poorly represented in this record. This shortage is due to preservational conditions on the one hand, as well as the often uncertain attribution of osseous single finds to archaeological entities on the other. Hence, a synoptic analysis of osseous remains of Late Glacial northern Germany and southern Scandinavia is desirable.

The recently introduced partially laminated biostratigraphic lake sequence from Nahe LA 11 contains three cryptic tephra layers including the first geochemically identified evidence of the Laacher See Tephra in Schleswig-Holstein. The palynological analysis of this archive interlinks palaeoenvironmental with archaeological research questions. Amongst other implications, the data provided here suggest a continuity of human and reindeer presence in the area until the early Holocene. This result lines up with observations of shifting ecological zones throughout the Weichselian Late Glacial in Schleswig-Holstein.

Keywords

Schleswig-Holstein, Final Palaeolithic, Weichselian Late Glacial, chronology, osseous material

INTRODUCTION

At the MONREPOS Archaeological Research Centre and Museum for Human Behavioural Evolution Elaine Turner and Martin Street represented the well-established field of zooarchaeology to inform us about past human settlement and land use behaviour (Turner, 2004; Street et al., 2006; Street and Turner, 2013). Their studies in the Central Rhineland were made possible by the excellent preservation of organic material underneath the ignimbrites and pumices of the Laacher See volcanic eruption. The organic preservation further allowed for the establishment of a reliable chronology of the Late Glacial re-settlement of north-western central Europe after the Last Glacial Maximum (Street et al., 1994; Housley et al., 1997; Terberger and Street, 2002; Street and Terberger, 2004; Stevens et al., 2009; Fiedel et al., 2013). With the increasing industrial exploitation of the Laacher See pumice in the 1950s and 1960s, Late Glacial / Allerød surfaces were uncovered and thereby revealing archaeological remains from Late Magdalenian and *Federmessergruppen* (FMG) contexts which accordingly became a focus of research (Bosinski, 1979; Baales, 2002). Besides the excellent preservation conditions, these relatively recent discoveries also paved the way to apply modern standards of excavation, documentation, and archiving. These conditions allowed for some of the most

In: S. Gaudzinski-Windheuser · O. Jöris (Eds.), The Beef behind all Possible Pasts. The Tandem-*Festschrift* in Honour of Elaine Turner and Martin Street. Monographien des RGZM 157 (Mainz 2021). DOI: 10.11588/propylaeum.950.c12572

detailed insights into the reconstruction of Late Upper and Final Palaeolithic lifeways. Furthermore, the Laacher See volcano – like many of the volcanic craters in the Eifel volcanic field – has transformed into a maar lake. Laminated sequences from these natural sediment traps were used to build up a stacked record of Late Glacial climatic and environmental change, which is in large parts annually laminated (ELSA; Sirocko, 2016). Hence, for the Late Glacial and early Holocene periods, a detailed vegetation history with relevance for the wider region was also established (Litt and Stebich, 1999; Sirocko et al., 2016). These high-resolution records helped to contextualise the archaeological findings of the Central Rhineland. Researchers in other areas aimed to synchronise their records with these high-resolution archives through the use of archaeological comparison or by bio- or tephrochronology (Housley et al., 2013). The Laacher See tephra (LST) has been of particular interest as a short-term chronostratigraphic marker horizon (Litt et al., 2001; Blockley et al., 2008; Wulf et al., 2013).

Recently, the LST has been geochemically confirmed for the first time in Schleswig-Holstein (Krüger and van den Bogaard, 2021). In contrast to the Rhineland, research on the Late Glacial in Schleswig-Holstein has been more or less continuous since the 19th century, with numerous collections but few excavations and variable standards of documentation (Schwantes, 1923, 1928, 1933; Schwabedissen, 1944; Taute, 1968; see below). Hence, to understand the occupation history of the region and attempting to base this on a solid chronostratigraphic framework, this area offers a large amount of legacy data and all the challenges that come with it. In the last years, some new analyses were made, especially at the Centre for Baltic and Scandinavian Archaeology (ZBSA) and in the context of the subproject "Pioneers of the North" of the DFG-funded collaborative research centre 1266 "Scales of Transformation". The results allow new insights that are outlined in the following, with a focus on the Late Glacial chronology of Schleswig-Holstein, supplemented with data from adjacent areas.

RESEARCH HISTORY

The excavations of Alfred Rust and his interdisciplinary team in the Ahrensburg tunnel valley in the 1930s, 1940s, and early 1950s (**Fig. 1**; Rust, 1937, 1943, 1958) provide a first milestone in the Palaeolithic archaeology of Schleswig-Holstein. In these campaigns, Palaeolithic organic material uncovered from Late Glacial lake deposits included the oldest wooden arrows (unfortunately lost during World War II; cf. Hartz et al., 2019). Especially the excavations at Stellmoor (Ahrensburg LA[1] 78.1) provided the stratigraphic evidence that the Hamburgian preceded the Ahrensburgian. Furthermore, these technocomplexes were associated with the palynologically well-defined bio zones that were (later) named Meiendorf and Younger Dryas (i. e., Dryas 3) (Menke, 1968; cf. Krüger et al., 2020) and allowed for a first general chronostratigraphy. Following this pioneering work, few systematic excavations of Late Glacial material have been conducted in the Ahrensburg tunnel valley and in entire Schleswig-Holstein. This research will be shortly presented in the following.

In the late 1960s/early 1970s Gernot Tromnau excavated different concentrations of Late Glacial archaeological material on the sandy Teltwisch ridge in the Ahrensburg tunnel valley. This showed the potential for further excavations of Late Glacial organic material by corings and test trenches in nearby kettle holes (Tromnau, 1975). Besides Hamburgian and Ahrensburgian material, he also identified two small concentrations with FMG material. In the Vierbergen area in the northern part of the Ahrensburg tunnel valley,

1 LA = Landesaufnahme (register of prehistoric and historic artefacts and archaeological sites and monuments of Schleswig-Holstein).

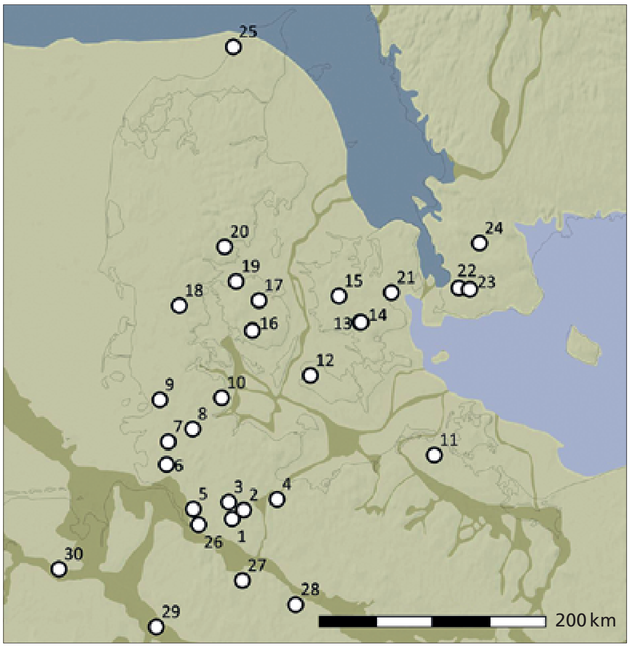

Fig. 1 Map of northern Germany and southern Scandinavia during GI-1c-a with major glacial valleys and drainage channels indicated (darker green) and sites mentioned in the text and the tables (map: www.epha.zbsa.eu – Allerød map with the addition of drainage systems). **1** Ahrensburg tunnel valley; **2** Lasbek; **3** Nahe; **4** Lüdersdorf; **5** Klein Nordende; **6** Eggstedt; **7** Schalkholz; **8** Alt Duvenstedt; **9** Ahrenshöft; **10** Klappholz; **11** Endingen; **12** Krogsbølle; **13** Trollesgave; **14** Fensmark Skydebane; **15** Bromme; **16** Arreskov; **17** Odense Kanal; **18** Slotseng; **19** Fogense Enge; **20** Tyrsted; **21** Køge Bugt; **22** Bara Mosse; **23** Hässelberga; **24** Mickelsmosse (Munkarp); **25** Nørre Lyngby; **26** Rissen; **27** Melbeck; **28** Grabow 15; **29** Hämelsee; **30** Querenstede.

east of the Borneck site (Ahrensburg LA 76), in 1985 Klaus Bokelmann could not find any archaeological remains in a 6-7 m deep survey trench and hence identified the limits of the concentration of Palaeolithic sites that he assumed was due to the geomorphology of the Late Glacial landscape (Bokelmann, 1996). In 2008 Ingo Clausen conducted a survey of test trenches and corings (Ahrensburg LA 78.2) to locate A. Rust's Stellmoor excavation trenches more precisely and to test if archaeological material was still present and preserved (Clausen, 2010). In January 2010, most of the Ahrensburg tunnel valley became a "Natura 2000" conservation area within the EU Habitats Directive (92/43/EEC) and the accompanying management plan prohibited any further penetration into the ground. However, in the context of the planned expansion of the railway line S4 through the Ahrensburg tunnel valley, further test pits and trenches on the mineral soils near Stellmoor (Stellmoor-Lusbusch, Ahrensburg LA 105, 160, 162, and 187), around Meiendorf (Ahrensburg LA 79 and 140), and into the Hamburgian area of the tunnel valley became possible in summer 2015 (Clausen and Guldin, 2016, 2017). These identified the limits of the accumulation of Late Glacial sites around Meiendorf, which was almost congruent with the modern border of the federal states of Schleswig-Holstein and Hamburg. Furthermore, corings in Late Glacial lake sediments south of Stellmoor (Ahrensburg LA 187-191) revealed the preservation of bone and antler material in an area larger than hitherto known. New palynological samples were taken during these efforts (Krüger, 2015) and, most importantly, Sascha Krüger could obtain access to the archival data of the region collected by Hartmut Usinger.

Outside the Ahrensburg tunnel valley, Hermann Schwabedissen's work in 1948 at the site of Rissen 14/14a to the west of Hamburg, where an Ahrensburgian horizon was underlain by a FMG horizon, clarified the chronostratigraphic sequence of the northern German Final Palaeolithic (Schwabedissen, 1954): The Hamburgian present during the Meiendorf period was followed by the FMG during the Allerød period and in turn was followed by the Ahrensburgian during the Dryas 3. In 1959, Wolfgang Taute excavated typical Ahrensburgian material associated with long and large blades in Eggstedt (LA 50), but only some material was recovered *in situ* as previous amateur excavations had disturbed the area (Taute, 1968). In 1960 he excavated Ahrensburgian material including a few faunal remains in an area of the Lieth Moor near Klein

Nordende (LA 2; Taute, 1968). South-west of this site, K. Bokelmann and the amateur Alfred Rasmussen uncovered several concentrations of FMG and faunal material in the 1970s (Klein Nordende LA 37: Bokelmann et al., 1983). In 2013, Ingo Clausen and Annette Guldin tested an area north-west of this and west of W. Taute's site because – over the course of several decades – collectors had reported (mainly) Ahrensburgian artefacts from there, and geologists had reconstructed Late Glacial wetlands in the vicinity. However, only fragmented stratigraphic sequences were found that showed significant movement of sediment due to various natural processes such as water level changes or cryoturbation. This was explained by the very complex geomorphological situation in the region that often included significant changes over short distances.
Furthermore, in 1970 another Hamburgian site was rescue excavated in a single day by A. Rust and G. Tromnau at the limits of a gravel pit near Schalkholz (LA 116; Tromnau, 1974). Nearby, Volker Arnold found a partially destroyed FMG concentration (Schalkholz LA 65) that was also uncovered in a rescue excavation by K. Bokelmann and Dieter Stoltenberg in late 1975 (Bokelmann, 1978). From the mid-1980s to the early 1990s I. Clausen and Sönke Hartz – excavating near Alt Duvenstedt – uncovered a total of nine Late Glacial concentrations of lithic material that in some cases centred around a still identifiable hearth (Clausen and Hartz, 1988; Clausen, 1995, 1996a; Kaiser and Clausen, 2005). Most assemblages were attributed to the FMG but two were of a very early Ahrensburgian origin (Clausen and Schaaf, 2015). In the mid-1990s two sites with Hamburgian material were excavated at Ahrenshöft in the context of a renaturalisation program (Clausen, 1997). Especially the site Ahrenshöft LA 73 has major relevance for the Late Glacial chronology as, for the first time, a horizon containing an inventory dominated by classic Hamburgian shouldered points was overlain by a horizon with mostly Havelte tanged points. Palynological analyses further showed that both horizons were deposited at different stages within the Meiendorf period (Usinger, 1997). In 2008 Mara-Julia Weber extended the excavation area at the Havelte concentration Ahrenshöft LA 58 D (Weber et al., 2010). Finally, the most recently identified area of finds is situated around the north-western outlet of the modern Lake Itzstedt where Thomas Poelmann had collected Ahrensburgian and Hamburgian material since 1986 (Nahe LA 11). In 2003, I. Clausen made some test trenches in the wetlands of the present-day Rönne valley and found some faunal material dominated by reindeer (Weber et al., 2011; Wild, 2017). I. Clausen's work was complemented by 68 sediment cores that H. Usinger took along and across the valley. The results of these corings helped S. Krüger to identify the basin of a former incision lake (palaeolake Nahe) and to locate the currently best Late Glacial environmental archive of Schleswig-Holstein. This was cored in October 2017 (Dreibrodt et al., 2021; Krüger, 2020; Krüger and van den Bogaard, 2021; Krüger et al., 2020). In addition, H. Usinger has left a large archive of palaeoenvironmental information from his coring campaigns in different locations throughout Schleswig-Holstein. This material is currently under revision.
In summary, most excavated sites with Late Pleistocene archaeology are clustered in seven find areas: the Ahrensburg tunnel valley, Rissen, Klein Nordende, Nahe, Alt Duvenstedt, Schalkholz, and Ahrenshöft. Therefore, most research was focused on these areas, making predictive modelling across most of Schleswig-Holstein rather difficult (Hamer et al., 2019). Furthermore, in total very few pieces of faunal material were found after the Ahrensburg tunnel valley excavations of the 1930s to 1950s, no further wooden artefacts could be detected. In addition, some mostly single faunal remains were collected during different dredging works. Hence, the material from A. Rust's excavations remained the most relevant assemblages and have been re-analysed on different occasions (Grønnow, 1985; Bratlund, 1990, 1996; Weinstock, 2000a, 2000b; Pasda, 2009; Wild, 2020). In contrast to the Central Rhineland, a documentation record that allows each artefact to be located precisely within the site is mostly missing; this is partially due to the excavation standards at the time and partially due to difficult excavation circumstances underneath the groundwater table (cf. Slotseng; Wild, 2020). The exclusive preservation of organic material in discard zones or as single finds

from waterlogged contexts makes the approach to understanding the occupation history and settlement behaviour through zooarchaeological analyses for the Final Palaeolithic of Schleswig-Holstein impossible. Nevertheless, especially in combination with palynological data, this material allows for further chronological considerations. In a few publications, radiocarbon dates from northern German sites were compiled and re-evaluated, in collaborations including researchers from both MONREPOS and Schleswig (Grimm and Weber, 2008; Riede et al., 2010; Weber et al., 2011). Based on these and on additional studies and analyses of the last decade, we will establish a more detailed chronology of the Final Palaeolithic of this region and discuss human-environment interactions during the Weichselian Late Glacial.

ARCHIVES

As the research history in Schleswig-Holstein encompasses more than 150 years, a wealth of material and data is known. It can roughly be divided into two categories: on the one hand the actual material that was collected from surface surveys or during excavations and coring programs, and on the other hand the documentation and reports of such activities or materials. Archaeological sites in Schleswig-Holstein including those of single finds are reported in the register of prehistoric and historic artefacts and archaeological sites and monuments of Schleswig-Holstein (*Landesaufnahme*, see footnote 1). This collection of sites, their location, reports about their discovery, and description of the identified features and archaeological material is maintained at the Archaeological State Office Schleswig-Holstein (*Archäologisches Landesamt Schleswig-Holstein*: ALSH). The actual archaeological material as well as the documentation that does not remain with the collector is archived at the State Museum for Archaeology in Schloss Gottorf (*Museum für Archäologie*: MfA). These archives allow queries on authenticity, spatial and chronological attribution, and different new approaches, but they also require different lines of source criticism. Many of the archaeological excavations and collections and / or their documentation do not conform to modern standards. Before the reliability of the data can be assessed, meticulous comparisons with the old documentation and the results of modern analytical methods and techniques are necessary so that further information from the material can be extracted (e. g., Groß et al., 2021; Hinrichs, 2020).

For the identification of potential taphonomic processes and possible palimpsests, more precise documentation of the context and location of artefacts is necessary. However, this is rarely available for older excavations. For instance, A. Rust recorded the spatial position of artefacts in two dimensions only during his later excavations, and only on a square metre basis (Rust, 1958). Although there are some uncertainties with the available coarse-grained 2D spatial information, it does allow some testing of the integrity of assemblages and implications for understanding settlement behaviour (Hinrichs, 2020). A general outline of the stratigraphy is also usually given and frequently accompanied by a palynological analysis allowing insights into the chronostratigraphic development of the site. 3D documentation of artefact positions and of higher resolution stratigraphic data became standard much later in Schleswig-Holstein, but proved that many of the sites studied with these refined methods were affected by complex geomorphological processes (Bokelmann et al., 1983; Kaiser and Clausen, 2005; Wild, 2017).

Usinger's palaeoenvironmental archive – comprising the documentation of analysed stratigraphic sequences – includes information on their location, counting sheets of the samples taken from these sequences, as well as occasional personal comments. In general, remains of the sediment cores or samples are preferably stored in cooling chambers, while prepared samples (such as the material from palaeolake Nahe) are stored in the archives of the respective laboratories.

RECENT CONTRIBUTIONS TO LATE GLACIAL CHRONOLOGY AND ARCHAEOLOGY

The general stratigraphic succession of the Palaeolithic archaeological units in Schleswig-Holstein has been known for over 70 years (see above research history); also, the vegetation history of the region has been well established for several decades (Usinger, 1985). Yet the biostratigraphic terminology occasionally causes some confusion and discussion. For the Rhineland, this was settled by the definitions based on the nearby maar sequences from the Eifel (Litt and Stebich, 1999), whereas in northern Germany and especially in Denmark the use of the term Bølling remained controversial, depending on which part of Iversen's classical palynological definition (Iversen, 1942) was used: "the first spread of tree birch" in the sense of a "biozone" (Usinger, 1978, 1985) or "the temperate climatic oscillation that preceded the Allerød" in the sense of a "chronozone" (Krüger and Damrath, 2020). Hence, in the following the INTIMATE event stratigraphy with its recognition of Greenland Stadials (GS) and Interstadials (GI) will be used in a chronozone and event stratigraphy approach (**Tab. 1**; Rasmussen et al., 2014). In a recently published article about a sequence from the Lake Bølling type locality (Krüger and Damrath, 2020), one of the authors highlighted the problem of the double characterisation of Bølling that was previously addressed (Usinger, 1997; De Klerk, 2004). Nevertheless, with the new stratigraphy from the palaeolake Nahe, some new considerations about the development of the biozones in Lower Saxony, Schleswig-Holstein, and southern Denmark became possible (Krüger et al., 2020). Inter-regional comparison of three high-resolution palaeoenvironmental archives from these regions showed different onsets, durations, and appearances of woodland phases shifting from south to north (Krüger et al., 2020: fig. 7). This puts Schleswig-Holstein in a transitional zone for most of the Late Glacial, making precise palaeoenvironmental studies accompanying archaeological research important tools for locating the sites not only chronologically but also ecologically. Furthermore, it indicates that chrono- and biozones must be clearly differentiated when discussing this area.

The record of palaeolake Nahe comprises a robust age-depth model based on radiocarbon dates, three crypto-tephra layers including the first geochemical finger-print of the LST from the region (Krüger and van den Bogaard, 2021), and a laminated section covering the period of GI-1c_3 to GI-1a (Dreibrodt et al., 2021). The palaeoenvironmental data from the palaeolake Nahe reflects the developments in southern Schleswig-Holstein with relevant find areas such as the Ahrensburg tunnel valley, Klein Nordende, the immediate surroundings of the palaeolake itself, and the Hamburg area of Rissen. Based on lithological, geochemical, and palynological data, the Dryas 3 biozone has been bisected in this stratigraphy into an upper, more humid, and a lower, drier part at around the fallout deposition of the Islandic Vedde Ash (Krüger et al., 2020), a distinction that was already observed in other archives (Overbeck, 1975; Bakke et al., 2009; cf. Weber et al., 2011). Although the generally accepted development of the vegetation in Schleswig-Holstein is confirmed by the palaeolake Nahe sequence, the development within the biostratigraphically defined Allerød period can be further refined here. Furthermore, the Meiendorf period proves to be more complex than generally considered. When comparing the onset of these biozones to the onsets in the western German Meerfelder Maar (Litt and Stebich, 1999) with the chronozones based on the current INTIMATE event stratigraphy (Rasmussen et al., 2014), we find offsets that can only partially be explained with the successive ecological reaction to general climatic changes, reflecting the complexity of regional environmental transformations (Krüger et al., 2020). Yet, the palaeolake Nahe sequence also demonstrates that charcoal particles and non-pollen palynomorphs (NPPs) can help answering archaeological questions (Krüger, 2020).

The palaeoenvironmental studies were embedded in the previously mentioned large scale cooperation project (CRC 1266), in which also some archaeological and genetic studies were accomplished (Burau, 2019;

Palaeolake Nahe			INTIMATE event stratigraphy	Meerfelder Maar		
Palynological characteristics of NAH PAZ lower boundaries	Age estimate for boundaries **[yrs cal BP]**	NAH bio-stratigraphic terminology	Mean Age for boundary **[yrs cal BP]**	MFM bio-stratigraphic terminology	Age estimate for boundaries **[varve yrs BP]**	Palynological characteristics of MFM PAZ lower boundaries
Betula pub.-type ↑, Filipendula, Typha lat.-type ↗ Poaceae, Artemisia, Empetrum, other NAP-types ↘		Preboreal	Holocene	Preboreal		Betula, Pinus ↑, Juniperus ↓, NAP-types ↓
	11,560 *		**11,653**		**11,590**	
Betula pub.-type ↘, B. nana-type ↗ Poaceae, Artemisia, other NAP-types ↗		Dryas 3	GS-1	Younger Dryas		Betula, Pinus ↓, Salix ↑ NAP-types ↑
	12,540		**12,846**		**12,680**	
Betula pub.-type ↗, Juniperus ↘ Poaceae, other NAP-types ↘		Allerød 3	GI-1c_1-1a	Allerød		Pinus, Filipendula ↑ NAP-types, Artemisia ↓
	13,610		**13,550**		**13,350**	
Betula pub.-type ↘, Juniperus ↗ Poaceae ↗		Allerød 2/ Dryas 2	GI-1c_2	Older Dryas		Betula ↓ Artemisia ↑
	13,710		**13,610**		**13,650 ****	
Betula pub.-type ↑, Hippophaë ↗ Poaceae, Helianthemum ↘		Allerød 1	GI-1c_3	Bølling		Betula ↑ NAP-types, Artemisia ↓
	13,830		**13,904**		**13,780 ****	
Hippophaë, AP ↘ Poaceae, Helianthemum, Rumex acet.-type ↗		Dryas 1	GI-1d	Oldest Dryas		Betula, Salix ↓ NAP-types ↑
	13,940		**14,025**		**13,910 ****	
Pinus ↘, Betula pub.-type, B. nana-type ↗ Artemisia, Hippophaë ↗		Meiendorf	GI-1e	Meiendorf	end of lamination: **14,560 ****	Pinus ↓, Betula, Salix, Juniperus ↑
	14,510		**14,642**		unknown	
		Pleniglacial	GS-2.1	Pleniglacial		

Tab. 1 Comparison of terminology and age estimate of the Meerfelder Maar (MFM; Litt and Stebich, 1999: Tab. 2), the Palaeolake Nahe (NAH; Dreibrodt et al., 2021: Tab. 2 modified according to Krüger et al., 2020 for boundaries and terminology), and the INTIMATE event stratigraphy (Rasmussen et al., 2014). PAZ Pollen assemblage zones.
* age estimate (varve yrs cal BP; cf. Merkt and Müller, 1999) used to create present age- depth modelling.
** original age estimates of Litt and Stebich (1999) have been shifted by 110 years to the older, considering a hiatus according to Brauer et al. (2001).

Hamer et al., 2019; Grimm et al., 2020; Hinrichs, 2020). Additionally, a number of dissertations and smaller cooperation projects increased our knowledge of the Late Glacial in the last decade (Rivals et al., 2020; Wild, 2020; Wild et al., in press). Results from all these projects are combined in the following overview.

Classic Hamburgian / Havelte Group

The available radiocarbon dates have been discussed in a previous review of the Hamburgian (Grimm and Weber, 2008). Since then 20 new radiometric results have been obtained in the course of various projects (**Tab. 2**). Five additional dates on worked reindeer antler (**T2: 15-17, 19-20**[2]) confirmed the thus far accepted dating range for the Meiendorf site (Ahrensburg LA 79) in an early phase of GI-1e, which cannot be defined chronologically more precisely due to a radiocarbon plateau during this interval (Wild, 2020). Two new results (KIA-53517; KIA-53518; **T2: 12-13**) obtained on petrous bones in the framework of a genetic study of reindeer confirm this picture and even extend the dating range into GS-2.1, whereas a third one (KIA-53519; **T2: 21**) prolongs the range to mid-GI-1e (cf. **Tab. 1**), which corresponds to the occupation of the neighbouring Poggenwisch site (Ahrensburg LA 101 and 137; Wild, 2020). The genetic study considerably enlarged the radiocarbon record for Stellmoor by seven new dates (**T2: 3-9**), which, when calibrated, show a similar distribution to the dates from Meiendorf. Another five measurements were made on reindeer bones attributed to the classic Hamburgian sites of Stellmoor (n = 3) and Meiendorf (n = 2), but produced dates that fall into the Ahrensburgian (**T2: 47, 50, 52, 69-70**; cf. Rivals et al., 2020; see below Ahrensburgian). Hence, in total we currently know of 61 dates that are associated with the Hamburgian in Schleswig-Holstein, of which 32 appear to be reliable (cf. Pettitt et al., 2003).
In Denmark, two further dates were obtained on a modified reindeer antler and bone dredged from the Køge Bugt, where another worked reindeer antler had already been found that was dated to the Hamburgian (**Tab. 3**; Fischer and Jensen, 2018; Wild, 2020). The new date on the antler from the Køge Bugt (AAR-18732; **T3: 13**) is very similar to the previous one (AAR-1036; **T3: 14**), and the date on a reindeer bone (AAR-18733; **T3: 12**) is only slightly older. Both dates support a presence of hunter-gatherers in eastern Denmark during the second half of GI-1e. Altogether 13 radiocarbon dates are published and judged as reliable for the Hamburgian in Denmark mostly coming from Slotseng in eastern Jutland (n = 10; Grimm and Weber, 2008). In addition to the radiocarbon dates, the excavation of the new site Krogsbølle – containing material attributable to the Havelte Group – substantiated the corpus of Havelte Group material in Denmark (Riede et al., 2019). After correction of the marine reservoir effect, a gull (*Larus* sp.) from a palaeolake adjacent to Krogsbølle dates to GI-1e, but cannot be linked to human activity (AAR-17464: 12,710 ± 55 ^{14}C-BP; Riede et al., 2019).
In sum, the calibrated radiocarbon dates for the Hamburgian indicate that hunter-gatherers visited the area of Schleswig-Holstein throughout GI-1e and GI-1d. According to isotope analyses on reindeer bone and micro-wear analyses on reindeer molars from Meiendorf and Stellmoor, the GI-1e environment of these animals presented little soil maturation and provided limited lichen availability, but more than in other European regions (Drucker et al., 2011; Rivals et al., 2020). The Havelte Group occupation at Ahrenshöft LA 58 D may even be attributed to GI-1c_3, which would correspond to the palynological characterisation of the occupation layer confirmed by analyses in 2008 and 2009 (Weber et al., 2010). Nevertheless, the calibrated date (AAR-2784; **T2: 32**) also spans into GI-1d and the site underwent considerable post-depositional processes.

2 References to specific radiocarbon dates listed in **Table 2** and in **Table 3** are referred to in the following format: **T2/3: #ID#**, where it is specified whether **Table 2** or **Table 3** are meant, followed by the reference to the ID(s) within that table.

At a chronological micro-scale, the combination of zooarchaeological and technological observations on different Hamburgian sites and on the French Magdalenian site of Verberie led to a model of hunter-gatherer economy and settlement throughout different phases of the autumn season (Wild, 2020).

Federmessergruppen (FMG)

The number of radiocarbon dates associated with the FMG in Schleswig-Holstein is limited (n = 12). Some dates have previously been revised, highlighting the frequently problematic association of the dated material and the archaeological remains (Riede et al., 2010). In total, only eight dates can be associated with human occupation during the time of the FMG (**Tab. 2**). The uncertain association with the FMG is partially due to the generally limited and/or poor preservation of organic material from this period and the subsequent lack of identified human modification of the material, and partially due to the lack of knowledge about what happened to the Hamburgian groups as well as about how the Brommean and Ahrensburgian developed. Only charcoal from Alt Duvenstedt LA 120 b (AAR-2244; **T2: 38**) was found in association with lithic material (Kaiser and Clausen, 2005); a bone sample from the same site lacked collagen and resulted in a much too young age (AAR-2243-3: 4,420 ± 70 ^{14}C-BP; Kaiser and Clausen, 2005), and was consequently excluded from our compilation.

The faunal material from Borneck was mostly recovered in wetland excavations adjacent to the site where Hamburgian, FMG, and Ahrensburgian material had been excavated (Rust, 1958). Although the dated specimens from box trench ("*Kammer*") III display no cut-marks, their position near the accumulation of archaeological remains at Borneck suggests a connection to human activities, yet a natural origin (background fauna) cannot be excluded. The dates (Riede et al., 2010) rule out an attribution to the Ahrensburgian but an association of a reindeer humerus (KIA-33949; **T2: 36**) with a very late Hamburgian is still possible though not likely (see above Classic Hamburgian/Havelte Group). Rudolf Schütrumpf conducted a palynological analysis of the stratigraphy in this trench and attributed the lower horizon from which the faunal material originated to the Older Dryas period (Rust, 1958: 88; Allerød 2/Dryas 2 according to: Krüger et al., 2020; **Tab. 1**). This attribution fits well with the calibrated results but makes an attribution to the late Hamburgian very unlikely (see above).

For Klein Nordende LA 37, the fish remains seem to form part of a natural thanatocoenosis (Benecke and Heinrich, 2003), and the previously dated twigs (**T2: 33-34**) also reflect a natural event that was stratigraphically correlated with the lower archaeological deposits of the area CR (Bokelmann et al., 1983). However, the stratigraphy in the area of Klein Nordende is highly complex not only due to halokinetic processes but also due to soil creep and displacing of layers due to changing water levels, sediment admixture at the banks, freezing and thawing processes. Hence, the relation of the dated samples to the archaeological material remains uncertain but likely determines a *terminus post quem* for the human presence at the locality (cf. Riede et al., 2010). Hence, only the cut-marked elk bone from the Allerød gyttja in the area D unambiguously dates human activity at Klein Nordende (KIA-33951; **T2: 35**), but in this area no lithic archaeology was found, potentially allowing its attribution to the FMG or to the early Ahrensburgian. A conventional radiocarbon date (Y-442: 11,220 ± 350 ^{14}C-BP; Barendsen et al., 1957) from the site of "Lieth" (i. e., Klein Nordende LA 33) was obtained from a peat sample but was excluded from the study for technical reasons, although the top of the dated peat-lens within dune deposits produced a curve-backed point indicative of a FMG context. Certainly, the area of the Lieth Moor around Klein Nordende was visited repeatedly during the Late Glacial by different groups, but in order to reconstruct the settlement history more radiocarbon dates would be required.

Outside of Schleswig-Holstein, five dates were measured in the late 1950s on samples from the Rissen area in Hamburg that is known for its FMG material. Unfortunately, the association of the sample material with the archaeology remained uncertain and the results are technically questionable. Moreover, two samples were dated from Grabow 15 (T3: 15-16), which is located near to the well-known site of Weitsche (Veil and Breest, 2002; Veil et al., 2012), and yielded some evidence of amber working and amber artefacts besides a rich FMG assemblage (Tolksdorf et al., 2013). The Grabow samples originated from archaeological features associated with FMG artefacts similar to the lithic material found in Weitsche (Tolksdorf et al., 2013). The sedimentation as well as the palynological analysis suggests that the site dates to the transition from the Dryas 1 to the Allerød period. This attribution matches with the calibrated ages. The dates are slightly older than the dates correlated with the lower horizon of Klein Nordende CR and, hence, represent the earliest FMG in northern Germany. Two dates on bulked samples of cremated bones from Weitsche are slightly younger. The younger date (T3: 18) had a sufficient amount of carbon preserved (5.2 mg), whereas the older date (T3: 17) yielded small amounts only (0.5 mg). But the very similar results indicate no significant source of contamination affected the samples. Both dates further support the presence of FMG in northern Germany during this period.

In total, the FMG radiocarbon record reflects discontinuous settlement in northern Germany and Schleswig-Holstein. However, the appearance of this discontinuous record may result from the poor preservation of datable material from this period. This contrasts with the amount and the distribution of sites associated with FMG material; both suggest a wide extent over a period of noticeable duration. Additionally, the major results of a modelling approach indicate that the FMG were rather well established in their local environments (Hamer et al., 2019), from which we can cautiously conclude that they knew their environments well, supporting a more continuous presence in the landscape. In contrast, the number of Danish FMG (lithic) assemblages is small. Association of lithic assemblages with radiocarbon dates is not given in a single case (Pedersen, 2009; Petersen, 2009). Hence, this could well reflect the only occasional presence of FMG groups in this area (Eriksen, 2000, 2002).

Furthermore – due to their radiocarbon dates pointing into the Late Glacial Interstadial – two artefacts made of reindeer antler have to be mentioned in the context of the FMG occupation of the region: the double bevelled point from Lasbek LA 14 (T2: 73; Wild and Weber, 2017; ZooMS-determination by Th.T.Z. Jensen) and the so-called antler axe (Lyngby type artefact) from Klappholz LA 63 (T2: 72; Clausen, 2004). However, the technological habitus in which these specimens were made resembles other Final Palaeolithic technocomplexes, namely the Hamburgian in the case of the Lasbek piece (Wild and Weber, 2017), and the Brommean or Ahrensburgian for the Klappholz specimen (Clausen, 2004).

This discrepancy may suggest (i) problems with the radiometric results, (ii) that our current knowledge about the presence of the various archaeological entities is incomplete, or (iii) that the osseous industry may have developed asynchronously to the lithic industries. The first aspect does not appear very likely in view of increasingly rigorous protocols at the radiocarbon laboratories. That our knowledge is incomplete should become apparent in this contribution and also the desideratum for osseous studies from Late Glacial northern Germany and southern Scandinavia. In fact, several other osseous artefacts were dated to this overlapping period of the FMG, the Brommean, and, possibly, the early Ahrensburgian.

For Denmark, some further dates in this age range need to be discussed in this context (Tab. 3), although the sampled material is usually associated with the Brommean. In particular, results from Nørre Lyngby were frequently mentioned in this context, since one of the first Bromme points was found and described from this site; also the eponymous Lyngby antler artefact has been defined at this locality (Eriksen, 1999; Fischer et al., 2013a; cf. Petersen, 2021). However, these finds were not made together and, although the new palaeontological investigation focused on the same freshwater deposits, there is no established connection with the

previous artefact finds. From the new investigations, only one specimen showed traces of possible human modification and was dated to the GI-1c_1 (AAR-1511; **T3: 28**; Aaris-Sørensen, 1995). The original Lyngby antler artefact dates to the early Holocene (AAR-8919: 9,110 ± 65 ^{14}C-BP), which is comparable to the antler artefact from the Swedish Bara Mosse (OxA-2793: 9,090 ± 90 ^{14}C-BP; Larsson, 1996; Fischer et al., 2013a); yet, both were subject to contamination with conservation material and considered as potentially too young. The date from Arreskov (OxA-3173; **T3: 32**) was made on a single find of a reindeer antler artefact (Fischer, 1996). It dates slightly later than the Brommean dates from Denmark (see below). The slightly older Lyngby antler artefact from Odense Kanal (AAR-9298; **T3: 30**; Stensager, 2006) dates close to the dates from Alt Duvenstedt LA 121 (AAR-2245-1; AAR-2245-2; **T2: 40-41**) and 123 (AAR-2246; **T2: 39**) and, hence, could be viewed in an early Ahrensburgian context. The bone point from Fogense Enge (AAR-15025; **T3: 31**) dates between these two implements (Petersen, 2021), and can also be discussed within FMG, early Ahrensburgian as well as Brommean contexts (Jensen et al., in prep). An antler club from Mickelsmosse in southern Sweden (OxA-2791; **T3: 29**) was dated to a similar period as the Odense Kanal specimen (Larsson, 1996), but – due to its geographical position – should rather be discussed within the Brommean.
This short review reveals some important points: firstly, reindeer seems to have been used as a resource throughout the Final Palaeolithic, thus revising a long obsolete picture of FMG as only elk hunters (Clausen, 2004; Riede et al., 2010, Wild and Weber, 2017; Weber and Wild, 2019). Further, newly dated reindeer antler artefacts suggest that in Denmark reindeer antler may even have been used predominantly as osseous raw material during the Allerød (Wild et al., in press). Secondly, the transitional character of the environment in Schleswig-Holstein and southern Scandinavia may have played a role in the potential co-occurrence of groups adapted to different environments (cf. Eriksen, 2000, 2002; Mortensen et al., 2014; Burau, 2019; Krüger et al., 2020).
Moreover, in northern Germany and southern Scandinavia, remains of giant deer (*Megaloceros giganteus*) were found occasionally (Bratlund, 1993; Street, 1996; Aaris-Sørensen and Liljegren, 2004), and at least the northern German specimens from Lüdersdorf (Bratlund, 1993) and Endingen, Horst VI showed traces of human modification (Street, 1996). Both were directly dated but the Lüdersdorf date (OxA-3615: 11,600 ± 105 ^{14}C-BP; Hedges et al., 1993) might be subject to technical problems (column resin bleed; Burky et al., 1998) and – as the δ^{13}C value was considerably low for Late Glacial giant deer – this date has been rejected. The Endingen date (ETH-13585; **T3: 27**) fell well within GI-1c_1; hence, giant deer was probably also a prey of the Final Palaeolithic hunters as an increasing number of identified Late Glacial specimens suggest (Immel et al., 2015; Baales et al., 2019). However, the cultural association remains also a matter of debate for these finds. Furthermore, we do not yet know enough about the variability and development of the lithic technology of the FMG in Schleswig-Holstein to be certain about the distinction to the material of the late Hamburgian, the Brommean, and early Ahrensburgian. Currently this desideratum is approached by an on-going dissertation (Reuter, in prep.). Only a better understanding of this chronologically intermediate group will facilitate more precise interpretations of the cultural developments during the Late Glacial in northern Germany and southern Scandinavia.

Brommean

The Brommean forms the most uncertain archaeological unit in Schleswig-Holstein. Although large Brommean points are well known from this region, their relation to the FMG assemblages remains unclear. Inventories that were stratigraphically attributed to the Allerød period and thought to represent the Brommean or FMG in Alt Duvenstedt (LA 85, 86, and 89; Clausen and Hartz, 1988; Kaiser and Clausen, 2005: fig. 2) became subject to discussion when very early Ahrensburgian material was found in Allerød sediments of the same site (LA 121 and 123). Besides the lack of knowledge about the variability of the FMG (see above), the small numbers of datable material from archaeological sites limits our understanding of the presence and possible development of the Brommean in Schleswig-Holstein. Due to these uncertainties, there are no ^{14}C-dates that are reliably connected with the Brommean in the region, and we cannot reach conclusions regarding their presence and/or duration (see above FMG).

In contrast, Brommean presence and preferences are well established in Denmark (Eriksen, 1991, 1999, 2000; Mortensen et al., 2014), but the development there also remains a matter of debate (Eriksen, 2002). Although single finds of the prominent Bromme tanged point may result in a biased picture of the settlement activity, the number of reliable settlement sites remains significant (cf. Eriksen, 1999; Fischer et al., 2013b). The small number of radiocarbon dates (n = 6) originates from only three, geographically close Brommean sites (Bromme, Fensmark Skydebane, Trollesgave; cf. Fischer et al., 2013b). A further sample of a reindeer antler fragment from Bromme lacked collagen and delivered no result (AAR-4538; Heinemeier and Rud, 2000).

In addition, reindeer antler material was found near Tyrsted in a kettle hole in a well-preserved Late Pleistocene/Early Holocene palaeoenvironmental sequence with lithic material that was partially washed in from a small concentration on the north-western shore of the kettle hole (Borup and Nielsen, 2017; Eriksen et al., 2018). The lithic material can be attributed to the Brommean. Some characteristics of the archaeological material may already suggest a very late date and possibly displays even Ahrensburgian resemblance. Geophysical investigations have shown additional kettle holes in this area with high potential for Late Glacial archaeology (Corradini et al., 2020). Palaeoenvironmental and archaeological analyses are still on-going.

The limited amount of datable faunal remains and the lack of information on osseous typo-technology restricts the insights in Denmark as in Schleswig-Holstein. A project on reindeer in Denmark during the ice age aimed to revisit the faunal material and to record and study the potential human modifications. This project increased the corpus of modified osseous material significantly (Wild et al., in press).

The reliable dates assigned to the Brommean span a relatively short period. Compared to the considerable number of Brommean sites over most of Denmark (Eriksen, 1999), this would speak for intensive settlement activities and/or a particularly well-preserved section of the Late Glacial. In light of the generally difficult preservation conditions for this period, such an interpretation appears highly unlikely. Moreover, the samples of the few reliable dates come from one region only and possibly represent just one stage of a longer development (Fischer et al., 2013b). However, the numerous Brommean sites indicate the first established settlement of southern Scandinavia.

Ahrensburgian

In total we currently know of 44 dates that are associated with the Ahrensburgian in Schleswig-Holstein. Of these we consider 32 dates to be reliable (**Tab. 2**).

In comparison to a previous evaluation (Weber et al., 2011), eleven more dates can be attributed to the Ahrensburgian in Schleswig-Holstein. Three measurements were carried out on mammal bones from species other than reindeer recovered at Stellmoor: a date on bison (KIA-3331; **T2: 62**; Benecke, 2004) was overlooked in the previous evaluation, a date on elk (KIA-51382; **T2: 56**; Wild and Weber, 2017) was obtained in order to check if the remains of this species are intrusive into the Ahrensburgian horizon or not (cf. Bratlund, 1999), and a date on horse (KIA-48960; **T2: 54**; Drucker et al., 2016; Rivals et al., 2020) was made in the context of a project on understanding Late Glacial reindeer migrations. The remaining new dates on reindeer also originate from this project (**T2: 46-49, 51-52, 61**; Rivals et al., 2020) as well as from ongoing genetic studies (**T2: 50**). Four Ahrensburgian dates (**T2: 46-49**) confirmed a date which was produced at Yale University during the early years of the development of the radiocarbon method (Y-159.2: 10,320 ± 250 ^{14}C-BP; Barendsen et al., 1957), which is not considered here due to its large standard deviation but which points to Ahrensburgian presence in Stellmoor at around the middle of GS-1.

Five further samples from Stellmoor (n = 3; KIA-48959; KIA-53523; KIA-47378; **T2: 47, 50, 52**) and Meiendorf (n = 2; KIA-46301; KIA- 47380; **T2: 69-70**) were attributed to the classic Hamburgian but resulted in Ahrensburgian dates (cf. Rivals et al., 2020). In Stellmoor this can be explained by the mixture of material during its recovery or during the following storage period. However, no younger horizon has been suggested for Meiendorf thus far, although a barbed point from the pond has been discussed as an Ahrensburgian specimen (Tromnau, 1992). This attribution is further strengthened by different studies indicating that various bone point types that were previously attributed only to the Mesolithic seem to have a longer tradition and to originate in the Final Palaeolithic (Cziesla and Pettitt, 2003; Groß et al., 2020). Wild (2020) showed that collagen was preserved in the aforementioned barbed point from the site of Meiendorf, but in contrast to other faunal remains from the site the collagen yield was so low that currently a too large sample would be necessary to date the specimen directly. Another sample from Meiendorf was previously considered as a falsely labelled specimen from the Stellmoor site when it was dated to the Ahrensburgian (K-4330; **T2: 71**; Fischer and Tauber, 1986; Weber et al., 2011). Yet, this date and the two additional Ahrensburgian dates from Meiendorf as well as the barbed point could alternatively indicate that the Meiendorf pond preserved a second, younger archaeological horizon which remained undetected during the early excavations.

In the context of Ahrensburgian chronology, a series of seven radiocarbon measurements intended to determine the age of two potential arrow shaft fragments found in A. Rust's legacy need to be mentioned (Meadows et al., 2018). As their provenance remains unknown and both items have been contaminated with consolidants, the dates cannot serve as evidence for the Ahrensburgian settlement. The oldest and reliable results of the seven dates (KIA-49753: 10,050 ± 90 ^{14}C-BP; KIA-49754: 9,915 ± 45 ^{14}C-BP; Meadows et al., 2018) fall into the range of the accepted Ahrensburg dates obtained from faunal remains.

At Nahe LA 11, four radiocarbon dates indicate the presence of Ahrensburgian hunters at both the beginning and the end of GS-1 (Weber et al., 2011). Continued human presence into the Preboreal period is indicated from sediment cores retrieved in the vicinity of the archaeological site within the palaeolake (Krüger, 2020; Krüger et al., 2020). This indication consists of charcoal particles most likely to originate from anthropogenic fires at the shores of the lake. The situation at Nahe thereby corresponds to that at Poggenwisch where reindeer remains were found in peat attributed to the Preboreal period (Herre and Requate, 1958), and to that at Stellmoor where the uppermost Ahrensburgian horizon can be associated with the early Preboreal period on the basis of the partly revised biostratigraphy (Krüger, 2020). In addition, the Stellmoor radiocarbon dates confirm a continuation of the Ahrensburgian into the early Holocene, and a comparison of Ahrensburgian and Mesolithic radiocarbon dates shows that in northern Germany the transition between the two archaeological entities only occurred at the end of the GH-11.4 ka event (Grimm et al., 2020). Considering all reliable radiocarbon dates for Schleswig-Holstein, the presence of Ahrensburgian groups from possibly as early as GI-1b throughout GS-1 into GH-11.4 can be suggested.

The most restrained explanation for the continuation of the Ahrensburgian into the early Preboreal would lie in the development of favourable feeding conditions for reindeer during this period. For GS-1, the results of isotope and micro-/meso-wear analyses of reindeer remains suggest that a tundra landscape with a considerable amount of lichen was present in southern Schleswig-Holstein (Drucker et al., 2011; Rivals et al., 2020). At the onset of the Preboreal period, an increasing availability of young birch shoots can be observed in the Nahe record, where they coincide with maximum values of coprophilous fungal spores (originating from fungi that germinated on reindeer feces). This coincides with the highest frequency of larger charcoal

particles indicative of local anthropogenic fires (Krüger, 2020), leading to the hypothesis that longer seasonal stays of reindeer herds led to the intensification of human presence at the site.
Groups classified as Mesolithic due to techno-typological criteria seem to have established earlier in Denmark than in Schleswig-Holstein (Jessen et al., 2015; Jensen et al., 2020). However, the Ahrensburgian technological tradition has continued in the osseous material adapted to different faunal species (Wild et al., in press).
At an annual scale, seasonal migrations in east-west direction of the reindeer hunted at Stellmoor and Meiendorf are suggested on the basis of further isotope analyses carried out within the abovementioned reindeer project (Price et al., 2017). An even smaller temporal scale was aimed at by attempts to refit the lithic material from two neighbouring Ahrensburgian units at Borneck. The analysis showed, however, that a contemporaneous occupation of both units under study can be excluded (Hinrichs, 2020).

CONCLUSION

If we focus on the chronological indications of the material and their relation to human activity, we can identify the presence of humans throughout most of the Late Glacial in Schleswig-Holstein and their frequent presence in Denmark. However, if we try to link the dating evidence to specific technocomplexes defined on the basis of lithic material (Hamburgian, FMG, Brommean, Ahrensburgian), we clearly see the limits of our legacy data and single finds. For several sites in Schleswig-Holstein we must admit that much desirable information is forever lost with respect to old excavations or collections. Nonetheless, material studies of this old material are still possible and new analyses show the potential of these old finds to speak for themselves beyond chronological considerations. Furthermore, the surveys showed that at a site such as Stellmoor more material is still preserved in the ground. Although hydrological changes and interventions occasionally lead to the destruction of archaeological organic remains which had preserved until now (e.g., Star Carr, Satrup), demanding archaeological rescue, so long as natural protection remains high and the hydrology of this area is monitored, the archaeological remains seem well protected and waiting for future investigations requiring only minimal invasive and destructive measures.
The lack of additional data makes it difficult to correlate archaeological and palaeoenvironmental data. The need of this correlation becomes particularly relevant in transitional areas of different ecological zones such as in Schleswig-Holstein during the Late Glacial. A potential step forward for bringing together the palaeoenvironmental and archaeological data lies in the examination of additional charcoal particles, as the palaeolake Nahe data showed (Krüger, 2020). The observation of shifting ecological zones implies that in different parts of Schleswig-Holstein different habitats existed contemporaneously during the Late Glacial, which might explain observed temporal overlaps of different technocomplexes, such as the Hamburgian in northern Schleswig-Holstein and the FMG in southern Schleswig-Holstein (Burau, 2019). Comparably, in later phases the geological and pedological differences could explain different developments of the landscapes and subsequent cultural phenomena in a roughly east-west direction (Mortensen et al., 2014). The picture is further complicated by species that are not restricted to one of these ecological zones. Hence, a simple eco-deterministic correlation is not possible in these areas.
Finally, another consequence of these shifting ecological zones is the irregular offset of chronozones (as in the INTIMATE event stratigraphy) and biozones documented for Schleswig-Holstein and most of northern Europe during the Late Glacial. This calls for rigorous considerations of the chronology of archaeological sites to allow comparison on a supra-regional European scale.

ID	site	district	material	species	method	lab. no.	Age ^{14}C [BP]	± [BP]	Age [cal BP*]	Age [cal BP**]	$\delta^{13}C$ [‰]	comment	references
	Hamburgian												
1	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, bulked material	x	conv.	KN-2223	12,590	80	15,200-14,560	15,258-14,453	-	classic Hamburgian	Grimm and Weber, 2008
2	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone/antler, bulked material	Cervidae	conv.	KN-2224	12,530	160	15,340-14,060	15,291-14,126	-	classic Hamburgian	Grimm and Weber, 2008
3	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53524	12,510	55	15,060-14,420	15,072-14,352	-20.0	classic Hamburgian	this contribution
4	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53520	12,485	55	15,000-14,360	15,011-14,317	-19.2	classic Hamburgian	this contribution
5	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53522	12,485	55	15,000-14,360	15,011-14,317	-20.1	classic Hamburgian	this contribution
6	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53525	12,460	55	14,970-14,290	14,973-14,308	-17.8	classic Hamburgian	this contribution
7	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53527	12,450	55	14,950-14,270	14,962-14,297	-20.0	classic Hamburgian	this contribution
8	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53521	12,305	50	14,600-14,000	14,812-14,081	-19.8	classic Hamburgian	this contribution
9	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53526	12,210	55	14,350-13,910	14,772-13,887	-19.4	classic Hamburgian	this contribution
10	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4261	12,190	125	14,650-13,730	14,835-13,792	-18.6	classic Hamburgian	Fischer and Tauber, 1986
11	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	K-4328	12,180	130	14,630-13,710	14,838-13,787	-18.0	classic Hamburgian	Fischer and Tauber, 1986
12	Meiendorf (Ahrensburg LA 79)	Stormarn	bone	*R. tarandus*	AMS	KIA-53517	12,525	55	15,080-14,480	15,112-14,371	-20.6	classic Hamburgian	this contribution
13	Meiendorf (Ahrensburg LA 79)	Stormarn	bone	*R. tarandus*	AMS	KIA-53518	12,520	55	15,060-14,460	15,101-14,361	-19.5	classic Hamburgian	this contribution
14	Meiendorf (Ahrensburg LA 79)	Stormarn	bone		conv.	KN-2220	12,470	250	15,480-13,760	15,521-13,817	-	classic Hamburgian	Grimm and Weber, 2008
15	Meiendorf (Ahrensburg LA 79)	Stormarn	antler, humanly modified	*R. tarandus*	AMS	KIA-52178	12,455	55	14,960-14,280	14,967-14,304	-18.3	classic Hamburgian	Wild, 2020
16	Meiendorf (Ahrensburg LA 79)	Stormarn	antler, humanly modified	*R. tarandus*	AMS	KIA-52180	12,425	55	14,920-14,200	14,938-14,260	-18.7	classic Hamburgian	Wild, 2020
17	Meiendorf (Ahrensburg LA 79)	Stormarn	antler, humanly modified	*R. tarandus*	AMS	KIA-52176	12,405	55	14,880-14,160	14,896-14,208	-19.2	classic Hamburgian	Wild, 2020
18	Meiendorf (Ahrensburg LA 79)	Stormarn	antler	*R. tarandus*	AMS	K-4329	12,360	110	14,940-13,940	14,948-14,077	-18.3	classic Hamburgian	Fischer and Tauber, 1986
19	Meiendorf (Ahrensburg LA 79)	Stormarn	antler, humanly modified	*R. tarandus*	AMS	KIA-52177	12,355	55	14,770-14,050	14,841-14,115	-19.2	classic Hamburgian	Wild, 2020
20	Meiendorf (Ahrensburg LA 79)	Stormarn	antler, humanly modified	*R. tarandus*	AMS	KIA-52179	12,355	55	14,770-14,050	14,841-14,115	-19.1	classic Hamburgian	Wild, 2020
21	Meiendorf (Ahrensburg LA 79)	Stormarn	bone	*R. tarandus*	AMS	KIA-53519	12,270	50	14,520-13,960	14,805-14,056	-20.2	classic Hamburgian	this contribution
22	Poggenwisch (Ahrensburg LA 101)	Stormarn	bone	*R. tarandus*	AMS	K-4332	12,570	115	15,280-14,320	15,268-14,299	-18.6	classic Hamburgian	Fischer and Tauber, 1986
23	Poggenwisch (Ahrensburg LA 101)	Stormarn	bone		conv.	KN-2754	12,470	95	15,090-14,170	15,077-14,213	-	classic Hamburgian	Grimm and Weber, 2008
24	Poggenwisch (Ahrensburg LA 101)	Stormarn	wood	*Betula* sp.	conv.	GrN-11254	12,460	60	14,990-14,270	14,982-14,297	-28.6	classic Hamburgian	Tromnau, 1992: 81, Anmerk. 8
25	Poggenwisch (Ahrensburg LA 101)	Stormarn	bone	*R. tarandus*	AMS	K-4331	12,440	115	15,090-14,050	15,069-14,135	-18.8	classic Hamburgian	Fischer and Tauber, 1986
26	Poggenwisch (Ahrensburg LA 101)	Stormarn	bone, humanly modified	*R. tarandus*	AMS	K-4577	12,440	115	15,090-14,050	15,069-14,135	-17.4	classic Hamburgian	Fischer and Tauber, 1986
27	Poggenwisch (Ahrensburg LA 101)	Stormarn	antler, humanly modified	*R. tarandus*	AMS	KIA-32926	12,365	60	14,790-14,070	14,848-14,138	-20.4	classic Hamburgian	Grimm and Weber, 2008

Tab. 2 Reliable radiocarbon dates of Final Palaeolithic material from Schleswig-Holstein. * 95 % confidence interval, using the CalPal-2019-Hulu calibration curve in CalPal program, Version 2020.2 (Weninger and Jöris, 2008) ** 95,4 % confidence interval, unmodelled, using IntCal 20 (Reimer et al., 2020) in the OxCal program, version 4.4 (Bronk Ramsey, 2009)

ID	site	district	material	species	method	lab. no.	Age ^{14}C [BP]	± [BP]	Age [cal BP*]	Age [cal BP**]	$\delta^{13}C$ [‰]	comment	references
28	Poggenwisch (Ahrensburg LA 101)	Stormarn	antler with attached cranial bone	*R. tarandus*	AMS	KIA-32927	12,330	55	14,700-14,020	14,829-14,091	-21.3	classic Hamburgian	Grimm and Weber, 2008
29	Poggenwisch (Ahrensburg LA 101)	Stormarn	antler, humanly modified	*R. tarandus*	AMS	KIA-32925	12,265	55	14,490-13,970	14,804-14,051	-21.6	classic Hamburgian	Grimm and Weber, 2008
30	Ahrenshöft LA 73 South, layer I	Nord-friesland	charcoal	*Pinus* sp.	AMS	KIA-3605	12,200	60	14,340-13,900	14,777-13,871	-	Havelte Group	Clausen, 1997
31	Ahrenshöft LA 73 North, layer II	Nord-friesland	charcoal	*Salix/ Populus*	AMS	KIA-3833	12,130	60	14,170-13,850	14,153-13,807	-	classic Hamburgian and Havelte Group	Clausen, 1997
32	Ahrenshöft LA 58 D	Nord-friesland	charcoal		AMS	AAR-2784	12,030	60	14,050-13,730	14,050-13,794	-25.7	Havelte Group	Clausen, 1997
	Federmessergruppen (FMG)												
33	Klein Nordende LA 37 C	Pinneberg	wood, twigs	*Hippophaë* sp.	conv.	KI-2124	12,035	110	14,180-13,620	14,166-13,607	-	archaeological connection uncertain	Bokelmann et al., 1983
34	Klein Nordende LA 37, erosion channel (south of A)	Pinneberg	wood, twigs	*Hippophaë* sp.	conv.	KI-2152	11,990	100	14,070-13,590	14,075-13,607	-	archaeological connection uncertain	Bokelmann et al., 1983
35	Klein Nordende LA 37 D	Pinneberg	bone, femur proximal sin.	*A. alces*	AMS	KIA-33951	11,035	50	13,090-12,810	13,086-12,840	-20.5	with cut-marks	Riede et al., 2010
36	Borneck Kammer III (Ahrensburg LA 76)	Stormarn	bone, humerus distal sin.	*R. tarandus*	AMS	KIA-33949	11,940	50	13,950-13,630	14,025-13,609	-17.5	archaeological connection uncertain	Riede et al., 2010
37	Borneck Kammer III (Ahrensburg LA 76)	Stormarn	bone, tibia distal sin.	*A. alces*	AMS	KIA-33950	11,770	55	13,750-13,430	13,766-13,502	-19.5	archaeological connection uncertain	Riede et al., 2010
38	Alt Duvenstedt LA 120 b	Rendsburg-Eckernförde	charcoal		AMS	AAR-2244	11,780	110	13,880-13,360	14,003-13,430	-		Clausen, 2004
	Ahrensburgian												
39	Alt Duvenstedt LA 123	Rendsburg-Eckernförde	charcoal		AMS	AAR-2246	11,060	110	13,150-12,750	13,161-12,761	-		Clausen, 2004
40	Alt Duvenstedt LA 121	Rendsburg-Eckernförde	charcoal		AMS	AAR-2245-1	10,810	80	12,900-12,660	12,920-12,627	-		Clausen, 1996b
41	Alt Duvenstedt LA 121	Rendsburg-Eckernförde	charcoal		AMS	AAR-2245-2	10,770	60	12,820-12,660	12,830-12,679	-		Clausen, 1996b
42	Nahe LA 11	Segeberg	bone, humic acid, humerus	*R. tarandus*	AMS	KIA-23369	10,610	80	12,820-12,340	12,747-12,336	-		Weber et al., 2011
43	Nahe LA 11	Segeberg	antler with cranial bone attached	*R. tarandus*	AMS	KIA-23372	10,544	49	12,740-12,340	12,699-12,473	-20.5		Weber et al., 2011
44	Nahe LA 11	Segeberg	bone, lumbar vertebra	*R. tarandus*	AMS	KIA-23370	10,172	45	11,930-11,650	11,969-11,620	-19.3		Weber et al., 2011; Wild, 2017
45	Nahe LA 11	Segeberg	bone, lumbar vertebra	*R. tarandus*	AMS	KIA-23371	10,142	49	11,900-11,540	11,943-11,406	-16.7		Weber et al., 2011; Wild, 2017
46	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, mandibula	*R. tarandus*	AMS	KIA-46300	10,445	40	12,680-12,080	12,614-12,102	-16.3		Rivals et al., 2020
47	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, tibia sin.	*R. tarandus*	AMS	KIA-48959	10,335	30	12,350-11,870	12,461-11,949	-18.6	attributed to classic Hamburgian	Rivals et al., 2020
48	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, mandibula dext., human modification (part of the so-called Kultpfahlschädel)	*R. tarandus*	AMS	KIA-51367	10,294	54	12,340-11,740	12,461-11,830	-17.9		Rivals et al., 2020

Tab. 2 (continued)

ID	site	district	material	species	method	lab. no.	Age ^{14}C [BP]	± [BP]	Age [cal BP*]	Age [cal BP**]	$\delta^{13}C$ [‰]	comment	references
49	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, tibia dext.	*R. tarandus*	AMS	KIA-48958	10,245	32	12,040-11,760	12,095-11,818	-18.5		Rivals et al., 2020
50	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	KIA-53523	10,205	40	11,980-11,700	12,001-11,741	-18.4	attributed to classic Hamburgian	this contribution
51	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, mandibula	*R. tarandus*	AMS	KIA-46299	10,200	40	11,970-11,690	11,998-11,739	-17.0		Rivals et al., 2020
52	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, mandibula	*R. tarandus*	AMS	KIA-47378	10,195	40	11,960-11,680	11,996-11,655	-19.2	attributed to classic Hamburgian	Rivals et al., 2020
53	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, bulked material		conv.	KN-2222	10,160	90	12,130-11,330	12,433-11,338	-		Grimm and Weber, 2008
54	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, costa sin., possible human modification	*Equus* sp.	AMS	KIA-48960	10,155	35	11,880-11,640	11,940-11,626	-21.9		Drucker et al., 2016; Rivals et al., 2020
55	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	K-4326	10,140	105	12,140-11,260	12,432-11,274	-		Fischer and Tauber, 1986
56	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, scapula	*A. alces*	AMS	KIA-51382	10,136	51	11,900-11,500	11,941-11,405	-20.1		Wild and Weber, 2017: Anm. 1
57	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4327	10,130	105	12,110-11,230	12,429-11,269	-17.7	attributed to classic Hamburgian	Fischer and Tauber, 1986
58	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4262	10,110	105	12,040-11,240	12,098-11,261	-		Fischer and Tauber, 1986
59	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	K-4578	10,100	100	12,000-11,240	12,001-11,266	-		Fischer and Tauber, 1986
60	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone/antler, bulked material	Cervidae (*R. tarandus*?)	conv.	KN-2221	10,080	80	11,900-11,260	11,934-11,317	-		Grimm and Weber, 2008
61	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone, mandibula	*R. tarandus*	AMS	KIA-47379	10,080	+45 / -40	11,850-11,330	11,821-11,399	-17.0		Rivals et al., 2020
62	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*Bison* sp.	AMS	KIA-3331	10,070	50	11,830-11,310	11,820-11,351	-		Benecke, 2004
63	Stellmoor (Ahrensburg LA 78.1)	Stormarn	bone	*R. tarandus*	AMS	K-4325	10,010	100	11,850-11,170	11,872-11,238	-		Fischer and Tauber, 1986
64	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4581	9,990	105	11,830-11,150	11,829-11,218	-		Fischer and Tauber, 1986
65	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4579	9,980	105	11,830-11,150	11,821-11,218	-		Fischer and Tauber, 1986
66	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4323	9,930	100	11,760-11,120	11,805-11,196	-		Fischer and Tauber, 1986
67	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4324	9,900	105	11,760-11,080	11,811-11,166	-		Fischer and Tauber, 1986
68	Stellmoor (Ahrensburg LA 78.1)	Stormarn	antler	*R. tarandus*	AMS	K-4580	9,810	100	11,520-10,960	11,687-10,794	-		Fischer and Tauber, 1986
69	Meiendorf (Ahrensburg LA 79)	Stormarn	bone, mandibula	*R. tarandus*	AMS	KIA-46301	10,350	45	12,420-11,860	12,471-11,951	-18.3	attributed to classic Hamburgian	Rivals et al., 2020
70	Meiendorf (Ahrensburg LA 79)	Stormarn	bone, mandibula	*R. tarandus*	AMS	KIA-47380	10,145	55	11,940-11,500	11,946-11,404	-19.0	attributed to classic Hamburgian	Rivals et al., 2020
71	Meiendorf (Ahrensburg LA 79)	Stormarn	bone	*R. tarandus*	AMS	K-4330	10,110	85	11,990-11,270	11,971-11,315	-18.3	attributed to classic Hamburgian, considered as falsely labelled Stellmoor	Fischer and Tauber, 1986
	Osseous artefacts												
72	Klappholz LA 63	Schleswig-Flensburg	Lyngby antler artefact	*R. tarandus*	AMS	AAR-2785	11,560	110	14,180-13,620	13,731-13,179	-		Clausen, 2004
73	Lasbek LA 14	Stormarn	antler artefact: double bevelled point	*R. tarandus*	AMS	KIA-51380	11,169	64	13,190-12,910	13,181-12,910	-18.7		Wild and Weber, 2017

Tab. 2 (continued)

ID	site	country	material	species	method	lab. no.	Age ^{14}C [BP]	± [BP]	Age [cal BP*]	Age [cal BP**]	$\delta^{13}C$ [‰]	comment	references
	Hamburgian												
1	Querenstede	D (Lower Saxony)	charcoal		conv.	KN-2707	12,650	320	16,020-13,780	15,988-13,879	-	Hamburgian	Lanting and Van der Plicht, 1996
2	Slotseng, kettle hole	DK (South Jutland)	antler/bone, humanly modified	*R. tarandus*	AMS	AAR-906	12,520	190	15,400-13,960	15,365-14,069	-18.6	Havelte Group	Holm and Rieck, 1992; Holm, 1991
3	Slotseng, kettle hole	DK (South Jutland)	antler	*R. tarandus*	AMS	AAR-8159	12,410	70	14,920-14,120	14,938-14,191	-19.6	Havelte Group	Aaris-Sørensen et al., 2007
4	Slotseng, kettle hole	DK (South Jutland)	antler, humanly modified	*R. tarandus*	AMS	AAR-8157	12,299	41	14,540-14,020	14,806-14,083	-19.1	Havelte Group	Aaris-Sørensen et al., 2007; Grimm and Weber, 2008
5	Slotseng, kettle hole	DK (South Jutland)	bone, vertebra with flint projectile	*R. tarandus*	AMS	AAR-8165	12,290	75	14,660-13,940	14,831-14,050	-19.4	Havelte Group	Aaris-Sørensen et al., 2007
6	Slotseng, kettle hole	DK (South Jutland)	bone, vertebra with flint projectile	*R. tarandus*	AMS	AAR-8160	12,240	50	14,400-13,960	14,782-14,042	-19.0	Havelte Group	Aaris-Sørensen et al., 2007
7	Slotseng, kettle hole	DK (South Jutland)	antler	*R. tarandus*	AMS	AAR-8162	12,220	100	14,610-13,810	14,822-13,809	-18.9	Havelte Group	Aaris-Sørensen et al., 2007
8	Slotseng, kettle hole	DK (South Jutland)	bone, tibia	*R. tarandus*	AMS	AAR-8163	12,205	65	14,370-13,890	14,795-13,863	-19.5	Havelte Group	Aaris-Sørensen et al., 2007
9	Slotseng, kettle hole	DK (South Jutland)	bone, costa	*R. tarandus*	AMS	AAR-8164	12,190	50	14,290-13,890	14,311-13,881	-18.6	Havelte Group	Aaris-Sørensen et al., 2007
10	Slotseng, kettle hole	DK (South Jutland)	antler/bone, humanly modified	*R. tarandus*	AMS	AAR-8158	12,165	55	14,240-13,880	14,305-13,813	-19.0	Havelte Group	Aaris-Sørensen et al., 2007
11	Slotseng, kettle hole	DK (South Jutland)	antler, humanly modified	*R. tarandus*	AMS	AAR-8161	12,065	80	14,130-13,730	14,113-13,781	-19.7	Havelte Group	Aaris-Sørensen et al., 2007
12	Køge Bugt	DK (Zealand)	bone, humanly modified	*R. tarandus*	AMS	AAR-18733	12,238	46	14,390-13,950	14,769-14,045	-	Final Palaeolithic (Hamburgian?)	Fischer and Jensen, 2018; Wild, 2020
13	Køge Bugt	DK (Zealand)	antler, humanly modified	*R. tarandus*	AMS	AAR-18732	12,170	45	14,210-13,890	14,301-13,866	-	Final Palaeolithic (Hamburgian)	Fischer and Jensen, 2018; Wild, 2020
14	Køge Bugt 1 (also: off-shore Solrød Strand)	DK (Zealand)	antler, humanly modified	*R. tarandus*	AMS	AAR-1036	12,140	110	14,440-13,720	14,801-13,770	-	Final Palaeolithic (Hamburgian)	Fischer, 1996; Petersen and Johansen, 1996
	Federmessergruppen (FMG)												
15	Grabow 15	D (Lower Saxony)	charcoal	*Betula* sp.	AMS	KIA-41862	12,125	50	14,130-13,850	14,113-13,810	-27.7	from archaeological feature (FMG)	Tolksdorf et al., 2013
16	Grabow 15	D (Lower Saxony)	bone, calcined, one fragment unburnt		AMS	KIA-41861	12,070	100	14,200-13,680	14,218-13,614	-23.8	from archaeological feature (FMG)	Tolksdorf et al., 2013
17	Weitsche	D (Lower Saxony)	bone, cremated, bulked sample	*C. fiber* & unidentified	AMS	KIA-26439	11,980	120	14,120-13,520	14,108-13,591	-	from lithic (FMG) and amber concentration	Veil et al., 2012
18	Weitsche	D (Lower Saxony)	bone, cremated, bulked sample	*C. fiber* & unidentified	AMS	KIA-35664	11,755	50	13,720-13,440	13,756-13,501	-	from lithic (FMG) and amber concentration	Veil et al., 2012
	Brommean												
19	Trollesgave	DK (Zealand)	charcoal	*Salix* sp.	AMS	AAR-16021	11,126	44	13,130-12,890	13,155-12,916	-28.0	Brommean	Fischer et al., 2013b
20	Trollesgave	DK (Zealand)	charcoal	*Salix* sp.	conv.	K-2509	11,100	160	13,270-12,710	13,298-12,750	-24.6	Brommean	Fischer, 1996: 158; Fischer et al., 2013b

Tab. 3 Reliable radiocarbon dates of Final Palaeolithic material from adjacent areas. * 95 % confidence interval, using the CalPal-2019-Hulu calibration curve in CalPal program, Version 2020.2 (Weninger and Jöris, 2008) ** 95,4 % confidence interval, unmodelled, using IntCal 20 (Reimer et al., 2020) in the OxCal program, version 4.4 (Bronk Ramsey, 2009)

ID	site	country	material	species	method	lab. no.	Age ^{14}C [BP]	± [BP]	Age [cal BP*]	Age [cal BP**]	$\delta^{13}C$ [‰]	comment	references
21	Trollesgave	DK (Zealand)	charcoal, bulked material	*Salix / Betula / Populus*	conv.	K-2641	11,070	120	13,180-12,740	13,166-12,761	-24.5	Brommean	Fischer, 1996: 158; Fischer et al., 2013b
22	Trollesgave	DK (Zealand)	charcoal	*Salix* sp.	AMS	AAR-16019	10,826	49	12,860-12,700	12,838-12,722	-27.0	Brommean	Fischer et al., 2013b
23	Fensmark Skydebane	DK (Zealand)	charcoal	x	AMS	OxA-3614	10,810	120	12,990-12,590	13,071-12,510	-25.5	Brommean	Fischer, 1996: 158 f.
24	Bromme	DK (Zealand)	bone fragment, vertebra lumbalis	*A. alces*	AMS	AAR-4539	10,720	90	12,810-12,570	12,835-12,491	-20.4	Brommean	Heinemeier and Rud, 2000: 302
	Ahrensburgian												
25	Melbeck	D (Lower Saxony)	charcoal	*Pinus sylvestris*?	conv.	Hv-17306	10,515	95	12,790-12,030	12,722-12,060	-	Long Blade Technology	Richter, 1992
	Osseous artefacts												
26	Endingen, Horst VI	D (Mecklenburg-West Pomerania)	bone, blade-like shaped rib	*Equus* sp.	AMS	UtC-5681	11,830	50	13,820-13,500	13,792-13,526	-	Final Palaeolithic (FMG / Brommean)	Kaiser et al., 1999: 115
27	Endingen, Horst VI	D (Mecklenburg-West Pomerania)	antler with groove and splinter technique remain	*M. giganteus*	AMS	ETH-13585 (UZ-3798)	11,555	100	13,560-13,200	13,601-13,186	-	Final Palaeolithic (FMG / Brommean)	Terberger, 1996; Kaiser et al., 1999
28	Nørre Lyngby, new investigations	DK (North Jutland)	bone, costa, cut-marks	*R. tarandus*	AMS	AAR-1511	11,570	110	13,600-13,200	13,737-13,182	-17.9	Final Palaeolithic (FMG / Brommean)	Aaris-Sørensen, 1995: 358
29	Mickelsmosse (Munkarp)	S (Scania)	antler club	*R. tarandus*	AMS	OxA-2791	10,980	110	13,110-12,710	13,094-12,749	-19.4	Final Palaeolithic (FMG / Brommean / Ahrensburgian)	Hedges et al., 1995; Larsson, 1996
30	Odense Kanal	DK (Funen)	Lyngby antler artefact	*R. tarandus*	AMS	AAR-9298	10,815	65	12,880-12,680	12,890-12,700	-	Final Palaeolithic (FMG / Brommean / Ahrensburgian)	Stensager, 2006
31	Fogense Enge	DK (Zealand)	bone rod	*A. alces*	AMS	AAR-15025	10,726	27	12,760-12,680	12,747-12,698	-	Final Palaeolithic (FMG / Brommean / Ahrensburgian)	Petersen, 2021
32	Arreskov	DK (Funen)	Lyngby antler artefact	*R. tarandus*	AMS	OxA-3173	10,600	100	12,840-12,240	12,756-12,105	-18.4	Final Palaeolithic (FMG / Brommean / Ahrensburgian)	Fischer, 1996: 158-162

Tab. 3 (continued)

Acknowledgements

We would like to thank Kristina Hüntemeyer for her help with literature search and editing. The research was mainly conducted and financed in the context of subproject B1 "Pioneers of the North" within the Collaborative Research Centre 1266 "Scales of Transformation – Human-environmental interaction in prehistoric and archaic societies" of the German Research Foundation (DFG, German Research Foundation, project number 2901391021-SFB 1266).

REFERENCES

Aaris-Sørensen, K., 1995. Palaeoecology of a Late Weichselian vertebrate fauna from Nørre Lyngby, Denmark. *Boreas* 24, 355-365.

Aaris-Sørensen, K., Liljegren, R., 2004. Late Pleistocene remains of giant deer (*Megaloceros giganteus* Blumenbach) in Scandinavia: chronology and environment. *Boreas* 33, 61-73.

Aaris-Sørensen, K., Mühldorff, R., Petersen, E.B., 2007. The Scandinavian reindeer (*Rangifer tarandus* L.) after the last glacial maximum: time, seasonality and human exploitation. *Journal of Archaeological Science* 34, 914-923.

Baales, M., 2002. Vulkanismus und Archäologie des Eiszeitalters am Mittelrhein: Die Forschungsergebnisse der letzten dreißig Jahre. *Jahrbuch des Römisch-Germanischen Zentralmuseums* 49, 43-80.

Baales, M., Birker, S., Kromer, B., Pollmann, H.-O., Rosendahl, W., Stapel, B., 2019. Megaloceros, reindeer and elk – first AMS-^{14}C-datings on Final Palaeolithic finds from Westphalia (western Germany). In: Eriksen, B.V., Rensink, E., Harris, S. (Eds.), *The Final Palaeolithic of Northern Eurasia*. *Proceedings of the Amersfoort, Schleswig and Burgos UISPP Commission meetings.* Schriften des Museums für Archäologie Schloss Gottorf, Ergänzungsreihe 13. Verlag Ludwig, Kiel–Schleswig, pp. 137-153.

Bakke, J., Lie, Ø., Heegaard, E., Dokken, T., Haug, G.H., Birks, H.H., Dulski, P., Nilsen, T., 2009. Rapid oceanic and atmospheric changes during the Younger Dryas cold period. *Nature Geoscience* 2, 202-205.

Barendsen, G.W., Deevey, E.S., Gralenski, L.J., 1957. Yale natural radiocarbon measurements III. *Science* 126, 908-919.

Benecke, N., 2004. Faunal succession in lowlands of northern Central Europe at the Pleistocene – Holocene transition. In: Terberger, T., Eriksen, B.V. (Eds.), *Hunters in a changing world. Environment and Archaeology of the Pleistocene – Holocene transition (ca. 11000-9000 B.C.) in Northern Central Europe.* Workshop of a UISPP commission, Greifswald 2002. Internationale Archäologie 5. Verlag Marie Leidorf, Rahden/Westf., pp. 43-51.

Benecke, N., Heinrich, D., 2003. Neue Daten zur Entwicklung der Huftierfauna im Tiefland zwischen Elbe und Oder im Spätglazial und Altholozän. *Archeozoologia* 21, 19-36.

Blockley, S.P.E., Bronk Ramsey, C., Lane, C.S., Lotter, A.F., 2008. Improved age modelling approaches as exemplified by the revised chronology for the Central European varved lake Soppensee. *Quaternary Science Reviews* 27, 61-71.

Bokelmann, K., 1978. Ein Federmesserfundplatz bei Schalkholz, Kreis Dithmarschen. *Offa* 35, 36-54.

Bokelmann, K., 1996. Ahrensburg, Kr. Stormarn. Zehnter Arbeitsbericht des archäologischen Landesamtes Schleswig-Holstein, Grabungsberichte der Jahre 1988-1993. *Offa* 53, 372.

Bokelmann, K., Heinrich, D., Menke, B., 1983. Fundplätze des Spätglazials am Hainholz-Esinger Moor, Kreis Pinneberg. *Offa* 40, 199-239.

Borup, P., Nielsen, M.K., 2017. Tyrsted – et kighul til senistiden. *Skalk* 6, 3-9.

Bosinski, G., 1979. *Die Ausgrabungen in Gönnersdorf 1968-1976 und die Siedlungsbefunde der Grabung 1968.* Der Magdalénien-Fundplatz Gönnersdorf 3. Franz Steiner Verlag, Wiesbaden.

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

Bratlund, B., 1993. Ein Riesenhirschschädel mit Bearbeitungsspuren aus Lüdersdorf, Kreis Greversmühlen. *Offa* 49/50, 7-14.

Bratlund, B., 1996. Hunting strategies in the late Glacial of Northern Europe: A survey of the faunal evidence. *Journal of World Prehistory* 10, 1-48.

Bratlund, B., 1999. A revision of the rarer species from the Ahrensburgian assemblage of Stellmoor. In: Benecke, N. (Ed.), *The Holocene history of the European vertebrate fauna*. Verlag Marie Leidorf, Rahden/Westf., pp. 39-42.

Brauer, A., Litt, T., Negendank, J.F.W., Zolitschka, B., 2001. Lateglacial varve chronology and biostratigraphy of lakes Holzmaar and Meerfelder Maar, Germany. *Boreas* 30, 83-88.

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 337-360.

Burau, T., 2019. *Technologische Transformationen am Ende der letzten Eiszeit – frühe Federmesser-Gruppen in Norddeutschland.* M.Sc. Thesis, University Kiel, Kiel.

Burky, R.R., Kirner, D.L., Taylor, R.E., Hare, P.E., Southon, J.R., 1998. ^{14}C Dating of Bone Using γ-Carboxyglutamic Acid and α-Carboxyglycine (Aminomalonate). *Radiocarbon* 40, 11-20.

Clausen, I., 1995. Alt Duvenstedt, Kreis Rendsburg-Eckernförde, LA 121. Ein Ahrensburger Kulturvorkommen in allerödzeitlichem Boden. *Archäologische Nachrichten aus Schleswig-Holstein* 6, 103-126.

Clausen, I., 1996a. Alt Düvenstedt LA 121, Schleswig-Holstein. Occurence of the Ahrensburgian culture in soils of the Alleröd Interstadial: A preliminary report. In: Larsson, L. (Ed.), *The earliest settlement of Scandinavia and its relationship with neighbouring areas*. Acta Archaeologica Lundensia 24. Almqvist & Wiksell International, Lund, pp. 99-110.

Clausen, I., 1996b. Alt Duvenstedt, Kr. Rendsburg-Eckernförde. Jungpaläolithische Stationen, LA 120A und LA 121. Zehnter

Arbeitsbericht des Archäologischen Landesamtes Schleswig-Holstein, Grabungsberichte der Jahre 1988-1993. *Offa* 53, 372-373.

Clausen, I., 1997. Neue Untersuchungen an späteiszeitlichen Fundplätzen der Hamburger Kultur bei Ahrenshöft, Kr. Nordfriesland: Ein Vorbericht. *Archäologische Nachrichten aus Schleswig-Holstein* 8, 8-49.

Clausen, I., 2004. The reindeer antler axe of the Allerød period from Klappholz LA 63, Kreis Schleswig-Flensburg/Germany: Is it a relict of the Federmesser, Bromme or Ahrensburg culture? In: Terberger, T., Eriksen, B.V. (Eds.), *Hunters in a changing world: Environment and Archaeology of the Pleistocene-Holocene Transition (ca.11000-9000 B.C.) in Northern Central Europe*. Workshop of a UISPP commission, Greifswald 2002. Internationale Archäologie 5. Verlag Marie Leidorf, Rahden/Westf., pp. 141-164.

Clausen, I., 2010. Auf den Spuren von Alfred Rust und seinen Rentierjägern: Aktuelle Untersuchungen am Stellmoorhügel bei Ahrensburg, Kr. Stormarn. *Archäologische Nachrichten aus Schleswig-Holstein* 16, 15-19.

Clausen, I., Guldin, A., 2016. Mit der Deutschen Bahn zu den Rentierjägern der späten Eiszeit… archäologische Voruntersuchungen im Zuge des geplanten Bahnbaus S4 im Ahrensburger Tunneltal, Kr. Stormarn. *Archäologische Nachrichten aus Schleswig-Holstein* 22, 6-17.

Clausen, I., Guldin, A., 2017. Die spätjungpaläolithischen Stationen des Ahrensburger Tunneltals in neuen Kartenbildern (Gem. Ahrensburg, Kr. Stormarn). In: Eriksen, B.V., Abegg-Wigg, A., Bleile, R., Ickerodt, U. (Eds.), *Interaction without borders. Exemplary archaeological research at the beginning of the 21st century*. Festschrift für Claus von Carnap-Bornheim zum 60. Geburtstag. Stiftung Schleswig-Holsteinische Landesmuseen, Schleswig, pp. 11-22.

Clausen, I., Hartz, S., 1988. Fundplätze des Spätglazials am Sorgetal bei Alt-Duvenstedt, Kreis Rendsburg-Eckernförde. *Offa* 45, 17-35.

Clausen, I., Schaaf, B., 2015. Zwanzig Jahre nach der Ausgrabung: Zusammengefügte Steinartefakte erzählen erstaunliche Geschichte(n)... Aktuelle Forschungsergebnisse zu den spätaltsteinzeitlichen Stationen der Ahrensburger Kultur von Alt Duvenstedt, Kreis Rendsburg-Eckernförde (LA 121 und LA 123). *Archäologische Nachrichten aus Schleswig-Holstein* 21, 9-17.

Corradini, E., Eriksen, B.V., Mortensen, M.F., Nielsen, M.K., Thorwart, M., Krüger, S., Wilken, D., Pickartz, N., Panning, D., Rabbel, W., 2020. Investigating lake sediments and peat deposits with geophysical methods – a case study from a kettle hole at the Late Palaeolithic site of Tyrsted, Denmark. *Quaternary International* 558, 89-106.

Cziesla, E., Pettitt, P., 2003. AMS-^{14}C-Datierungen von spätpaläolithischen und mesolithischen Funden aus dem Bützsee (Brandenburg). *Archäologisches Korrespondenzblatt* 33, 21-38.

De Klerk, P., 2004. Confusing concepts in lateglacial stratigraphy and geochronology: Origin, consequences, conclusions (with special emphasis on the type locality Bøllingsø). *Review of Palaeobotany and Palynology* 129, 265-298.

Dreibrodt, S., Krüger, S., Weber, J., Feeser, I., 2021. Limnological response to the Laacher See eruption (LSE) in an annually laminated Allerød sediment sequence from the Nahe palaeolake, northern Germany. *Boreas* 50, 167-183.

Drucker, D.G., Kind, C.J., Stephan, E., 2011. Chronological and ecological information on Late-glacial and early Holocene reindeer from northwest Europe using radiocarbon (^{14}C) and stable isotope (^{13}C, ^{15}N) analysis of bone collagen: case study in southwestern Germany. *Quaternary International* 245, 218-224.

Drucker, D.G., Rosendahl, W., van Neer, W., Weber, M.-J., Görner, I., Bocherens, H., 2016. Environment and subsistence in north-western Europe during the Younger Dryas: An isotopic study of the human of Rhünda (Germany). *Journal of Archaeological Science: Reports* 6, 690-699.

Eriksen, B.V., 1991. Den naturmæssige baggrund for den senglaciale Bromme bosættelse i Sydskandinavien. *LAG* 2, 5-29.

Eriksen, B.V., 1999. Late Palaeolithic settlement in Denmark – how do we read the record? In: Kobusiewicz, M., Kozłowski, J.K. (Eds.), *Post-pleniglacial re-colonisation of the great European lowland*. Folia Quaternaria 70. Polska Akademia Umiejętności, Krakow, pp. 157-173.

Eriksen, B.V., 2000. Patterns of ethnogeographic variability in Late Pleistocene northwestern Europe. In: Larsen Peterkin, G., Price, H.A. (Eds.), *Regional approaches to adaptation in late Pleistocene western Europe*. BAR International Series 896. Hadrian Books, Oxford, pp. 147-168.

Eriksen, B.V., 2002. Reconsidering the geochronological framework of Lateglacial hunter-gatherer colonization of southern Scandinavia. In: Eriksen, B.V., Bratlund, B. (Eds.), *Recent studies in the Final Palaeolithic of the European plain*. Jutland Archaeological Society Publications 39. Aarhus University Press, Højbjerg, pp. 25-41.

Eriksen, B.V., Krüger, S., Wild, M., Nielsen, M.K., Borup, P., Mortensen, M.F., 2018. Tyrsted – a Late Palaeolithic Christmas gift. In: von Carnap-Bornheim, C., Eriksen, B.V. (Eds.), *Zentrum für Baltische und Skandinavische Archäologie. Jahresbericht 2017*. Zentrum für Baltische und Skandinavische Archäologie, Schleswig, pp. 78-79.

Fiedel, S.J., Southon, J.R., Taylor, R.E., Kuzmin, Y.V., Street, M., Higham, T.F.G., van der Plicht, J., Nadeau, M.-J., Nawalade-Chavan, S., 2013. Assessment of interlaboratory pretreatment protocols by radiocarbon dating an elk bone found below Laacher See Tephra at Miesenheim IV (Rhineland, Germany). *Radiocarbon* 55, 1443-1453.

Fischer, A., 1996. At the border of human habitat. The Late Palaeolithic and Early Mesolithic in Scandinavia. In: Larsson, L. (Ed.), *The earliest settlement of Scandinavia and its relationship with neighbouring areas*. Acta Archaeologica Lundensia 24. Almqvist & Wiksell International, Lund, pp. 57-176.

Fischer, A., Tauber, H., 1986. New ^{14}C-datings of Late Palaeolithic cultures from Northwestern Europe. *Journal of Danish Archaeology* 5, 7-13.

Fischer A., Jensen, T.Z.T., 2018. Radiocarbon dates for submarine and maritime finds from early prehistory. In: Fischer, A., Pedersen, L. (Eds.), *Oceans of Archaeology.* Jutland Archaeological Society 101. Aarhus University Press, Aarhus, pp. 203-220.

Fischer, A., Clemmensen, L.B., Donahue, R., Heinemeier, J., Lykke-Andersen, H., Lysdahl, P., Mortensen, M.F., Olsen, J., Petersen, P.V., 2013a. Late Palaeolithic Nørre Lyngby – a northern outpost close to the west coast of Europe. *Quartär* 60, 137-162.

Fischer, A., Mortensen, M.F., Henriksen, P.S., Mathiassen, D.R., Olsen, J., 2013b. Dating the Trollesgave site and the Bromme culture – chronological fix-points for the Lateglacial settlement of Southern Scandinavia. *Journal of Archaeological Science* 40, 4663-4674.

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

Grimm, S.B., Groß, D., Gerken, K., Weber, M.J., 2020. On the onset of the early Mesolithic on the north German plain. In: Zander, A., Gehlen, B. (Eds.), *From the early Preboreal to the Subboreal period – current Mesolithic research in Europe. Studeies in honour of Bernhard Gramsch*. Welt & Erde, Kerpen-Loogh, pp. 15-37.

Groß, D., Lübke, H., Meadows, J., Jantzen, D. (Eds.), 2020. *Working at the Sharp End: From Bone and Antler to Early Mesolithic Life in Northern Europe.* Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum 10. Wachholtz Verlag, Kiel–Hamburg.

Groß, D., Berckhan, S., Hauschild, N., Räder A.-L., Sohst, A., 2021. Re-evaluating the old excavation from Pinnberg, Germany. In: Borić, D., Antonović, D., Mihailović, B. (Eds.), *Foraging Assemblages, Volume 2.* Serbian Archaeological Society – The Italian Academy for Advanced Studies in America, Belgrade–New York, pp. 312-317.

Grønnow, B., 1985. Meiendorf and Stellmoor Revisited. An Analysis of Late Palaeolithic Reindeer Exploitation. *Acta Archaeologica* 56, 131-166.

Hamer, W., Knitter, D., Grimm, S.B., Serbe, B., Eriksen, B.V., Nakoinz, O., Duttmann, R., 2019. Location modelling of Final Palaeolithic sites in Northern Germany. *Geosciences* 9; https://doi.org/10.3390/geosciences9100430

Hartz, S., Weber, M.-J., Meadows, J., Klooß, S., 2019. One in a hundred – the rediscovery of a potential arrow shaft from Stellmoor (Schleswig-Holstein, Northern Germany). In: Eriksen, B.V., Rensink, E., Harris, S. (Eds.), *The Final Palaeolithic of Northern Eurasia*. *Proceedings of the Amersfoort, Schleswig and Burgos UISPP Commission meetings.* Schriften des Museums für Archäologie Schloss Gottorf, Ergänzungsreihe 13. Verlag Ludwig, Kiel–Schleswig, pp. 155-168.

Hedges, R.E.M., Housley, R.A., Bronk Ramsey, C., van Klinken, G.J., 1993. Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 16. *Archaeometry* 35, 147-167.

Hedges, R.E.M., Housley, R.A., Bronk Ramsey, C., Van Klinken, G.J., 1995. Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 20. *Archaeometry* 37, 417-430.

Heinemeier, J., Rud, N., 2000. AMS ^{14}C dateringer, Århus 1999. *Arkæologiske udgravninger i Danmark* 1999, 296-313.

Herre, W., Requate, H., 1958. Die Tierreste der paläolithischen Siedlungen Poggenwisch, Hasewisch, Borneck und Hopfenbach bei Ahrensburg. In: Rust, A., *Die jungpaläolithischen Zeltanlagen von Ahrensburg*. Vor- und frühgeschichtliche Untersuchungen aus dem Schleswig-Holsteinischen Landesmuseum für Vor- und Frühgeschichte in Schleswig und dem Institut für Ur- und Frühgeschichte der Universität Kiel N. F. 15. Wachholtz Verlag, Neumünster, pp. 23-27.

Hinrichs, M., 2020. Re-evaluating the Ahrensburgian find concentrations from Borneck-North and -East, district of Stormarn, Schleswig-Holstein, Germany. *Offa* 73-77, 5-22.

Holm, J., 1991. Settlements of the Hamburgian and Federmesser cultures at Slotseng, South Jutland. *Journal of Danish Archaeology* 10, 7-19.

Holm, J., Rieck, F., 1992. *Istidsjægere ved Jelssøerne. Hamburgkulturen i Danmark*. Skrifter fra Museumsrådet for Sønderjyllands Amt 5. Museumsrådet for Sønderjyllands Amt, Haderslev.

Housley, R.A., Gamble, C.S., Street, M., Pettitt, P., 1997. Radioe carbon evidence for the lateglacial human recolonisation of northern Europe. *Proceedings of the Prehistoric Society* 63, 25-54.

Housley, R.A., MacLeod, A., Nalepka, D., Jurochnik, A., Masojć, M., Davies, L., Lincoln, P.C., Bronk Ramsey, C., Gamble, C.S., Lowe, J.J., 2013. Tephrostratigraphy of a lateglacial lake sediment sequence at Węgliny, southwest Poland. *Quaternary Science Reviews* 77, 4-18.

Immel, A., Drucker, D.G., Bonazzi, M., Jahnke, T.K., Münzel, S.C., Schuenemann, V.J., Herbig, A., Kind, C.J., Krause, J., 2015. Mitochondrial genomes of giant deers suggest their late survival in Central Europe. *Scientific Reports* 5, 10853; https://doi.org/10.1038/srep10853

Iversen, J., 1942. En pollenanalytisk tidsfæstelse af ferskvandslagene ved Nørre Lyngby: Med Bemærkninger om de senglaciale Naturforhold i Danmark. *Bulletin of the Geological Society of Denmark / Meddelelser fra Dansk Geologisk Forening* 10, 130-151.

Jensen, T.Z.T., Sjöström, A., Fischer, A., Rosengren, E., Lanigan, L.T., Bennike, O., Richter, K.K., Gron, K.J., Mackie, M., Mortensen, M.F., Sørensen, L., Chivall, D., Iversen, K.H., Taurozzi, A.J., Olsen, J., Schroeder, H., Milner, N., Sørensen, M., Collins, M.J., 2020. An integrated analysis of Maglemose bone points reframes the Early Mesolithic of Southern Scandinavia. *Scientific Reports* 10, 17244; https://doi.org/10.1038/s41598-020-74258-8.

Jensen, T.Z.T., Wild, M., Mortensen, M.F., Sørensen, L., Petersen, P.V., Mackie, M., Taurozzi, A.J., Henriksen, M.B., Sørensen, M., Collins, M.J., in prep. *Into the great yonder: Species identification and archaeological assessment of a decorated bone artefact dated to the Allerød / Younger Dryas transition from Fogense Enge, Denmark.*

Jessen, C.A., Pedersen, K.B., Christensen, C., Olsen, J., Mortensen, M.F., Hansen, K.M., 2015. Early Maglemosian culture in the Pree boreal landscape: Archaeology and vegetation from the earliest Mesolithic site in Denmark at Lundby Mose, Sjælland. *Quaternary International* 378, 73-87.

Kaiser, K., Clausen, I., 2005. Palaeopedology and stratigraphy of the late Palaeolithic Alt Duvenstedt site, Schleswig-Holstein (Northwest Germany). *Archäologisches Korrespondenzblatt* 35, 447-466.

Kaiser, K., De Klerk, P., Terberger, T., 1999. Die „Riesenhirschfundstelle" von Endingen: geowissenschaftliche und archäologische Untersuchungen an einem spätglazialen Fundplatz in Vorpommern. *Eiszeitalter und Gegenwart* 49, 102-123.

Krüger, S., 2015. *Ahrensburg, Sto. Altsteinzeitliche Kulturvorkommen im glazialen Seebecken LA 190. Bohrung ALSH 2015-11. Sediment- und Holzkohlenanalysen* [unpubl. report, Schleswig 2015].

Krüger, S., 2020. Of birches, smoke and reindeer dung – tracing human-environmental interactions palynologically in sediments from the Nahe palaeolake. *Journal of Archaeological Science: Reports* 32, 102370; https://doi.org/10.1016/j.jasrep.2020.102370.

Krüger, S., Damrath, M., 2020. In search of the Bølling-oscillation: A new high resolution pollen record from the locus classicus lake

Bølling, Denmark. *Vegetation History and Archaeobotany* 29, 189-211; https://doi.org/10.1007/s00334-019-00736-3.

Krüger, S., Mortensen, M.F., Dörfler, W., 2020. Sequence completed – palynological investigations on lateglacial / early holocene environmental changes recorded in sequentially laminated lacustrine sediments of the Nahe palaeolake in Schleswig-Holstein, Germany. *Review of Palaeobotany and Palynology* 280, 104271; https://doi.org/10.1016/j.revpalbo.2020.104271.

Krüger, S., van den Bogaard, C., 2021. Small shards and long distances – three cryptotephra layers from the Nahe palaeolake including the first discovery of Laacher See Tephra in Schleswig-Holstein (Germany). *Journal of Quaternary Science* 36, 8-19.

Larsson, L., 1996. The colonization of South Sweden during the deglaciation. In: Larsson, L. (Ed.), *The earliest settlement of Scandinavia and its relationship with neighbouring areas*. Acta Archaeologica Lundensia 24. Almqvist & Wiksell International, Lund, pp. 141-155.

Lanting, J.N., van der Plicht, J., 1996. De ^{14}C-chronologie van de Nederlandse pre- en protohistorie. I. Laat-Paleolithicum *Palaeohistoria* 37/38, 71-125.

Litt, T., Stebich, M., 1999. Bio- and chronostratigraphy of the lateglacial in the Eifel region, Germany. *Quaternary International* 61, 5-16.

Litt, T., Brauer, A., Goslar, T., Merkt, J., Bałaga, K., Müller, H., Ralska-Jasiewiczowa, M., Stebich, M., Negendank, J.F.W., 2001. Correlation and synchronisation of lateglacial continental sequences in northern Central Europe based on annually laminated lacustrine sediments. *Quaternary Science Reviews* 20, 1233-1249.

Meadows, J., Heron, C., Hüls, M., Philippsen, B., Weber, M.J., 2018. Dating the lost arrow shafts from Stellmoor (Schleswig-Holstein, Germany). *Quartär* 65, 105-114.

Menke, B., 1968. Das Spätglazial von Glüsing (Ein Beitrag zur Kenntnis der spätglazialen Vegetationsgeschichte in Westholstein). *Eiszeitalter und Gegenwart* 19, 73-84.

Merkt, J., Müller, H., 1999. Varve chronology and palynology of the Lateglacial in Northwest Germany from lacustrine sediments of Hämelsee in Lower Saxony. *Quaternary International* 61, 41-59.

Mortensen, M.F., Henriksen, P.S., Bennike, O., 2014. Living on the good soil: Relationships between soils, vegetation and human settlement during the late Allerød period in Denmark. *Vegetation History and Archaeobotany* 23, 195-205.

Overbeck, F.T., 1975. *Botanisch-geologische Moorkunde unter besonderer Berücksichtigung der Moore Nordwestdeutschlands als Quellen zur Vegetations-, Klima- und Siedlungsgeschichte*. Wachholtz Verlag, Neumünster.

Pasda, K., 2009. *Osteometry, and Osteological Age and Sex Determination of the Sisimiut Reindeer Population (Rangifer Tarandus Groenlandicus).* BAR International Series 1947. Hadrian Books, Oxford.

Pedersen, K.B., 2009. *Stederne og menneskene: Istidsjægere omkring Knudshoved Odde*. Museerne, Vordingborg.

Petersen, E.B., 2009. The human settlement of southern Scandinavia 12 500-8 700 cal BC. In: Street, M., Barton, N., Terberger, T. (Eds.), *Humans, environment and chronology of the late Glacial on the North European plain: proceedings of Workshop 14 (Commission XXXII "The Final Palaeolithic of the Great European Plain").* RGZM – Tagungen 6. Verlag des Römisch-Germanischen Zentralmuseums, Mainz, pp. 89-129.

Petersen, P.V., 2021. Zigzag lines and other protective patterns in Palaeolithic and Mesolithic art. *Quaternary International* 573, 66-74.

Petersen, P.V., Johansen, L., 1996. Tracking Late Glacial reindeer hunters in eastern Denmark. In: Larsson, L. (Ed.), *The earliest settlement of Scandinavia and its relationship with neighbouring areas*. Acta Archaeologica Lundensia 24. Almqvist & Wiksell International, Lund, pp. 75-88.

Pettitt, P.B., Davies, W., Gamble, C.S., Richards, M.B., 2003. Palaeolithic radiocarbon chronology: quantifying our confidence beyond two half-lives. *Journal of Archaeological Science* 30, 1685-1693.

Price, T.D., Meiggs, D., Weber, M.-J., Pike-Tay, A., 2017. The migration of late Pleistocene reindeer: Isotopic evidence from northern Europe. *Archaeological and Anthropological Sciences* 9, 371-394.

Rasmussen, S.O., Bigler, M., Blockley, S.P., Blunier, T., Buchardt, S.L., Clausen, H.B., Cvijanovic, I., Dahl-Jensen, D., Johnsen, S.J., Fischer, H., Gkinis, V., Guillevic, M., Hoek, W.Z., Lowe, J.J., Pedro, J.B., Popp, T., Seierstad, I.K., Steffensen, J.R.P., Svensson, A.M., Vallelonga, P., Vinther, B.M., Walker, M.J.C., Wheatley, J.J., Winstrup, M., 2014. A stratigraphic framework for abrupt climatic changes during the last glacial period based on three synchronized Greenland ice-core records: Refining and extending the intimate event stratigraphy. *Quaternary Science Reviews* 106, 14-28.

Reimer, P.J., Austin, W.E.N., Bard, E., Bayliss, A., Blackwell, P.G., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kromer, B., Manning, S.W., Muscheler, R., Palmer, J.G., Pearson, C., van der Plicht, J., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C.S.M., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S.M., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0-55 cal kBP). *Radiocarbon* 62, 725-757.

Reuter, T., in prep. *Federmessergruppen in Norddeutschland und Dänemark*. Dissertation, University Kiel, Kiel.

Richter, P., 1992. Ein spätglazialer Fundplatz auf dem Friedhof in Melbeck, Ldkr. Lüneburg. *Nachrichten aus Niedersachsens Urgeschichte* 61, 3-32.

Riede, F., Grimm, S.B., Weber, M.J., Fahlke, J.M., 2010. Neue Daten für alte Grabungen: Ein Beitrag zur spätglazialen Archäologie und Faunengeschichte Norddeutschlands. *Archäologisches Korrespondenzblatt* 40, 297-316.

Riede, F., Weber, M.J., Westen, B., Gregersen, K.M., Lundqvist Eriksen, K.K., Murray, A.S., Henriksen, P.S., Mortensen, M.F., 2019. Preliminary report on the Krogsbølle locale, a new Hamburgian site in eastern Denmark. In: Eriksen, B.V., Rensink, E., Harris, S. (Eds.), *The Final Palaeolithic of Northern Eurasia*. *Proceedings of the Amersfoort, Schleswig and Burgos UISPP Commission meetings.* Schriften des Museums für Archäologie Schloss Gottorf, Ergänzungsreihe 13. Verlag Ludwig, Kiel–Schleswig, pp. 11-30.

Rivals, F., Drucker, D.G., Weber, M.-J., Audouze, F., Enloe, J.G., 2020. Dietary traits and habitats of the reindeer (*Rangifer tarandus*) during the late Glacial of northern Europe. *Archaeological* *and Anthropological Sciences* 12, 98; https://doi.org/10.1007/s12520-020-01052-y.

Rust, A., 1937. *Das altsteinzeitliche Rentierjägerlager Meiendorf*. Wachholtz Verlag, Neumünster.

Rust, A., 1943. *Die alt- und mittelsteinzeitlichen Funde von Stellmoor*. Wachholtz Verlag, Neumünster.

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

Schwabedissen, H., 1944. *Die mittlere Steinzeit im westlichen Norddeutschland: Unter besonderer Berücksichtigung der Feuersteinwerkzeuge*. Offa-Bücher 7. Wachholtz Verlag, Neumünster.

Schwabedissen, H., 1954. *Die Federmesser-Gruppen des nordwesteuropäischen Flachlandes: Zur Ausbreitung des Spät-Magdalénien.* Offa-Bücher 9. Wachholtz Verlag, Neumünster.

Schwantes, G., 1923. *Die Bedeutung der Lyngby-Zivilisation für die Gliederung der Steinzeit*. Dissertation, University Hamburg, Hamburg.

Schwantes, G., 1928. Nordisches Paläolithikum und Mesolithikum: Festschrift zum fünfzigsten Bestehen des Hamburger Museums für Völkerkunde. *Mitteilungen aus dem Museum für Völkerkunde in Hamburg* 13, 159-252.

Schwantes, G., 1933, Die ältesten Bewohner des mittleren Norddeutschland. *Forschungen und Fortschritte* 9, 261-262.

Sirocko, F., 2016. The ELSA-stacks (Eifel-laminated-sediment-archive): An introduction. *Global and Planetary Change* 142, 96-99.

Sirocko, F., Knapp, H., Dreher, F., Förster, M.W., Albert, J., Brunck, H., Veres, D., Dietrich, S., Zech, M., Hambach, U., Röhner, M., Rudert, S., Schwibus, K., Adams, C., Sigl, P., 2016. The ELSA-Vegetation-Stack: Reconstruction of Landscape Evolution Zones (LEZ) from laminated Eifel maar sediments of the last 60,000 years. *Global and Planetary Change* 142, 108-135.

Stensager, A.O., 2006. Odense Kanal – et af Danmarks ældste fund. *Fynske Minder* 2006, 125-133.

Stevens, R.E., O'Connell, T.C., Hedges, R.E.M., Street, M., 2009. Radiocarbon and stable isotope investigations at the central Rhineland sites of Gönnersdorf and Andernach-Martinsberg, Germany. *Journal of Human Evolution* 57, 131-148.

Street, M., 1996. The Late Glacial faunal assemblage from Endingen, Lkr. Nordvorpommern. *Archäologisches Korrespondenzblatt* 26, 33-42.

Street, M., Baales, M., Weninger, B., 1994. Absolute Chronologie des späten Paläolithikums und Frühmesolithikums im nördlichen Rheinland. *Archäologisches Korrespondenzblatt* 24, 1-28.

Street, M., Terberger, T., 2004. The radiocarbon chronology of the German Upper Palaeolithic: Fifteen years of cooperation with ORAU. In: Higham, T.F.G., Bronk-Ramsey, C., Owen, D.C. (Eds.), *Radiocarbon and Archaeology*. Proceedings of the 4th Symposium, Oxford 2002. Oxford University School of Archaeology Monograph 62. Oxford University School of Archaeology, Oxford, pp. 281-302.

Street, M., Turner, E., 2013. *The faunal remains from Gönnersdorf.* Monographien des Römisch-Germanischen Zentralmuseums 104. Verlag des Römisch-Germanischen Zentralmuseums, Mainz.

Street, M., Gelhausen, F., Grimm, S., Moseler, F., Niven, L., Sensburg, M., Turner, E., Wenzel, S., Jöris, O., 2006. L'occupation du bassin de Neuwied (Rhénanie centrale, Allemagne) par les Magdaléniens et les groupes à Federmesser (aziliens). *Bulletin de la Société préhistorique Française* 103, 753-780.

Taute, W., 1968. *Die Stielspitzen-Gruppen im nördlichen Europa: Ein Beitrag zur Kenntnis der späten Altsteinzeit*. Böhlau, Köln–Graz.

Terberger, T., 1996. The Early Settlement of Northeast Germany (Mecklenburg-Vorpommern). In: Larsson, L. (Ed.), *The earliest settlement of Scandinavia and its relationship with neighbouring areas.* Acta Archaeologica Lundensia 24. lmqvist & Wiksell International, Lund, pp. 111-122.

Terberger, T., Street, M., 2002. Hiatus or continuity? New results for the question of pleniglacial settlement in Central Europe. *Antiquity* 76, 691-698.

Tolksdorf, J.F., Turner, F., Kaiser, K., Eckmeier, E., Stahlschmidt, M., Housley, R.A., Breest, K., Veil, S., 2013. Multiproxy Analyses of Stratigraphy and Palaeoenvironment of the Late Palaeolithic Grabow Floodplain Site, Northern Germany. *Geoarchaeology* 28, 50-65.

Tromnau, G., 1974. Der jungpaläolithische Fundplatz Schalkholz, Kreis Dithmarschen. *Hammaburg* NF 1, 9-22.

Tromnau, G., 1975. *Neue Ausgrabungen im Ahrensburger Tunneltal: Ein Beitrag zur Erforschung des Jungpaläolithikums im nordwesteuropäischen Flachland*. Wachholtz Verlag, Neumünster.

Tromnau, G., 1992. Anmerkungen zur Rengeweih-Harpune von Meiendorf. In: Krause, E.B., Mecke, B. (Eds.), *Ur-Geschichte im Ruhrgebiet. Festschrift Arno Heinrich.* Edition Archaea, Gelsenkirchen, pp. 79-83.

Turner, E., 2004. The carnivore and human occupations of the Wildscheuer cave, an upper Pleistocene "des. Res." in Hesse, Germany. *Revue de Paléobiologie* 23, 897-925.

Usinger, H., 1978. Pollen- und großrestanalytische Untersuchungen zur Frage des Bölling-Interstadials und der spätglazialen Baumbirken-Einwanderung in Schleswig-Holstein. Mit einem neuen Diagramm aus der Eichholz-Niederung bei Heiligenhafen. *Schriften des Naturwissenschaftlichen Vereins für Schleswig-Holstein* 48, 41-61.

Usinger, H., 1985. Pollenstratigraphische, vegetations- und klimageschichtliche Gliederung des „Bölling-Alleröd-Komplexes" in Schleswig-Holstein und ihre Bedeutung für die Spätglazial-Stratigraphie in benachbarten Gebieten. *Flora* 177, 1-43.

Usinger, H., 1997. Pollenanalytische Datierung spätpaläolithischer Fundschichten bei Ahrenshöft, Kr. Nordfriesland. *Archäologische Nachrichten aus Schleswig-Holstein* 8, 50-73.

Veil, S., Breest, K., 2002. The archaeological context of the art objects from the Federmesser site of Weitsche, Ldkr. Lüchow-Dannenberg, Lower Saxony (Germany) – a preliminary report. In: Eriksen, B.V., Bratlund, B. (Eds.), *Recent studies in the Final Palaeolithic of the European Plain.* Aarhus University Press, Aarhus, pp. 129-138.

Veil, S., Breest, K., Grootes, P., Nadeau, M.J., Hüls, M., 2012. A 14000-year-old amber elk and the origins of northern European art. *Antiquity* 86, 660-673.

Weber, M.-J., Clausen, I., Housley, R.A., Miller, C.E., Riede, F., 2010. New information on the Havelte Group site Ahrenshöft LA 58 D

(Nordfriesland, Germany) – preliminary results of the 2008 fieldwork. *Quartär* 57, 7-24.

Weber, M.-J., Grimm, S.B., Baales, M., 2011. Between warm and cold – impact of Dryas III on human behavior in Central Europe. *Quaternary International* 242, 277-301.

Weber, M.-J., Wild, M., 2019. Allein unter Elchen? *Archäologische Nachrichten aus Schleswig-Holstein* 25, 7-11.

Weinstock, J., 2000a. *Late Pleistocene reindeer populations in Middle and Western Europe. An osteometrical study of Rangifer tarandus.* BioArchaeologica 3. Mo Vince, Tübingen.

Weinstock, J., 2000b. Osteometry as a source of refined demographic information: Sex-ratios of reindeer, hunting strategies, and herd control in the Late Glacial site of Stellmoor, northern Germany. *Journal of Archaeological Science* 27, 1187-1195.

Weninger, B., Jöris, O., 2008. A ^{14}C age calibration curve for the last 60 ka: the Greenland-Hulu U/Th timescale and its impact on understanding the Middle to Upper Paleolithic transition in Western Eurasia. *Journal of Human Evolution* 55, 772-781.

Wild, M., 2017. The Ahrensburgian faunal assemblage from Nahe LA11 at lake Itzstedt (Kr. Segeberg, North Germany). *Archäologisches Korrespondenzblatt* 47, 441-460.

Wild, M., 2020. *Coping with risk through seasonal behavioural strategies. Technological analysis of selected Late Upper Palaeolithic antler assemblages from northern Germany, southern Scandinavia and the Paris Basin*. Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum 12. Wachholtz Verlag, Kiel–Hamburg.

Wild, M., Weber, M.J., 2017. Ein schräger Typ – eine Geweihspitze aus Lasbek und ihr Verhältnis zum europäischen Jung- und Spätpaläolithikum. In: Eriksen, B.V., Abegg-Wigg, A., Bleile, R., Ickerodt, U. (Eds.), *Interaction without borders. Exemplary archaeological research at the beginning of the 21st century*. Festschrift für Claus von Carnap-Bornheim zum 60. Geburtstag. Stiftung Schleswig-Holsteinische Landesmuseen, Schleswig, pp. 23-34.

Wild, M., Mortensen, M.F., Andreasen, N.H., Borup, P., Casati, C., Eriksen, B.V., Frost, L., Gregersen, K.M., Henriksen, M.B., Kanstrup, M., Olsen, J., Pedersen, K.B., Petersen, P.V., Ramskov, C., Sørensen, L., Sørensen, M., Wåhlin, S., in press. Palaeolithic bone and antler artefacts from Lateglacial and Early Holocene Denmark. *Quartär.*

Wulf, S., Ott, F., Słowiński, M., Noryśkiewicz, A.M., Dräger, N., Martin-Puertas, C., Czymzik, M., Neugebauer, I., Dulski, P., Bourne, A.J., Błaszkiewicz, M., Brauer, A., 2013. Tracing the Laacher See Tephra in the varved sediment record of the Trzechowskie palaeolake in central northern Poland. *Quaternary Science Reviews* 76, 129-139.

Sonja B. Grimm
Berit Valentin Eriksen
Mara-Julia Weber
Schleswig-Holstein State Museums Foundation
Schloss Gottorf
Centre for Baltic and Scandinavian Archaeology
Collaborative Research Centre 1266 Project B 1
"Pioneers of the North"
Schlossinsel
D - 24837 Schleswig
sonja.grimm@zbsa.eu

Sascha Krüger
The National Museum of Denmark
Environmental Archaeology and Materials Science
I. C. Modewegsvej
DK - 2800 Kongens Lyngby
and
Kiel University
Institute of Prehistoric and Protohistoric Archaeology
Johanna-Mestorf-Straße 2-6
D - 24106 Kiel

Tobias Reuter
Schleswig-Holstein State Museums Foundation
Schloss Gottorf
Centre for Baltic and Scandinavian Archaeology
Schlossinsel
D - 24837 Schleswig

Markus Wild
Schleswig-Holstein State Museums Foundation
Schloss Gottorf
Centre for Baltic and Scandinavian Archaeology
Schlossinsel
D - 24837 Schleswig
and
Kiel University
Cluster of Excellence ROOTS
Ohlshausenstraße 80 h
D - 24118 Kiel