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This innovative peer-reviewed journal is dedicated to the presentation, discussion and interpretation of the archaeological record of southern Scandinavia in its international, regional and local context. Providing a platform for publication and debate for professionals from the museum as well as the university sectors this journal is open for empirical, methodological and theoretical contributions covering all time periods and all kinds of archaeology with relevance for the Scandinavian, Baltic, and North Atlantic regions. In addition, the journal may publish articles of wider theoretical, discursive or global reach. *The Danish Journal of Archaeology* is published twice a year and includes original research articles, news and discoveries, and discussion pieces with the intention of fostering open debate about the archaeological record of southern Scandinavia in its broadest sense and the position of archaeology as a discipline in the modern world.

Cover: Divers excavating the submerged Hjarnø site. Photo with courtesy of Claus Skriver.

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Special Issue: Early Towns and Urbanisation

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Editorial

Denmark has a long tradition of urban archaeology, and in particular since the 1970s, excavations have been conducted regularly in the around 70 Danish medieval towns. Much new knowledge has been acquired from rescue excavations, ambitious research projects and large-scale infrastructural development projects. This Special Issue includes papers that present the most recent research on the upcoming and changing roles of two important Danish towns, Odense and Copenhagen. The first paper on Odense suggests that a permanent urban character gradually emerged in Odense from the late 8th until the late 10th century, when Odense developed into a town under royal influence, and it furthermore discusses general urbanisation processes in the southern part of Scandinavia. The second paper on Copenhagen presents a new interpretation of the earliest town formation and development from the 11th to the early 13th century using data from recent major excavations combined with Bayesian modelling of new radiocarbon dates and revisiting older archaeological information and written records. Both papers remind us of the importance of revaluating the very fragmented archaeological and written records, and they demonstrate how recent years' enormous building and construction activities as well as extensive metal-detector surveys can provide completely new perspectives on town formation and the development of urbanism.

In 2016, we decided to expand the portfolio of the journal by introducing Special Issues. The first Special Issue was *Law and Order in Early and High Middle Ages*, AD 400–1200 (volume 6, issue 2, 2017). The background for that issue was an international, cross-disciplinary conference that brought together archaeologists and legal historians, organised as a collaboration between the National Museum, Moesgaard Museum and the Faculty of Law at the University of Copenhagen. The second Special Issue is the present issue on *Early Towns and Urbanisation* (issue 1, 2018). We are very pleased to offer DJA as an opportunity to present research thematically to an international audience. There are no plans to make Special Issues a recurring feature in every volume, but we certainly invite readers to suggest themes for future special issues, as well as to participate as guest editors.

We have experimented with different formats in DJA's Special Issues, the first being a collection of conference papers. The current issue presents research based on many years of rescue excavations and archive studies. For this issue, we have exceptionally allowed long papers, but we do not intend to make this a permanent option at present. We have noticed a demand for longer papers in general and have raised the word count to 8000 for research papers. However, we would also like to encourage brief presentations of new discoveries from excavations, laboratories, museum collections and archives from all periods. Similarly, methodological and theoretical debates that reflect the archaeological research agenda and discoveries in Scandinavia are topics which will be looked upon favourably. To facilitate fruitful debates, we also encourage comments and reflections on as well as responses to already published papers.

Mette Svart Kristiansen
Department of Archaeology and Heritage Studies, Aarhus University
markmsk@cas.au.dk

Rune Iversen
Saxo Institute, Department of Archaeology, University of Copenhagen

Mads Dengsø Jessen
National Museum of Denmark, Ancient Cultures of Denmark and the Mediterranean

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RESEARCH ARTICLE

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The origins of Odense – new aspects of early urbanisation in southern Scandinavia

Mads Runge[a] and Mogens Bo Henriksen[b]

[a]Head of Research Centre, Odense City Museums, Odense C, Denmark; [b]Curator, Odense City Museums, Odense C, Denmark

ABSTRACT
The article presents an updated study of the centuries prior to Odense's traditional 'birth certificate' of AD 988, resulting in a new model for the urbanisation of Odense. The conclusion reached is that there was activity of a permanent and possibly urban character in Odense from the end of the late eighth century until the late tenth century. The town's development can be followed through three phases. Phases 1 and 2 cover the periods AD 700–900 and AD 900–100, respectively, while phase 3 covers the period AD 1000-1101. During phases 1 and 2, the proto-town develops through bottom-up processes, such as network, crafts and possibly trade. After AD 1000, Odense develops into a town proper, under royal influence. The model from Odense provides the background for a fresh view of urbanisation in southern Scandinavia in general. A three-phase model is proposed. Phase 0 constitutes the emporia of the eighth–ninth century, which perhaps primarily is satellites in a trading network controlled from the south. Phase 1 takes the form of locally initiated and based incipient urbanisation extending from the end of the eighth century until the tenth century. Phase 2 comprises the royally established towns from around AD 1000 onwards.

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Introduction

This article is based on the research project *The origins of Odense – New aspects of early urbanisation in southern Scandinavia* the aim of which is to analyse when Odense emerged as a city, the characteristics of the city's earliest structure and the background for the formation of the city. The project furthermore should give a new perspective on the general urbanisation process in southern Scandinavia.[1]

The early urbanisation of southern Scandinavia is conventionally perceived as being comprised of two stages, with the first defined by Hodges type B emporia, which were established from the eighth century, and the second by royally founded towns, from around AD 1000 (Hodges 1982, p. 50ff.; Skre 2007b, p. 45). Odense is mentioned for the first time in AD 988 in a deed of gift from the German emperor Otto III, and this document, Odense's so-called birth certificate, is the reason why the town normally is assigned to the latter group of town foundations (Albrectsen 1970, p. 128ff.; Thrane *et al.* 1982, p. 113ff.; Madsen 1988b, p. 97) (Figure 1).

The aim of the present article is, through a new appraisal of the evidence from Odense relating to the centuries preceding AD 1000, to provide a nuanced view of this bipartite development.[2] Although Odense should not be ascribed to the group of early emporia, below the central part of present Odense there were activities of a permanent and possibly urban character extending from the end of the eighth century until the end of the tenth century. Consequently, the town probably developed gradually rather than being a new establishment planned by the central power. Examples of other Danish towns where signs of a parallel development can be traced, are highlighted below.

Based on this overview, an alternative developmental sequence is suggested for urban development in southern Scandinavia, in which phase 0 constitutes the emporia of the eighth– century, which should perhaps primarily be seen as satellites in a trading network controlled from the south, while phase 1 takes the form of locally initiated and based incipient urbanisation extending from the end of the eighth century until the tenth century, and phase 2 comprises the royally established towns from around AD 1000 onwards. Phases 0 and 1 largely correspond to Hohenberg

CONTACT Mads Runge mtr@odense.dk Head of Research Centre, Odense City Museums, Overgade 48, 5000 Odense C, Denmark

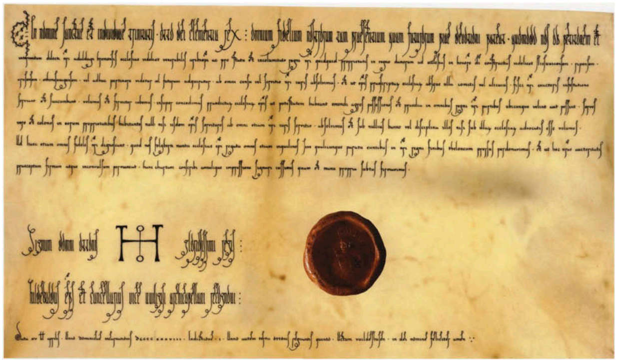

Figure 1. Odense's 'birth certificate' (Christensen and Nielsen 1975, p. 114, no. 343). The document shown here is a copy created from the handed-down text and documents from the emperor's administration. The original document disappeared centuries ago.

and Lee's 'Network Systems' and 'Central Place Systems', respectively (1995, p. 4f., p. 55ff.).

Data material

A major challenge to interpretations based on the archaeological record from Odense is the latter's fragmentary nature. The traces are thus relatively few and have predominantly been identified in minor excavation trenches, with their consequent limited opportunities with respect to the evaluation of broader contexts. Though the data material still is relatively sparse, there has been a development on three fronts. First, extensive metal-detector surveys in Odense's hinterland have yielded a large and auspicious assemblage of metal artefacts. This raises the question of whether Odense was the only place possessing central functions between the Late Iron Age and the earliest Middle Ages and, accordingly, helps to provide a perspective on the background for urbanisation (Henriksen 2013). Second, investigations associated with the enormous building and construction activities in the centre of Odense in recent years have posed several questions with respect to the emergence of the town and its earliest structure (Runge 2016). Third, the new investigations at the Viking fortress of Nonnebakken have provided a basis for a new perspective on the relationship between the town and the fortress (Runge 2017, p. 51ff.).

Despite this addition, the record from Odense's earliest history remains fragmentary. Given this situation, we could choose to ignore the evidence from these centuries and simply classify it as representing various scattered activities, or an agrarian settlement prior to the founding of the town proper around AD 1000, as is seen in the earliest traces of the town of Bergen in Norway (Hansen 2008, p. 22f.). The reason we do not take this approach, but instead attempt to pursue the urban elements, is because the record, despite its limitations, has the potential to nuance the general picture of Odense's foundation and thereby inspire rethinking of the general urbanisation process in southern Scandinavia.

Geographical and chronological framework

The study's primary geographical frame of reference is Odense's medieval urban extent and the land to the south of the river Odense Å that hosted the ring fortress of Nonnebakken. It therefore encompasses an area extending from Allégade in the south to Slotsgade in the north (c. 800 m) and from Ny Vestergade in the southwest to Fru Kirkestræde Gade in the northeast (c. 1000 m), a total of more than 700,000 m^2 (Figure 2).

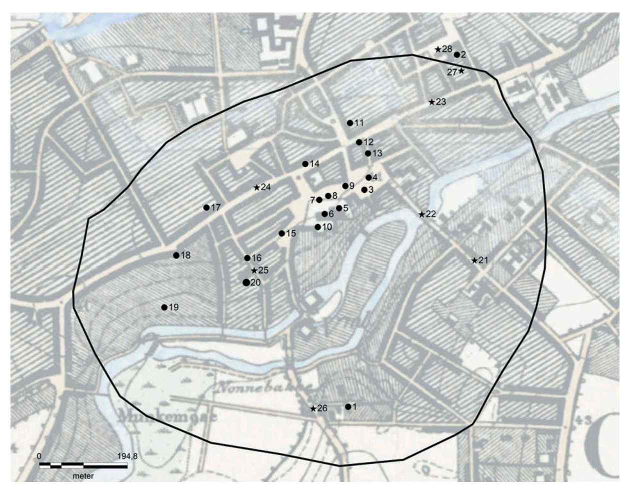

Figure 2. The primary study area (black line) marked on the first edition ordinance map from the second half of the nineteenth century. *1: Nonnebakken. 2: Møntergården. 3: St Alban's Church. 4: St Alban's churchyard. 5: St. Canute's Church. 6: St. Canute's churchyard. 7: The 13 graves at St. Canute's churchyard. 8. Skt. Knuds Kirkeplads I. 9: Skt. Knuds Kirkeplads II. 10: Klosterbakken. 11: Fisketorvet. 12: Skomagerstræde/Overgade 1–3. 13: I. Vilhelm Werners Plads. 14: Vestergade 13–15. 15: Klingenberg. 16: Mageløs/Klaregade. 17: Vestergade 43–49. 18: Vestergade 70–74. 19: Filosofgangen 9–17. 20: Bispegården. 21: Albanigade. 22: Torvegade. 23: Vestergade. 24: Overgade. 25: Klaregade. 26: Hunderupvej, 27: Møntestræde, 28: Sortebrødre Stræde, 29: Slotsgade, 30: Ny Vestergade, 31: Frue Kirkestræde, 32: Allégade*. Background map: *© The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

The timeframe for the study is from the Late Germanic Iron Age, i.e. from c. AD 700, until the canonisation of Canute IV, subsequently known as Canute the Holy, in AD 1101. The Late Iron Age is the period when the earliest indications of state formation and urbanisation are evident in southern Scandinavia (Näsman 1991a, Hansen 2015, p. 186ff.; Roesdahl 2016, p. 176f.), while Canute's canonisation marks a shift in Odense's history, when the town became characterised by powerful religious markers and thereby took a new path (Nyberg 1982, p. 159; Johannsen *et al.* 1998–2001, p. 1729; Bjerregaard and Runge 2017, p. 10ff.).

The subdivision of the chronology of the Late Germanic Iron Age and the Viking Age is conventionally based on animal styles and ornament inventories (Ørsnes 1966, Højlund Nielsen 1987, Lund Hansen 1988, p. 32f.; Skibsted Klæsøe 1999). The material evidence takes, however, a different form in the present context and only a coarse chronological subdivision is possible, which also cuts across the aforementioned period divisions. Consequently, a tripartite division is consistently employed here, i.e.: (1) final part of Late Germanic Iron Age-Early Viking Age (c. AD 700–900), (2) Late Viking Age (AD 900–1000) and (3) Late Viking Age-earliest Middle Ages (c. 1000–1101). The transition from the Germanic Iron Age to the Viking Age is fixed here at c. AD 750.

The topography and geology of Odense and its hinterland

Odense is situated on relatively flat, even terrain, comprised variously of clay, gravel and sand (Smed 1962). The terrain is cut through, from southwest to northeast, by a c. 175–500 m wide lateglacial meltwater valley in which the river Odense Å flows on its way to Odense Fjord. The town of Odense was established at precisely the point where the distance between the two sloping sides of the valley is least.

On Georg Braun's map of Odense from 1593 (Jørgensen 1981), islands can be observed in the middle of the river in two locations immediately to the south of the town (Figure 3). Both islands are undoubtedly sand banks that had formed in the river and which, in the Late Middle Ages and post-medieval times, made the crossing easier between the areas to the north and south of the river. One is at the western end of the medieval town, where Klaregade, on the north side of the river, is joined, via two bridges, with Hunderupvej, south of the river. About 400 m further downstream, the later Torvegade, on the north side of the river, is linked via a small island with the later Albanigade on the south side (see Figure 2). The degree to which these sand banks existed when the town developed is unknown, but it was apparently in precisely this stretch that the river dynamics provided the necessary conditions for their development. The earliest archaeological evidence of settlement in Odense was discovered close to the western crossing, and south of the river lay the Nonnebakken ring fortress beside the continuation of the road network. This could indicate that the western crossing, at least, has been in use since the tenth century, and perhaps even earlier, and that it played a central role in the town's development.

Figure 3. Braun's prospectus. After Füssel (2008), p.184.

The centre of medieval Odense developed on the level terrain on the north side of the river, and extended all the way out to the erosion slope created by the meltwater river at the end of the last Ice Age. The present-day terrain in the area of the medieval town has its highest point around 14 m above DNN (Danish Ordnance Datum), directly northeast of Odense Cathedral, St Canute's Church. In the same area, a long stretch of road running east-west has been investigated. This has the same orientation and location as the medieval, and still extant, Overgade-Vestergade route through the town. The cobbled road was laid around AD 1100 on a level surface at c. 11 m above DNN, from which the topsoil had been removed. By comparing the top levels for the glacial deposits in the archaeological trenches and in the cores taken across large parts of the medieval town (cf. Zinglersen 2004), it can be demonstrated that features from the tenth–twelfth centuries everywhere along a more than 800-m long stretch of the river were cut down from an even and well-drained surface around 11–12 m above DNN. To the south, this surface fell abruptly down towards the river, the water level of which presently lies around 4.7 m above DNN. To the north, c. 175–250 m distant from the northern slope of the meltwater valley, the level surface was bounded by a hollow that ran parallel with the river. A minor watercourse – Rosenbækken (see Figure 3) – flowed east along this hollow, into Odense Å. The town is, accordingly, situated on an elongated, even and – apart from in the west – naturally delimited and well-drained surface, covering no less than 20 ha. Investigations in the town centre in recent years have demonstrated that this surface was not, as previously stated (Christensen 1988, Figure 14) bisected north-south by a wetland area.

On the south side of the river, the ring fortress of Nonnebakken was built on an even, clayey promontory, which extended all the way out to the southern erosion margin of the meltwater valley. There was some levelling of the site in connection with the construction of the fortress, but pits and holes for structures associated with it appear to have been cut from a level around 9–9.1 m above DNN. Between the fortress and the river was an evenly sloping, c. 40 m wide surface, presumably a lateglacial river terrace, and investigations here have shown that the river course has, at no point in time, been closer to the fortress plateau (Jensen and Sørensen 1990).

The water route to Odense

Prior to 1803, when a canal was dug linking Odense Fjord with the northwestern periphery of the town, c. 1.6 km north of the cathedral (Harnow 2005), it was not possible to sail to Odense in larger vessels. The distance from the medieval town centre to the innermost and now drained and reclaimed branch of Odense Fjord, Bågø Strand, was about 3.5 km as the crow flies, while the journey along the meandering course of the river to its mouth in/at Seden Strand was about 11 km. About 1.3 km to the northwest lay

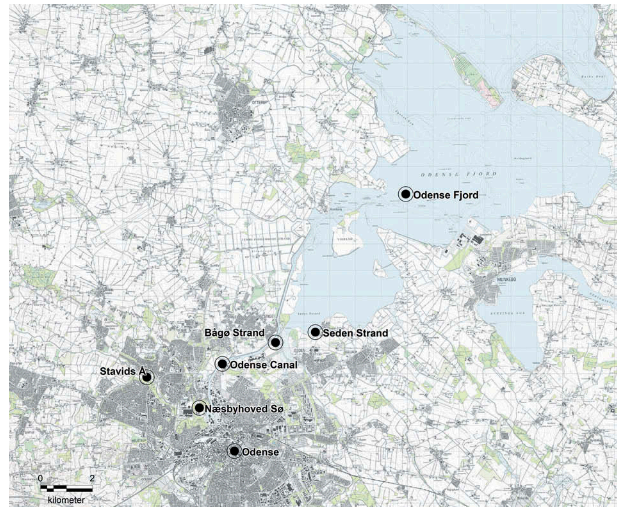

Figure 4. The locations of Odense, Odense Canal, Odense Fjord, Bågø Strand, Stavids Å, Næsbyhoved Sø and Seden Strand. Drawing: Mads Runge.

the lake Næsbyhoved Sø, which was connected to Odense Fjord via the watercourse Stavids Å; the lake was drained and reclaimed in the nineteenth century (Tårup 1934) (Figure 4).

In most works dealing with the first centuries of Odense's history, the assumption is made that it was possible to sail in to the town, via Odense Å or Stavids Å/Næsbyhoved Sø, with the vessels of Viking Age and Early Middle Age types (Lauritsen 1873, p. 1ff.; Tårup 1934, p. 518; Thrane *et al.* 1982, p. 22f., 108, 124ff.; Christensen 1988, p. 29, 47ff.; Moesgård 2015, p. 84; cf. also Crumlin-Pedersen *et al.* eds. 1996, p. 134). Two fundamental conditions for this assumption are: (1) that the water level in these watercourses was higher than is the case today (Thrane *et al.* 1982, p. 22f.; Madsen 1988a, p. 35) and (2) that the vessel types of the time were of shallow draught.

There is no evidence from the banks of Odense Å to suggest that the water level was higher at the transition from the Viking Age to the Middle Ages. The only available evidence that the river has, at any point in postglacial times, had a higher water level than that of the present day, comes from an excavation in the area between Nonnebakken and the river: A degraded and humified peat layer containing brick/tile fragments that is presumed to have been formed when the river was dammed in conjunction with the construction of mills downstream in the twelfth century (Madsen 1988a, p. 34ff.). This could have led to an/a – albeit periodic – raising of the water level in this area by 0.5–1 m. Given a higher water level, the area now known as Munke Mose (see Figure 3), which appears on Braun's map from 1593 as above water, would have been flooded. Mill dams are, however, not the only factor to have influenced the potential for navigation on the river. The water where the river meets the sea (i.e. Odense fjord) is important. Due to extensive drainage works, the shoreline in Odense Fjord has changed significantly since the Viking Age (Stenak 2005, p. 123ff.). On the other hand, there is nothing to indicate that the sea level was higher at that time than it is today. Given the fact that the world's oceans are presently in transgression, it is possible that the water level in the fjord may have been a little lower than it is today (Binderup 1996, p. 29). This would, in turn, have led to a lower water level in the river. The depth of water in the river has, however, also been influenced by the sedimentation which the river itself has created with the material it transported along the c. 60 km of its course (Riis *et al.* 1999). Moreover, where it met the sea, the sedimentation created a delta, and fluctuations in the morphology of this would mean that the approaches to the river channel could periodically have been difficult to navigate, as is known to have been the case in historical times (Lauritsen 1873, p. 2; Harnow 2005, p. 26ff.).

On its way from the town to the fjord, Odense Å, flows almost east-west along a c. 5.5 km stretch to Åsum, after which it turns sharply c. 80° and flows NNW-SSE along the remainder of its course to the sea. On the first stretch, its course is characterised by meanders and the river channel here can be termed as mature. Its course is erosive over long stretches and here it can be seen that the water cuts into and is delimited by the moraine deposits on both banks. On these stretches, the width of the Viking Age river cannot have exceeded the c. 12 m it measures today. Navigability would have been further hindered by unpredictable riverbed conditions in the meanders. Here, there is sedimentation of transported material at the lee side so that a considerable part of the bed consists of sand banks, over which the water depth is modest. On its final stretch towards the sea, the river flows largely through its own sediments and must consequently be termed an old watercourse of limited fall, with a width on its final reaches of 30–50 m. At Åsum, and thereby at the transition from the mature to the old watercourse, there is a threshold in the river and this has constituted a significant hindrance to further navigation upstream towards the town.

In evaluating of the river's navigability, it must also be taken into consideration that the vegetation along the banks of the river constituted a potential but realistic hindrance – especially for masted vessels. On the stretches where the river banks are formed by moraine deposits, it would not have been impossible to keep the vegetation down, even though this would have involved felling or pruning trees and bushes along a total stretch of around 10 km. On the lower reaches of the river, where it largely flows through unconsolidated sediments, cutting trees and undergrowth could have involved considerable difficulties.

An analysis of the lower reaches of Odense Å has shown that, overall, it must be considered inconceivable that Viking Age long-ship types, such as the Ladby ship, with a length of 22 m and a draught of c. 1 m, would have been able to sail up the river to the town and the ring fortress. The use of sail power is unthinkable and oar propulsion seems, at least in places, to be rendered impossible by the narrow course of the river, which can be assumed to have been further constricted by vegetation and sand banks. Furthermore, the risk of going aground in the bends of the river, which in some places form a right angle, would have been considerable for a vessel of these dimensions – and even for smaller vessels such as the Fotevik 1 type, with a length of c. 10 m and a draught of c. 1 m (cf. Crumlin-Pedersen 1991). Conversely, it seems likely that yet smaller vessels, such as the boat from Gislinge Lammefjord, with a draught of 0.3 m, a length of 7.7 m and a cargo capacity of c. 1 tonne (Gøthche 1995), would have been able to travel all the way up the river by oar power, possibly augmented by poling when navigating the sections where the banks are close together and there is only a narrow navigable channel.

On the lowermost reaches, where sailing with larger vessels must have been possible without major hindrance, the left bank of the river meets moraine deposits in several places. This is the case immediately north and south of the village of Biskorup, and on this latter section, place names such as *Skibmaden, Skibagre* and *Skibeng* testify to activities related to navigation (Crumlin-Pedersen *et al.* eds. 1996, p. 141f., Figure 12; Harnow 2005,

p. 26ff.). It seems obvious to conclude that there could have been an entrepot here, where goods from sea-going vessels could be transferred to smaller vessels and barges – or to forms of land transport, which then could proceed along a level, c. 4 km route in to Odense. Archaeological investigations have not been undertaken in the area, but a stray find of an axe dating from the Viking Age or Early Middle Ages provides an indication of activities here in the centuries around AD 1000.

Innermost in Odense Fjord there has been access, via the lower reaches of Stavis Å, to the lake Næsbyhoved Sø, the southern shore of which, until its final drainage and reclamation in the mid-nineteenth century, lay 1.6 km to the north of the cathedral (Tårup 1934, p. 518). As the area here has undergone major changes, it is no longer possible to evaluate the degree to which it was possible earlier to navigate the lower reaches of this watercourse using larger vessels. However, the lake was shallow and had the character of a bog that was growing out across the open water. This means it would not have been possible to land on the boggy shores without the construction of jetties or other forms of fixed structure. Nothing of this kind has been demonstrated and, similarly, there is a total absence of finds from the Iron Age and Viking Age from the lake's shore-near areas.

It must therefore be concluded that the areas of land on which Odense and Nonnebakken were established could not be reached with large vessels in the Late Iron Age or Viking Age. This demonstrates – as also shown by other studies (Ulriksen 2011) – that the growth of local centres was not necessarily conditional on ready access to the sea.

From central space to urban place

The area of Odense Fjord and the Hindsholm peninsula represents a marked regional centre of wealth throughout the Iron Age, reflected in particular by a concentration of graves containing Roman imports from the second to fifth centuries AD and several gold hoards from the fourth to sixth centuries AD (Henriksen 2009, p. 340ff., 2010, 2013, Henriksen and Horsnæs 2015, Feveile 2016, 2018) (Figure 5). From the Late Iron Age and Early Viking Age the Glavendrup monument, with ship setting and rune stone, the rich Rosenlund grave (with the Rønninge

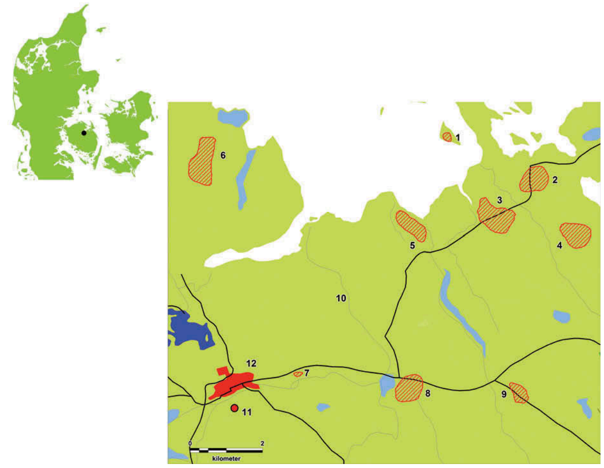

Figure 5. The area around Odense Fjord with the locations of Odense and the large metal-rich sites marked on the Royal Society Map from the second half of the eighteenth century (digitised by Peder Dam, University of Copenhagen). Dark grey (dark blue): Lake. Light grey (light blue): Meadow/bog. Thin line (light blue): Watercourse. Black line: Highway. 1: Tornø. 2: Dræby. 3: Vester Kærby. 4: Vesterskov. 5: Engløkken. 6: Lumby. 7: Ejby Mølle. 8: Åsum. 9: Marslev. 10: Odense Å. 11: Nonnebakken. 12: Odense. Background map: © *The Agency for Data Supply and Efficiency. Drawing: Mads Runge.*

rune stone nearby), the Ladby grave and the barrages in Kertinge Nor stands out (Crumlin-Pedersen 1996, p. 187f.; Jacobsen 2000, Sørensen 2001, Nørgaard Jørgensen 2002, p. 130f., 149f; Feveile 2016) (Figure 6). In total the area can be seen as a growth zone within which, with the possible exception of a couple of localities that, as will be seen, are conspic-

Figure 6. The locations of Odense, Kertinge Nor, Ladby, Rosenlund, Rønninge and Glavendrup. Drawing: Mads Runge.

uous due to their size, it is not possible to point out just one or two dominant localities, but rather observe a number of central functions distributed across the landscape (Henriksen 2013, Christensen 2014b, p. 86ff., 2016).

During the Late Iron Age, Viking Age and Early Middle Ages, the shores of the southern part of Odense Fjord and on the Hindsholm peninsula were characterised by a number of metal-rich sites, and the area should presumably be seen as a regional growth area. These sites are almost exclusively represented by the presence of metal artefacts in the plough soil, revealed by metal-detector surveys, whereas actual excavations have on the whole not been undertaken. Consequently, the role or function of these sites is poorly illuminated, but there is a good deal of evidence suggesting that elements of trade and handicrafts occur at most of them (Henriksen 2013, Henriksen and Horsnæs 2015, Feveile 2016, 2018). Until recently, the distribution of these localities was largely limited to the eastern side of Odense Fjord and the area extending out towards Hindsholm. Over the last few years, however, several new metal-rich localities have turned up, including some in the southern part of the fjord's western side. Much suggests that sites of this kind were associated with virtually all the bays and inlets on the fjord, where there must have been good anchorages and landing places. The locality of Vester Kærby, located east of the fjord, stands out among the metal-detector sites, possibly due to its very considerable extent (Henriksen and Horsnæs 2015) (Figures 7 and 8). A similar locality recently discovered at Lumby, west of the fjord, possibly also represents a level above the norm (Figures 9 and 10). To determine whether these extensive (in terms of area) finds distributions really constitute a single coherent locality or several smaller ones it would be necessary to carry out archaeological excavations.

Whether there was a metal-rich site in the Late Iron Age in what is now the centre of Odense, corresponding to those found by metal-detector in the hinterland, is difficult to ascertain, because very large parts of the town were built without prior archaeological investigation and at a time before metal detectors became an everyday part of archaeology. It is, however, possible that this area was one of many hosting trade and craft activities. As will become evident below, however,

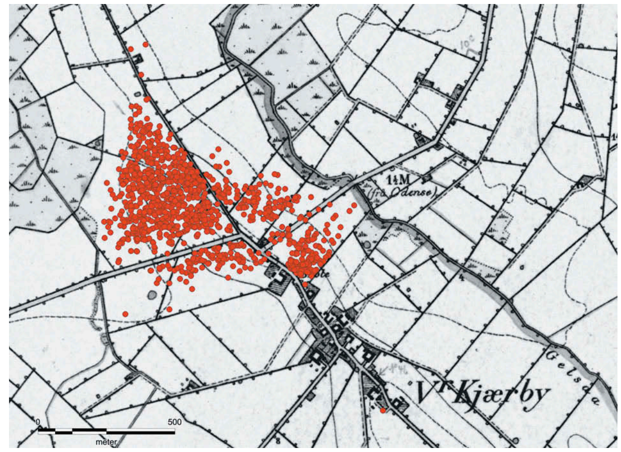

Figure 7. Metal-detector finds at Vester Kærby plotted on the first edition ordnance map from the second half of the nineteenth century. The finds extend in date from the Late Neolithic to modern times. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

Figure 8. Selected artefacts from Vester Kærby from the Late Germanic Iron Age (3,4,8,13,15,16), Viking Age (1,2,5,6,9,11) and Early Middle Ages (7,10,12,14). Photos: Asger Kjærgaard and Nermin Hasic.

the finds from the pit-house area at Vestergade 70–74 and Mageløs/Klaregade indicate that this first became established in the late eighth or

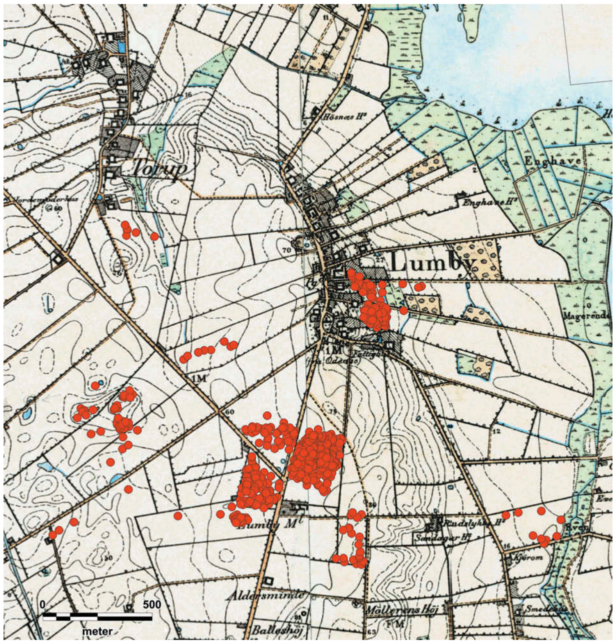

Figure 9. Metal-detector finds from Lumby plotted on the first edition ordnance map from the second half of the nineteenth century. The finds extend in date from the Early Bronze Age to modern times. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

Figure 10. Selected artefacts from Lumby, dating from the Late Germanic Iron Age (2, 3, 6–9, 11), Viking Age (1, 4, 5, 12, 14–17) and Early Middle Ages (10, 13). Photos: Nermin Hasic.

ninth century. At the same time the position of earliest Odense differed from the sites associated with the fjord. As described above, the centre of Odense lies some distance inland from the coast, a situation further emphasised by the fact that navigational conditions in Odense Fjord are and were extremely challenging.

Under any circumstances at the end of the Iron Age or beginning of the Viking Age, the prelude to the development of permanent and pre-urban features is seen in what later became Odense. By the turn of the millennium, at the latest, the central functions became concentrated here, and the establishment of Odense as a regional urban centre became a reality.

The question is then, why was it Odense, of all these localities, that became the central locality? Other questions are, why and how the change occurred? The questions are in these years treated in other projects, cf. note 2, but a few points can be outlined already.

Although Odense has an obviously advantageous position in relation to land traffic (Porsmose 1996, p. 201), it lies further away from water transport routes than the metal-rich sites around Odense Fjord. But perhaps it was this recessed, inland location that was the crucial factor in determining the site of the primary centre? The situation is consistent with for example the inland Iron Age centre at Gudme, where the associated landing place, Lundeborg, has an exposed location on the coast (Henriksen 2009, p. 340ff.). A recessed, inland location also characterised Late Iron Age central places on Zealand (Rindel 2002, p. 194f.).[3]

With the massive discovery of metal-rich sites in recent years, both to the east and west of the southern part of Odense Fjord, it has become still more evident, that Odense can now be seen to have occupied a very central position in the major trade networks constituted by the numerous natural landing places and metal-rich sites around Odense Fjord. The central position and role of Odense is underlined by the location of the afore mentioned magnates' monuments such as Glavendrup, Ladby, Rosenlund etc., within a radius of up to 10–20 km of Odense. It should possibly be seen as a parallel to the Gudme area in the Early Iron Age, where the warrior graves were sited around the periphery of the area. Glavendrup (18 km), Ladby (18 km), Rosenlund (18 km) (near Rønninge rune stone, 22 km) perhaps reflect magnates who were subservient to, and dependent on, the king and his predecessor in Odense (Crumlin-Pedersen 1996, p. 187f.; Jacobsen 2000, Sørensen 2001).

Urbanisation

Historical background

In general terms, two lines of thought can be followed in the analysis of the earliest urbanisation in southern Scandinavia. One takes its point of departure in the towns being an expression of a top-down or exogen process, in which the Crown plays a crucial, central role (Andrén 1985, 1994, Christensen 2004, Ulriksen *et al.* 2014). While the other emphasises that a number of bottom-up or endogen factors, such as trade networks and agrarian conditions, could have contributed to urbanisation (Mathiesen 1922, 1927, Hohenberg and Lees 1985, p. 4; Sindbæk 2007, Holst 2014). Some researchers even talk of urbanisation in terms of processes that collectively involve all members of society (Kleingärtner 2014, p. 235ff.). It has also been pointed out recently that, in general, operating with definitions of urbanity that are too narrow can be problematic: Absence of one of the defining aspects or features need not necessarily mean that a given locality should not be perceived as a town (Krongaard Kristensen and Poulsen 2016, p. 13ff.). On the other hand, one or a few urban elements do not, in themselves, mean that a locality should unequivocally be considered as urban. For example, localities such as Tissø, Lejre and Uppåkra contain several elements that can be considered as urban without these places otherwise being considered as towns. Furthermore, complexes such as the Trelleborg-type ring fortresses have structures and functions that, in other contexts, would justify an urban definition. The question of urbanity is therefore extremely complex, and one common uniform model probably cannot be proposed and sustained.

A starting point for the discussion of the definition of a town is the ten criteria for urbanisation proposed by Gordon V. Childe in 1950 (Childe 1950). Of these, it has since been highlighted that conditions relating to the following are the most important: (1) denser settlement relative to the surroundings, (2) presence of specialised occupations or trades unrelated to food production, (3) accumulation of a surplus production for leading families, (5) presence of a ruling class and (10) a centralised power or state organisation (Smith 2009).

Subsequently, several researchers have, with clear reference to Childe's model, pointed out that important criteria for urbanisation are population density, permanent settlement of a certain size, the majority of the population subsisting by trade and craft activities and a locality that is clearly delimited from its surroundings (Weber 1958, Hohenberg and Lees 1985, p. 22f., Skre 2007b, p. 46). A rough definition of a town is given in the Swedish project *Medeltidsstaden* (The Medieval Town), where it is suggested that a town, at least in a medieval context – must satisfy three groups of criteria: functional (position in relation to hinterland and other towns), topographic (internal organisation and layout) and legal and administrative conditions (privileges, town council, etc.) (Andersson 1972). Due to a town's many special functions, such as a trade and craft centre, it also becomes a hub for many meetings between people; the latter is a condition on which the network theory, in particular, focuses attention upon. In continuation of this line of thought, it has been debated whether networks and meetings between people which constitute a town relative to the surrounding world – or whether it is a town that creates these networks and encounters (Sindbæk 2007).

Proto-towns, market places, villages, towns and other sites with urban features

A crucial point in the discussions on early urbanisation relates to the minimum criteria that must be satisfied before a settlement can be classified as a town. The earliest towns, the proto-towns, have therefore interfaces with seasonal market places, contemporaneous villages and actual towns.

Several trade and craft sites from the eighth and ninth centuries have town-like features, but the requirement for permanence of the settlement, in particular, means that to date only four localities in southern Scandinavia – Birka, Ribe, Haithabu and

Figure 11. Locations of the emporia Ribe, Hedeby, Birka and Kaupang. Drawing: Mads Runge.

Kaupang – have qualified for classification as proto-towns or emporia, according to Frankish and Anglo-Saxon terms and models (Hodges 1982, Skre 2007c, p. 453, p. 461, 2011, p. 207; Croix 2015) (Figure 11). The term Special Economic Zones has also been suggested for these sites, for which a clear terminology in general is lacking (Kalmring 2016). It has been pointed out that emporia were established on the borders of the realm in order to signify and mark out its extent, while market places were positioned more centrally in the realm (Skre 2007b, p. 461f.). The placing of emporia on the periphery of the realm can, on the other hand, also be linked to the fact that this often constituted the ideal position in relation to their role in a long-distance network (Kalmring 2016, p. 15f.).

The physical difference between early towns and contemporaneous (larger) villages and magnate's farms was, in the eyes of the population at that time, probably not considered to be particularly marked, given that the earliest towns must be presumed to have been relatively small in size and also to have accommodated several agrarian functions (Reynolds 1977, p. ix; Nilsson 2015, p. 262). Conversely, the relatively dense permanent population and trade specialisation evident in the towns created a society that was characterised by a much greater degree of interaction than occurred in the rural environment (Skre 2007b, p. 46).

Proto-towns also differed from the better consolidated and multi-functional medieval towns. Factors such as special fiscal conditions, the presence of two or more churches and the minting of coins are characteristics of the latter (Andrén 1985), to which a role as an administrative centre for the hinterland can be added (Skre 2007b, p. 45). This difference naturally reflects developments in the associated society, with the consolidated power of the state and the development of ecclesial institutions around AD 1000 being decisive factors. Another way of looking at this is to see Late Iron Age trading places as points on the road towards early, partially spontaneous, urbanisation, while late tenth and eleventh century towns are viewed as being a completely new phenomenon, initiated by the monarchy and the Church, according to a western European model for the purpose of serving the interests of these two institutions (Callmer 1991, p. 30).

Definition of proto-town and town

The definition of a town must contain certain universal characteristics, while the town's description must be adapted to the historical and geographical context (Reynolds 1977, p. ixf., Skre 2007b, p. 46f., p. 454). The description of a town varies according to whether the period is the Late Iron Age/Viking Age or the Middle Ages (Krongaard Kristensen and Poulsen 2016, p. 13ff.). The basis for creation of a surplus production and possibly also a levy system may, as mentioned, have been established in villages as early as AD 600 (Hansen 2015), and the hint of a monarchy is perhaps discernible as early as the sixth century, although this possibility has been subject to intense debate (Näsman 1997, Christensen, T. 2015, p. 255ff.). It is more certain that the royal and, not least, ecclesial institutions of the Danish realm did not become consolidated until after the eleventh century. Both of them played a prominent role in the formation of urban environments (Christensen, T. 2015, p. 284). Even though there is a risk here of circular argument, it is obvious that both a town's functions and its background must be viewed differently, according to whether we assess it before or after the beginning of the eleventh century.

In addition to a requirement for the description of a town to be able to accommodate chronological developments, i.e. a dynamic, it is also necessary to be aware that each urbanisation process has its own individual characteristics (Mogren 2005, p. 18, Von Carnap-Bornheim 2010, p. 113).

Even though, given the above-mentioned variations and chronological dynamics in the urbanisation processes, it can be problematic to operate with a list of definitive criteria that must be satisfied (Mogren 2005, p. 17), it is also necessary to have some form of basis for comparison. In the following, use will therefore be made of a, broadly speaking, bipartite model, which covers some relevant criteria for urbanisation in the period AD 700–1000, and also some extra criteria for the period subsequent to this. This bipartition corresponds to the two waves of urbanisation proposed by Skre (2007b). The empirical data are compared with the criteria and then a concluding summary analysis is presented in which local conditions are also incorporated. In this way, the intention is to arrive at an overall explanatory model for the earliest urbanisation at Odense and subsequent developments towards an established medieval town.

The following criteria, proposed by Olaf Olsen in 1975 and Susan Reynolds in 1977, and which also characterise Ribe, Kaupang and other emporia, will be examined for the period AD 700–1000 (Olsen 1975, Reynolds 1977, p. ixf.):

- Population density
- Permanent settlement of a certain size
- Majority of the population subsisting by trade and craft production

Olsen and Reynold's final point, that the locality is clearly delimited with respect to its surroundings, may possibly not be applicable to the proto-towns, but is probably a phenomenon that first turns up in the eleventh century (Sindbæk 2007, p. 129). An exception to this is though again seen in the emporia: For example, there was already a town ditch in Ribe as early as the first half of the ninth century (Feveile 2006, p. 41ff.). After AD 1000, it is also crucial for a town to contain two or more churches and have minting of coins and special taxation rules.

Odense's earliest layout and topography

The sources relating to Odense's earliest history are, as already mentioned, rather fragmentary. Several major developments undertaken in particular between the 1950s and 1970s, before a more comprehensive legislative protection of the archaeological remains came into force, mean that central parts of the town's earliest settlement layers have been removed and destroyed without prior archaeological investigation. Consequently, no large coherent areas have been subjected to investigation in the same way as, for example, the so-called market place in Viking Age Ribe (e.g. Feveile 2006). The data must therefore be patched together on the basis of a number of minor, scattered excavation trenches, together with the large area involved in the recent investigations at Thomas B. Thriges Gade. This naturally has consequences for the reliability of proposed hypotheses.

Further to this, the individual urban-diagnostic elements for the entire study period are dealt with collectively. To obtain a clearer picture of the dynamics of the developments during this broad time period, these elements will be assigned to three narrow chronological groups, which are presented below. Several localities cannot be dated so precisely, but extend across a couple of phases. Nevertheless, the tripartite division is maintained as it sketches some broad and striking developmental stages.

In the following the main elements of Odenses' earliest structure is presented. The analysis behind are given in the Appendix.

Phases

Phase 1 (c. AD 700–900) (Figure 12)

- The oldest traces of activity at the plateau at Nonnebakken is placed in the 7–9th centuries, with the aid of a Valkyrie brooch, a hilt from a sword and several AMS dates for material that *may* be related to the construction of the ring fortress – perhaps as a reflection of a fortress phase that preceded the actual Trelleborg-type fortress phase. The early dates can, as discussed in the commented catalogue, also relate in some way to a presumed sanctuary, the so-called Odins Vi, or other activities. Regardless of their precise explanation, the circumstances support the conclusion that the eastern Danish fortresses of Trelleborg type have a more complex buildings

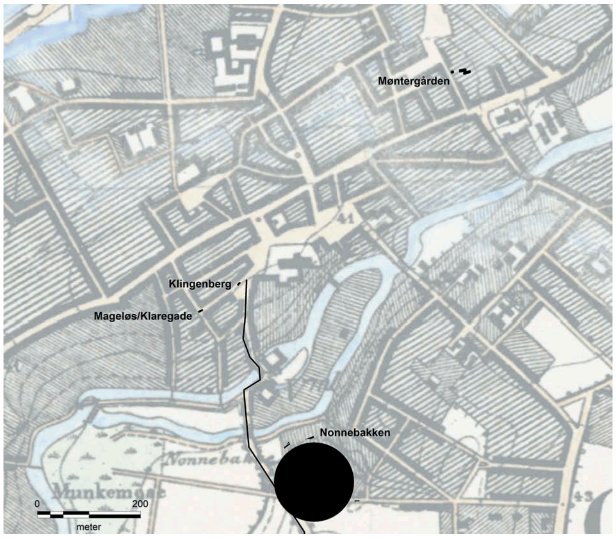

Figure 12. Phase 1 (c. AD 700–900). Marked on the first edition ordnance map from the second half of the nineteenth century. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

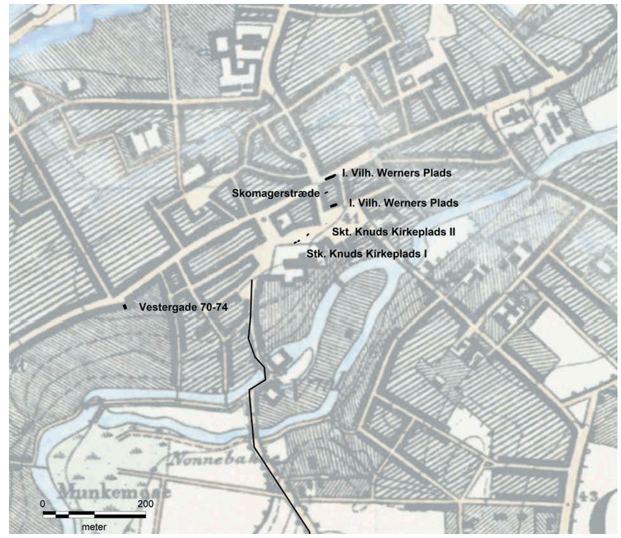

Figure 13. Phases 1–2 (c. AD 700–1000). Marked on the first edition ordnance map from the second half of the nineteenth century. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

history, and roots extending further back in time, than the western examples of these monuments.

- Two pit-houses at Mageløs/Klaregade are dated on the basis of hemispherical vessels and other vessel forms, in conjunction with a couple of AMS dates, to the end of the Late Germanic Iron Age/Viking Age. Scattered posts near the pit-houses could derive from a coeval permanent settlement.
- A possible dwelling house at Klingenberg is dated on the basis of sherds of hemispherical vessels to the Late Germanic Iron Age/Early Viking Age.
- A pit at Møntergården, containing sherds of hemispherical vessels and Baltic ware pottery,[4] is dated to the end of the Late Germanic Iron Age or Viking Age. Two possible dwelling houses west of the pit can be assigned typologically to the Bronze Age or Iron Age; a third one is perhaps coeval with the pit. A four-poster structure appears, based on its relative position, to be most likely related to (one of) the longhouses. The locality probably lies to the northeast of Viking Age Odense.

Phases 1–2 (c. AD 700–1000) (Figure 13)

- A possible pit-house, together with a number of postholes that form the corner of a fence or a house at Skomagerstræde/Overgade 1–3, are overlain by a cobbled road, on which was found a ring-headed pin from the Late Viking Age.
- A minimum of two or three longhouses and a section of fence were identified at Skt Knuds Plads. The structures are stratigraphically earlier than the medieval graves but cannot be dated more precisely.
- The early phase of a pit-house at Vestergade 70–74 could be coeval with a stray find of a patrix dated to around AD 900. The later phase of the pit-house could be contemporaneous with a possible permanent dwelling house. This horizon is dated on the basis of the finds to the second half of the Viking Age or the Early Middle Ages. The area could have been in use during phases 1, 2 and possibly 3.
- A house or a fence, APC, at I. Vilhelm Werners Plads appears, based on AMS dates, to have been in use at some time during the period AD 777–991. Another house, ACU, probably has two phases. The first phase probably extends from the end of the ninth century until the middle of the tenth century, while the second, when the north wall was moved c. 0.75 m towards the north and a possible outshot is constructed, extends into the eleventh century. In addition to the two possible house structures, material from a pit is dated to AD 722–945.

Phase 2 (c. AD 900–1000) (Figures 14 and 15)

- At the end of the tenth century, Nonnebakken became an actual fortress of Trelleborg type. This conclusion is based on a series of AMS dates, a silver hoard buried within the fortress which contained a Carolongian coin minted in the period AD 940–985 and constructional similarities with the other fortresses of Trelleborg type. It is also further supported by evidence from several hoards and stray finds from the area. The extent to which Nonnebakken managed to function as a fortification during this period is unknown. The fortress could – if it actually did manage to become functional – also have accommodated the royal residence of the time.
- The discovery of three iron axes at Nonnebakken should possibly be viewed in the context of the Trelleborg-type fortress phase.
- The reference in Odense's so-called 'birth certificate' of the town having both a cathedral and a bishop in AD 988. It has not yet proved possible to demonstrate this archaeologically.
- At Vestergade 13–15, three cut-through floor layers were discovered, probably associated with dwelling houses. The floors have been AMS dated and fall within the period AD 897–1148.
- AMS dates for the possible house structure ATN at I. Vilhelm Werners Plads, together with a small sector of the finds assemblage, indicate that it was in use from the second half of the tenth century.

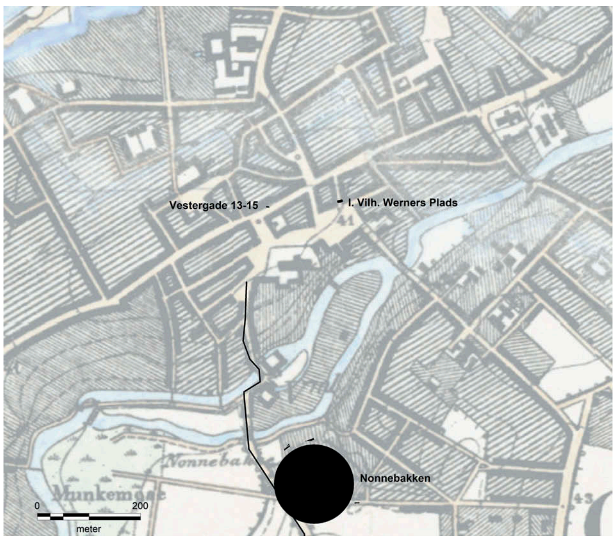

Figure 14. Phase 2 (c. AD 900–1000). Marked on the first edition ordnance map from the second half of the nineteenth century. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

Phase 3 (c. AD 1000–1101) (Figure 16)

- A bone comb from disturbed fill at Filosofgangen 9–17 is dated to the eleventh century.

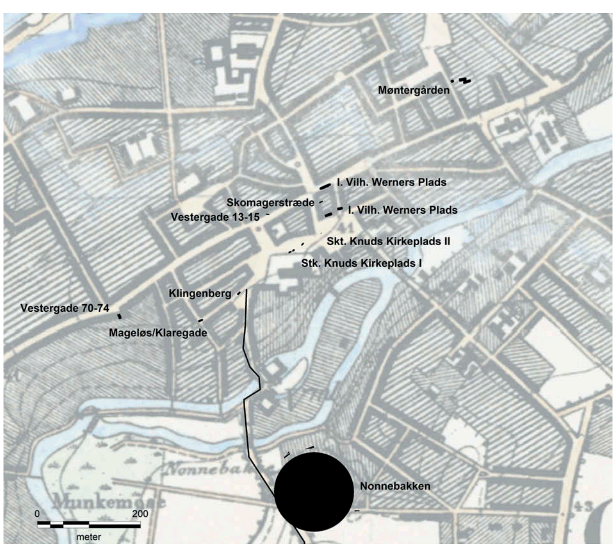

Figure 15. Phases 1, 1–2 and 2 together (c. AD 700–1000). Marked on the first edition ordnance map from the second half of the nineteenth century. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

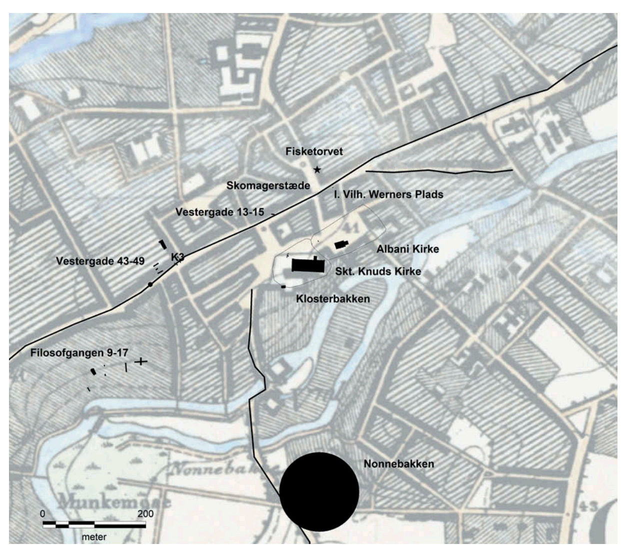

Figure 16. Phase 3 (c. AD 1000–1101). Marked on the first edition ordnance map from the second half of the nineteenth century. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

- The western end of a three-aisled house at Klosterbakken is dated on the basis of Baltic ware pottery and travertine fragments to the eleventh or twelfth century.
- The earliest phase of St Canute's Church is constructed at the end of the eleventh century.
- St Alban's Church is probably built in the eleventh century. An AMS date for a grave that predates the church's latest wooden phase does not conflict with this conclusion. The discovery of a bishop's grave from the eleventh century in the earliest phase of the church means that St Alban's Church was already a cathedral at this time. Whether the church had an earlier phase, which can confirm the statement in Odense's so-called 'birth certificate' about the existence of a cathedral already in AD 988, is unknown. Based on written sources, there appears to have been a royal residence near St Alban's Church.
- A cluster of 13 graves in St Canute's churchyard is, based on the AMS dates, unlikely to be later than the end of the eleventh century. This conclusion is supported by an overlying layer of travertine fragments which is ascribed to the construction of St Canute's Church at the end of the eleventh century.
- During excavations on I. Vilhelm Werners Plads, the predecessors of the modern streets of Vestergade-Overgade were discovered. Their earliest phases are dated to the twelfth and perhaps even the eleventh century. A series of brooches from the second half of the eleventh–twelfth centuries were found in the cultural layers.
- At Vestergade 13–15, three cut-through floor layers were discovered, probably associated with dwelling houses. The floors have been AMS dated and fall within the period AD 897–1148.
- At Skomagergade/Vestergade 1–3, a series of floor layers was found in which there were a number of pits containing skulls and other skeletal elements, in particular of cats. The contents of the pits are interpreted as evidence of a cat farm or furriery. The pits are AMS dated to AD 1070 ± 100.
- A stray find from Fisketorvet of a perforated and ornamented stone is dated typologically to no earlier than the eleventh/twelfth century.
- Pits at Vestergade 43, 49 and 55 are dated on the basis of finds to c. AD 900–1100.

Summary of the phases

Phases 1 and 2, as is evident, encompass several localities that can be placed in both phases. The overall structure is also very uniform, with Nonnebakken located to the south of Odense Å, while crafts, and perhaps trade and dwellings, lie north of the river. As there is, nevertheless, a dynamic, for example in the development of Nonnebakken and the possibly dawning ecclesial aspect mentioned in the deed of gift from AD 988, the two phases will be examined separately in the following.

Apart from Nonnebakken, which lies south of the river, the structures in phase 1 constitute an east-west-oriented sequence extending over a c. 400 m stretch to the north of the relatively steep slope down towards Odense Å. The identified localities lie about 100 m apart. To the west is the pit-house area at Vestergade 70–74 and Mageløs/Klaregade. Between the pit-houses there may be permanent houses. In the eastern part of the area these appear to have been exclusively ordinary dwellings. The exception to this is a possible pit-house at Skomagerstræde/Overgade 1–3. Møntergården, which probably lies outside the Odense of the time, also belongs to phase 1. There are activities at Nonnebakken during this phase, but whether these are of a defensive character or should perhaps be ascribed to a possible ritual site – an Odins Vi – is uncertain. The location of the pit-houses at Vestergade and Mageløs/Klaregade, on a level plateau that is directly opposite Nonnebakken on the south side of the river, indicates the existence of links between these two phenomena. Both localities are oriented towards the place where the sides of the meltwater valley lie closest together, i.e. the most obvious and natural crossing point over Odense Å. This crossing corresponds to present-day Klaregade-Hunderupvej.

Nonnebakken is also the only locality south of the river in phase 2, and it is at this time it became transformed into an actual fortress of Trelleborg type, presumably at the behest of the king. It has been suggested that the Trelleborg-type fortresses could have a supplementary function as royal residences (Christensen 1988, p. 33, Olsen 2015,

p. 326). North of the river, approximately the same layout is apparent as in phase 1, i.e. structures oriented in an east-west sequence that now extends over a c. 500 m stretch of land immediately north of the relatively steep slope running down towards Odense Å. The existence of a possible cathedral, mentioned in the deed of gift from AD 988, has not yet been demonstrated archaeologically. As in phase 1, the pit-house area at Vestergade and Klaregade/Mageløs appears to be linked to Nonnebakken south of the river by a crossing over Odense Å.

A central discussion with regard to phases 1 and 2 is the relationship between Nonnebakken south of the river and the incipient town on the north side. Uncertainty about precise identification of the functions associated with the activities at Nonnebakken during phase 1, i.e. the centuries immediately prior to AD 1000, naturally complicates this discussion. But regardless of whether the activities reflect an earlier fortress phase, a sanctuary called Odins Vi or something else, there is very probably a link to the partially coeval activities on the north side of the river. Conversely, it cannot be determined whether one or the other came first, or whether the activities on each side of the river developed under mutual positive influences. As mentioned in the introduction, we must confine ourselves to the evidence showing that the location of the activities in this place has its foundation in a traffic and communicative hub, in the broadest sense of the term. In relation to phase 2, it seems more certain that Nonnebakken is established in a landscape that already enjoys a certain degree of importance, and where the proto-town becomes established. It seems obvious that the establishment of a large fortress immediately next to an incipient town would provide the latter with a boost.

In phase 3, Nonnebakken ceases to function as a fortress. The area is though probably still the property of the king, and both the AMS dates and the finds indicate activities at the site during this period. The establishment of a convent in the second half of the twelfth century, presumably on royal land, supports this conclusion. The picture is now dominated by the newly constructed churches, first St Alban's Church, followed later by St Canute's Church. With their associated churchyards, and possibly also a bishop's residence,[5] the ecclesial institutions occupy a significant proportion of the town. This is though, at present, still pure speculation. In phase 3, the various localities are, in general, located within a 6–700 m long and c. 200 m wide belt running east-west. A few of them have, accordingly, moved a little closer to the slope – defined by the 10 m contour – running down towards Odense Å, as well as further to the north. As the ecclesial area occupies a large part of the town's southern settlement area, it is obvious that the secular settlement, in the form of possible dwelling houses and potentially also workshops such as the cat farm/furriery at Skomagerstræde/Overgade 1–3, has, to a major extent, been moved northwards. The secular settlement now clusters predominantly around the street of Vestergade and its continuation into Overgade, which have now been established. The furriery at Skomagerstræde/Overgade 1–3 could perhaps be perceived as an indication of increased occupational specialisation with the aim of supplying a market that possibly encompassed more than the immediate hinterland.

The formation of Odense as a town and early urbanisation in southern Scandinavia

In the following, an overall assessment is undertaken of whether the tripartite urbanisation model is sustainable, i.e. whether, in the case of the foundation of Odense, we can speak of a bottom-up development prior to AD 1000. Significant parameters in this evaluation are: (1) Whether we can speak of a (proto-)town prior to AD 1000? (2) Whether the town was founded by a central power or had a bottom-up origin? (3) Whether there was any form of continuity from proto-town to medieval town or whether the earlier activities should simply be ascribed to agrarian settlement/seasonal craft and/or trade activities or something quite different? These three questions will be addressed for Odense in the following section. In the final section, an assessment will be undertaken of whether the model can be applied generally to other towns in southern Scandinavia.

When did Odense become a town?

The juxtaposition of the possible urbanisation factors in the three phases leaves us with the question of when the settlement that became Odense can be termed a town? As described initially, the characteristics defining a town fall into two temporally distinct groups. For the period AD 700–1000, there is a requirement for the locality to have: (a) a certain population density, (b) a permanent settlement of a certain size and (c) the majority of the population subsisting by trade and crafts. From the eleventh century, the locality must also have a clearly defined boundary with respect to its surroundings, and it is equally crucial that it has two or more churches as well as coinage and special taxation rules. As already mentioned, several researchers have pointed out that the absence of a single criterion is not crucial to the determination of whether or not a locality can be defined as a town. A certain degree of flexibility is necessary with respect to the individual criteria.

In the evaluation of whether phases 1 and 2 satisfy the three criteria for early urbanisation, it is naturally challenging – particularly in relation to the aforementioned uncertainty regarding the contemporaneity of the structures at the individual localities – that the record from Odense is so fragmentary. This situation is not uncommon for Danish medieval towns, but should nevertheless be kept in mind when the evidential value is assessed with respect to future interpretation. Of course similar uncertainties apply to phase 3, too.

The first question to be clarified with respect to an evaluation of phases 1 and 2 is whether the aforementioned longhouses should be perceived as permanent buildings. And, similarly, whether such possible permanence can be extended to apply to the craft activities of the possible 'market place'. The dwelling houses in phases 1 and 2 are all post-built constructions with or without internal roof-bearing posts. They correspond to the structures that, in the agrarian settlements, are termed main houses in the farmsteads (Hansen 2015). There is therefore no reason to perceive the structures in Odense as anything other than permanent.

Another question is whether any form of trade took place in Odense in the centuries prior to AD 1000. As is discussed below, this is uncertain. At the same time, however, it is argued that a town like Odense has perhaps, in its earliest period, a local exchange of goods which, all things being equal, is difficult to detect in the archaeological record.

A third question relates to whether the specialised craft activities and potentially resulting trade activities in the pit-house area at Vestergade 70–74 and Mageløs/Klaregade were also permanent. In this respect, it is argued that the second phase of the pit-house and the possible dwelling house at Vestergade 70–74 may be coeval. Similarly, some of the postholes by the pit-houses at the Mageløs/Klaregade locality should perhaps be seen as indications of the same phenomenon. The small number of postholes render this interpretation uncertain. The close proximity of a longhouse and a possible pit-house at Skomagerstræde/Overgade 1–3 may be a third example of the linking together of crafts and permanent dwelling houses. This locality appears though to lie outside the craft production area that was identified around Mageløs/Klaregade and Vestergade 70–74.

The areal extent of Odense's two earliest phases is no greater than many coeval – and earlier – agrarian settlements, but a specific requirement for relative superiority in size is not included in the urban definition. Seen in relation to other contemporaneous towns, the extent of phases 1 and 2, i.e. c. 500 × 100 m not including the area over towards Nonnebakken, is quite large and not dissimilar to that of Ribe in the eighth and ninth centuries (Feveile 2006, p. 38, Figure 18, 41, Figure 20; Krongaard Kristensen and Poulsen 2016, p. 43). Other early urban localities, such as Birka (7 ha) and Kaupang (5.4 ha), also match very well. Haithabu, on the other hand, is remarkable with its 24 ha (Skre 2007c, p. 453). If the population density is examined in relation to for example Ribe in the eighth and ninth centuries, there does not appear to be any great deviation.

A further requirement in the definition of an early town is that the population must earn its living primarily by trade and craft production. As mentioned above, the composition of the finds assemblages from the pit-houses at Mageløs/Klaregade and Vestergade 70–74 is of an extent and a character that make it seem likely that these items were not exclusively intended for self-sufficiency. There are no other known indications that, in phases 1 and 2, the inhabitants subsisted primarily by craft production – and perhaps trade. On the other hand, there are no indications that the house remains uncovered here constituted an agrarian settlement. Any way the fact that towns of the Viking Age and Middle Ages, as in later times (Hoff 2000, Elkjær 2001), had a certain element of agrarian activities is not surprising, and would certainly not be a unique feature of Odense. For example, it has been pointed out that around AD 1000 Lund had a substantial agrarian component, while trade and crafts had relatively limited significance (Nilsson 2015, p. 262).

With the conversion of Nonnebakken to a Trelleborg-type fortress in phase 2, the royal presence in Odense appears to have become a reality. Whether there also was a central power behind the earlier possible defensive activities in Nonnebakken's first phase cannot be ascertained, but it seems likely.

Overall, it appears that in phases 1 and 2 – with all the afore mentioned reservations for the fragmentary nature of the evidence – Odense can be termed a proto-town. Whether we consequently should add Odense to the list of Denmark's early towns is in many respects uncertain. First, we are unable to put a precise date on the establishment of the town. The present analyses merely indicate that a (proto-)town was established *at some time* between the end of the eighth century and AD 900. Second, there is much to indicate that the earliest urban phenomena were the emporia, which were generally placed on the edge of the realm with the intention of reaching out to a large market. Possibly only Ribe, Haithabu, Kaupang and Birka should be included under this category (Skre 2007c, p. 453f.). Neither the composition of the finds assemblages nor the location of Odense suggests the enormous trading activities and long-distance connections that can be recognised at the other localities.

Phase 3, in addition to the continued presence of the urban elements evident in phases 1 and 2, has two churches, traces of coinage and demarcation with respect to its surroundings in the form of both natural depressions and man-made water-filled ditches, possibly supplemented by a rampart and/or a palisade (Madsen 1988a), and is clearly an actual town. It is not possible, however, to ascertain whether it had special taxation rules.

Who founded Odense?

Previous analyses of the town's origins have highlighted that Odense first had the character of a town, or was possibly actually first founded as a town, after AD 1000, probably as part of Sweyn Forkbeard's establishment of some of the early bishoprics – including Roskilde, Lund and Viborg. Urbanisation is thereby linked to the king's takeover of central functions from nearby pagan centres and urbanisation thereby also acquired a function relative to the shift from paganism to Christianity. On the other hand, it is pointed out that these early towns were not established at trading hubs. However, it is shown in this study that the description of Odense's development is based on a relatively flimsy evidence base because of the limited empirical material available at the time (Ulriksen *et al.* 2014).

The founding of the earliest towns in Scandinavia, the emporia, has also traditionally been perceived as being influenced by a central power's need to organise trade and craft production. This applies for example to the description of Ribe's early phases. A more recent interpretation does, however, indicate that it may instead have been Frisian merchants who took the initiative to establish Ribe (Feveile 2006, p. 30f.). Ribe's consequent involvement in the Frisians' long-distance network has been highlighted as a basis for urban foundation there, and in the other emporia in southern Scandinavia. In this way, the emporia can, to some degree, be perceived as the central European centres' northernmost trading stations, rather than actual southern Scandinavian towns. This, in turn, questions the necessity of a controlling central power in the urbanisation process (Sindbæk 2007).

It has been demonstrated that, in the case of Odense, gradual development of a town was already taking place in the centuries preceding possible royal intervention. Its networks were probably of a more local or regional character and links with the hinterland were of greater importance than in the case of the emporia, where attention was focussed on the long-distance contacts instead. The demonstration by a recent study of the fixed location of Funen villages by as early as the 7th century AD is important in this respect as this development created the basis for a surplus production (Hansen 2015), prompting these villages to go from a relatively high degree of self-sufficiency to a situation where there was a need to find new outlets. The many metal-rich localities from the Late Iron Age could reflect an early fragmented version of this marketing pattern. Over time, however, a certain degree of centralisation developed in the form of the proto-towns.

This shift could have had several tangible causes. It has previously been highlighted that the development from the Iron Age's metal-rich sites with evidence of trade and craft production to the towns of the Viking Age and Middle Ages, as new trade and craft centres, can be linked to the appearance of new trading routes and goods (Jensen 1990, Näsman 1990). A concrete illustration of a similar phenomenon is demonstrated by the development from the emporium of Haithabu to the market town of Schleswig (Rösch 2016). The detailed analysis of the finds and raw materials here can trace the continuity between the two localities in relation to everyday products and local raw materials, while a break between the two localities is seen in the imports of new raw materials and artefacts (Müller *et al.* 2014).

Consequently, the preconditions were created for a new trading centre, where the surplus production could be sold. This means, in turn, that the preconditions for an urban identity, whereby the population primarily earns its living via secondary occupations, were also present.

All in all, the evidence suggests first and foremost that, at the time when Harald Bluetooth established a ring fortress at Nonnebakken and later, when Sweyn Forkbeard made the town a bishopric, Odense already had a long history as a prototown and perhaps had a central position for the Northeastern-Funen area. There appear to have been functions associated with both specialised occupations and local exchange of goods, as well as a religious role of long duration. It is therefore difficult to see Odense as having been founded by a king.

On the contrary, Odense obtained its central importance due to its pivotal communicative significance – including in relation to religious and trade-related matters. In fact the historical main roads met at the spot where Odense to day is situated (Porsmose 1996, p. 201). At the same time, it seems likely that the presence of the king, and not least the Church, together with general societal developments and pan-European trends and tendencies meant that the town expanded and a great many new functions were added. This must, however, be seen simply as a phase in the town's development, not an expression of its starting point. In this respect, the many finds and functions have overshadowed earlier, less marked phases in Odense's development. The urbanisation of Odense was a dynamic process involving several actors and controlling processes that were both top-down (exogen) and bottom-up (endogen).

From proto-town to town – continuity or discontinuity?

On the basis of the above, it can be debated whether a connection can be traced between the proto-town, defined as phases 1 and 2, and the town proper, defined as phase 3. As outlined in the introduction, there is some controversy about the degree to which the early urbanisations were a locally developed phenomenon totally divorced from the later medieval royal urbanisations, as proposed by Callmer (1991, p. 30), or whether there was a link, a common developmental history, shared by the two phenomena. The question of continuity or discontinuity between proto-town and town is obviously crucial when the age of a town is to be determined and relates to a general research problem that has for example been addresses in the case of Ribe (Feveile 2006, p. 48ff., Alrø Jensen 2013, p. 20ff., Kleingärtner 2014, p. 235ff.).

The documentation of a fixation of the Funen villages already around AD 600 is also relevant in this context (Hansen 2015). It means that there was a continuity in the villages that extended across the introduction of Christianity and the institutional reinforcement of the monarchy. Moreover, it can be argued that several of the structures that have otherwise been linked to the appearance of a strong central power are perhaps of greater age. This applies for example to the aforementioned potential to create a surplus production and to establish a system of taxation and duties, both of which are factors supported by an established and fixed village pattern. It is then possible to see a long developmental history, in which the traditional perception of the sequence of monarchy, then village communality should perhaps be reversed. The permanent village structures and the resulting situation and conditions surrounding taxes, duties and surplus production are more likely a prerequisite for the monarchy rather than a consequence of it.

Odense's phase 3, from the eleventh century onwards, with its established churches, appears to build itself on to the existing (proto-)town. St Alban's Church is, accordingly, sited on the eastern periphery of the proto-town, simply because it was here that there was space, i.e. in many ways a pragmatic solution and a situation that concurs well with the developments in the villages (Hansen 2015, p. 182ff.) (Figure 17). It was not until after the church had been established that a centre developed in this eastern part of the town centre. Later, St Canute's Church is added to this, in an area that appears to have been previously built on. Phase 3, the town proper, belongs then to the king and the Church and, as a consequence, marks top-down developmental stages. But these take place as a further development of an existing proto-town and not as a new initiative on virgin soil.

With the progression from a pagan proto-town in the western part of Odense and the addition of a Christian town to the east, established with the construction of St Alban's Church, Odense underwent a development at this point which corresponds to that seen in Ribe, Haithabu and Aarhus. On the contrary the development differs from the situation in Roskilde and Lund, which were established with a church and without any

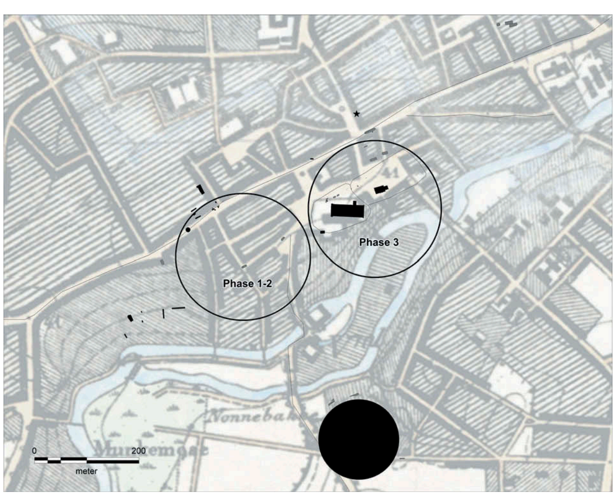

Figure 17. Displacement of the centre of Odense from phases 1–2 (dark grey) to 3 (black). Marked on the first edition ordnance map from the second half of the nineteenth century. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

links with a previous trading and craft-production site (Krongaard Kristensen and Poulsen 2016, p. 59). It is unclear whether Viborg should be seen in the same context as the developments evident in Roskilde and Lund, or whether there was also continuity here from an existing proto-town, merely with displacement of the centre due to the addition of a church etc.

It has been pointed out that Roskilde, Lund and perhaps Viborg were founded by a Christian king in the vicinity of, but – at least in the case of Roskilde – also some distance away from a former pagan centre. The aim was, on the one hand, to mark a shift in power, and on the other, to benefit from the power structures that already existed in the area under pagan governance. In the case of Odense, the situation also appears to reflect a development whereby a Christian king took over central functions from a pagan centre, but the criterion with respect to maintaining a certain physical distance from the old centre seems not to apply. Perhaps the explanation here is that Odense's location was so strategically optimal that it made no sense to relocate (cf. also Callmer 1991, p. 30).

Summing up it can be concluded, that in Odense, there seems to be continuity from the proto-town, in phases 1 and 2, to the actual town, in phase 3. This development was apparently initiated by different factors and actors: During phases 1 and 2, trade and craft-related factors were responsible, and in phase 3, the dominance of the two actors, state and Church, was crucial.

A new perspective on the earliest urbanisation of southern Scandinavia

For a number of years, the earliest urbanisation of southern Scandinavia has been one of the core research questions in archaeology, and with the founding of the Centre for Urban Network Evolutions (UrbNet) at Aarhus University in 2015 it has become the subject of further attention at the present time. Nevertheless, there is still a tendency for urbanisation to be described in terms of some rather fixed and inflexible professional preconceptions and traditions. This is clearly evident from the fact that the date AD 1000 (or a few decades earlier) is often cited as the turning point in urbanisation. The general perception is that, prior to this date, there were by and large no towns, as several urban phenomena were not present.

In southern Scandinavia, the date around AD 1000 is, quite simply, taken to be coincident with the transition from prehistory to the Middle Ages. This means that the written sources, most often dealing with noble families, and kings in particular, make their appearance from this date, and that Christianity is introduced as the religion, leading to the founding of new institutions: churches, monasteries etc. At the same time, the Church supports the monarchy and thereby helps define the king's position, both mentally and physically, in the urban space, and urban characteristics consequently become clearer and more numerous. These developments are supported by the fact that kings in southern Scandinavian, to some degree, model their behaviour and actions on western European urban patterns (Callmer 1991, p. 30, p. 42).

It is obvious that if the definition of a town is to be based on these factors, then no settlement predating AD 1000 – apart from emporia such as Ribe, Haithabu, Kaupang and Birka – will be able to meet these requirements. At the same time, these preconceptions and traditions have become so firmly rooted that in archaeological investigations of the existing town cores there might have been a tendency, presumably subconsciously, to seek their confirmation rather than looking for possible indications of earlier urban factors. In the case of Odense, this means that earlier urban characteristics, such as the pit-house settlement at Vestergade and Klaregade/Mageløs, have been interpreted as representing a separate and independent agrarian settlement (Nielsen 1984, Jacobsen 2001, Ulriksen *et al*. 2014, p. 173).

The simple bipartition of urban definitions employed here, which Johan Callmer, Dagfinn Skre and others have also argued in favour of, opens the way for a more contextual interpretation of the term 'town', and with that, a model whereby urban factors are perceived in relation to their actual time. As for the question of whether a place had the function of a town, the crux of the matter is whether, via its urban character, it stood out relative to other settlements of the time.

Odense's proto-town phases can therefore be seen as parallels to development in a group of other southern Scandinavian towns – e.g. Aarhus, Aalborg, Viborg, Horsens and perhaps Næstved – where, in the centuries prior to AD 1000, a number of urban characteristics are evident. These often take the form of pit-house areas with evidence of trade and craft production, as well as in some places traces of 'town ditches'. Another distinctive feature is that the urban characteristics at these early localities appear to occupy a different spatial location to the centre that grows up in the town in the eleventh century. It is possible that the spatial displacement of the centre here can be explained in terms of the introduction of Christianity and, with this, the construction of churches. These were built on the periphery of the established settlement and would therefore, over time, generate a new town centre.

Aarhus is mentioned in an imperial document from AD 948, but there is known to have been a ditch-enclosed settlement covering an area of 11 ha here already in the eighth–ninth century (Linaa 2016, p. 32f.). The character of the settlement is not described clearly in the literature, but at least from around AD 900 it appears to have been of considerable extent with both permanent houses and workshops/pithouses (Krongaard Kristensen and Poulsen 2016, p. 47; Linaa 2016, p. 33). It is unknown whether there was an actual town at this point (Krongaard Kristensen and Poulsen 2016, p. 48 with note 73). In the first half of the tenth century, the settlement was fortified and its area reduced slightly, and Aarhus is now considered to have been a town. The church was probably situated to the west of the fortifications (Krongaard Kristensen and Poulsen 2016, p. 47f., Linaa 2016, p. 32f., Linaa and Krants 2016).

Like Odense, Aalborg has traditionally been seen as being founded after AD 1000 (Roesdahl 1980, p. 91), but new investigations and analyses have shed light on the centuries prior to this time (Vrængmose Jensen 2017). Aalborg too has a relatively limited archaeological record. After an earliest ard-mark phase, a pithouse settlement appeared in the seventh, eighth and ninth centuries on the eastern side of the outflow of the river Østerå in Limfjorden. The pithouses are thought to represent one of several large metal-rich localities along the eastern and central Limfjord, and Aalborg is not considered to have been a town at this time. At the end of the ninth century, the settlement was furnished with a bank and ditch and there was possibly parcelling-out of the trade and workshop area. The settlement was still primarily on the eastern side of Østerå, but it also expanded west of the river. The period up to c. AD 975 consequently had several urban characteristics. Subsequently, an actual town developed, with further urban elements including churches, and grew westwards. An early churchyard was established around AD 1000 close to, or on top of, the trading place. The associated church has not been identified archaeologically (Møller 2008, Vrængmose Jensen and Møller 2009, Vrængmose Jensen 2017, p. 77ff.).

Viborg is traditionally thought to have developed into a town around the eleventh century, at a location by Viborg Søndersø (Krongaard Kristensen 1998, Krongaard Kristensen and Poulsen 2016, p. 55ff.). But in the southwestern part of the town, in the area around Pederstræde, there was a settlement in several phases already from the eighth–ninth century, with both permanent houses and possible booths and workshops. The finds include traces of both bronze- and iron-working. In the most recent analyses, however, the settlement is perceived as being associated with a magnate's settlement based primarily on an agrarian economy. There are no traces of a church or a churchyard in either the Pederstræde quarter or the area by Viborg Søndersø (Levin Nielsen 1969, p. 49f., Krongaard Kristensen 1998, p. 349f., Krongaard Kristensen and Poulsen 2016, p. 57).

Horsens is believed to have first become an actual town in the twelfth century, but there was an earlier fortified site with pithouses already in the ninth–tenth century, and AMS dates from the ditch even extend as far back as the middle of the eighth century. The settlement was located in the same place as the later, larger medieval town. The churches stood to the west and southeast of the pithouse area (Schørring 2000, p. 118ff., Pagh 2016, p. 116, Krongaard Kristensen and Poulsen 2016, p. 38).

Næstved could have its foundations in a settlement which had roots extending back to the Late Iron Age and Viking Age, and which, in the latter period, appears to have been a trading site (Petersen 1988, Krongaard Kristensen and Poulsen 2016, p. 69). A form of continuity can be traced from the tenth century onwards. The church was established to the northeast of the earliest archaeological remains in the town (Andersen 1987, p. 51f.). Næstved is considered to have been an actual town by 1135, at the latest (Krongaard Kristensen and Poulsen 2016, p. 69).

This account of the history of establishment of these five towns is by no means exhaustive, as such a study lies beyond the scope of the present work. The aim here has been to focus attention on the fact that they all have traces of urban elements prior to AD 1000. These often extend back to the end of the eighth century, but at least from around AD 900 there appear to be relatively extensive urban features. The urban elements comprise pithouses (or the booths or workshops in Viborg), in combination with permanent settlement and delimitation of the settlement in the form of a ditch. Another characteristic is that the location of the early settlement is often displaced relative to the centre which emerged later in conjunction with a newly established church after AD 1000. A third common aspect is that finds from the centuries prior to AD 1000 are generally described as being relatively sparse and much less impressive than those in the emporia such as Ribe, Haithabu etc. from the eighth and ninth centuries. Structures and features too are generally said to be sparse and not as pronounced as after AD 1000. Finally, there is the continuity in the place-name evidence from Odense and Viborg, with the pagan roots in the names of these towns being retained following the transition to Christianity.

As is evident from the above, the traces from these towns prior to AD 1000 have, as in Odense, generally not been perceived as being urban in nature. It should, however, be considered whether this is due to variations in source material. The data material from the emporia thus is distinguishable from the contemporary non-urban localities with their very characteristic elements of 'exotica' in terms of artefacts, and their stringently structured market places. Similarly, the newly established towns from c. AD 1000 is distinguishable from the surroundings with their striking building works in the form of churches, large fortifications etc. In comparison, towns of the ninth and tenth centuries – except perhaps the fortified town of Aarhus from c. AD 900 – appear much less conspicuous. Trade was probably locally or regionally based and perhaps comprised a larger element of organic materials than the emporia. Churches and other top-down established structures had not yet made their appearance.

The fragmentary character of the evidence from the centuries prior to AD 1000 in Odense and some of the other towns mentioned above make it difficult to link this period directly to the urban development from AD 1000 onwards. But an openness about the possibility of a continuous development should hopefully be evident from the above. The apparent hiatus in the finds and the sporadic archaeological record should perhaps not be interpreted as a break in development, but more an indication that towns from the ninth and tenth centuries cannot be expected to stand out and differ markedly from agrarian settlements. The finds associated with these early urban localities were not exotic, and neither were their buildings distinguishable from the house constructions of the agrarian settlements.

The background for the emergence of (proto-) towns in the centuries prior to AD 1000 is probably to be found in general societal changes and developments. A significant factor here is the shift in trading patterns, from a focus on southerly orientated networks, as expressed in the emporia from the eighth and ninth centuries, to the more local and northerly oriented networks that became increasingly dominant through the Viking Age (Jensen 1990, Näsman 1990, Alrø Jensen 2013, p. 20ff.). With time, this could have meant that the emporia had played out their role, while centres such as Odense etc., with a foundation in the local hinterland, emerged instead.

Another relevant factor is that, by the beginning of the Viking Age, the agrarian environment appears to have achieved a stable structure with a well-established village society and rigid organisation of landscape resources. With this came the basis for the creation of a surplus production, and a levy system was possibly established too. In rural settlements, new analyses suggest that a great settlement-historical shift took place around AD 600. After about AD 800, minor organisational adjustments were undertaken, including the splitting off of torp settlements. The latter appear, at least initially, to have related to the primary infrastructure (Hansen 2015, p. 123f.).

The more rigid system with exploitation of all, or at least very large parts of, the landscape, together with a greater focus on locally based trade, also means that a greater need could have arisen for dominance of the local infrastructure, perhaps especially the land-based traffic. This saw expression in the orientation of the torp settlements and metal-rich sites towards the general road net, as illustrated on the Royal Society's maps from the end of the eighteenth century; a road net that is thought to have its roots back in prehistory (Henriksen 2017, p. 25, p. 30). The locations of the proto-towns fit well into this system. This is certainly true of Odense – and also of Aalborg, Aarhus, Viborg, Horsens and perhaps Næstved.

Notes

1. http://museum.odense.dk/forskning/projekter/odenses-opstaaen/projektbeskrivelse. The project was primarily undertaken by the authors, funded by a grant from the Research Committee of the Ministry of Culture of Denmark. The manuscript was updated until the end of March 2018 and translated by Anne Bloch and David Earle Robinson, HSLS, Ebeltoft.
2. This article forms part of a current research-based focus on the earliest Odense and its hinterland which encompasses several projects. The first part comprised preliminary analyses of the metal-rich localities in Odense's hinterland and their relation to the town (Henriksen 2013). The second part is the present work, where the focus is on Odense itself. The third part is the large research project *From Central Space to Urban Place* (http://museum.odense.dk/forskning/projekter/from-central-space-to-urban-place), which runs from 2017 to 2020 and addresses Odense and Aalborg as case studies illuminating the transition from Late Iron Age central places to the towns of the Viking Age and Middle Ages. The fourth part comprises analyses of the development of the established town onwards in the research project *Urbaniseringens Møder og Mennesker* (http://museum.odense.dk/forskning/projekter/urbaniseringens-moeder-og-mennesker), which is being undertaken from 2016 to 2019, including the PhD project *Livet i byen – urbane praktikker, netværk og identitet i Odense i perioden 1100–1500* (http://museum.odense.dk/forskning/projekter/livet-i-byen). The projects have several mutual interfaces and will have a reciprocal influence. Despite this, it has been important to publish the results underway, well aware that the project *From Central Space to Urban Place* will for example address central questions with respect to the origin of Odense, not least the relationship between hinterland and town. A

thorough analysis of this aspect falls outside the scope of the present work.

3. While Odense's more sheltered location is clear in relation to the metal-rich sites, the picture is more blurred when a comparison is made with a locality such as Åsum, situated east of Odense. Åsum, by virtue of its location on a central forced route during the Iron Age and Middle Ages, also occupies a notably strategic position relative to terrestrial traffic (Henriksen 2002, p. 174ff.). Furthermore, the place name Åsum *could*, as will become evident, have a sacral meaning as 'home of the Ases', i.e. also a counterpart to Odense. But with a possible advantage relative to Odense in terms of the place name's relation to the main deity of the time? The primary difference between Odense and Åsum is perhaps their situation relative to water-based traffic. While it was not feasible to sail larger ships in to Odense, this was possible in to Åsum. Perhaps this rendered Åsum too exposed and vulnerable and its role therefore became more that of a landing place?.
4. The presence of Baltic ware pottery in southern Scandinavia is typically dated to a period extending from the tenth century to AD 1250/1300. Moreover, it can be divided into an early, soft-fired, relatively coarse variant, which includes the so-called Menkendorf type, and a later, harder fired, thinner variant. The early variant is dated earlier than AD 950–1050, and the late variant has a broad dating frame of 1000–1300 (Madsen 1991, p. 224ff., Roslund 2001, p. 231ff., Langkilde 2007, p. 26f., Madsen and Sindbæk 2014, p. 280ff.). But in the area immediately to the south of Denmark and southern Scandinavia, however, Baltic ware pottery appears as early as the eighth century (Meier 1994, p. 145, Roslund 2001, p. 91). It can in the authors opinion therefore not be ruled out that an earlier date of the Baltic Ware pottery could also be the case in Southern Scandinavia.
5. The earliest known episcopal residence in Odense lies to the east of the contemporaneous St Alban's Church and is dated, on the basis of two dendrochronological dates for oak wood from a well located north of the main building for the present Odense Adelige Jomfrukloster (OBM 137, 080407–152), to after AD 1293 (dendro.dk, report no. 27, 2011). It is unknown how far back in time a possible earlier phase of the episcopal residence can be followed (Jakob Tue Christensen: oral communication).
6. It could be considered whether the term 'Trelleborg-type fortress' should be used exclusively in reference to Aggersborg, Fyrkat and Trelleborg on Zealand, as these are the only sites that satisfy all the defining criteria for this type of structure. Another possibility is to make a distinction between ring fortresses and circle fortresses, with the latter term applied to geometrically exact structures (Svanberg and Söderberg 1999, p. 59). In the following, the Trelleborg term will be used in reference to all the ring fortress structures with an active period around AD 980, i.e. in the reign of Harald Bluetooth. They must also be located in the Danish realm of that time, have dimensions commensurate with the classic Trelleborg-type fortresses and, in their outer fortifications, have a corresponding construction to the latter. The presence of axial roads and buildings grouped uniformly in fours around a quadrangle – i.e. a 'square' or 'squares', has been omitted from the definition, as these features are not crucial to the structure's function as an element in Harald Bluetooth's overall system of defences. The latter also included other major coeval building works such as the rampart around Aarhus, Danevirke, the Jelling complex and the bridge across Ravning Enge (Roesdahl and Sindbæk 2014b, p. 443ff.).
7. The latest tree ring on the piece of wood was formed in AD 956, resulting in the felling date being determined as after AD 967 (Jensen and Sørensen 1990, p. 329, cf. Sønderby 1989, p. 244). In theory, the tree could have been felled later and could perhaps be totally unrelated to the fortress. Another piece of wood from the ditch takes the form of an oak-wood spade. The last tree ring formed on the spade is from AD 882 and the tree could have been felled in c. AD 900 at the earliest, but this could also have taken place later. Due to their finds circumstances, the relationship of these pieces of wood to the time when the fortress was constructed is uncertain.
8. Skovmand (1942) does not mention the two pieces of hack silver, the association of which to the coins does however appear certain. These pieces are illustrated in Moesgård (2015, Figure IV, 9–10).
9. Identification of the dirham fragment was undertaken by René Laursen, Bornholm Museum, and Tobias Bondesson, Malmö, Sweden.
10. Information on the *pfennig* kindly provided by Jens Christian Moesgaard of the National Museum of Denmark. See also: http://www.sachsenpfennig.de/tpk_kn.html (accessed 02.01.17).
11. Four other iron axes, three working axes and a battle-axe with brass inlays (OBM5337; 080407–271), have previously been ascribed to Nonnebakken (Grandt-Nielsen 1982, p. 173f.). They were discovered in 1908, during digging works along the southern bank of the now filled-in northern arm of Odense Å, about 1 m below the riverbed. The axes were found spread over a distance of 10 ft, between the demolished mill, Munke Mølle, and the bridge Klaregadebroen. Whether they represent votive finds or lost objects – for example from a toolbox – cannot be determined on the basis of the available evidence. The axes date from the Early Middle Ages and therefore cannot be directly related to the Viking Age activities at Nonnebakken.
12. On Mikkelsens collection, see Albrectsen (1941).

13. As these lines are written the conservation is ongoing. The determination of the ornamentation type is thus not known. The classification is made on the basis of observations of the hilt in this state of conservation and with important input from Anne Pedersen, The Danish National Museum. Anne Pedersen has only seen the x-ray photos of the hilt.
14. During the 2015 investigation, it was possible to demonstrate that on the actual spot there was up to 2 m of soil – presumably made ground – on top of the surface inside the fortress. Consequently, sieving of the soil layers was neither realistic nor appropriate. Sieving of the lower parts was also not seen as a priority, as it was not possible to identify a primary horizon. On the other hand, the lowermost parts of the deposits above subsoil level were excavated in several layers and scanned with a metal detector. Similarly, fill excavated from the features was sieved. None of these initiatives yielded many finds.
15. Laboratory numbers Poz-78622–78630, 78632, 79881–79882, 80425–80428.
16. From the same feature, there is a date of 58,269–40,298 BC. This date must be for contaminated material, for example percolating oil.
17. From the same feature, there is a date of 47,890 BC (68.2%) 47,344 BC. This date must be for contaminated material, for example percolating oil.
18. Laboratory number Poz-83167.
19. Laboratory numbers Poz-83214, 83283–83285.
20. Laboratory numbers Poz-98125–98128, 98130, 98380, 98381, 98383.
21. At Borgring, there does not, as yet, appear to be earlier fortress phases, and here too the fortress forms a perfect circle (Jonas Christensen, Museum Southeast Denmark: oral communication).
22. Laboratory number Poz-73229.
23. Laboratory numbers Poz-72419, 72420.
24. Laboratory numbers Poz-98680, 98681, 98789.
25. Already in a letter of 18 February 1985, Anemette S. Christensen draws the excavators' attention to the fact that the locality should not necessarily be ascribed to the possible village of Heden, but could just as well be ascribed to Odense (unpublished correspondence).
26. K-1887 (Hatting 1992, p. 179).
27. A discussion of the possibility of demonstrating short-distance networks in the archaeological record was for example raised at the seminar: *Towns as meeting places – exploring urban encounters, networks and people in Northern Europe 1000–1700 AD*, 13.-14.10.16 at Aarhus University.
28. In Anemette S. Christensen's letter of 18 February 1985 to the excavators, the question is similarly asked whether 'plough marks' actually means 'ard marks' (unpublished correspondence).
29. Laboratory numbers AAR-14651-14653.
30. Kirstine Haase is thanked for information on the investigation.
31. Laboratory numbers Poz-73169-73173, 73306, 73174–73176, 73178, 73205, 73207–73215, 73217–73225, 73227–73230, 73307, 73231–73233, 73235–73239.
32. Laboratory number Poz-73237.
33. Laboratory numbers Poz-73205, 73207, 73208, 73209.
34. Laboratory number Poz-73172.
35. Laboratory numbers Poz-73173, 73175, 73232, 73300.
36. In the Middle Ages, Odense contains a number of ecclesial institutions, but as these are later than the study period (Christensen 1988, p. 94ff.), they have been omitted.
37. Odense also to day houses a Sct. Alban's Church. This church was founded in 1906 and located c. hundred meters east of the ruins of the first Sct. Alban's Church.
38. Work is presently in progress to separate inclusions of charred organic material from mould fragments from the pit to obtain an AMS date.
39. For the complex argumentation on the relation between the bishop's grave and the oldest wooden phase of the church (see Christensen and Hansen 2017, p. 14–15).
40. Laboratory number AAR-23976.
41. Laboratory number Poz-72618.
42. It is suggested that the church had also an earliest wooden phase (Krogh 2001, p. 100). This has not, however, been found, and it would also fit poorly with the proposed model of the construction of a travertine church following the murder of Canute IV.
43. Laboratory numbers Poz-72615–72616, 72619–72620.

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Appendix. Analysis of the archaeological record for Odense in the Late Germanic Iron Age and Viking Age

Introduction

The extensive archaeological investigations undertaken in advance of a major urban renewal project in the centre of Odense, the so-called Thomas B. Thriges Gade project has yielded significant new information about the earliest town. The excavation findings are supplemented by an investigation of an early bishop's grave in the original St Alban's Church, and in conjunction with the present project, minor research excavations have been carried out at Nonnebakken and the locality of Bispegården.

A number of scientific investigations have been undertaken in connection with the new excavations, including the acquisition of several AMS dates. There has also been the opportunity to undertake supplementary AMS dating of material recovered during some earlier excavations.

To achieve uniform recording of finds assemblages from the new and the old archaeological excavations in Odense, selected artefact groups recovered from the entire medieval town were examined in the spring of 2015 (Henriksen 2016).

Analyses have also been undertaken of a selection of the place-name evidence from the area (Christensen, L.E. 2015).

In the following, the extensive empirical foundation for an analysis of Odense's early history will be drawn together to produce an overall description of the main structural characteristics of the early town.

The appendix is not a presentation of one locality after the other, but is structured after important characteristics of urbanisation: central power, crafts, trade, permanency, cult and religion. Stray finds and written sources are, to present the full picture, included as 'other sources to the earliest story of Odense'. The structure means that localities can appear more than once if it for instance has both permanent house and traces of specialised craft.

Central power

Nonnebakken

Excavations

Nonnebakken (OBM 9782, 080407–27) is a central locality in Odense's early history and a long series of archaeological investigations and stray finds have led to many researchers, over the years, attempting to interpret its function and historical context (e.g. Olsen 1977, p. 86f., Arentoft 1993, Lundø 2012, 2013) (Figure 18). Between 1953 and 2015, about 25 excavation trenches, with an area of between 2 and 255 m^2, have been cut within the area thought to be delimited by the fortress ditch. A number of archaeological investigations have also been undertaken immediately outside the ring

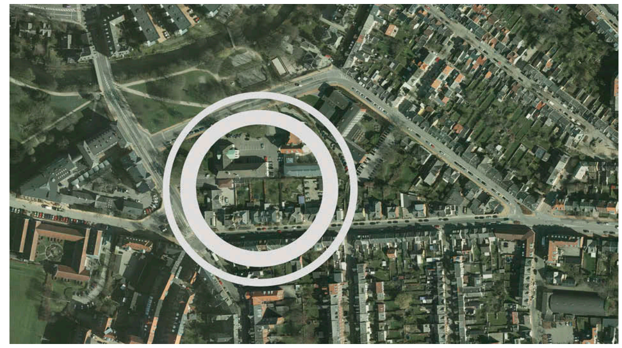

Figure 18. The outline of Nonnebakken in relation to present-day Odense. The outermost ring represents the ditch and the inner one marks the rampart. Background map: © Danish Geodata Agency.

fortress structure (Figure 19). Following digitalisation of the plans from these excavation trenches in 2012, the external diameter of the ditch was fixed at 184 m (Lundø 2012, p. 51) and the structure consequently covered a total area of c. 26,600 m^2.

Previous investigations at Nonnebakken have revealed several features that constitute parallels to the classic Trelleborg-type ring fortresses, Aggersborg and Fyrkat in Jutland and Trelleborg on Zealand, and the most recently discovered example Borgring at Køge, also on Zealand. The Scanian ring fortresses Trelleborg and Borgeby show similar features, too (Lundø 2012, Roesdahl and Sindbæk 2014a, Christensen et al. 2015, Ulriksen et al. 2016, Goodchild

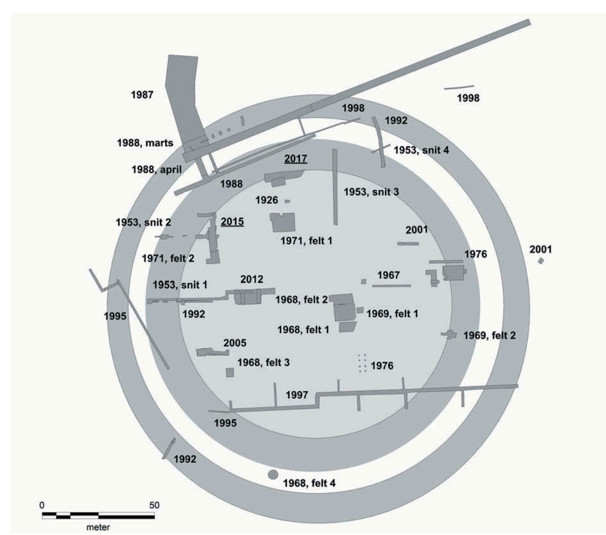

Figure 19. Locations of the excavation trenches at Nonnebakken and year of investigation. In 1953, 1967 and 1968–1971, the excavations were undertaken by the National Museum of Denmark, whereas subsequent investigations were carried out by Odense City Museums. The outer ring represents the ditch, the inner ring the rampart. Drawing: Mads Runge.

Figure 20. The distribution of Trelleborg-type fortresses. It is uncertain whether Trelleborg in Scania actually is a fortress of Trelleborg-type. Drawing: Mads Runge.

et al. 2017) (Figure 20), but the function of the former as a Trelleborg-type fortress is, however, subject to some controversy (Olesen, M.B. 2000, Sindbæk 2014a, Roesdahl and Sindbæk 2014b).[6]

Nonnebakken's similarity to the Trelleborg-type ring fortresses comprises several plan- and construction-related features, including the circular shape and the form and dimensions of the ditch and rampart. As for the date, the narrowly datable finds, as will be seen below, points unequivocally towards a date at the end of the tenth century (Roesdahl 1977, p. 167f., Roesdahl and Sindbæk 2014a, p. 253ff.). The same goes for a group of AMS dates. Finally, several researchers have interpreted a dendrochronological date of post-AD 967 for a stray find of a piece of wood, lacking sapwood, recovered from the ditch as support for this interpretation (Jensen and Sørensen 1990, p. 329, Lundø 2012, p. 53, Roesdahl and Sindbæk 2014a, p. 253f.). In truth, both the date and the link between the wood and the fortress' period of construction and use are though tentative.[7]

In the hope of resolving the question of whether Nonnebakken was an actual Trelleborg-type ring fortress or 'just' a ring fortress, in August 2015 and October 2017 Odense City Museums undertook minor research excavations in the northern and northwestern part of the site. The aim was to answer the question by determining whether or not there were traces of the aforementioned 'squares', a matter Olaf Olsen also attempted to resolve in his excavation campaigns of 1968–1971 (Olsen 2009, Lundø 2012, p. 36ff., 2013), and a northern gate. Subordinate aims were the achievement of a narrow dating of the structure, demonstration of possible earlier activity at the site and illumination of the environment in which the structure was constructed.

The investigation in 2015 revealed that the monument was very well preserved in these areas and several new constructional details emerged with respect to the rampart (see also Runge *et al.* 2016, Figure 21, see also Figure 40). It could also be shown that the rampart in at least the northwestern part is preserved to a height of at least 1 m (Figure 22). As a new feature for Nonnebakken, an inner ring road became apparent, like that seen at Fyrkat, Trelleborg and Aggersborg. The road had a width of c. 1.6 m, corresponding to that at Fyrkat, and evidence of a few sloping posts found on its inner side could suggest the presence of a railing or lean-to, as has also been suggested for Fyrkat (Olsen 1977, p. 81f.) (Figures 23 and 24). Several postholes and pits were uncovered on the internal fortress surface. Some of the postholes appear to form lines, corresponding to fences or house walls, but the limited extent of the excavation trench did not permit the identification of actual constructions. Finally, it could be demonstrated that some ground levelling had been undertaken prior to construction of the fortress, involving the addition of soil. The original ground surface had a very marked downward slope from east to west.

The excavation in 2017 had the specific aim of searching for the northern gate of the fortress (for details see Runge in press). The classical ring fortresses of Trelleborg type thus

Figure 21. The excavation trench for the investigations at Nonnebakken in 2015 at an advanced stage. Note how deep the fortress surface lies below the present terrain. Photo: Mads Runge.

Figure 22. A cross-section through the rampart at Nonnebakken. Lowermost is the yellow (light grey) subsoil and above this an old, darker soil layer. On top of the soil is an orange (light grey) layer of solid clay and then a turf-built rampart. Uppermost is a fill layer/made ground from modern times. Photo: Mads Runge. Drawing: The periodical *Skalk*.

Figure 23. Two sets of double postholes at the inner edge of the ring road at Nonnebakken. The road was to the right. From the excavation in 2015. Photo: Mads Runge.

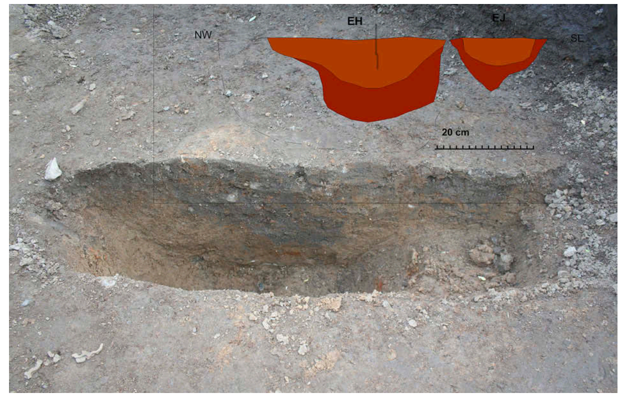

Figure 24. Northwest-southeast section through a set of ring road postholes (EH and EJ) at Nonnebakken. Photo and drawing: Mads Runge.

have four covered gates in the rampart, orientated almost towards the points of the compass. No gates had so far been demonstrated archaeologically at Nonnebakken, but on Braun's prospectus the ring fortress has two openings, one to the northeast, the other to the southwest (Figure 25). The fact that only two openings are shown on the prospectus can perhaps be explained by the fortress being 600 years old at the time and it might therefore have seen many changes over the years. A similar situation is evident on drawings of Trelleborg from the nineteenth century, where one or three openings can be seen (Nørlund 1948, 13ff.).

The state of preservation was good also in the excavation trench of 2017 and the ring road was also recorded here. The rampart had been removed at this spot by a developer's project in 1909 and the gate itself was therefore no longer to be found

Figure 25. Part of Braun's prospectus from AD 1593 with Nonnebakken in the foreground. The crossing over Odense Å between Nonnebakken and the early town also is seen. The mill Munke Mølle can be seen in the middle of the picture on a natural island in the river. After Füssel (2008, p. 184).

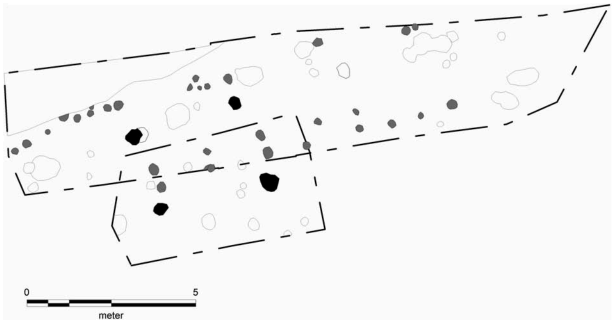

Figure 26. All the features in the excavation trench from 2017. The ring road (grey) and the four large posts (black) that potentially could mark the position of the gate are shown. Drawing: Mads Runge.

here. But two sets of large postholes were recorded in the middle of the excavated area measured out (Figure 26). The four posts potentially could mark the point of contact between the axial road and the gate; the positioning of such large posts here is also seen at Aggersborg. Incidentally, the four posts were placed at a 90° angle to the central point in the eastern and western openings shown on the historical map from 1785 (Figure 27). The distance east-west between the posts was 3.1–3.2 m, which would concur with the widths of the gates at the other ring fortresses of Trelleborg type (Nørlund 1948, p. 56, Olsen 1977, p. 64ff., Sindbæk 2014b). The exception is Borgring, where the distance was c. 4.4–5 m, internally, in the middle of the gate, and externally, respectively (Goodchild *et al.* 2017, p. 1037f.).

The hypothetical positioning of the gate was tested via a series of AMS dates. The results of these, however, did not, as shall be seen, support the interpretation of the posts being part of the Viking Age fortress. As conclusion we might say that the location of the northern gate – and the other gates – at Nonnebakken still need to be established archaeologically.

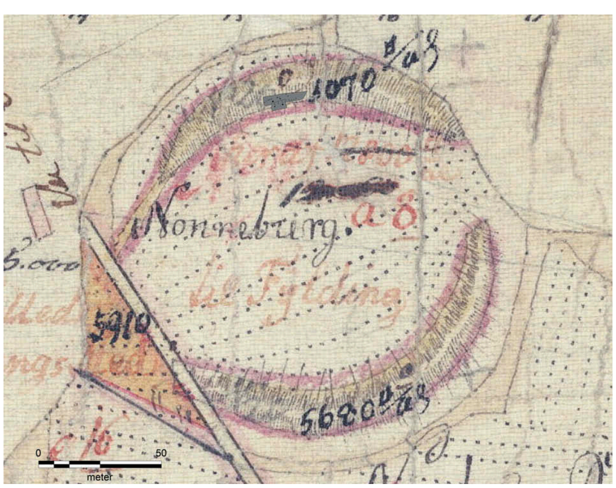

Figure 27. Historical map from 1785 showing openings to the east and west. The position of the excavation from 2017 (grey) is also shown. Drawing: Mads Runge. Background map: © Geodatastyrelsen.

Artefacts

The most striking artefacts found at Nonnebakken comprise a series of fine silver objects, which can be assigned to a total of five hoards. Four of these are unsystematically recovered and the fifth was discovered during the 2015 investigation. Even though the finds circumstances are not equally well illuminated in the four cases before 2015, there are no reasons to believe that all of them originate from the same deposition event.

– In 1775, a circular filigree brooch and a band-like arm ring, the so-called 'Odin's ring', were discovered (Figure 28(a,b)) (Thrane 1973). These objects must have

Figure 28. Circular filigree brooch (a) and band-like arm ring (b), the so-called 'Odin's ring', (diameter 7.3 cm) found at Nonnebakken in 1775. Photo: Søren Greve, The National Museum of Denmark.

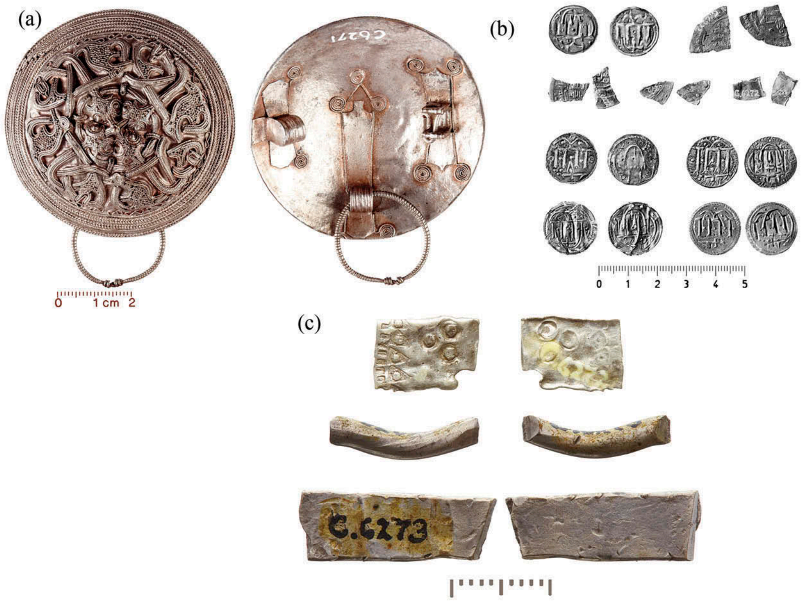

Figure 29. Circular filigree brooch (diameter 6.2 cm) (a), nine coins (b) and three pieces of hack silver (c) deposited together as a hoard and found at Nonnebakken in 1889. Photo, filigree brooch: Nermin Hasic. Photo, coins: John Lee, The Danish National Museum. Photo, hack silver: Søren Greve, The Danish National Museum.

been buried at some time after c. AD 970 (Skovmand 1942, no. 30).

- A combined deposition of a circular filigree brooch, nine coins and three pieces of hack silver turned up in 1889 (Figure 29(a–c)). The hoard is dated to the end of the tenth century (Skovmand 1942, no. 28), but according to Moesgaard (2015, p. 157) earlier than c. AD 975/988.
- In 1909, a combined hoard was found of 25 (perhaps 26, cf. Moesgård 2015, p. 158f.) silver coins, with the latest coin from AD 973, and two pieces of hack silver (Skovmand 1942, no. 28a) (Figure 30). Moesgård (2015, p. 158) suggests a deposition date before c. AD 975/980.[8]
- Prior to 1901, a circular filigree brooch (FS7021) came from the estate of the theologian Rasmussen, who was the owner of the property at Nonnebakken. As a result, and due to the piece's similarity to the circular filigree brooches found in 1775 and 1889, FS7021 has been assigned to Nonnebakken (cf. Skovmand 1942, no. 28; Thrane 1982) (Figure 31).
- A small pit found in the 2015 excavation inside the fortress, by a row of postholes, yielded a small silver hoard comprised of a sheet-silver bead, a quarter dirham and a *Sachsenpfennig* (Figures 32(a–c) and 40). The bead is dated to the tenth century, while the dirham fragment is dated to the period after AD 815.[9] The *pfennig* is difficult to identify precisely to type, but comes closest to types CNP 324 and 354, which are subtypes of, respectively, KN 1 and KN 3. These are often seen as two developmental phases in the same coin production in Magdeburg (c. AD 940–985). Given this interpretation, the Nonnebakken coin lies at the transition between the two types, or early in the time when KN 3 was produced, probably in the AD 970s. A secure, precise date within the maximum dating interval of AD 940–985 is, however, not possible.[10] The coin is not worn and therefore still has burrs from minting round its edge; this means that it could only have been in circulation for a short time.

Else Roesdahl assigns the silver hoards found between 1775 and 1909 to the time around AD 975–90 and most certainly no later than AD 1000 (Roesdahl 1977, p. 167f.; Roesdahl and Sindbæk 2014a, p. 253f.). Recent analyses of the coins have not altered this picture (Haupt 2006, Moesgård 2015, p. 157ff.), and the dating of the hoard found in 2015 is also consistent with this.

Three iron axes were discovered when soil was dug away from Nonnebakken in 1909, but these were submitted to the museum without any further information on their precise find spot or circumstances (Figure 33). As the southern part of the structure was presumably already built upon at this time, it can be assumed that the axes come from the northern half of the ring fortress. The axes represent Jan Petersen's types C, G or H and M (1919, p. 36ff.). While the two former types date primarily from the Early Viking Age, the latter continued in use into the eleventh century. The first two axes could tentatively be said to be coeval with the active period of the fortress, while it is possible that the third axe reflects later activities at the site.[11]

Four glass beads from pharmacist C. Mikkelsen's collection[12] from the first half of the twentieth century are said to have been found at Nonnebakken, and given the small size of these objects, it is remarkable that these were discovered during ground works, and that no other and larger artefacts were found at the same time (Figure 34). Even though several phases of sorting could have taken

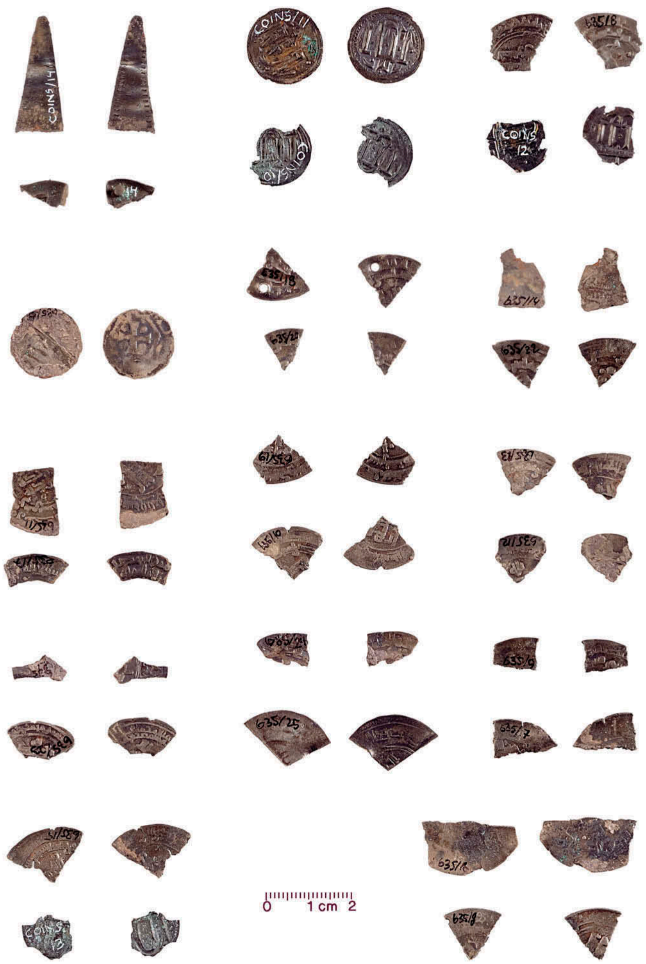

Figure 30. Twenty-five silver coins and two pieces of hack silver (top left corner) deposited together as a hoard and found at Nonnebakken in 1909. Photo: Nermin Hasic.

Figure 31. Circular filigree brooch presumed to be from Nonnebakken, found before1901. Photo: Jørgen Nielsen.

place between the beads being found and them ending up in the museum, it seems almost certain that they constitute part of a larger composite finds assemblage, for example a grave from the actual ring fortress or possibly its immediate environs. In general, it is unlikely that the beads can be more precisely dated than to the Viking Age.

From archaeological excavations, there are finds of a few glass beads and an unornamented band-shaped piece of hack silver. These objects cannot be dated precisely, but they may be from the Viking Age (Roesdahl 1977, p. 168; O. Olsen's report from the 1969 excavation: 3). A bronze ring-headed pin with a smooth ring and loop head (cf. Fanning 1990) can be broadly dated to the Viking Age (Figure 35), while parts of a double-shelled tortoise brooch, probably belonging to Jan Petersen's type JP51, dates from the tenth century (cf. Jansson 1985, p. 67ff.) (Figure 36).

A spindle whorl in finely tempered clay and parts of one or more crucibles, together with iron slag and a tablet-shaped lead weight are artefacts which show that craft and possibly trade activities have taken place at Nonnebakken (Figure 37). These objects are, however, not narrowly datable in themselves, and as they were not found in well-dated contexts, it cannot be determined whether they relate to the ring fortress' period of use – or to activities before or after its active period.

In the 2015 excavation, a Valkyrie brooch was found by metal detector in soil excavated by machine from a level immediately above the fortress surface (Figure 38). It is dated to the ninth century, and at least a further two examples are known from Funen: A fragment of similar brooch was recovered from a metal-rich locality at Engløkken, near the southeastern shore of Odense Fjord, while an intact example was found in the village of Rynkeby (the place name meaning 'the warrior village') in central Funen (Hansen 2017, p. 176). This brooch type is relatively rare in Denmark and is generally ascribed to localities that are thought to have had a degree of significance at the time (Petersen 2005, p. 76ff., 2010). From the same excavation a few sherds of flat-based, handmade Viking Age pottery were found in the rampart fill.

From the 2017 excavation, part of a hilt from a sword was found in a posthole on the fortress surface (Figure 39 (a,b) and 43). The mounting is curved in the length and made of iron. Thin layers of brass and copper are layed on the broad sides. The small hole in the middle indicates that the hilt is probably an upper hilt from a sword of special type 7 of Jan Petersen. The type is according to Petersen dated to the first half of the ninth century (Petersen 1919, p. 89).[13] This date contradicts with an AMS date of the posthole to 652–768 AD; a date which obviously might be affected by wood age or other factors.

In general, the number of artefacts that, with reasonable certainty, can be dated to the Viking Age at first glance seems small and the material has an atypical composition when compared with the greater and more varied material richness encountered during the excavations at Aggersborg, Fyrkat and Trelleborg. The overall picture is however distorted as the investigations at the three classic ring fortresses are of much greater extent than those at Nonnebakken. Moreover, particularly at Aggersborg, there are relatively few finds that can be ascribed to the fortress phase (Sindbæk 2014b, p. 227,

Figure 32. Sheet-silver bead (a), cut fragment of a dirham (b) and *Sachsenpfennig* (c) from Nonnebakken. Photo: Nermin Hasic.

Figure 33. Three iron axes from Nonnebakken, found in 1909. Photo: Jørgen Nielsen.

Figure 34. Four glass beads presumed to be from Nonnebakken. From pharmacist C. Mikkelsen's collection. Photo: Nermin Hasic.

Figure 35. Ring-headed pin from Nonnebakken. Photo: Nermin Hasic.

Figure 36. Part of an oval brooch found during the 1953 excavation at Nonnebakken. Photo: Nermin Hasic.

Pedersen and Roesdahl 2014, p. 261). If a comparison is made with Borgring, where the finds of Viking Age date are relatively sparse, the quantity of Viking Age artefacts recovered from Nonnebakken is quite substantial (Ulriksen *et al.* 2016).

One reason for the nevertheless limited number of finds recovered from Nonnebakken is the random nature of the collection of the artefacts up until the middle of the twentieth century. It can therefore be assumed that only the most

Figure 37. Tablet-shaped lead weight. Photo: Nermin Hasic.

spectacular artefact types have been recognised or have come to the attention of the museum. Another factor is probably that parts of Nonnebakken has been dug away, including material above the investigated areas, while other parts have been disturbed by medieval and later structures. A third factor that may have had an influence is that the archaeological excavations have not consistently employed sieving of the soil layer.[14]

Over and above these source-related aspects, it is also possible that the number of finds reflects the actual situation, i.e. that the activities at Nonnebakken were not so extensive or extended over the same length of time as was the case at Trelleborg, Fyrkat and Aggersborg. A very limited amount of

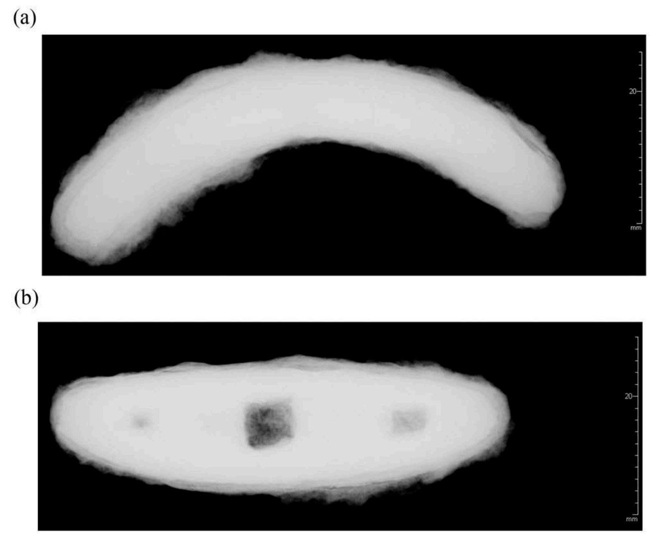

Figure 39. Mounting from sword hilt seen from the side (a) and top (b) from a sword. Nonnebakken. X-ray. Photo: Jannie Amsgaard Ebsen.

charcoal and ordinary household refuse, such as fire-brittled granite, potsherds and animal bones in the earliest archaeological horizon at Nonnebakken could suggest that this may well be a significant factor. The systematic excavations undertaken at Nonnebakken in 2012, 2015 and 2017 have, incidentally, not altered this picture.

Examination of the artefact material leads to three main conclusions: (1) Only few of the artefacts have been recovered from a sealed primary context. (2) Apart from the ninth century Valkyrie brooch and the hilt, the material does not appear to contain artefacts from the time prior to the tenth century, and the later material comprises mainly pottery. The latter has not been examined under the auspices of the present project and a previous examination showed that it predominantly dates from the Middle Ages and can consequently be ascribed to the time of the convent. (3) The few, narrowly datable artefacts were – as far as it can be determined from the

Figure 38. Valkyrie brooch from Nonnebakken. On the front, a standing shield maiden can be seen to the right and a Valkyrie mounted on a horse to the left. Below the horse is a rectangular tapestry woven from the intestines of fallen warriors. Photo: Nermin Hasic.

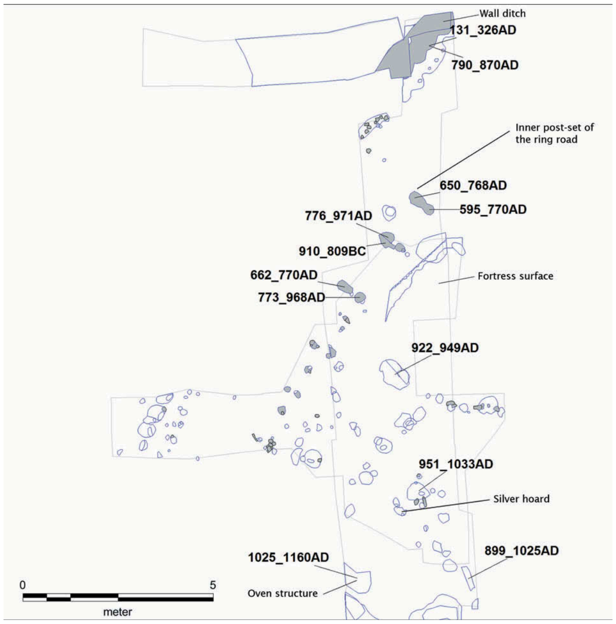

Figure 40. Distribution of AMS dates from the 2015 excavation at Nonnebakken. Grey: Stone and structures associated with the ring road and inner foot of the rampart. Broken grey line: Trench boundaries. Solid grey line: Other features and structures. Drawing: Mads Runge.

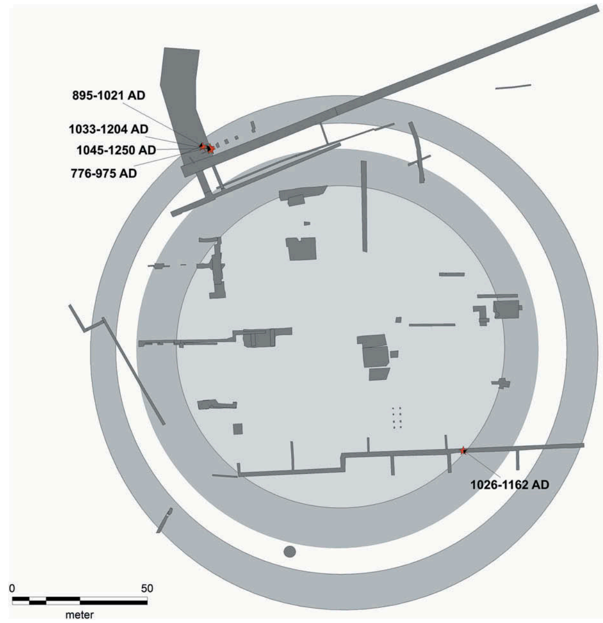

Figure 41. Distribution of AMS dates from earlier excavations at Nonnebakken. Drawing: Mads Runge.

available documentation – found scattered across most of the area enclosed within the ring fortress structure.

AMS dates

In all, 14 AMS dates were obtained in conjunction with the investigations at Nonnebakken in 2015 (see Figure 40). Unless stated otherwise, all AMS dates in this article are cited at 2 σ (95.4% probability).[15]

- *From the wall ditch for the inner rampart base* comes a date of AD 790–870 (charcoal, alder, young trunk(?), one tree ring, no bark) and a date of AD 131–326 (charcoal, unidentified species, diffuse porous hardwood, twig, c. ten tree rings, no bark).
- *From the inner post-set fortification of the ring road* come six dates of, respectively, 910–809 BC (charcoal, alder, young trunk(?), one tree ring, no bark), AD 595–770 (charcoal, alder, young trunk(?), one tree ring, no bark), AD 650–768 (charcoal, poplar/willow trunk/branch wood, two tree rings, no bark), AD 662–770, AD 773–968 and AD 776–971 (charcoal, ash, trunk/branch wood, one tree ring, no bark).
- *From postholes in the inner fortress surface* there are three dates of, respectively, AD 922–949[16] (charcoal, oak, from young trunk(?), one to two tree rings, no bark), AD 951–1033 (charcoal, ash, young trunk, two tree rings, no bark) and AD 898–1025[17] (charcoal, birch, young trunk, > six tree rings, no bark).
- *From a presumed medieval oven structure* comes a date of AD 1025–1160 (charcoal, beech, older trunk(?), outer five tree rings removed for dating, no bark).

To shed further light on the history of Nonnebakken, five new dates were obtained in 2016 for material recovered during previous excavations (Figure 41). Even though the material was sparse, it proved possible to obtain a date for a possible drainage layer towards the south and four dates from the lower layers in the northern part of the ditch. All five dates are for animal bones.

- *The drainage layer* was dated via a bird bone (OBM 9396 × 5) to AD 1026–1162.[18]
- The four dates *from the ditch* are for mammal bones (unidentified species) and are distributed as follows: basal layer BQ (NB88-BQ-1) dated to AD 895–1021; layer BT (NB88-BT-4), directly overlying layer BQ, dated to AD 776–975; layer BS (two dates), directly over layer BT, AD 1033–1204 (NB88-BS-22) and AD 1045–1250 (NB88-BS-23) (Figure 42).[19]

From the 2017 excavation ten dates were obtained (Figure 43).[20]

- *From the four posts that could mark the position of the northern gate* comes six dates of, respectively, BC 39,636–36,380 (charcoal, pine, trunk/branch wood, one tree ring, no bark), AD 652–768 (charcoal, oak, trunk, one tree ring, no bark), AD 1475–1641 (charcoal, probably spruce, trunk/branch, one tree ring, no bark), AD 1648–1918 (charcoal, birch, trunk/branch

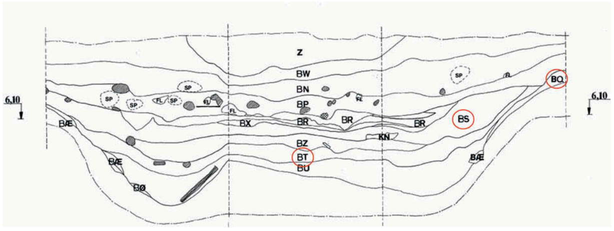

Figure 42. Section through the northern part of the ditch around Nonnebakken, showing the positions of the AMS dates. Drawing: Mads Runge.

wood, four tree rings, no bark), AD 1671–1943 (charcoal, unidentified species, trunk/branch, unknown number of tree rings, no bark) and AD 1677–1940 (charcoal, pome, birch, young trunk (?), one tree ring, no bark).

- *From the ring road there* comes four dates of, respectively, older than BC 45.000 (charcoal, oak (?), one tree ring, no bark), AD 695–891 (charcoal, oak, trunk/branch wood, one tree ring, no bark), AD 777–896 (charcoal, beech, trunk, four tree rings, no bark) and AD 887–1013 (charcoal, birch, trunk/branch wood, four tree rings, no bark).

The heterogenous result of the AMS dates from the site means that a great deal of caution in the use of them must be applied. Wood age on charcoal material, the use of possible redeposited material from the ditch, pollution by overlying cultural layers and so on are all factors that might alter the picture. To this might be added disturbances in the last centuries.

However, looking at all the AMS dates from Nonnebakken some general trends become visible. First there are two marked groups of dates. One in the period AD 600–800 and another in the period AD 780–1030. The first group of dates relates to activities before the Trelleborg type ring fortress phase and derives primarily from the ring road. The second group might reflect activities related to the Trelleborg type ring fortress phase and derives from both the ring road, the features in the fortress surface and the lower layers of the ditch. Besides these major groups there's dates that demonstrate a link with the Benedictine convent that stood on the site during the second half of the twelfth century, and which has given its name to the locality (Madsen 1988b, p. 106f.) Apart from these group of dates, there's a number of odd dates, ranging from BC 58.000 to AD 1950.

Discussion

Nonnebakken prior to the end of the tenth century.

The AMS dates indicate scattered activities during the Late Bronze Age and Early Iron Age, but these are not supported by finds and, consequently, nothing can be said about the nature of these activities. More significant are the group of dates, which fall in the Late Germanic Iron Age and Early Viking Age. The dating of the Valkyrie brooch and the hilt underlines these earlier activities at the site. Their more precise nature, given the limited extent of the investigated areas at Nonnebakken, is difficult to ascertain. If an attempt is nevertheless made, two possibilities emerge: Either that the dates represent an actual early fortress phase or that they relate to the existence of a pagan cult site, for example Odins Vi (Odin's shrine), as reflected in the place name Odense (cf. Kousgård Sørensen 1969, p. 13ff.). The arguments for and against these interpretations will be examined in the following.

An early fortress phase?.

The dates from the centuries prior to the Trelleborg phase and their contexts could

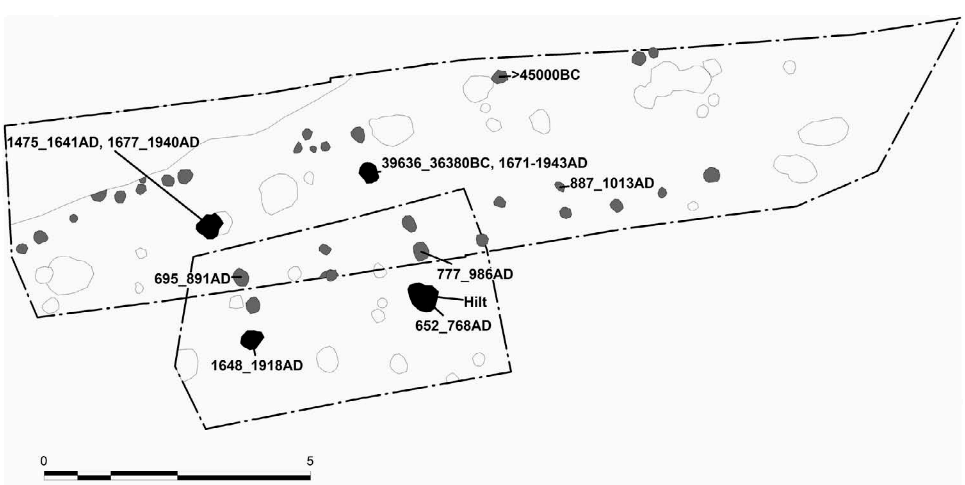

Figure 43. Distribution of AMS dates from the 2017 excavation at Nonnebakken. Grey: Structures associated with the ring road. Black: The four large posts marking the position of the gate. Broken black line: Trench boundaries. Solid grey line: Other features and structures. Drawing: Mads Runge.

indicate that there was already a fortress on the site prior to this. The appearance of a possible earlier fortress phase is though not known. Earlier fortress phases or, at least, a more complicated building tradition, are also known from Trelleborg on Zealand and the ring fortresses in Scania. Of the latter, possibly only Borgeby represents an actual Trelleborg-type ring fortress (Nielsen 1990, Svanberg and Söderberg 1999, Olesen 2000, Sindbæk 2014a, p. 235ff.).

An argument in support of an earlier fortress phase is that defensive structures in the eighth–ninth centuries are not exceptional in Denmark and other countries. Several continental ring fortresses were established in the Early Viking Age, and other defensive sites on Funen and adjacent islands are of the same date. The impressive rampart structure at St Albert's Chapel on Ærø springs to mind in this respect (Skaarup 1997, 2005, Henriksen 2012, p. 63). The dating of this structure rests on a rather flimsy foundation, but the excavator concludes that it was probably established during the Germanic Iron Age/Viking Age. The striking rampart and ditch at St Albert's Chapel can be readily compared with the defensive qualities of the classic Trelleborg-type ring fortresses. At a national level, the extension and reinforcement of the Danevirke and the establishment of the Kanhave Canal on Samsø constitute examples of military structures from the eighth century AD (Roesdahl and Sindbæk 2014b, p. 443; Nørgaard Jørgensen 2002). In a regional perspective, there is also a barrage in Henninge Nor on Langeland from the eighth–ninth century (Nørgaard Jørgensen 2002, p. 148, Skaarup 2005, p. 351).

Some degree of uncertainty is, however, associated with the interpretation of an early fortress phase at Nonnebakken. First, the ring road and the rampart base form part of a structure that is perceived as a Trelleborg-type ring fortress. If the ring road and the rampart base are to be linked to an earlier fortress structure, the Trelleborg-type fortress then 'lacks' some constructional elements. Second, the section through part of the rampart indicates that the fortress only has one phase. And finally stray and excavation finds from the area are in general from the second half of the tenth century. All in all, the possibility cannot be dismissed that the dates represent residual material from an earlier phase of activity which should not be viewed in the same context as the defensive structures.

An early pagan cult centre?. Alternatively, the same dates can perhaps be assigned to an early pagan cult centre. Together with the Valkyrie brooch, they fall directly in the active period and mythological universe of the Nordic Ase religion. There are no definite traces of a possible cult centre, but perhaps an up to 25 cm thick cultural layer containing charcoal, a few animal bones and, in particular, numerous pieces of fire-brittled granite discovered to the north of Nonnebakken during the excavation in 1987 should be seen in this context (Jensen and Sørensen 1990, p. 326ff.) (Figure 44). The layer's many large fire-brittled stones indicate that this is a primary deposit and not eroded-out

Figure 44. The southernmost part of the north-south section north of Nonnebakken, seen from the east. The black layer containing fire-shattered granite can be seen at the base of the section. This layer is overlain by redeposited medieval and later deposits. Photo: Nils M. Jensen.

material. Furthermore, the major content of fire-brittled granite and the absence of settlement refuse, i.e. finds such as potsherds, animal bones in significant numbers and iron and slag fragments, indicate that the deposit is unlikely to represent a refuse layer resulting from an ordinary settlement or from craft activities.

If the absence of definite cult-related artefacts, prestige objects etc. is ignored, the composition of the layer can be said to show some similarities to the thick layers of burnt stones encountered at the Late Bronze Age settlement of Kirkebjerg in Voldtofte (Berglund 1982, p. 55ff.) and, in particular, at central settlements from the Late Iron Age/ Viking Age. In the latter contexts, not least, deposits of this character are associated with cultic activities, perhaps the *hörgar* (altars) mentioned in the sagas (Christensen 2015b, p. 173ff.).

Another argument in favour of linking the early AMS dates with a pagan cult centre is provided by parallels with Harald Bluetooth's other fortresses. Trelleborg on Zealand was constructed on top of an earlier pre-Christian cult site (Nørlund 1948, p. 243ff., Jørgensen 2009, Dobat 2014, p. 54f.; Jørgensen *et al.* 2014). Similarly, the place name Onsild, near Fyrkat, indicates a possible relationship with the Ase religion (Olsen 1977, p. 35, Dobat 2014, p. 56). Aggersborg, too, has yielded evidence of possible ritual activities from pits and pit-houses. The activities should presumably be dated to the Viking Age, but cannot be securely placed in the chronological sequence of activities at the site (Sindbæk 2014c, p. 142f.). Perhaps the establishment of a Christian king's – i.e. Harald Bluetooth's – fortresses directly on top of the pagan cult centre should be perceived as an intentional demonstration of power, showing that the king can use these former pagan centres as he sees fit. Conversely, there is no indication that the king's new religion, Christianity, had to exclude the former pagan beliefs. On the contrary, some of Harald Bluetooth's other monumental constructions encompass both Christian and pagan elements. For example, the combination of rune stones, burial mounds and a church at Jelling and the pagan graves evident at Fyrkat (Roesdahl 1977, p. 151).

In contradiction of the interpretation of the early AMS dates as representing traces of a pagan cult centre is, primarily, the total absence of actual structures and artefacts associated with a site of this kind. It must be said, however, that traces of this type must be assumed to be difficult to detect archaeologically.

Recent research findings also speak against this latter interpretation. These indicate that when a demonstration of power takes place in connection with a change of religion, the new authority will position its power base in the vicinity of the old power centre, but at some distance from it. This situation is illustrated by the establishment of Roskilde some kilometres away from the pagan centre at Lejre and is also suggested in relation to Uppåkra and Lund and the establishment of Viborg (Ulriksen *et al.* 2014, Krongaard Kristensen and Poulsen 2016, p. 37). The conversion from paganism to Christianity appears, however, less crucial as the background for the shift of central place from Uppåkra to Lund than in the shift from Lejre to Roskilde. Because at Uppåkra, the presence of Christian burials, and possibly indirectly that of a Christian church, has been demonstrated by the beginning of the eleventh century at the latest. The Christian burials lie only about 200 m from the cult house at the Uppåkra site, and there may have been a chronological overlap with its final phase (Anglert and Jansson 2001, Larsson and Lenntorp 2004, p. 42).

If, in spite of these caveats, the Roskilde-Lejre model is to be applied to Odense, it would be most obvious to assume that Odins Vi lay some distance away from Odense, for example on one of the rich metal-detector sites in Odense's hinterland. At the same time, it would be more likely to see a church as a marker of the new religion, rather than a fortress. Moreover, it has been previously suggested that the *vi* (shrine) more probably lay north of the river, i.e. Odense Å, in the area of the possible royal residence in the vicinity of St Alban's Church (Thrane and Porsmose 1996, p. 176). No traces of such a structure have, however, been demonstrated here.

Nonnebakken as a fortress of trelleborg type. As outlined above, a number of circumstances indicate that Nonnebakken was planned as a Trelleborg-type ring fortress, on the initiative of the king. The minor excavations that to date have been undertaken over time in the interior of Nonnebakken indicate, on the other hand, that the 'squares', i.e. groups of four buildings arranged around a quadrangle are absent. There can be different reasons for this.

One possible explanation could be that Nonnebakken never managed to function as a Trelleborg-type fortress. This conclusion is supported by the fact that the Trelleborg-type fortresses are, in general, only thought to have functioned for a very short period of time, perhaps 10–15 years (Roesdahl and Sindbæk 2014a, p. 255, Sindbæk 2014a, p. 236ff.). An even shorter period is possible in the case of Nonnebakken, as it may have been constructed after Aggersborg, Fyrkat and the early phase of Trelleborg on Zealand (Sindbæk 2014a, p. 241). The relatively few finds recovered from Nonnebakken support this idea. Preliminary investigations at Borgring indicate similarly that it was only briefly used, if at all. Investigations undertaken so far have not demonstrated the presence of buildings in 'squares' and the finds assemblage from the Viking Age is of very limited extent (Ulriksen *et al.* 2016, Goodchild *et al.* 2017, p. 1038). Even though Fyrkat as was taken into use, it too was probably not fully developed, as suggested by the incomplete southwestern ditch (Olsen 1977, p. 89).

Another possibility is that Nonnebakken did function as a Trelleborg-type fortress, but that not all of these fortresses were built according to the same internal plan. Maybe the requirement for interior buildings in 'squares' was less at Nonnebakken than at Aggersborg, Trelleborg and Fyrkat. Perhaps because Nonnebakken, as is seen, stood directly next to a functioning settlement, located on the opposite side of the river? A similar explanation possibly also applies in the case of the two Scanian ring fortresses (Jacobsson 2003, Svanberg and Söderberg 1999, p. 48), while it is not thought to be relevant in the case of Borgring, as it is located without connection to a functioning settlement.

The regional variations in the trelleborg-type ring fortresses. The possibility that the Trelleborg-type ring fortresses differed with respect to their internal layout is supported by the inclusion of the newly-discovered Borgring near Køge, Zealand, and the Scanian ring fortresses in the discussion. Though there has been some discussion of the degree to which the Scanian examples, and not least the Scanian Trelleborg, should be seen as actual fortresses of Trelleborg type (Olesen 2000, Sindbæk 2014a).

The presence of buildings in 'squares' has also not (yet) been demonstrated at the Scanian ring fortresses or at Borgring (Ulriksen *et al.* 2016, Goodchild *et al.* 2017, p. 1038). In this respect, it is interesting that Trelleborg on Zealand also possibly has an early phase without the strictly laid-out buildings and quadrangles (Ödman 2014, p. 268). Furthermore, the Scanian Trelleborg, like Nonnebakken, was possibly established on an existing settlement (Jacobsson 2003). A further regional variation is that there is a great deal to suggest that only Aggersborg and Fyrkat were built in a single operation as actual ring fortresses of Trelleborg type (Svanberg and Söderberg 1999, p. 57). On the other hand, Trelleborg on Zealand, and Trelleborg in Scania, together with Borgeby, all have several phases; respectively six, two and four. Moreover, the Zealand Trelleborg's earliest phase does not have either a rampart construction with horizontal beams or a ditch. Another special characteristic is that the two Scanian ring fortresses have a round-bottomed ditch, while the Danish examples have a V-shaped case. Finally, Trelleborg in Scania has a first phase that is AMS dated to the second half of the ninth century (Ödman 2014).

On the basis of the above, it has been highlighted that discussions of the fortresses of Trelleborg type have most often focussed on the similarities between the monuments, while the differences are actually greater (Ödman 2014). These differences could reflect a division into a western and an eastern group of ring fortresses, with the former comprising Aggersborg and Fyrkat and the latter Trelleborg on Zealand and Trelleborg in Scania, together with Borgring and Borgeby (Jacobsson 1999, p. 148, Svanberg and Söderberg 1999, p. 57). The differences between the Scanian fortresses and the Zealand Trelleborg on the one hand, and Aggersborg, and Fyrkat on the other, could possibly reflect a 'boundary' between east and west Denmark, which may have run down through the Great Belt (Sindbæk 2008, p. 69, Ödman 2014, p. 270f.).

In summary of the above, it can be pointed out that only Fyrkat and Aggersborg appear to have been established over a short period of time. The eastern group has a more complex constructional history and shows greater constructional variation (Svanberg and Söderberg 1999, p. 43ff., p. 57, Lundø 2012, p. 20). At least the earliest phase of Trelleborg in Scania must, with its dating to around AD 800, more likely be related to the contemporaneous fortress structures along the southern North Sea coast (Olesen 2000, p. 105ff., Sindbæk 2014a, p. 235). The early AMS dates for Nonnebakken can be paralleled with Trelleborg in Scania, and it is possible that Nonnebakken also had an early fortress phase, modelled on southern precedent.

At Aggersborg, there were other activities at the site prior to the construction of the fortress in the form of a magnate's settlement and a trade/craft site (Sindbæk 2014c). At Fyrkat, there are no traces of earlier activity on the fortress area (Olsen and Schmidt 1977, Dobat 2014, p. 55). Aggersborg and Fyrkat contain no traces of a previous fortification, but earlier fortress phases may have existed at the eastern Danish and Scanian fortresses of Trelleborg type. The strict layout of Aggersborg and Fyrkat may reflect that there was an opportunity here to establish the fortresses completely from scratch, while there were certain restrictions at the other sites as a consequence of the development being based on existing structures (Svanberg and Söderberg 1999, p. 57).[21] In functional terms, all the Trelleborg-type fortresses could readily have constituted a single entity, forming part of Harald Bluetooth's extensive construction works and as a part of the collective defences of the realm at that time, with the Jelling complex placed at their centre.

Nonnebakken and its surroundings. A remarkable feature of the distribution of finds from the period from the end of the Late Germanic Iron Age to the Early Middle Ages is that, apart from the site of Nonnebakken itself, these are all more or less located on the north side of the river. Not a single find from this period has been recorded within a semicircle of c. 1 km radius, centred on Nonnebakken. There could be several explanations for this situation. For example, the area is largely characterised by older private houses and gardens that were built without archaeological monitoring or prior archaeological investigation. However, given what has been found, also in the way of smaller artefacts, elsewhere in the town over time, the picture does appear to reflect a real tendency.

The aforementioned semicircle is closed to the north by the river, Odense Å, and on the first edition ordnance map from the second half or the nineteenth century it is evident that, to the southeast, there is a boundary in the form of a curved depression along the line of the semicircle, i.e. present-day Munkedammen (Figure 45). There are no immediately evident topographic boundaries to the southwest. The evidence suggests that the fortress was established in an area with no actual settlement itself, but adjacent to settlement located on the opposite side of the river. Moreover, the circumstances illustrate that the fortress and its master, the king, had the authority to keep the area to the south free of settlement. This was perhaps both a manifestation of power and a way of securing against attack from that direction. It may also have been a way of accentuating the fortress' visibility from a distance; a feature that also characterises the other fortresses of Trelleborg type (Roesdahl and Sindbæk 2014b, p. 438). To the north, the river and a possible town rampart constituted the defences.

The 'cleared' surroundings show strong parallels at other prehistoric power bases. The most obvious of these is the gap seen in relation to weapon graves and other prestige traces in the area around Viking Age Jelling. Here, it is suggested that the gap reflects the fact that the Jelling dynasty absorbed all power and prestige (Lindblom 2014, p. 29f.), and it is suggested that the weapon graves and, not least, the equestrian

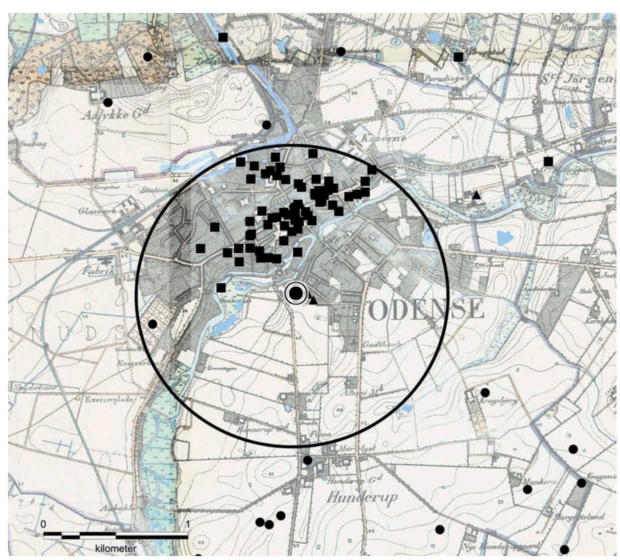

Figure 45. Nonnebakken (center circle) and coeval finds from the hinterland, plotted on the first edition ordnance map from the second half of the nineteenth century. Circle: Iron Age. Triangle: Viking Age. Square: Middle Ages. Diameter of the large circle is 1 km. Excerpt from the database *Fund og Fortidsminder* (Sites and Monuments) 16.3.2016. © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

graves could mark a protective circle around the power centre (Randsborg 1980, p. 127). This latter conclusion has though been questioned (Näsman 1991b, p. 171). The Early Iron Age Gudme dynasty is also characterised by an absence of weapon graves in its immediate vicinity. These are, conversely, located within a 'protective' semicircle at a distance from the dynasty's core area (Henriksen 2009, p. 340ff.).

The boundaries of the Viking Age town

In an article in *Fynske Minder* in 1974, Aage Lauritsen suggested that the curved course of the street Paaskestræde (OBM 3191, 080407–312), c. 100 m west of the square Albani Torv, could represent the eastern part of a semicircular town ditch around a Viking Age settlement on the north side of Odense Å (Lauritsen 1974) (Figure 46). In which case, the western boundary must most probably follow one of the present-day streets of Klaregade or more likely Munkemøllestræde. No archaeological observations have been made in support of Lauritsen's hypothesis. A minor investigation in 2013, in a narrow trench prior to laying a district heating pipe in Paaskestræde, did touch the area where the town ditch, according to Lauritsen, could have been, but no relevant features were observed. The fact that the town ditch was not recorded here does not necessarily mean that it has not existed, and future investigations should obviously exploit the opportunity to dig or take auger samples in places where this question can be addressed.

The boundaries of the medieval town are better illuminated. They consisted partly of natural depressions and partly of man-made, water-filled ditches, possibly augmented by ramparts and/or palisades (Madsen 1988a). From the thirteenth century onwards, the town's boundaries enclosed an area somewhat larger than that proposed by Lauritsen for the Viking Age defences (Christensen 1988, p. 67).

All in all, Lauritsen's suggestion can neither be confirmed nor dismissed. If what he suggests was true, the pit-house settlement at Mageløs/Klaregade and Vestergade 70–74, mentioned below, would have stood to the west of the town ditch. As will become apparent later, it is perhaps possible that a potential boundary more likely relates to the major ecclesial complex which, from the eleventh century, developed around St Alban's Church, with an associated churchyard and possibly an episcopal residence. But this remains pure speculation.

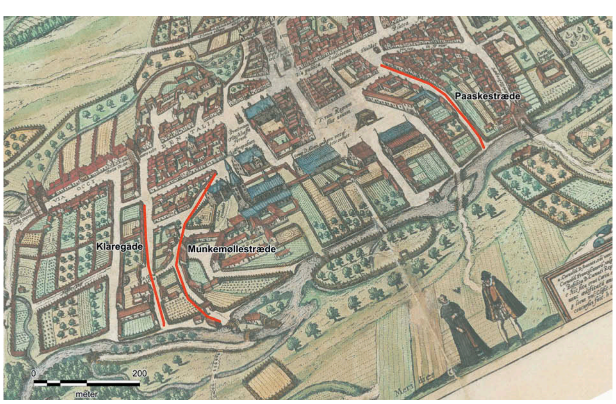

Figure 46. The proposed town ditch around the Viking Age town, in the form of Paaskestræde and possibly also Klaregade or Munkemøllestræde. Illustrated here on Braun's prospectus of 1593. © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

A royal residence?

In AD 1120, Ælnoth, an English monk who lived in Denmark from the beginning of the twelfth century, describes how, at the time of the murder of Canute IV in 1086, the royal residence stood near St Alban's Church (Johannsen *et al.* 1998–2001, p. 1729f.) (Figure 47). Tore Nyberg believes that the royal residence was located on the promontory at Klaregade/Mageløs, close to the later convent of St Clara and the present-day bishop's palace on an area later described as *kongsmark* – i.e. king's field (1982, p. 14). Based on the most recent translation of Ælnoth's chronicle, Anemette S. Christensen holds the alternative view that St Alban's Church was the church for the royal residence and the two were therefore located closer together, with the site of the royal residence perhaps being where the later St Canute's Abbey was built (Albrectsen 1984, p. 79f, Christensen 1988, p. 33, 70). Her view is supported by the discovery in 2015 of a bishop's grave in the earliest St Alban's Church, thereby identifying the church as a cathedral (Bjerregaard *et al.* 2016a, p. 152, 2016b). Archaeological traces of the royal residence have not, however, been demonstrated. This is perhaps not surprising in the light of the many later construction activities on this area, together with uncertainty about how such a royal residence would distinguish

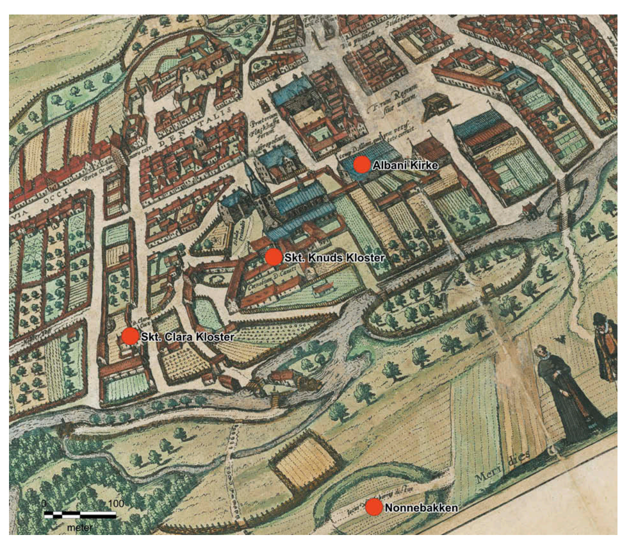

Figure 47. The proposed locations of a royal residence, shown on Braun's prospectus of 1593. © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

itself archaeologically from other traces. Moreover, it has been suggested that the royal residence was previously located in the fortress at Nonnebakken (Christensen 1988, p. 33, Olsen 2015, p. 326).

Coinage

The earliest evidence for coinage in Odense is from the time of Magnus the Good and Sweyn II Estridsson, i.e. the AD 1044/46–1048/50. Coinage continued to a limited extent in Odense in the eleventh century (Becker 1982, Christensen 1988, p. 33, 121f.). The earliest coinage is not documented in the archaeological evidence from excavations in Odense. Conversely, a Canute IV coin (AD 1080–86) minted in Odense was found during the ongoing investigation of the earliest course of Overgade-Vestergade under the auspices of the *Fra Gade til By* project (Jesper Hansen, oral communication; see also Poulsen 2016, p.132) (Figure 48).

Infrastructure

It has previously been suggested that the main east-west traffic route across Funen, marked in Odense by the streets Overgade and Vestergade, provided the basis for establishment of the town (Christensen 1988, p. 65, Madsen 1988a, p. 35) (Figure 49). It is not certain, however, that this theory can be maintained, given the results of the new investigations undertaken during the present project. As will become evident in the following, the earliest settlement phases appear to lie some way south of the road, and further down the slope towards Odense Å than the later medieval town. Perhaps the route running north-south past Nonnebakken, towards the town, was just as central to Odense's development?

Figure 48. Canute IV (top) and Niels coins from Odense. Photo: Nermin Hasic.

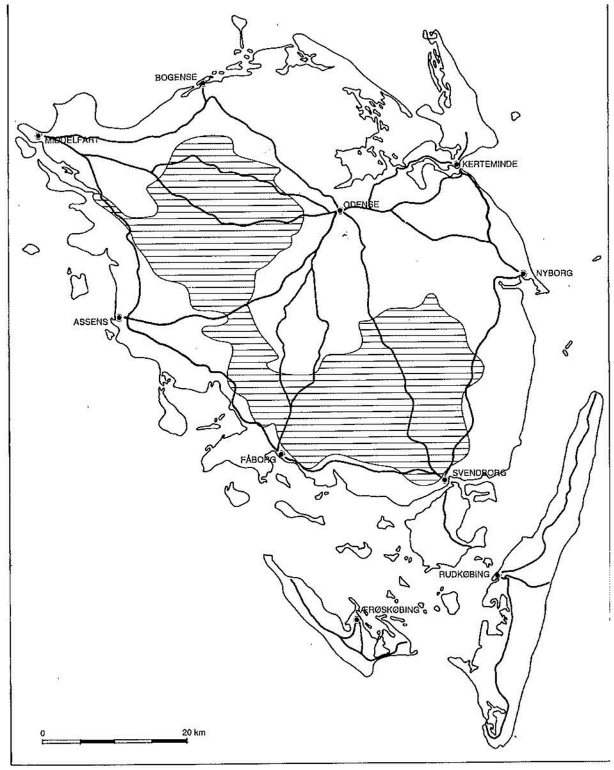

Figure 49. Funen's main medieval terrestrial/land traffic routes. The hatched area marks the Funen highlands. After Jørgen Elsøe Jensen (1992, p. 11).

The east-west traffic route across Funen must, under any circumstances, have played a significant role in the development of Odense. Through the investigations undertaken around I. Vilhelm Werners Plads it has been possible to demonstrate that the Overgade-Vestergade route can be traced far back in time (Figure 50). Immediately beneath the present road lay a series of predecessors, beginning with a phase laid directly on the subsoil, following removal of the original topsoil. This earliest road phase could, based on the stratigraphy and incorporated finds, be dated to the late eleventh or the twelfth century. The road layer immediately above this contained coins of Canute the Holy (1080–86) and Niels (1104–34) (Jesper Hansen and Jens Christian Moesgaard, oral communication) (cf. Figure 48). The earliest road layer overlies a posthole that has been AMS dated to AD 1026 (95.4%) AD 1062,[22] thereby providing a terminus post quem date for it. Finally, it could be demonstrated that the medieval settlement here was oriented with its main house facing out towards the road.

The possibility that the road could extend even further back in time is suggested by evidence of activities here as early as the eleventh century (cf. phase 3 in the settlement development). The results of an earlier investigation at Skomagerstræde/Overgade 1–3, where a stretch of cobbled road was uncovered that overlay the possible pit-house and fence mentioned above, support this suggestion. In the Viking Age and Middle Ages, as now, this was a north-

Figure 50. During the excavation at I. Vilhelm Werners Plads, the earliest phases of the Overgade-Vestergade route turned up beneath the present-day road. Photo: Odense City Museums.

south-oriented side road leading off the south side of Overgade-Vestergade. The road fill contained a number of finds from the eleventh and twelfth centuries: a ring-headed pin, a finger ring and a comb. The random way in which these finds could have been deposited on the road means their date can only tentatively be transferred to the road itself (Nielsen 1998, p. 27ff., Jacobsen 2001, p. 107). Its stratigraphic position and the associated finds mean that the eleventh century surface of Skomagerstræde could have formed part of a larger road network that also included Overgade-Vestergade (Nielsen 1998, p. 30), but it is not possible to link these together with certainty.

Other central routes in the medieval town included the topographically determined roads radiating out to other important areas of Funen. With their *stræde* suffixes, the north-south-oriented roads appear to have constituted side roads to Overgade-Vestergade (Christensen 1988, p. 52ff.). Traces of other medieval roads and lanes have also been identified archaeologically in several places in the town (Nielsen 1998).

As stated previously, the crossing over Odense Å, linking Nonnebakken with the early town on the north side of the river, probably lay in approximately the same place in the Viking Age as it does today, i.e. at the Munke Mølle crossing, where the river valley was narrowest and where a sand bank in the river made passage easier (Thrane *et al.* 1982, p. 109, Christensen 1988, p. 65ff.) (see Figure 25).

Crafts and trade

Traces of specialised crafts

Vestergade 70–74 and Mageløs/Klaregade

The localities of Vestergade 70–74 and Mageløs/Klaregade both contain traces of craft activities in the form of pit-houses associated with a finds assemblage of a composition and extent that indicate more than self-sufficiency.

In 1984, an area of c. 90 m^2 was excavated at Vestergade 70–74 (OBM8236, 080407–65), revealing a partially disturbed pit-house and parts of a presumed longhouse, as well as pits and postholes that could not be assigned to definite constructions (Figure 51). Both buildings showed probable signs of repairs and had therefore been in continual use over an extended period. No cultural layers were observed in the area, which was characterised by disturbances. The basal layer of the pit-house yielded sherds of flat-bottomed Viking Age vessels with an in-turned rim and/or hemispherical vessels, as well as two conical spindle whorls. Further to these were an iron leister and an ornamented single-sided comb with plates of flat, rounded cross-section (Figure 52). In the material recovered from Århus Søndervold, similar comb types form part of pottery horizon 1, which is dated to the ninth–tenth centuries (Andersen *et al.* 1971, p. 151). The upper fill layers in the pit-

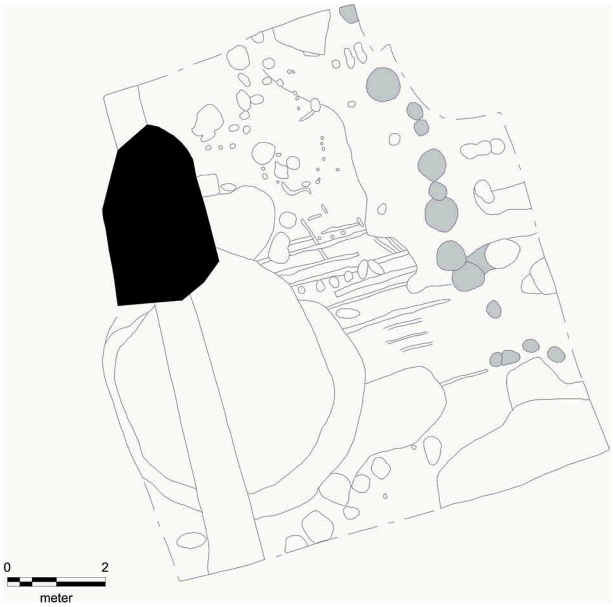

Figure 51. Plan of excavation at Vestergade 70–74. Black: Pit-house. Light grey: Postholes, possibly a house wall. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

Figure 52. An iron leister and an ornamented, single-sided comb from the basal layer in a pit-house at Vestergade 70–74. Photo: Nermin Hasic. Drawing: Steffen P. Maarup.

house contained Baltic ware pottery, which can probably not be linked to the primary use of the structure. On the excavation surface, directly east of the pit-house, a bronze patrix was found that had been used in the production of disc brooches of Jansson's types II or III, or pendants decorated in Borre style (Jansson 1984, p. 62ff.) (Figure 53). Iben Skibsted Klæsøe has, on the basis of photos and a drawing of the patrix, dated it to around AD 900. Several features around the pit-house contained crucible fragments and lumps of melted bronze, reflecting bronze-casting activities that could be coeval with the patrix. Several of the features did, however, also contain Baltic ware pottery, which presents the possibility that this material could be slightly later than the patrix – or that it had become mixed in from earlier deposits. The features around the pit-house also contained slag, loom weights, a soapstone sherd, a glass ring and a glass bead. Sherds of Baltic ware pottery from the post-holes in the presumed longhouse indicate that this construction

Figure 53. Drawing and photo of a bronze patrix from Vestergade 70–74. Photo: Jørgen Nielsen. Drawing: Steffen P. Maarup.

belongs to the same phase as the back-fill layer in the pit-house. All in all, the finds assemblage reflects crafts such as bronze casting, smithing and textile production in the ninth–eleventh centuries. The locality is therefore interpreted as part of a craft site or workshop area with activities extending from the time around AD 900 up until AD 1100 and, at least from AD 950, the latest date of the longhouse if the Baltic Ware pottery is counted as primarily deposited, see note 4, possibly also associated with permanent settlement. Two later wells from, respectively, the fourteenth century and the renaissance period show that the area was also occupied subsequently. Similarly, cultivation traces beneath the Viking Age features reflect earlier activities in the area (Jacobsen 2001, p. 72f.).

In 1998, in a narrow trench running along the streets of Mageløs and Klaregade (OBM9787, 080407–131), a total of c. 135 m^2 was excavated, leading to the discovery of two pit-houses (Figure 54). Based on the pottery from both the basal layer and upper fill layers, which consists predominantly of hemispherical

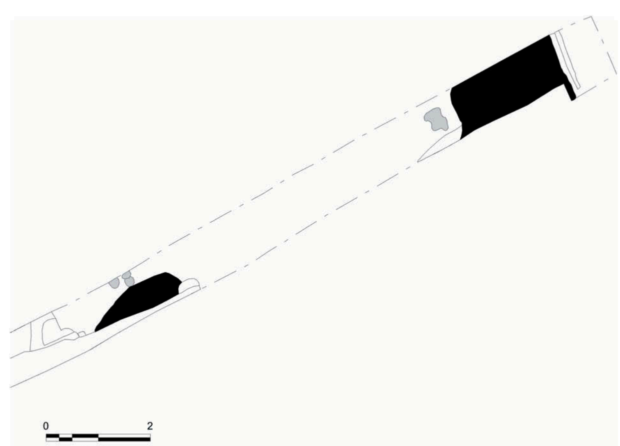

Figure 54. Plan of excavations at Mageløs/Klaregade. Black: Pithouse. Grey: Postholes. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

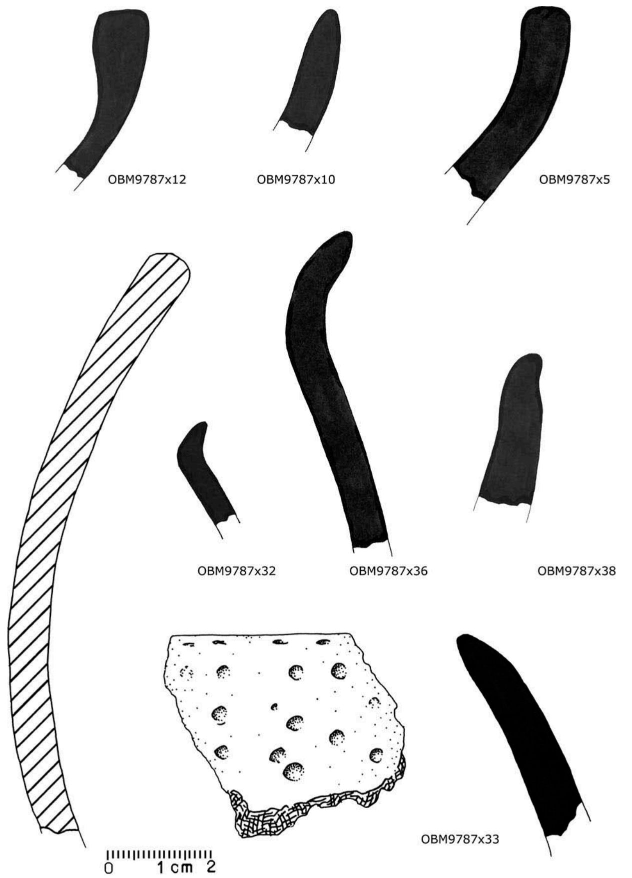

Figure 55. Pottery from the Late Germanic Iron Age/Early Viking Age found at Mageløs/Klaregade. Drawing: Steffen P. Maarup.

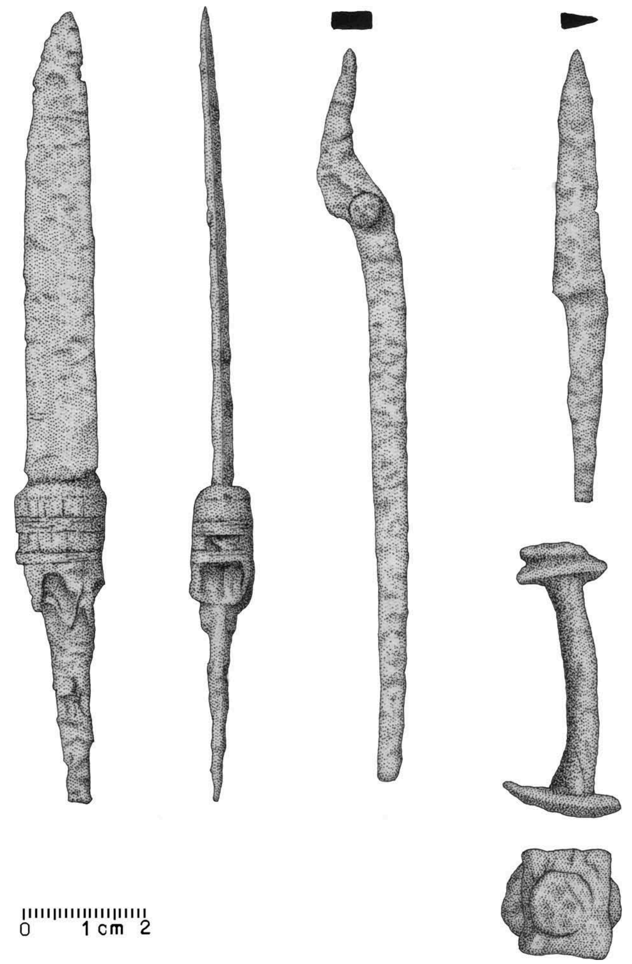

Figure 56. Iron knife wound with bronze and partially preserved wooden handle, iron tang, simple iron knife and iron rivet found in pit houses at Mageløs/Klaregade. Drawing: Steffen P. Maarup.

vessels, the pit-houses were dated to the Late Germanic Iron Age or Early Viking Age. This date is supported by the presence of potsherds that possibly originate from a bucket-shaped vessel, together with sherds from vessels with a narrowing below the rim (Figure 55). At other localities, the latter type is found in contexts from the Late Germanic Iron Age and Early Viking Age, but only to a limited extent from the end of the tenth century (Henriksen 1997, p. 33). This pottery date was, in part, further confirmed by the AMS dating of a bone from a ruminant from each of the two pit-houses to, respectively, AD 775–973 and AD 891–1019.[23] The contents of the pit-houses included an iron knife, wound with bronze and with a partially-preserved wooden handle, chisel fragments, an iron buckle to horse or dog harness, iron plates, iron bars, iron needles, bronze and iron fragments and pieces of iron slag, as well as spindle whorls and loom weights (Figure 56). The pit-houses also contained a well-preserved bone assemblage that included fish bones. The surrounding excavated postholes lacked datable finds and are not directly linked with the pit-houses, but could be coeval with them (Jacobsen 2001, p. 102f.). The finds from the two pit-houses indicate specialised craft activities, and the buildings are therefore unlikely to have belonged to a single isolated farm.

In December 2016, a small construction project in Mageløs, just north of the pit-houses excavated in 1998, prompted a minor investigation of a few small trenches, each of a couple of square metres in area. These trenches were excavated down to the subsoil, and in one of them a posthole and a larger feature, perhaps representing a pit or a pit-house, was found at subsoil level 8.5m northwest of the western most pithouse from 1998. Overlying these features a cobbled surface with an activity layer was registered. The posthole is AMS dated to AD 652–768, the large feature to AD 895–1021 and the activity layer to AD 809–1013.[24] The datings support the frame of the 1998-datings.

The archaeological finds from the pit-house area at Vestergade and Mageløs/Klaregade indicate that these, in contrast to many sites on Funen showing traces of specialised trade and craft activities, do not have roots extending back to the sixth century. On the contrary, the finds recovered to date indicate that the area was established late in the eighth or in the ninth century, at the earliest. This concurs with the settlement at Ejby Mølle (OBM 6050, 080407–79), immediately east of Odense, which was established in the ninth century (Jacobsen 2001, p. 76ff.). Its position on a level, well-drained plateau extending out to the river, Odense Å, and very close to a point where the meltwater valley's slopes are fairly close together, is unlikely to have been random. Precisely this location must have been preferred when crossing from the area south of the river to that north of it, and vice versa. Consequently, the pit-house complex enjoyed a central location relative to the north-south traffic corridor, which later developed into the streets Hunderupvej-Klaregade.

New investigations near the pit-house area, Bispegården. The localities at Vestergade 70–74 and Klaregade/Mageløs therefore represent the earliest archaeological traces of settlement in Odense and thereby possibly parts of the earliest town. It was consequently a major aim of the current project to trace other parts of this area with the intention of upgrading the evidence via a more precise identification of function, a better dating foundation and a sharper evaluation of the area's extent. Unfortunately, more or less all of the potential area is densely built upon or located below central traffic routes in the town centre. A few minor areas, including the garden of the present bishop's palace (Bispegården, OBM 9789, 080407–128) do lie under grass. Under the auspices of the current project, the museum was permitted to dig a couple of short trial trenches here (Figure 57). The investigation also included metal-detector surveys of the exposed surfaces and the excavated soil.

Figure 57. Plan of the excavation at Bispegården. Grey: Trench boundary. Black: Features and structures. Drawing: Mads Runge.

The trenches revealed a relatively flat and undisturbed subsoil surface at a level of 7.5–8.5 m above DNN. No wetland deposits were observed on the subsoil surface and, together with the very limited slope of the terrain, the surface must be considered as well suited to settlement. Despite this, no artefacts, objects or cultural layers were found that were earlier than the sixteenth century. With some reservation, due to its relatively limited area, the investigation could indicate that here we are outside the town's settled area. Cultural layers, scattered features or stray finds from the Late Iron Age, Viking Age or Early Middle Ages would be expected if there had been actual *in situ* settlement here or a trade/craft site from this period.

Analyses of the place name Hetby. The archaeological and scientific dating of the pit-houses at Vestergade 70–74 and Mageløs/Klaregade to the end of the Late Germanic Iron Age or Early Viking Age means that these structures are some of the earliest in the centre of Odense. At the same time, these localities are situated around the western margin of the medieval town, if it is assumed that this coincided more or less with the town boundaries shown in Braun's prospectus from 1593. It has therefore been debated whether the finds should be ascribed to the earliest phase of Odense as a town or to an independent (rural) settlement.

In the report for the excavation at Vestergade 70–74, the possibility is mentioned that the finds relate to the remains of an abandoned village, Hetby or Heden. This suggestion is supported by the fact that there are several place names with the prefix *Hede* in the near vicinity (Arentoft 1984). The village is mentioned in a document dated 25 June 1175, in which King Valdemar the Great bequeaths the village and three smallholdings to St Canute's Abbey. The document's central passage in this respect reads as follows: '*… we have decided to convey the exchange of landed property which we have undertaken with the brothers in the monastery in Odense [St Canute's Abbey] by a letter, issued by virtue of our authority, and entrust this to posterity. He [the king] therefore gives by exchange of property these friars the village Heden and three smallholdings, "ornum, reb, gasetunge", and other* [i.e.] *that the citizens of Odense may not take their corn anywhere but to the friars' mill. […] Renders/Rendered by Emer's hand, curate in Søllested, AD 1175 …*' (Christensen and Nielsen 1977, p. 47, no. 49).

The link between the Vestergade (and Mageløs) locality and the village of Hetby is also mentioned as being likely in other later works (Nielsen, J. 1984, Jacobsen 2001, Ulriksen *et al.* 2014, p. 173). The project *Middelalderbyen* (The Medieval Town) similarly raises the possibility that the finds should be ascribed to the village of Hetby, but then points out that they could just as well belong to an early phase of the town of Odense (Christensen 1988, p. 33).[25] Conversely, in both *Trap Danmark* and Funen county's so-called village index, the document from 1175 is linked with the village of Heden in Sallinge, located 16 km south of Odense (Trap 1957, p. 765; Fyns Amt 1992).

Under the auspices of the present project, Lisbeth E. Christensen, with input from Bent Jørgensen, Department of Nordic Research, University of Copenhagen, has examined the evidence relating to whether the place name Heden should possibly be ascribed to the area around Vestergade 70–74.

According to this analysis, the following points speak *in favour of* a location for Heden near Odense:

- The 1175 document's linking of Heden with St Canute's Abbey.
- The mention of the mill Munke Mølle (the monks' or friars' mill) in the same document.
- The occurrence of the place name Heden directly south of Odense Å.

While the following points speak *against* a location near Odense:

- The document was signed in Søllested in Båg district in southwestern Funen, more than 30 km southwest of Odense.
- The earliest maps of Odense have no villages with the name Heden or similar, only names of natural features. The latter, in which *hede* is included, also occur commonly across all of Funen. It is first in 1533 that the name Hedehus appears near Odense, more precisely on a level area c. 1.6 km south of the town centre (Kousgård Sørensen 1969, p. 7).
- The name Heden occurs in Sallinge, the neighbouring district to Søllested (c. 20 km east of Søllested). This is a well-established village with roots extending back at least to the transition between the Viking Age and the Middle Ages (Fyns Amt 1992).
- The fact that St Canute's Abbey is mentioned in the document does not mean that the endowment of landed estate is necessarily placed in Odense, as the abbey had lands in several places on Funen. There were also still abbey lands at Heden in Sallinge district in the seventeenth century.
- The locality of Vestergade 70–74 lies on the periphery of the medieval town of Odense, and not outside it, like a separate, independent village would.

All in all, Lisbeth E. Christensen's view is that the place name Heden mentioned in the document from 1175 should most probably be ascribed to the village in Sallinge district (Christensen 2015a). On this basis, the craft activities at Vestergade 70–74 and at Mageløs/Klaregade cannot be dismissed as part of the earliest settlement of the land that later hosted the medieval town of Odense.

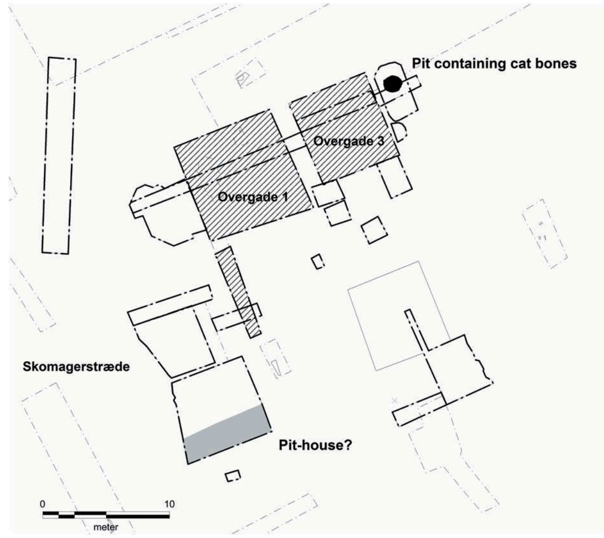

Figure 58. Plan of the excavation at Skomagerstræde/Overgade 1–3. The approximate positions of the pit-house and on the pits containing cat bones (part of the 'cat farm') are marked. The traces of permanent settlement could not be plotted in precisely. Black lines: Excavation trenches. Crossed areas: Medieval buildings. Grey: Possible pit-house. Solid grey lines: Other features and structures. Broken grey lines: Other trench boundaries. Drawing: Mads Runge.

Skomagerstræde/Overgade 1–3

In 1970–1971, in connection with the demolition of a building complex at the crossroads between the former streets of Skomagerstræde, which ran along the eastern side of the town hall, and Overgade, an archaeological investigation was undertaken of an area covering a total of 274 m^2 (Skomagerstræde/Overgade 1–3, OBM 8201, 080407–153) (Figure 58). In a few places, there was up to 0.5 m of undisturbed culture layers and the earliest activity on the site was represented by a possible pit-house and a number of postholes which formed the corner of a fence or a building. The fence/house and the possible pit-house are not plotted precisely in on the plans, but it is stated that the building lay in the southern part of the 1971 excavation trench, i.e. the area bordering the former street of Skomagergade (Grandt-Nielsen 1972, p. 206). The structures were overlain by a compact cobbled surface, laid out on top of the original soil surface, which could be followed over a distance of 25 m. Finds from within this cobbled layer included a ring-headed pin with a facetted head (cf. Fanning 1990, p. 130), dated to the Viking Age (Figure 59), a comb, dated to the eleventh century (Grandt-Nielsen 1972, p. 211f.; Jacobsen 2001, p. 107) and a finger ring, which is probably not earlier than AD 1100. With reservations for the difficulties associated with dating a road surface based on the finds found incorporated within it, a date of Late Viking Age/Early Middle Ages can perhaps be assigned to the cobbled surface (Jacobsen 2001, p. 107). Consequently, the

Figure 59. Ring-headed pin with facetted head found at Skomagerstræde/Overgade 1–3. Photo: Asger Kjærgaard.

Figure 60. Enamelled brooch found at Skomagerstræde/Overgade 1–3. Photo: Asger Kjærgaard.

pit-house and the post structure are probably earlier than this.

Alongside the cobbled surface, probably also from the eleventh century onwards, were settlement traces in the form of pits, wells, wall trenches, postholes and stone-built hearths (Grandt-Nielsen 1972, Jacobsen 2001, p. 107f.). The earliest well, dendrochronologically dated to AD 1113–14 (Bartholin and Grandt-Nielsen 1974, Bartholin 1977), was found to contain a large amount of refuse from shoemaking activities as well as traces of combmaking, etc. (Grandt-Nielsen 1972, Jacobsen 2001, p. 107f.). Another well, dendrochronologically dated to AD 1117, yielded an enamelled brooch of Anglo-Saxon/south Scandinavian type (Bartholin 1977, Baastrup 2009, p. 239: no. 40, Figure 29), which is dated broadly to the Viking Age or Early Medieval period (Figure 60).

The excavation also investigated a series of floor layers, through which had been dug several pits that proved to contain skeletal remains, including skulls, of cats in particular, interpreted as remains from a cat farm/furriery. The bones from one of the pits have provided an AMS date of AD 1070 ± 100[26] (Hatting 1992, Jacobsen 2001, p. 107f.). During the 2012–2016 investigations on I. Vilhelm Werners Plads, a layer from around AD 1100 was also found to contain some cat bones, including a couple of skulls displaying cutmarks, which perhaps should also be seen in relation to the furrier's workshop/furriery (Kirstine Hasse, oral communication).

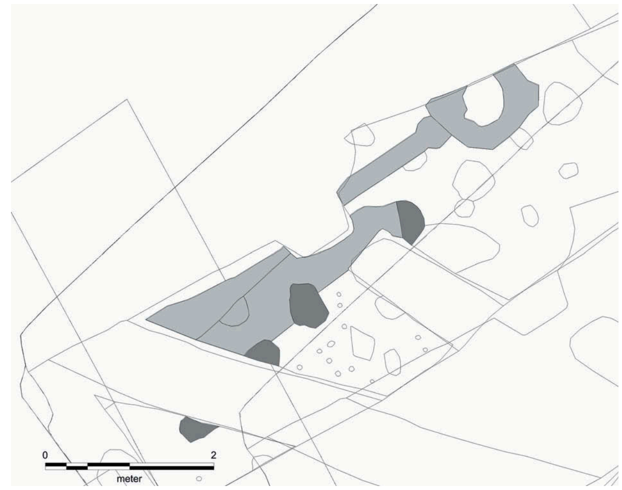

Figure 61. Plan of the excavation at Klingenberg. Dark grey: Postholes. Light grey: Pits or possibly parts of pit-house(s). Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

Klingenberg

At the locality of Klingenberg (OBM 9791, between Skomagerstræde/Overgade and Mageløs/Klaregade, 080407–109), an activity area was investigated at subsoil level, which included a number of pits that contained worked bone and antler, thereby testifying to combmaking, as well as ironworking activities (Figure 61). One or more of the pits could in the excavators' opinion perhaps represent pit-houses, only partly uncovered in a small trench. The activities cannot be dated more precisely than to the period from the Late Iron Age to the Early Middle Ages.

I. Vilhelm Werners Plads

During the extensive investigations at I. Vilhelm Werners Plads (OBM 9776, 080407–130), only sporadic traces emerged of trade and craft activities from the Early Middle Ages in the form of very limited quantities of workshop waste. No actual workshops were identified.

Traces of trade?

The specialised production represented by several of the pit-houses could implicitly indicate some form of basis for trade activities. Apart from a couple of sherds of soapstone and a large piece of basaltic lava, actual traces of trade activities from the period prior to the eleventh century, in the form of imported goods, hack silver, Arabic coins and weights, have not been demonstrated here (Henriksen 2016). Before this is taken as an indication of an actual absence of this activity, a couple of possible explanations will be presented for the lack of archaeological evidence for trade.

First, there are some source-related aspects relating to the degree of preservation and the form of the investigations. For example, the modest extent of the excavated areas is a significant aspect. Another factor is the absence – possibly due to the intense activities that have taken place from the Middle Ages until today – of cultural layers across more or less the entire area within which the pit-houses described above lie.

Second, it can be considered whether the trade activities in Odense were of a different character to those in the emporia; one that leaves fewer clear indications of trade. The emporia were, as described above, oriented towards long-distance networks, and because of this, the frequency of artefacts of foreign origin is clear and relatively easy to decipher for modern archaeologists. The next wave of proto-towns, of which Odense was one, were apparently oriented towards their immediate hinterland. Exchange of goods, i.e. 'trade', was therefore focussed to a much greater extent on everyday products, whereby for example foodstuffs came to Odense from agrarian settlements, and Odense, in return, provided specialised craft products indicated by the aforementioned pit-houses. Local exchange of goods/trade involving short-distance contacts of this kind is much more difficult to trace in the archaeological record than more distant links.[27]

A similar characteristic might be recognised in the case of Ribe from the middle of the 9th and the tenth century, the period of Ribe's history that has proved so difficult to recognise archaeologically (Feveile 2006, p. 48ff., Alrø Jensen 2013, p. 20ff.). In the case of Ribe it is suggested, that an explanation for the poor representation of artefacts with definite dating to the period might be due to a shift from an internationally orientated trade founded in the emporia to trade based to a higher degree on organic and local material (Alrø Jensen, p. 24).

The relatively numerous metal-rich sites from the Late Iron Age and Viking Age in the coastal zone along Odense Fjord could, in this context, have played a role as the places where the off-island network was maintained; so-called 'gateway communities' (Baastrup 2012, p. 329ff., 2014). The placing of a pivotal locality for this exchange could obviously be in the centre that already had been created at Odense, at the land traffic hub, the possible pagan cult site Odins Vi, and perhaps an early fortress phase at Nonnebakken.

Permanency

The pit-houses at Vestergade 70–74, Mageløs/Klaregade, as well as possibly Skomagerstræde/Overgade 1–3 and perhaps Klingenberg, have a finds assemblage that in its extent and complexity of composition indicates production over and above the norm for pit-houses at ordinary rural settlements. This specialised production could indicate that the aim was not self-sufficiency but trade or exchange to some degree or other.

It is not known whether the pit-houses at these localities actually constitute one or more entities. Consequently, it cannot be determined whether they formed part of a large specialised workshop area, such as the market place in early Viking Age Ribe, or whether these buildings represent more sporadic activities. Neither are there traces of a strict layout or structure as evident in the division into plots at Ribe's market place (cf. e.g. Feveile 2006). Extensive, deep cultural layers, as seen at Ribe – as well as at Funen workshop localities such as Hjulby (090611–116) (Henriksen 2000, p. 35ff., 2002, Feveile 2006, p. 31ff., Juel 2010), Hårby (080209–146) (Henriksen and Petersen 2013) and Vester Kærby (Henriksen 2013) – are completely absent from Odense. It is unknown whether this absence could be due to the localities in Odense, unlike the others mentioned, having been subjected subsequently to an enormous level of activity in both the Middle Ages and, not least, modern times. Similarly, direct evidence of trade is also lacking in Odense. The degree to which the pit-houses in Odense represent permanent or sporadic activities is, of course, a crucial factor in the discussion of whether or not there was a town. The relative proximity, i.e. 140 m, between Vestergade 70–74 and Mageløs/Klaregade, combined with the topographic conditions, means that interconnection was not impossible. In which case, it must have been an area of a considerable size.

Several circumstances therefore indicate that the aforementioned pit-house localities do not simply reflect the self-sufficiency of an agrarian settlement. Their products and number indicate that, at least partially, their activities were directed towards sale and not merely self-sufficiency. But it is not yet clear whether the area should be perceived as a seasonal trade and craft site or as a permanent, urban structure, typologically classified by Hodges as 'gateway communities' of types A or B (Hodges 1982, p. 50ff., Skre 2007a, p. 329ff.).

This discussion has recently been brought sharply into focus in a new analysis of the earliest phases of the market place in Viking Age Ribe (Croix 2015). Previous studies here indicated that it was not until the second half of the eighth century AD that Ribe could be considered an actual town, with year-round habitation and permanent activities on the market place. At the beginning of the eighth century, on the other hand, the market place appears only to have had seasonal use, and it was suggested that an actual year-round, permanent settlement could have been located nearby (Feveile 2006, p. 40, Skre 2007a, p. 336f.).

The new analysis of Ribe has focussed on the search for permanent settlement on the earliest part of the market place. Permanence here is reflected primarily by the fact that, from the outset, turf was laid out in parts of the market place, in order to stabilise the terrain with the aim of creating a basis for a more permanent and substantial settlement. This would have required a more stable foundation than the flimsy structures associated with trade and craft activities at a seasonal market place. Permanence is also evident from finds of loom weights and quernstones, which may indicate textile production and the presence of women on the site, as well as food production. All of these can be perceived as signs of everyday life rather than seasonal activity. A third argument for permanence in the earliest phase of the market place is provided by the discovery of the southeastern corner of a house defined by a clay floor and wall trench. The fact that the building was apparently of lighter construction than houses in coeval rural settlements is not an unusual situation for urban dwellings. Remains of the building can be traced over an area of c. 6 × 1.5 m and the finds assemblage is perceived as being associated with everyday activities (Croix 2015, p. 50ff.).

The individual points made in this study can all be questioned in tangible terms. For example, large numbers of loom weights have been found at the landing site at Strandby (080209–57) in southwest Funen, and in the later part of its active phase this site was bounded seawards by two ditches, despite it being a seasonal locality (Henriksen 1997). As conditions for, and a methodological approach to, the identification of permanence in a settlement, the points made do appear appropriate. With regard to the pit-house localities in earliest Odense, there are certain signs of permanence: At Skomagerstræde, the course of adjacent roads and the craft activities do appear to indicate an urban context (Jacobsen 2001, p. 108). However, it should be emphasised that the road layers and (most of) the craft activities appear to be later than the actual pit-house.

At both Vestergade 70–74 and Mageløs/Klaregade, the artefact assemblage from the pit-houses includes several indications of textile production. Similarly, cultivation traces have been recorded at Vestergade 70–74. However, at least some of these are stratigraphically earlier than the pit-house activities. The cultivation traces are also apparently ard marks and should, on this basis, most probably be assigned to the period Late Bronze Age/Early Iron Age (Runge 2009, p. 117).[28]

At Vestergade 70–74, Skomagerstræde/Overgade and Klingenberg there are rows of postholes, and at Mageløs/Klaregade scattered postholes, which could be coeval with the pit-houses. The postholes at Skomagerstræde/Overgade and Mageløs/Klaregade lack finds, which makes it difficult to link them to the pit-houses. At the other two localities, the finds enable a connection to be made between the pit-houses/workshop activities and the ordinary houses.

According to the excavator, the post row at Vestergade 70–74 comprises a slightly irregular, 6 m long row of seven closely-spaced postholes. The close proximity of the postholes indicates that several of the posts had been replaced. The postholes contain no brick or tile fragments, but two did hold Baltic ware pottery. Several pits at the site have yielded daub fragments, without it being possible to ascribe these to the building. The excavator sees no basis in the evidence for interpreting the house's construction or orientation, and the excavation report states that a date in the twelfth century seems reasonable (Arentoft 1984).

Christensen (1988) maintains that the post row is associated with a later layer than the pit-house. But this is not stated in the excavation report, from which it is also apparent that there was no cultural layer preserved at the site. Similarly, the site plan shows no stratigraphic overlap between the pit-house and the post row (Arentoft 1984, Christensen 1988, p. 33).

It is evident from the site plan that the post row can be followed further south and therefore has a length of c. 8 m. To the south, it possibly terminates at a house corner that turns eastwards. It is also clear from the report that the interpreted postholes do not contain brick or tile fragments, but a few of the features are said to be 'barely deep enough to be postholes' (Arentoft 1984). In the light of the present much greater knowledge and experience of houses from the period spanning the Late Iron Age to the Early Middle Ages, the latter statement no longer seems either valid or an argument for not linking these features to the post row. The houses of this period can be very irregular in shape and in the form of the individual postholes (Hansen 2015, p. 89f.). At the same time, we do not know the original surface level, i.e. the possible floor level. Consequently, a statement of the base level would actually have been more revealing than the feature depth. If the new interpretation of the construction is correct, it is possible that the longhouse and the pit-house could have been partly coeval.

The dating of the structure, based on the Baltic ware pottery, to the twelfth century is similarly open to question. Baltic ware pottery is difficult to date precisely but can, as mentioned, be divided into an early, non-thrown variant, earlier than AD 950–1050, and a late, secondarily thrown variant with a broad dating frame of 1000–1300. Here, the early variant is present, though it is not soft-fired ware. Overall, the house can, as also shown by the above-mentioned analyses of the locality's deposits, features and structures, be coeval with the fill phase of the pit-house, and with its replaced posts, it marks a relatively high degree of permanence at the 'market place'.

The post row at Klingenberg could constitute part of a house wall, but the limited number of posts renders an interpretation difficult (cf. Figure 61). The fact that the posts represent a more permanent structure is, however, a possibility. Consequently, there could have been a permanent longhouse settlement associated with the specialised craft activities.

Possible permanent dwelling houses

In the following, localities in the town centre will be examined where, from the study period, there are records of either (a) actual house outlines or ground plans, (b) post rows that could possibly have been part of walls or (c) internal post constructions in buildings or concentrations of unsystematically distributed postholes that could possibly represent parts of houses. The two latter categories are a natural consequence of the fact that urban archaeological investigations are often of limited areal extent. Unlike the possible permanent houses at the pit-house localities mentioned previously, the houses dealt with here cannot be assigned to a similar context and appear more likely to represent an ordinary settlement.

Vestergade 70–74

The possible remains of a permanent house at this location are mentioned in the part regarding 'specialised craft'.

Møntergården

The locality Møntergården (OMB 8231, 080407–170) lies at the eastern edge of the medieval town and adjacent to the medieval streets of Møntestræde and Sortebrødre Stræde (see Figures 2 and 62). Møntestræde is mentioned in written sources from the thirteenth century and must have linked Overgade with the predecessor of Sortebrødre Stræde. Excavation of a coherent area of 1200 m^2 revealed the remains of a three-aisled longhouse at subsoil level. South of this house was a post row that could represent the northern row of roof posts of a similar house. To the west was a four-poster structure. It is not known whether these three structures, or even two of them, stood at the same time. East of the gable of the fully-uncovered house were a couple of pits that contained sherds of Baltic ware pottery and hemispherical vessels, probably from the Early Viking Age. It is unknown whether the houses and pits are coeval. Typologically, the three-aisled house appears, on the face of it, to be of Bronze Age or Early Iron Age date. But as there is still some uncertainty with regard to the house typology on Funen in the Late Germanic Iron Age and Early Viking Age (cf. Hansen 2015, p. 89f.), it is possible that these buildings could be coeval with the aforementioned pits. An Urnes brooch, of eleventh–twelfth century date, was found in an excavation in 1982 directly south of the house sites (Lønborg 1994, p. 377, Bertelsen 1994, p. 365) (Figure 63).

Vestergade 13–15

n connection with the renovation of a cellar, three overlaying clay floors were discovered in one of the cellar walls; the middle layer of the three had two phases (OMB 8212, 080407–158) (Figure 64). Due to their robust clay composition, the presence of overlaying floor deposits (i.e. dirt layers) and associated hearths, the floors are interpreted as

Figure 63. Urnes brooch found in Møntestræde at Møntergården. Photo: Asger Kjærgaard.

representing dwelling houses. The stratigraphically earliest house, house 1, has been AMS dated, using charcoal from a dirt layer on top of the clay floor, to the period AD 991–1148. Moreover, the earliest floor layer overlies a feature that is dated to the period AD 989–1114 by an AMS date for a bone. This constitutes a terminus post quem date for the earliest floor layer. Finally, charcoal from a fire-affected layer, a possible hearth, immediately beneath the floor layer of the stratigraphically second-earliest house, house 2a-b, has been dated to AD 897–1016.[29]

The dates for the floor layers are remarkable because those from the stratigraphically earliest house are later than the date for the stratigraphically second-earliest house. An explanation might of course be that the dates are on redeposited material. A modern disturbance, in the form of a large concrete foundation directly between the two floor phases, means that it is difficult to gain a comprehensive

Figure 62. Plan of the excavation at Møntergården. Dark grey: Postholes from houses. Light grey: Pits. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

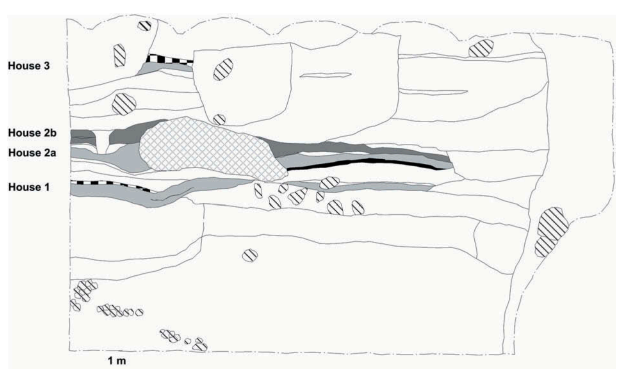

Figure 64. North-south section through a series of floor and cultural layers at Vestergade 13–15. Light and dark grey: Floor layers. Check pattern: Dirt layers. Black: Heat-affected layers. Cross-hatching: Modern disturbance. Drawing: Mads Runge.

overview of the mutual relationships between the layers. On this basis, we are only able to say that we have here three cut-through house floors that broadly date to the period AD 897–1148. Due to a lack of suitable material, it was not possible to AMS date the stratigraphically latest house, house 3. Finally, it should be noted that there were also cultural deposits beneath the earliest house which must represent traces of earlier activities.

Vestergade 43–49

Through a combination of several minor excavations and watching briefs undertaken between 1985 and 1999, a total of c. 300 m^2 has been investigated within an area of c. 5800 m^2 around Vestergade 43, 49 and 55 (OBM 8240, 8260, 9793, 080407–80) (Figure 65). Most of the locality's features and structures – a hearth, fragments of a cobbled surface, one or two presumed wells and part of the town's western ditch – are dated broadly to the Middle Ages. Three pits with no traces of brick or tile fragments did, however, contain sherds of Baltic ware pottery, a wooden trencher, a bone comb fitting and a brass pin. On this basis, the three pits can be assigned to the Late Viking Age or the Early Middle Ages. The finds and recorded structures and features reflect settlement activities that were associated with a permanent settlement area which, based on the pottery, cannot be dated more precisely than to c. AD 900–1100.

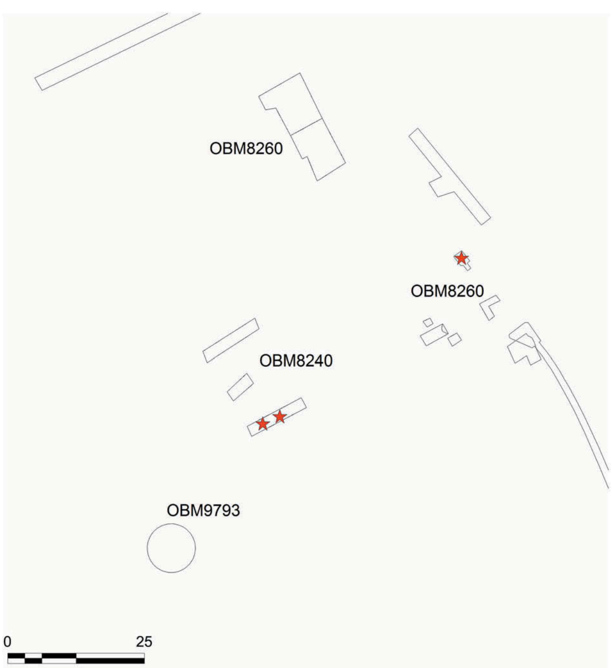

Figure 65. Plan of the excavations at Vestergade 43–49. The stars mark the positions of three pits without brick/tile containing sherds of Baltic ware pottery. Black line: Trench boundary. Drawing: Mads Runge.

Figure 66. Plan of the excavation at Skt. Knuds Plads I (OBM 9784). Black: Postholes and possible wall trench. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

Skt. Knuds plads

Through excavations associated with narrow trenches and minor test pits undertaken in the area between the cathedral and the town hall, parts of the two former churchyards have been exposed that belong to, respectively, St Canute's Church and St Alban's Church (Skt. Knuds Plads, OBM 9784, and Skt. Knuds Plads II, OMB 9785, 080704–100) (Figure 66). In a trial trench, a total of 18 postholes were found cut into the subsoil beneath the medieval burials. From these, it was possible to distinguish two southwest-northeast-oriented rows of, respectively, three and six postholes. About 40 m east of the postholes lay a (wall) trench running north-south, which was similarly cut into the subsoil. The excavator has suggested that these features are of Early Iron Age date, apparently due to the occurrence of a possible wall trench. There are, however, no finds from the features to confirm or refute this date (Jacobsen 2001, p. 89f.).

In another trial trench located further north and six minor test pits (OBM 9785), a row of brick-/tile-free postholes was discovered below medieval burials, cut into the subsoil (Figure 67). The postholes contained no datable

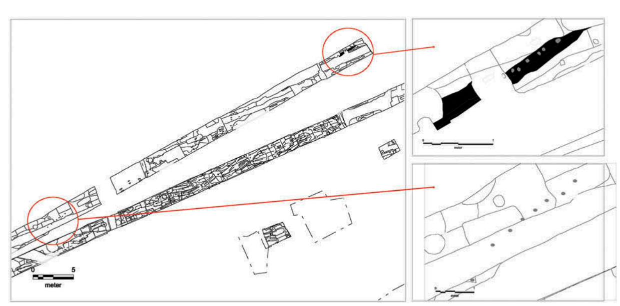

Figure 67. Plan of the excavation at Skt. Knuds Plads II (OBM 9875). Grey: Postholes. Black: Possible wall trench. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

finds, but were overlain by a layer of travertine debris presumed to have arisen from the levelling out of stonemasons' waste from the earliest construction phase of St Canute's Church. The layer was also observed in the southern trial trench. Furthermore, in two places it was possible to demonstrate a sequence of postholes, the easternmost in a possible wall trench, which are interpreted as a fence. These postholes presumably represent a settlement that preceded the establishment of the ecclesial institutions St Alban's Church and St Canute's Church.

Filosofgangen 9–17

On the basis of the settlement traces from the Viking Age and Early Middle Ages recorded in 1984 prior to construction work at Vestergade 70–74, five trial trenches covering a total of 201 m^2 were laid out across a large area between Vestergade and Filosofgangen (OBM 8236, 080704–89) (Jacobsen 2001, p. 86) (Figure 68). In one of the trenches, a pit was investigated that resolved into three postholes, two of which contained post pipes. One of the postholes, with traces of a c. 40 cm wide post, contained soft-fired, coarsely-tempered sherds from a spherical vessel. Like the other pits in the trial trench, the feature contained brick/tile fragments. These pits can, based on finds of sherds from spherical vessels and black-fired and glazed jugs, be dated to the Middle Ages. A bone comb was found in the disturbed fill which, judging from parallels in the material from Århus Søndervold, can be assigned to the eleventh century (Andersen *et al.* 1971, p. 150ff.; Jacobsen 2001, p. 86f.) (Figure 69).

The recorded features, in the form of pits and postholes, reflect settlement activities. The presence of brick/tile, together with the majority of the finds, indicates a medieval date, though a few artefacts point further back in time.

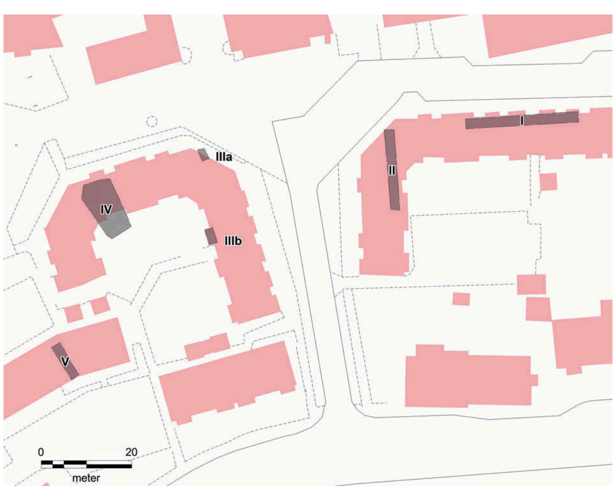

Figure 68. Plan of the excavation at Filosofgangen 9–17. Black cross-hatching: Excavation trenches. Background map: Technical map showing buildings, roads and paths. © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

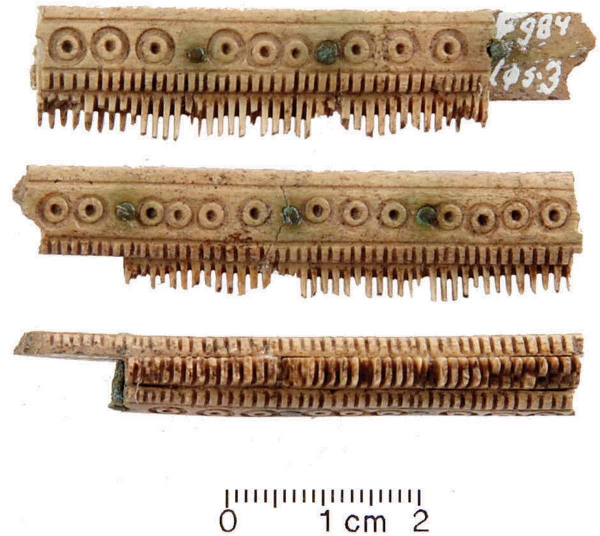

Figure 69. Fragment of a bone comb found at Filosofgangen 9–17, seen from three sides. Photo: Nermin Hasic.

Klingenberg

In the investigation at Klingenberg, four posts were found in a row, and these were interpreted as parts of a SW-NE-oriented house, K1, which can be traced over a distance of about 4 m (cf. Figure 61). There may have been a further post between the two easternmost ones, in which case it has been removed by later disturbance. It is not known whether the post row forms part of a wall or of an internal roof-bearing construction. One or two sherds (x98) found in one of the postholes are from a hemispherical vessel that can be dated to the Late Germanic Iron Age or Early Viking Age. Another posthole contained daub fragments (Jacobsen 2001, p. 95). The distance from the easternmost pit-houses at Mageløs was c. 85 m.

Klosterbakken

The investigation at Klosterbakken (OBM 9397, 080407–109) uncovered the western end of an east-west-oriented, three-aisled longhouse, K7, the eastern end of which extended beyond the excavation trench (Figure 70). The house's west gable, together with parts of its north and south walls, are preserved in the form of closely-spaced posts. Sherds of Baltic ware pottery from the house's postholes date it to the Late Viking Age, while fragments of travertine in several postholes show that the building must have been constructed in connection with, or after, the building of St Canute's Church at the end of the eleventh century. Several of the posts appear to have been replaced, showing that the building had a longer period of use. It may have been linked with the construction of St Canute's Church, but clear distinction of the secular and ecclesial structures is difficult (Jacobsen 2001, p. 95, Krogh 2001, p. 104f.).

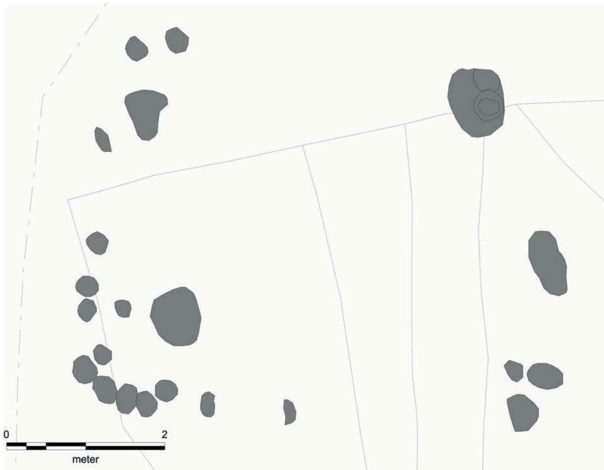

Figure 70. Plan of the excavation at Klosterbakken. Dark grey: Postholes. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

I. Vilhelm Werners plads

The closure and abolition of the central traffic route Thomas B. Thriges Gade, and the construction of large underground car parks here, means that extensive archaeological investigations could be undertaken in 2012–2016 in a central part of Odense's early urban core. The archaeological remains date predominantly from the period AD 1000–1500, with a centre of gravity around the fourteenth century. Post-sixteenth century deposits and structures have been more or less removed during the extensive road and construction projects of recent centuries. The focal point of the investigations has been the earliest archaeological horizons, and several post-built structures, wells and pits were first identified at subsoil level.

In 2013–2014, as part of the urban renewal project, an area of c. 2600 m^2 was investigated on I. Vilhelm Werners Plads (Figure 71).[30] During the investigation, material for 42 AMS dates was obtained from primarily brick-/tile-free features and structures associated with the lowermost layers.[31] The dates were obtained for a number of postholes associated with possible house structures and for pits. The results are largely consistent with the archaeological observations at the site, i.e. they fall predominantly within the period from the eleventh century to the fourteenth century onwards. A single date does, however, lie in the Early Germanic Iron Age, and a group of dates spans the period from the late eighth to the tenth century.

Two possible house structures have been identified from the earliest phase at the site, which could predate AD 1000. One of these, APC, comprises a SW-NE-oriented, c. 20 m long row of eight posts, of which a couple, judging from their position, could represent replacements (Figure 72). The posts could represent part of a house, either as a row of roof-bearing posts or the line of a wall. Alternatively, they could be from a fence or be posts that retained horizontal rods in a light road construction (Jørgensen 1988, p. 103). The dimensions of the posts in APC are though more robust than the relatively slender posts in such a road construction. The interpretation of APC as representing a house or a fence therefore seems most plausible. Charred grain from a postholegave an AMS date of AD 777–991.[32] There are no finds from the structure.

The second possible house structure, ACU, is a single-aisled, SW-NE-oriented building, measuring 3.5–4.5 x 12–15 m and defined by 34 postholes that trace an irregular wall sequence (Figure 73). It is uncertain whether the many posts in the north wall actually represent a wall or an internal

Figure 71. Plan of the excavation at I. Vilhelm Werners Plads. Black: All features and structures linked to the excavation. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

Figure 72. The possible house, APC, at I. Vilhelm Werners Plads showing the position of the AMS sample. Black: Postholes. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

Figure 73. The possible house, ACU, at I. Vilhelm Werners Plads showing the position of the AMS sample. Black: Postholes. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

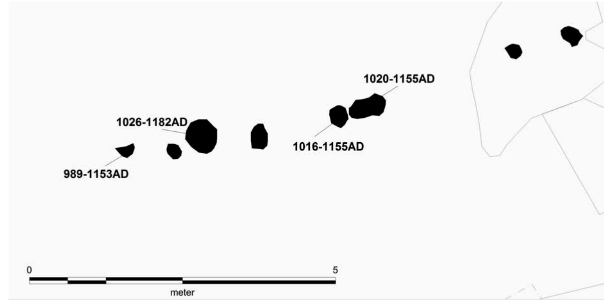

Figure 74. The possible house, ATN, at I. Vilhelm Werners Plads showing the position of the AMS sample. Black: Postholes. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

Figure 75. Sherds, possibly from hemispherical vessel found at I. Vilhelm Werners Plads. Photo: Nermin Hasic.

construction, or whether the posts reflect the fact that the building has more than one phase. Charcoal from four of the postholes has been AMS dated with the following results: AD 770–1012, AD 771–965, AD 892–1014 and AD 1028–1184.[33] The posthole dated to AD 771–965 yielded a small belly sherd, which is difficult to date. The posthole dated to AD 892–1014 contained a few very small sherds. The largest sherd has two shallow, horizontal circumferential furrows and comes from a thin-walled, hand-shaped vessel of Baltic ware type.

The distribution of the AMS dates, the pottery from the postholes and the many postholes at the north wall could indicate that the building had several phases and consequently a long lifetime of perhaps 75–100 years. The Baltic ware pottery could originate from the demolition of the building, while the early AMS dates could be for material deposited prior to construction of the house (cf. also Hansen 2015: appendix 6). A cautious interpretation is therefore that the house was built at some time towards the end of the ninth century, as a realistic estimate of the lifetime of one phase of a building such as ACU is around 50 years. The first phase of the house presumably extended from the end of the 9th to the middle of the tenth century AD, while the second phase, when the north wall was moved about 0.75 m to the north, and a possible outshot was constructed, extends into the eleventh century.

In addition to the two possible house structures, material from a pit, has been AMS dated to AD 722–945.[34]

A third possible house structure, ATN, can be dated to the period AD 989–1182 and therefore most likely postdates AD 1000. The structure comprises a 7.8 m long, east-west-oriented row of eight posts (Figure 74). The posts stand quite close together, which could indicate that some of them have been replaced. The post row is presumed to reflect the roof-bearing construction of a two-aisled house. There are AMS dates for four of the postholes: AD 989–1153, AD 1016–1155, AD 1020–1155 and AD 1026–1182.[35] A few sherds from the postholes are of Baltic ware character.

The finds assemblage contains only sporadic traces of activity at the site in the centuries prior to AD 1000, in the form of a few possible sherds of hemispherical vessels from redeposited layers (Olesen 2014, p. 30) (Figure 75). Also recovered was a total of 1949 sherds of both secondarily-thrown and non-thrown *or* soft- or hard-fired Baltic ware pottery, represented by 308 finds numbers, corresponding to more than 21% of the total sherd assemblage, as well as 13 sherds of Pingsdorf pottery, corresponding to 0.14% of the total assemblage (Olesen 2014, p. 31f.). Pingsdorf pottery is generally dated to c. AD 900–1225/50 (Madsen 1982, p. 39f., p. 83ff.; Sanke 2001, p. 301ff.) (Figures 76 and 77).

The earliest finds from the excavations, apart from coarse-tempered handmade pottery and Baltic ware pottery, are four brooches. Two of these are pseudo-coin brooches, dated to the Late Viking Age/Early Middle Ages (Baastrup 2009, p. 217ff.). From the time around AD 1100 comes an animal brooch from the 'Aalborg group' (Bertelsen 1992, Figure 1) and a small Urnes fibula (Bertelsen 1994) (Figure 78).

Figure 76. Baltic Ware pottery found at I. Vilhelm Werners Plads. Photo: Nermin Hasic.

Figure 77. Pingsdorf pottery found at I. Vilhelm Werners Plads. Photo: Nermin Hasic.

Finally, 20 glass beads were recovered, but most of these are medieval, and the rest cannot be assigned more precisely than to the period from the Roman Iron Age to the Middle Ages (Figure 79). The deposits from the Early Middle Ages were found to contain tools and waste associated with crafts such as bronze casting and textile processing. The same deposits also yielded a few weights.

Conclusions and summary of the permanent settlement from the late Iron Age and Viking Age

As is evident from the above, houses or parts of houses have been recorded in several places across the study area that must represent the existence of some form of permanent settlement prior to AD 1000 (Figure 80). There is, however, still only evidence of a couple of houses, at most, at each of the sites, but the individual localities actually lie so close to each other that several of them could have been linked and

Figure 78. Two early medieval bronze brooches found at I. Vilhelm Werners Plads. 'Aalborg brooch' (bottom). Urnes brooch (top). Photo: Nermin Hasic.

Figure 79. Selection of glass beads from I. Vilhelm Werners Plads. Photo: Nermin Hasic.

therefore reflect a somewhat larger settlement. Conversely, it has proved difficult and challenging to give very precise dates for the individual houses, and the question of contemporaneity is therefore difficult to address. For the moment, we must content ourselves with the conclusion that at the end of the Late Germanic Iron Age and in the Viking Age settlement with and without associated craft activities was distributed over a large part of the study area. Traces of trade activities, in the form of imported goods, hack silver and, not least, Arabic coins, recorded at several of the sites in the hinterland, are however absent here. As described in the introduction, a combination of a substantial size and permanence can lead to a settlement being characterised as urban.

Similarly, it is evident that the excavated sites with permanent dwelling houses, with or without links to traces of

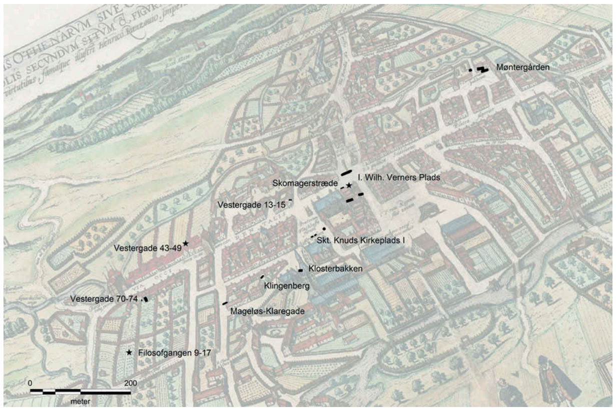

Figure 80. Locations of sites with traces of permanent settlement, fences and pit-houses. No proper houses were identified at Vestergade 43–49, Filosofgangen 9–17 and Skomagerstræde/Overgade 1–3. Marked on Braun's prospectus of 1593. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

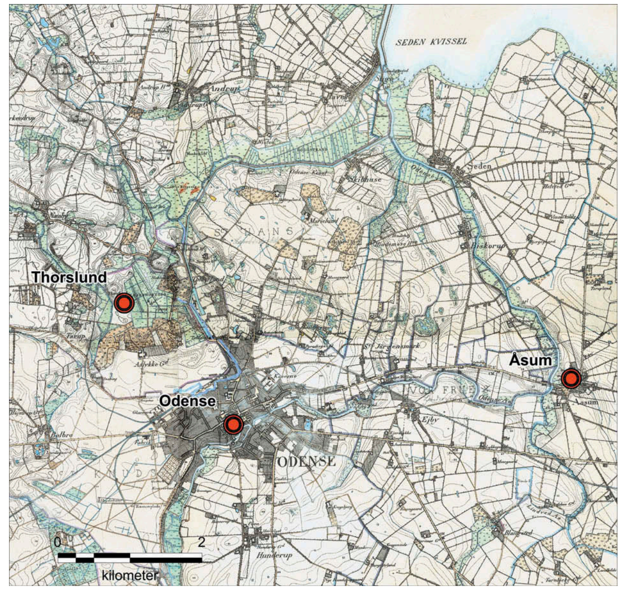

Figure 81. Odense and its immediate hinterland, with the locations of the place names Odense (Odins Vi), Thorslund and Åsum marked on the first edition ordnance map from the second half of the nineteenth century. Background map: © *The Agency for Data Supply and Efficiency*. Drawing: Mads Runge.

specialised crafts, show no clear zonation or distinction. There does, however, appear to be a tendency for pit-houses and craft activities to be concentrated in the western part of the earliest town, while the permanent settlement lacking these aspects lies to the east. It is also possible, however, that there were permanent houses in the area with workshop activities, the potential 'market place'.

Cult and religion

The place name Odense has been repeatedly associated with the presence of a pagan cult centre, Odins Vi. This cult centre has never been found and – given its presumed few archaeological remains – perhaps never will be. Odin was the god of the elite and the sacred place could therefore have occupied a significant position (Christensen 2014a, p. 188). It has already been mentioned that the AMS dates from the centuries preceding the Trelleborg phase at Nonnebakken, together with the finding of a Valkyrie brooch at the same locality, could perhaps indicate that the *vi* was located here. This interpretation concurs well with the fact that other of the Trelleborg-type fortresses have also had an initial function as a pagan cult centre (Nørlund 1948, p. 243ff., Jørgensen 2009, 2014, p. 239ff., Dobat 2014, p. 54ff., Jørgensen *et al.* 2014, Sindbæk 2014c, p. 142f.). Other possibilities are that the *vi* was located on the other side of the Odense Å, near St Alban's Church (Thrane and Porsmose 1996, p. 176), or that the term Odins Vi referred to the entire workshop area around the southern part of Odense Fjord.

Another place name with a relation to the pagan cult is Thorslund, which was associated with an island in the later drained and reclaimed lake of Næsbyhoved Sø, immediately north of Odense. The place name is known from 1245 as the term for a woodland area (Andersen 1998, p. 24, Christensen 2014a, p. 188f.), but no physical traces of a possible sacred site have been found at this location, which has now been dug away.

Finally, there is the village of Åsum, located east of Odense. Its name could refer to *as'* (god's) home, but the prefix *Ås* can also be used in reference to a topographical feature, a long, extended hill. However, it is difficult to identify a feature in the landscape that could give rise to this use of the name here (Kousgård Sørensen 1969, p. 99, Christensen 2014a, p. 188f.) (Figure 81).

Churches and churchyards[36]

St Alban's church

In a number of small excavation trenches at Albani Torv, covering a total area of 1225 m^2, investigations between 1886 and 1993 have revealed extensive traces of medieval settlement in the form of postholes, stone foundations, cultural layers, house remains and wells (OBM 8541, 080407–117) (Figure 82).

Most spectacular of these are the remains of St Alban's Church, which was abolished after the Reformation.[37] Excavations took place here in 1955 and again in 1980–83. It proved possible not only to locate the foundations of the stone church, presumed to have been constructed in the middle of the twelfth century, but also traces of no less than two wooden churches. One replaced the other, and they constitute the earliest phases of St Alban's Church (Arentoft 1985, Johannsen *et al.* 1998-2001, p. 1736ff.). In a minor excavation in 2015, in connection with the replacement of district heating pipes, further observations were

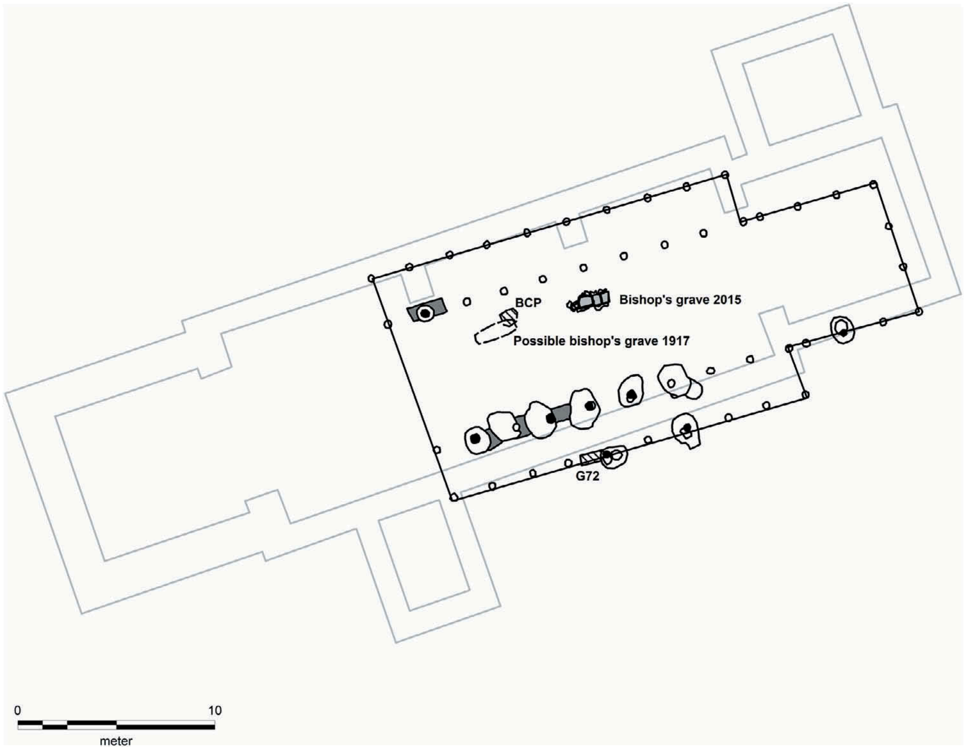

Figure 82. St Alban's church. The ground plan of the stone church is shown with grey lines, while the latest wooden church is marked with black lines. The plans are proposed interpretations (cf. Arentoft 1985, p. 17ff.). The few traces of the earliest wooden church are shown in dark grey (wall trenches and a posthole). Also shown are the bishop's grave found during the excavation in 2015 and – marked with broken lines – the possible bishop's grave encountered during an investigation in 1917. The bell-casting pit (BCP) and grave G72 are marked with crossed areas. Drawing: Mads Runge.

made with respect to the church's construction, and a bishop's grave belonging to the earliest phase of the church was investigated (Bjerregaard *et al.* 2016a, 2016b).

The earliest feature at the site is possibly a bell-casting pit. The resulting bell was c. 40 cm in diameter and c. 55 cm high, i.e. approximately the same dimensions as the Haithabu bell (Kalmring 2010, p. 440f.). The pit is difficult to date, but it is presumed to immediately precede, or be coeval with, the earliest wooden church. A thermoluminescence date of AD 1030 ± 60 was obtained from the pit in 1985 (Arentoft 1985, Johannsen *et al.* 1998–2001, p. 1736ff.). As a supplement to this date, given the limitations associated with thermoluminescence dating (Mejdahl 1993, Runge 2009, p. 53ff.), an attempt – unfortunately unsuccessful – was made under the present project to obtain suitable material for AMS dating of the bell-casting pit.[38]

The earliest wooden church was c. 7 m wide. The chancel has not been located, but the building is unlikely to have been less than 15–20 m in length. The church possibly had two rows of internal roof-bearing posts, a clay floor and may have had stave walls. The building appears to have burned down, and it should possibly be dated to the first half or the eleventh century. It is believed to have been this church in which Canute IV was murdered (Johannsen *et al.* 1998–2001, p. 1736). The discovery in 2015 of a bishop's grave in the building firmly established that the church already had cathedral status in its earliest phase.[39] Stylistic analyses of a sacrament set, comprising a chalice and paten, placed in the grave, together with an AMS date for the skeleton, shows that the burial took place in the eleventh century.[40] Another bishop's grave found in 1917 should perhaps, in the light of the new information from the 2015 discovery, also be ascribed to the earliest wooden church (Bjerregaard *et al.* 2016a, p. 151f., 2016b, p. 4).

The fact that St Alban's Church, in its earliest phase, already functioned as a cathedral is interesting in relation to Odense's so-called 'birth certificate', the deed of gift of AD 988 from the German emperor Otto III to the Archbishop of Hamburg-Bremen. In this document, Odense – *Othenesuuig* (Odensvig) – is mentioned for the first time and is referred to as an episcopal seat. Whether Odense actually had a bishop or a cathedral at that point in time has been questioned, as the letter should probably be primarily perceived as way of underpinning the archbishop's financial situation and power in relation to the immediate environs. The discovery of the bishop's grave shows that Odense must have had a cathedral from at least the first half of the eleventh century. This is consistent with the fact that the first definite bishop of Funen, Reginbert, who presumably resided in Odense, is mentioned in AD 1020 (Henrichsen 1968, p. 118, Nyberg 1982, p. 139ff.), i.e. only 32 years after the deed of gift of AD 988. Consequently, the idea that a cathedral – the earliest phase of St Alban's Church or a predecessor in another location – could have existed in Odense in AD 988 does not seem impossible (Albrectsen 1970, p. 128ff., Thrane *et al.* 1982, p. 113ff., Madsen 1988a, p. 97, Runge 2016, p. 29).

Regardless of whether Odense had a cathedral and a bishop in AD 988, the deed of gift demonstrates that it hosted an urban settlement of a certain size and significance at that time (Albrectsen 1970, p. 128ff., Thrane 1982, p. 113ff., Madsen 1988a, p. 97, Runge 2016, p. 29).

The next wooden church was probably built after AD 1086 and was larger than its predecessor. It was c. 11.5 m wide and had a minimum length of 28 m. The building probably had two rows of internal posts, which supported the roof, but this assumption is based a flimsy foundation. The church floor consisted of a layer of clay clods that had been stamped together. This building too appears to have burnt. The church is traditionally dated, on the basis of a coin from AD 1047–74/76 and the presence of travertine fragments in the postholes, maybe from the erection of St Canute's Church nearby, to the period after 1086. The theory is, accordingly, that the second wooden church was erected on the site of the first wooden church after the latter had burnt down in connection with the murder of Canute IV (Arentoft 1985, Johannsen *et al.* 1998–2001, p. 1736ff., Christensen and Hansen 2017, p. 14–15).

Under the auspices of the present project, in an attempt to obtain a more precise date for the earliest wooden church, AMS dates were obtained for a human femur from a grave, G72, which was disturbed during the construction of the south wall of the latest wooden church and which is therefore stratigraphically earlier than the church (Andrén 1985, p. 17ff.). The dates obtained are AD 909–1147 and AD 969–1046.[41] To take account of the reservoir effect resulting from possible consumption of food of marine origin, the dates may require correction by up to 80 radiocarbon years (Tomasz Goslar, Poznań Radiocarbon Laboratory, Poland, oral communication). The dating of G72 therefore does not seem able to provide a secure basis for adjusting the date of St Alban's Church further back in time. Neither was it possible to find material for an AMS date directly associated with the earliest phase of the church.

The stone church, which postdates the period dealt with in this study, is thought to have been constructed in the middle of the twelfth century and demolished in 1542 (Arentoft 1985, Johannsen *et al.* 1998–2001, p. 1736ff.).

St Canute's church

St Canute's Church (OBM 8200, 080407–100) has two phases. The first phase was a travertine building and the second is the existing brick-built building (Figure 83).[42] It is uncertain when the construction of St Canute's Church was begun, but it was probably one of the consequences of the murder of Canute in 1086. In 1095, Canute IV's bones were moved from St Alban's Church to the crypt beneath St Canute's Church, which at that time was under construction, and the cathedral function was transferred to St Canute's Church from then on. Throughout the greater part of the Middle Ages, St Alban's Church and St Canute's Church therefore functioned in tandem; the former as the parish church and the latter as the cathedral (Johannsen and Johannsen 1995, p. 172ff., Christensen 1999, p. 84, Bjerregaard *et al.* 2016a, p. 141).

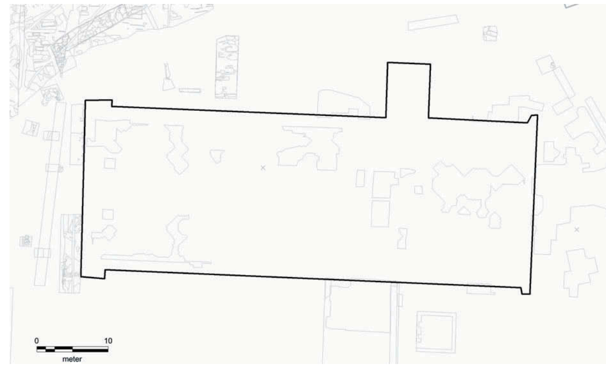

Figure 83. Plan of the excavations below and around St Canute's Church. Black lines: Outline of the present day's church. Solid grey lines: Other features and structures. Broken grey lines: Trench boundary. Drawing: Mads Runge.

The travertine church was damaged by fire in 1247, but parts of it remained standing for a century or two afterwards. Between 1247 and 1499, gradually more and more brick-built elements were added, culminating in the brick-built church that constitutes the foundation of the cathedral which stands today (Johannsen and Johannsen 1995, p. 172ff.).

The churchyards for St Alban's and St Canute's churches

The churchyards for the churches of St Alban and St Canute have, based on the archaeological investigations, been localised in an arc running along the west, north and east sides of these buildings. There may also have been graves on the south side, but this is not supported by the investigation results, and the area also has a natural boundary in the form of a slope running down towards Odense Å. Large parts of the area therefore appear unsuited as a churchyard.

The extent of St Canute's churchyard is not known precisely (Christensen 1999, Krogh 2001, p. 97), but the burials could be followed on the north side of St Canute's Church over a c. 30 × 80 m area and on the west side of the church over a c. 20 × 50 m area, i.e. a total of c. 3400 m^2. The extent of St Alban's churchyard is estimated to be c. 50 × 120 m, i.e. 6000 m^2 (Pedersen and Bjerregaard 2016, p. 159).

In 1998, between the two churchyards, the foundation trench for a churchyard wall was investigated which – with the exception of a few overlying graves – had separated the two churchyards. The burials are relatively few in number here and they presumably represent the graves of monks and possibly also higher ranking individuals. At the same time, judging from the arm positions of the deceased, there is a centre of gravity in the later part of the Middle Ages. The eastern part belonged to St Alban's Church. There are more burials here and they are consequently spaced much closer together and in several overlying layers. The burials presumably reflect the average population, as indicated by the presence of child graves. The centre of gravity here, again based on the arm positions, lies in the beginning of the Middle Ages (Kieffer-Olsen 1993, p. 21ff., Christensen 1999).

The investigations of the two churchyards have been undertaken in a series of stages:

(1) In 1998, in two narrow trench excavations and several minor test pits, a total area of just less than 400 m^2 was investigated between the cathedral and the town hall. In all, a total of 344 burials from the Middle Ages and modern times were located. There were 220 graves in St Alban's churchyard and 124 in St Canute's churchyard (Christensen 1999).
(2) In 2000, an area of 1750 m^2 of the churchyard for St Canute's Church was excavated, revealing more than 500 medieval burials (Krogh 2001).
(3) During ongoing investigations of Thomas B. Thriges Gade, east of the former St Alban's Church, in 2015 and 2016 an area of c. 600 m^2 of the churchyard for St Alban's Church, with c. 300 burials, was investigated (Pedersen and Bjerregaard 2016).

Consequently, a total of c. 800 m^2 and c. 520 graves have been excavated in St Alban's churchyard, together with just less than 2000 m^2 and c. 620 graves at St Canute's churchyard (Figure 84). The churchyard for St Alban's Church functioned throughout the Middle Ages, while the churchyard for St Canute's Church was in use from the end of the eleventh century until the beginning of the nineteenth century.

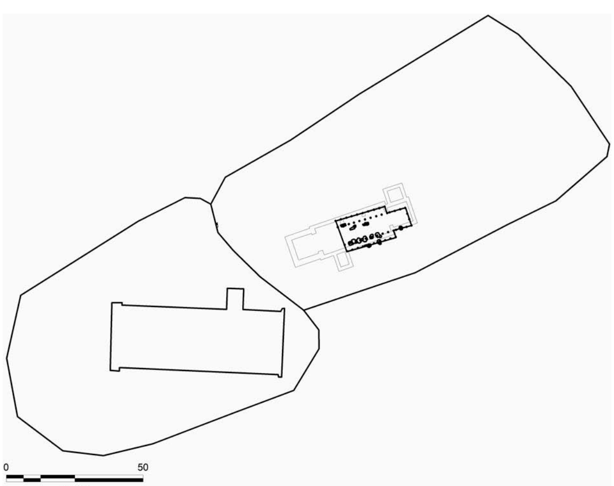

Figure 84. Plan of the excavation at St Alban (right) and St Canute's (left) churches and churchyards. The extent of the two churchyards shown is approximate. Drawing: Mads Runge.

Figure 85. St Canute's churchyard. The 13 graves (black) and the positions of the AMS samples (stars). Solid grey lines: Other features and structures. Drawing: Mads Runge.

A cluster of 13 graves, three of which were of children, in the northwest part of the churchyard for St Canute's Church, were overlain by the travertine debris layer that is thought to be associated with the construction of the earliest phase of the church (Figure 85). The graves are therefore earlier than the late eleventh century, when construction of the travertine church commenced, and they could reflect an earlier or earliest churchyard phase. As the graves appeared to be roughly coeval, a preliminary interpretation was that they may represent Canute IV's housecarls who were killed during the attack on the king in AD 1086. This theory was, however, swiftly abandoned due to the presence of women and children among the 13 interred individuals (Krogh 2001, p. 99f.). AMS dates obtained from four of the 13 graves under the auspices of the present project gave the following results[43]:

- Grave QA (x781): Arm position A, male 25–35 years old. Stratigraphically, QA is probably one of the churchyard's earliest graves. AD 895–1021.
- Grave GGA (x2181): Arm position A, presumably male 25–35 years old. The grave had traces of a coffin and was overlain by the travertine layer. AD 772–967.
- Grave GAB (x2200): Arm position A, probably male 30–45 years old. Coffin traces, a little travertine in the fill. AD 887–1013.

- Grave GFS (x2379): Arm position A, female 25–35 years old. Coffin traces. AD 989–1153.

Due to the reservoir effect resulting from the possible consumption of food of marine origin, the dates may require correction by up to 80 radiocarbon years (Tomasz Goslar, Poznań Radiocarbon Laboratory, Poland, oral communication). The dates partly confirm that the graves belong to the earliest phase of the churchyard, no later than the end of the eleventh century, but the results are by no means unequivocal.

Figure 87. Gold-foil bead found at Fisketorvet. Photo: Nermin Hasic.

Figure 88. Beak-shaped brooch found at Skt. Jørgensgården. Photo: Nermin Hasic.

Other sources to the earliest history of Odense

Stray finds

While features and structures provide solid evidence that activities of some kind or other have taken place, single finds lacking a secure context can only very tentatively be used to say something definite about contemporaneous activities. A single stray find could for example have been transported to its find spot from a completely different locality. In the case of the centre of Odense, this is a very likely scenario, considering the many extensive construction and development works that have taken place during the last century. At a very local level, bioturbation can have effected both vertical and horizontal displacement.

Despite the limitations in their value as evidence, single finds from Odense, dated to the period from the Late Germanic Iron Age to the earliest Middle Ages, are examined in the following in order to complete the account of the archaeological record relating to the description of the earliest Odense.

From Fisketorvet (OBM 446, OBM 9780, 080407–25), which has roots extending back to the Middle Ages (Christensen 1988, p. 53ff.), there is a stray find of a perforated, polished stone, resembling a loom weight. Its surface bears geometric ornamentation, an inscription of rune-like characters and an animal head in Ringrike or Urnes style, and it is dated to no earlier than the eleventh–twelfth centuries (Anne Pedersen, National Museum of Denmark: oral communication). From the same locality, there is a stray find of a bead with gold foil (Jeppesen 1981, p. 112, Christensen 1988, p. 32), which is from the late tenth century or later (Figures 86 and 87).

Figure 86. Perforated, polished stone found at Fisketorvet. The measuring stick is 5 cm. Photo: CC-BY-SA Emilie Howe Gersager, The Danish National Museum.

From Skt. Jørgensgården (OBM 8215, 080407–159), c. 250 m east of the study area, comes a fragment of a beaked brooch dated to the Late Germanic Iron Age (Arentoft 1999, p. 171) (Figure 88), as well as large

Figure 89. Ring-headed pin found at Møllerløkken. Photo: The Danish National Museum.

Figure 90. Ring-headed pin found in St Canute's churchyard. Photo: Nermin Hasic.

parts of a soft-fired, hand-formed vessel (Arentoft 1999, p. 148).

From Møllerløkken (OBM1630, 080307–23), just less than 1 km east of the study area, there is a presumably Norwegian silver ring-headed pin from the beginning of the tenth century (Skovmand 1942, p. 85, no. 29) (Figure 89). The pin was found on an area that slopes down to the north side of Odense Å and at a distance of 100–200 m from the latter.

From St Canute's churchyard, there is a bronze ring-headed pin, found in a secondary context in a medieval inhumation grave (Figure 90). The pin has a loop head (cf. Fanning 1990) and is broadly dated to the Viking Age.

Selected cartographic and written sources relating to the earliest history of Odense

Odense is mentioned in several medieval documents, most of which revolve around the murder of Canute IV and his subsequent canonisation. Information on the town's topography and layout is, on the other hand, sparse and scattered. In the following, the most relevant of these sources, in the present context, will be outlined, i.e. sources which provide fairly reliable information on Odense's topography and possibly also the appearance of St Alban's Church. Sources such as Knýtlinga Saga (Ægidius 1977), which to a major extent provide a dramatic description of Canute IV/ Canute the Holy's life and work, have been omitted.

Odense's 'birth certificate'

Odense's so-called 'birth certificate' dates from AD 988 and is a deed of gift from the German emperor Otto III to the Archbishop of Hamburg-Bremen (Christensen and Nielsen 1975, p. 114, no. 343) (cf. Figure 1). In this document, Odense – *Othenesuuig* (Odensvig) – is mentioned for the first time and is referred to as a bishopric. Whether Odense actually had a bishop or a cathedral at this point in time is much debated as the document should probably be perceived primarily as a means of bolstering the archbishop's finances and power in relation to the immediate surroundings (Albrectsen 1970, p. 128ff., Thrane *et al.* 1982, p. 113ff., Madsen 1988a, p. 97, Runge 2016, p. 29).

Saxo's Gesta Danorum (deeds of the Danes)

This text is from the twelfth century and is only preserved in fragments. The manuscript was printed in Latin in 1514. The 11th book, chapter 11, 13–15, deals with the events leading up to, during and after the murder of Canute IV in 1086 in St Alban's Church. The information on Odense is limited to references to the church and the suggestion of a nearby churchyard. The church is said to have wooden walls and windows and Canute is said to have been killed inside the church, by the altar (Zeeberg 2000, p. 86ff.).

Ælnoth's chronicle

The text is from the decades around AD 1100 and, among other things, also provides a detailed account of Canute's murder. The royal residence is said to be near St Alban's Church. The church is also referred to here as a wooden building with windows. Moreover, it is stated that the church contains a relic casket holding remains of the martyrs Alban and Osvald. It also describes how Canute lay buried for nine years beneath the church floor in St Alban's Church before his remains were moved to a stone cist in the crypt of the still unfinished St Canute's Church. In 1101, his bones were moved into a magnificent casket lined with silk (Albrectsen 1984, p. 79ff.).

Passio Sancti Kanuti Regis et Martyris (passion of St Canute, king and martyr)

The text is from the first half of the thirteenth century and describes the murder of Canute. It states, for example, that the murder took place in St Alban's Church, which at that time was the bishop's church, i.e. the cathedral (Johannsen *et al*. 1998–2001, p. 173; Bjerregaard *et al*. 2016a, p. 141).

Adam of Bremen

Around 1075, Adam of Bremen describes the archbishopric of Hamburg-Bremen and the history of its archbishops. Adam addresses, among other things, ecclesial-political interactions between the archbishopric Hamburg-Bremen and an independent Danish bishopric. Adam mentions Odense as a large town ('*Odansue … magna civitas*') (Henrichsen 1968, p. 65, Bjerregaard *et al*. 2016a, p. 151f.).

Braun's prospectus

This prospectus is from 1593 and is therefore considerably later than the period dealt with here. Nevertheless, the map is a significant source of information on the early structure of the town. Nonnebakken, St Alban's Church, St Canute's Church and the earliest streets and roads are all drawn in (Jørgensen, O. 1981) (see Figure 3). The prospectus also illuminates important aspects of the town's immediate hinterland, for example roads and the complete lack of settlement in the area to the south of Odense Å (Füssel 2008, p. 184).

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RESEARCH ARTICLE

From a port for traders to a town of merchants: exploring the topography, activities and dynamics of early medieval Copenhagen

Hanna Dahlström[a], Bjørn Poulsen[a,b] and Jesper Olsen [a,c]

[a]Centre for Urban Network Evolutions (UrbNet), Aarhus University, Højbjerg, Denmark; [b]School of Culture and Society, Department of History, Aarhus University, Aarhus, Denmark; [c]Department of Physics and Astronomy, Aarhus University, Aarhus, Denmark

ABSTRACT

Copenhagen's earliest history has long been shrouded in uncertainties. This is mainly due to insufficient source material. Basic questions – how old is the town, how did it originate, and where was the oldest settlement situated? – are still under discussion, as are questions regarding specific features of the early medieval town. Was Absalon's twelfth-century castle preceded by an earlier one? What does a centrally placed, early medieval horseshoe-shaped enclosure surrounded by a massive ditch represent? Using archaeological results from recent major excavations, combined with Bayesian modelling of new 14C dates from the two early cemeteries of Sankt Clemens and Rådhuspladsen, older archaeological information and the medieval written sources on Copenhagen are revisited to form a new interpretation of the early development of the town. Three phases of topographical development from the eleventh to the early thirteenth century are recognised. The changes tell of a dynamic first two hundred years of the town's history and of its changing role in Danish society. The article explores the people, activities and networks that lie behind the outstanding development from the small early settlement of the eleventh century to the flourishing merchant town of the thirteenth century.

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Medieval Copenhagen; trading centre; church topography; medieval towns; early medieval Denmark; Bayesian modelling of radiocarbon dates

Introduction

As the capital of Denmark from the fifteenth century onwards, Copenhagen's importance in international trade networks is well known, and evidence of the metropolitan lifestyles of its elites is plentiful (Riis 1994, p. 73ff). It is also known from written sources to have been an important medieval merchant town at this time, with a strong role in the Baltic trade and closely connected to German towns. The early phases of the town are, however, much less well known. It has long been evident that there was some kind of activity in Copenhagen from the eleventh century and onwards, but the location, scale and functions of the settlement have been debated for just as long. It is certainly problematic that very few written sources exist from the period before the mid-thirteenth century, and the archaeological information from the medieval period has until recently been quite meagre and fragmentary.

The results of the Metro Cityring excavations from 2009 onwards, together with other excavations undertaken in central Copenhagen since 2008, have vastly improved the archaeological source situation. The excavation at Rådhuspladsen (see Figure 1) in particular has yielded new information about fundamental aspects of the early town: its size and extent, its church topography, the development of the town fortifications, and the types of activities taking place within the town.

Utilising the new and contextually well-documented archaeological source materials, including Bayesian modelling of new AMS dates taken together with information from the documentary sources, we discuss in this paper what it was that made this small, seemingly anonymous early settlement into one of the most important towns in Denmark. Who and what were the driving forces in Copenhagen in the eleventh and twelfth centuries? With the new material at our disposal, we hope to present a nuanced story about some of the people, activities and networks that paved the way for the prosperous high and late medieval town of Copenhagen.

CONTACT Hanna Dahlström Hanna.dahlstrom@cas.au.dk Centre for Urban Network Evolutions (UrbNet), Aarhus University, Moesgård Allé 20, building 1522, Højbjerg DK-8270, Denmark

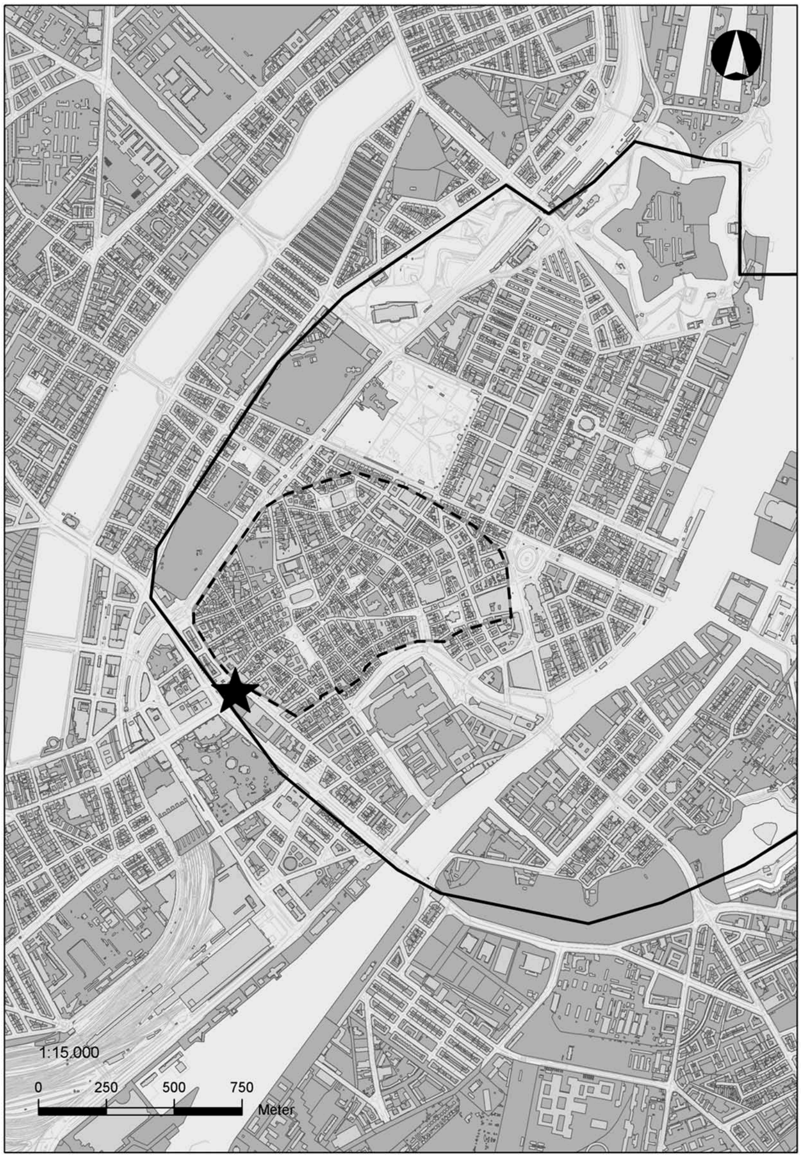

Figure 1. Modern Copenhagen showing the late medieval extent of the town (with a dashed line) together with the seventeenth-century extent (with a solid line). Placement of the excavation at Rådhuspladsen (the Town Hall Square), yielding important information about the early phases of Copenhagen, is marked with a star. After Lyne and Dahlström (2015). Figure has been reproduced with permission from Museum of Copenhagen.

A note of clarification: the term 'early medieval' refers to the Scandinavian use of the concept, namely c. 1050–c. 1250.

The written sources

What's in a name?

The written sources speaking of early medieval Copenhagen are few and, as so often, were written down some years after the period or events referred to. During its first two hundred years, the town is named either 'Købmannahafn' (first documented 1253; DD 2. ser., vol. 1., no. 105, 113) or variations on this name (which means 'the merchants' port'), or simply as 'Hafn' (port, from Old Norse 'höfn').

The first occurrence of the name is in the *Knýtlingasaga*, in connection with an episode in the year 1043 when King Sven Estridsen was attacked outside Höfn on Zealand. The text of the *Knýtlingasaga* was written down in the thirteenth century, and its reference to Havn has often been seen as secondary, particularly as this information was for a long time not corroborated by any other eleventh-century archaeological or historical source (Ægidius 1977, p. 37f).

The oldest source in which the town of Copenhagen is mentioned is a charter from Pope Urban, written in 1186, where it is termed 'Hafn' (DD 1. ser., vol. 3, no. 137). This is the famous letter in which the Pope states that Bishop Absalon has been given the castle ('castrum de Hafn') by the King (king Valdemar I), together with the town ('villa') and a number of manors in the vicinity of the town (DD 1. ser., vol. 3, no. 137). We shall return to this charter later.

The royal gift of Hafn to Absalon is commonly believed to have taken place in the middle of the twelfth century, perhaps in the year 1158. This is based on descriptions in the *Gesta Danorum* (History of the Danes) by the chronicler Saxo Grammaticus, writing around 1200. His Latin text describes Copenhagen as 'vicus qui mercatorum portus nominatur' (the town which is called the merchants' port/harbour: Saxo 2005, p. 340).

The appellative 'havn' (harbour/port) seems quite logical and the addition of 'købmand' (merchant) in front identifies and perhaps separates it from other 'havns' on the Zealand coast, including the documented settlement of Skåningehavn (Skaningæhafn, now Kalvehave) in South Zealand (Kristensen and Poulsen 2016, p. 200). The two parts of the name Købmannahafn point to the two aspects that probably characterised the early settlement: its coastal location, with its function as a port, and the presence of merchants, which means it was a site for trade. The first part of the name 'Køben' – 'køb' – can be seen in the same context as the contemporary and well-known place name, 'köping'. A number of 'köpingar' exist in the eastern Danish province of

Figure 2. The region of Zealand and western Scania, including some of the small early medieval trading sites and towns mentioned in the text. Ill: Ea Rasmussen, Moesgaard Museum and Ann-Lisa Pedersen.

Scania, across the Øresund in western Sweden: one in Halland, one in Blekinge, with the best known being Löddeköpinge on the west coast (see Figure 2; Svanberg and Söderberg 2000). These are distributed along the coast but, unlike Købmannahafn, not directly *on* the coast. It seems that these 'köping' trading places functioned mainly as local and regional trading centres, even if their function is not fully clear (Svanberg and Söderberg 2000). The word 'köping' is believed to stem from the Old English 'ceaping' or 'chipping' and is best known from the Norwegian Viking town Kaupang, which has the same etymological origin (Söderberg *et al.* 2009, p. 191, Sørensen 2017). A direct parallel to 'Køben' is, for instance, the Jutlandic name 'Københoved' on the river Kongeåen. Such place names attesting to trade seem mostly to belong to a phase preceding the near-monopolisation of trade to towns in the medieval period, that is, before 1200. They can consequently be seen as elements of broad regional trade structures predating the medieval period (Nielsen 2014, p. 198ff). We suggest that the early settlement in Copenhagen should be understood as a local trading centre, being one of many such small commercial places in the regional landscape. What historically separates Købmannahafn from most other local trading centres was that it had the luck, or the qualities, that enabled it to succeed as a town as well.

The name implies a *port* in which *trade* was conducted, perhaps already in the Viking Age. This raises several central questions: What was traded? Who were the traders? How was the trade organised and protected? The fact that Copenhagen does not stand out in the archaeological record as a particularly important centre for trade during this period makes the name somewhat puzzling, but it is nevertheless an important piece of information to be taken into account within the framework of this article.

Bishop Absalon, the castle and the town

Bishop Absalon, a member of the important Hvide family, is traditionally seen as the founder of Copenhagen. From 1158 he was Bishop of Roskilde, and from 1177/78 Archbishop of Lund until his death around 1201 at 73 years of age. The papal charter of 1186 mentioned above, together with the prominent role assigned to him in Saxo's *Gesta Danorum*, gave the Bishop an almost mythical role in the nation-building project that was led by patriotic nineteenth- and early twentieth-century historical researchers (Olrik 1908–9, Rerup *et al.* 1996). Even if Absalon's role was toned down considerably in later research, he is still regarded as having a central role in the town's early history (Fabricius 1999, El-Sharnouby and Høst-Madsen 2008). It is evident that Absalon's interest in Copenhagen gave the town a push forward and led, among other things, to the undertaking of large construction projects. The most important of these were the castle and the Church of Our Lady (Vor Frue Kirke). Absalon was also probably a driving force behind the large fortification project which began construction in the early thirteenth century (see the following).

The main discussion points arising from the written sources relating to Absalon and the origin of Copenhagen revolve around two questions. First, what can be said about the status of Copenhagen at this point? Was it a village or a town? And second, did Absalon build the first castle, or had a forerunner already been established? The first point is discussed throughout the present paper, although a comment on the words used in the written sources to describe Copenhagen may be in order at this point. We should not be confused by the term 'villa' as used in connection with 'Hafn' in the papal charter of 1186. As shown by Hans Andersson, 'villa' is a normal Latin term used for a smaller town in Denmark before c. 1250 (Anderson 1971). On the second point, there is a genuine question over the existence of an earlier castle. On the small islet of Strandholmen (beach islet), a castle or stronghold is known from archaeological evidence to have been erected in the mid-to-late-twelfth century (Stiesdal 1975, Figure 9). Saxo Grammaticus writes in *Gesta Danorum* that Archbishop Absalon built a new castle ('novi castelli') in the 'port of the merchants' in 1167. In the above-mentioned papal charter of 1186, Absalon is said to have previously been given 'Castrum de Hafn', together with the town and a number of manors surrounding the settlement (DD 1. ser., vol. 3, no. 137). The wordings in the sources have given rise to speculation as to whether Absalon built the first (in other words, a new) castle, or whether he built a new castle replacing an *older* castle. There has also been speculation as to whether 'castrum' refers to a castle or a fortified town (Fabricius 1999, p. 154ff). As will be argued in the present article, we do not consider it likely that the town was fortified at this point. We can also conclude that the archaeological information about Absalon's castle does not point to an older castle on the same location.

The castle at Copenhagen should be seen in the light of expanding castle-building activity in Denmark in the twelfth century. A Zealandic example is Søborg in North Zealand, where the Danish king took over the Bishop of Roskilde's castle in 1161 (Pavón 2013). The Copenhagen castle can also be seen in the context of the castle of Skeingeborg, in the northern part of the eastern Danish province of Scania. This was probably built by Bishop Absalon in the same period as his castle at Copenhagen, as a control point in the iron-distribution network of Scania, and with some resemblance to the castle at Copenhagen (Ödman 2009, p. 19ff). First and foremost, however, the castle at Copenhagen should be seen, as has often been stressed, as a part of the Danish crown's coastal defence against Slavonic attackers, a vast building endeavour taking place in the reign of Valdemar the Great (1157–82) and including the castles of Vordingborg, Nyborg, Kalundborg and Sprogø (Engberg and Frandsen 2011, Kristensen and Poulsen 2016, p. 138f). It is interesting however that, unlike most of these towns with prominent castles, the term 'castle' (borg) is not reflected in the town's name. This should be seen as an indication of the importance of Copenhagen's function as a trading centre before the construction of the castle.

Despite large-scale excavations in the early twentieth century, the only solid information about the original castle is that it had a ring-shaped wall built of lime stone blocks. The stronghold had a circumference of 53 m, only partly preserved. It had been added to in several phases.

Even if it is difficult to conclude much about the castle from its appearance, the mere fact that the small town at Havn was one of the very few Danish towns with a castle to defend it says something about its importance in the Danish realm in the mid-twelfth century. What was it about Copenhagen in this period that made the elite of society claim this place as theirs, among other things by taking on the massive work of building a castle?

Before 1186, Absalon had transferred Copenhagen, with its castle, to the Bishopric of Roskilde, making the once-personal gift permanent. Absalon made sure that the gift was confirmed by the Pope on several occasions (in 1186, 1192, 1193 and 1198). We know from different sources that Absalon continued to use Copenhagen castle (DD 1. ser., vol. 3, no. 253). According to one charter of 1199, Absalon donated land at his castle to his family's 'Hauskloster' Sorø. The transaction was witnessed by his brother Esbern Snare, builder of the castle of Kalundborg, as well as a fair number of other members of the Hvide family (DD 1. ser., vol. 3, no. 253).

Churches in Havn

The earliest written information about a church in Copenhagen is two letters written between 1192 and 1201, mentioning 'the church' in 'Haffn' (DD 1. ser., vol. 3 no. 174, 180). They do not state when the church was built or what its name was. The wording of the letters, however, indicates that it had been in use for some time (DK Vol. 6 1987, p. 13). The words '*the* church' have been taken to indicate as a matter of fact that Copenhagen in its earliest phase had only one church (ibid.). As we shall see later on, this story requires revision.

In the later of the two documents, Absalon approves the payment by the parishioners ('comparrochianis') of the church in Haffn of some of their tax for the ongoing construction of the Church of Our Lady. After years of speculation among scholars, some kind of consensus has been reached that the original church referred to in these letters is a church of Sankt Clemens (Saint Clement). Saint Clemens in Copenhagen is first mentioned by name in 1304 (Nielsen 1879, KD 4, no. 3). Later documents indicate that the church was poor, and after the Reformation, it was demolished (Ramsing 1940, vol. 2, p. 29). Saint Clemens was the patron saint of sailors, which emphasises the town's role as a port. These churches were often connected to royal interests in the early medieval period; in the case of Copenhagen, this points to a royal presence there before Havn was given to Absalon in 1158 (Crawford 2006, p. 235ff). The arguments for the oldest church being the church of Sankt Clemens can therefore be summed up as follows: we know from written documents that the Church of Our Lady was not the first church here, and the church of Sankt Clemens is mentioned in 1304, then later described as poor (and may therefore have been the one obliged to pay for the construction of the Church of Our Lady). Moreover, churches were frequently devoted to Sankt Clemens in the early medieval period, which would concur with its being the oldest in the town.

A number of churches therefore existed in thirteenth-century Copenhagen (Figure 3). The building of the large and stately Church of Our Lady was most likely begun as early as the late twelfth century during the time of Bishop Absalon. This church was to become the new principal church of Copenhagen. In 1209, it was officially consecrated and became a collegial church connected to Roskilde Cathedral (Kornerup 1929–30). In this connection, a cathedral school was opened (the origin of the present-day Metropolitanskole). The Church of Our Lady was situated centrally in the thirteenth century town on the road leading into the town centre if one was travelling from the north. It was built as a Romanesque limestone church; after a number of fires, it was rebuilt in 1316 as a Gothic brick church, very

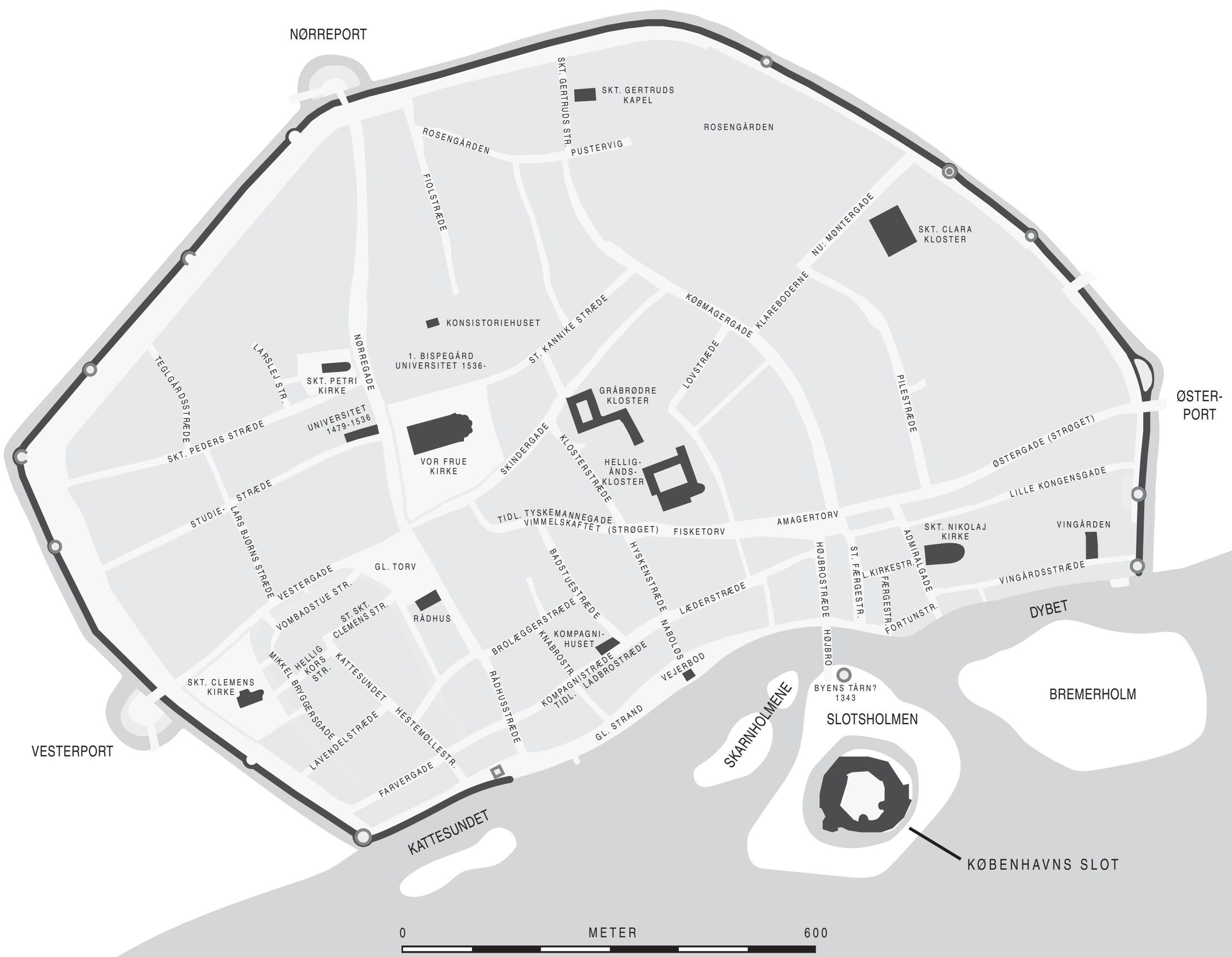

Figure 3. Reconstruction of late medieval Copenhagen with its fortifications. After Fabricius (1999, p. 190) and Kristensen and Poulsen (2016, p. 226). Figure has been reproduced with permission from the authors.

similar indeed to the Saint Petri church of Malmö (DK 1, Fabricius 1999, p. 212).

Soon, another church was built in the eastern part of town. The Church of Saint Nikolai, close to the present-day Kongens Nytorv and practically on the seashore, is mentioned for the first time in 1261 (DD 2. ser., vol. 1, no. 332). It was built as a Romanesque church, then later remodelled and enlarged to become a church of late Gothic style (DK 1, p. 475). Saint Nikolai was a saint of seafaring, which seems appropriate in view of the church's location. As with the Sankt Clemens church, this further underlines the importance of the sea for Copenhagen's existence. The placement of the Church of Saint Nikolai has been thought to indicate the existence of an eastern manorial property in Copenhagen, supposedly located around the site of the present-day Magasin du Nord and Kongens Nytorv (see Figure 3 (marked 'Østerport'), 9 and 25b; (Ramsing 1940, vol. 3, p. 59, Stiesdal 1975, p. 2). Such a manor is mentioned a number of times in the written sources, although whether it goes back to the early or high medieval period is not known.

A church of Sankt Peder (Saint Peter) is first mentioned in a will of 1304 (DD 2. ser., vol. 5, no. 344), but was probably built in the thirteenth century. It functioned as a parish church for the north-west part of town and also for the villagers of Serridslev, located a few kilometres north of the town (see Figure 8). There is no information concerning how the original church of Sankt Peder looked.

By the end of the thirteenth century, then, four parish churches are known in Copenhagen: Sankt Clemens, the Church of Our Lady, Sankt Nikolai, and Sankt Peder. This differs markedly from towns such as Malmö, situated across the Øresund strait, which became a town in the thirteenth century (Reisnert 2006, p. 66ff). The presence of several churches seems to be common in numerous Danish towns prior to c. 1150–1200, apparently reflecting a situation in which the parish structure was not fixed, with churches sometimes built on private initiatives (so-called proprietary churches; Nyborg 1979, 2004).

The thirteenth century was also a period when other clerical institutions were established in Copenhagen. In 1221 a brother of the Dominican Order met with Archbishop Anders Sunesen of Lund in 'Copendhafn' (DD 1. ser., vol. 5, no. 196), but it was the Franciscans who settled in Copenhagen. Around 1238 the rich widow Duchess Ingerd of Regenstein founded a Franciscan convent here (Gallén 1959, Kjersgaard 1980, p. 58). She granted them a property in central Copenhagen on the site of the present-day square of Gråbrødre Torv. Little, however, is known of their foundation. The semi-monastic beguines were also represented in Copenhagen. A member of this typical urban movement, which had its centre in the Rhine area and the Netherlands, is mentioned in 1274 when a woman in Dortmund, Germany, gave a plot of land to the house of the beguines in Copenhagen, to feed the virgins who lived there (DD 2. ser., vol. 2, no. 228).

The leprosy hospital – Jørgen's hospital (the hospital of Saint George, not on map), with its own chapel – is mentioned in a will of 1261 and is believed to have been established shortly before that date. The hospital is said to have had a forerunner, devoted to Sankt Olav (DD 2. ser., vol. 2, no. 252). On pictorial material of the sixteenth century it is placed some distance west of the town, but its location in the medieval period is not known (DK 6, p. 25ff). It is quite possible that the Sankt Olav church/chapel goes back to the twelfth century, which would add this foundation to the earliest church topography of Copenhagen.

Helligåndshuset (the Hospital of the Holy Spirit, 'domus sancti spiritus Hafnis'; later in the medieval period known as Helligåndskloster; see Figure 3) was established in 1296 by Bishop Jens Krag in a central location in the town. Nothing is known, however, about its earlier buildings (Fabricius 1999, DK 1, p. 625ff).

The written accounts of the medieval churches of Copenhagen are not very informative and leave quite a few questions unanswered. This is especially evident in the light of the recent excavations at Rådhuspladsen, which will be discussed below. Here the remains of an, until now, unknown cemetery, most likely belonging to a church of the early medieval period, have come to light. Where does this church belong in the history of the town churches, and what does it tell us about the early development of Havn? And consequently – what else is not mentioned in the historical sources?

Large-scale fortifications

During the thirteenth century, a massive boundary and defence structure was seemingly constructed in

Copenhagen (see Figure 3; Kristensen and Poulsen 2016, p. 216f) – or at least started upon, as we shall see below. In the case of some Danish towns, there is discussion of whether the primary function of their fortifications was defensive or more an administrative and judicial marking, but the structure surrounding Copenhagen was so extensive that it was certainly meant as a defence. A defence also proved to be very much needed when Copenhagen was stormed in 1249 and 1368, both times by the Hanseatic town of Lübeck (DD 2. Ser., vol. 1, no. 34, 42, DD 2. ser., vol. 2, no. 52). Its location, easily accessible from the sea but at the same time vulnerable to attack, also by pirates, made fortifications necessary.

The fortifications are mentioned in the first town law of 1254 and 1294, where it is stated that the law is in force within the walls and moats ('infra muros et fossata') of the town (Kroman 1951-61, vol. 3, p. 3, § 1). The law of 1254 also speaks of the town's fences ('infra septa'; Kroman 1951-61, vol. 3, p. 5, § 7). Later in the thirteenth century the fortifications are described with several different wordings, so the type of construction material used for the fortification and its appearance cannot with certainty be concluded from the written sources (Kristiansen 1999a, p. 166). There are, however, indications that it was not uniform. A house in the parish of Sankt Nikolai situated near the walls ('juxta murum') is mentioned in a letter of 1298 (DD 2. ser, vol. 4, no. 284). Five years before, in 1293, a townsman of Copenhagen is heavily fined for breaking through the 'fence' of the town at night (DD 3. ser. vol. 4, no. 96).

Together with the castle on Slotsholmen, the fortifications surrounding the town should be seen as evidence of the willingness to invest in and to protect Copenhagen. The dimensions of the construction, covering 70 ha, are comparable to the fortifications of Lund and Roskilde (84 and 73 ha, respectively: Kristensen and Poulsen 2016, p. 227). The large scale also points to plans for future expansion, since much of the northern and north-west parts were built at this time (Fabricius 1999). Perhaps we could even see the generous scale of the fortifications as also including some space for grazing and cultivating, making the town inhabitants self-sufficient in the case of a siege.

Even if the fortification project is mentioned in 1254, it cannot be concluded that it was finished by then. The source of 1254 speaks of the walls and moats in a judicial sense as the geographical *boundary* of where the laws ruled. This could mean that it was enough to know where the boundary was, without the wall and moat physically being there. Some passages in the written sources describing the process of construction could be interpreted as evidence of potential problems. In the 1254 town law, for instance, it is stated that no individual may prevent the execution of the common good, such as the construction of moats and roads, and that if the town requires stone, iron or chalk for its constructions from a townsman, no one may refuse it (Kroman 1951-61, vol. 3, p. 3, §15). A letter from the Bishop in 1289 thanks the townsmen of Copenhagen for their good will in fortifying their town and in compensation gives them a tax relief (DD 2. ser., vol. 3, no. 374). These sources could be seen as indications of internal conflicts between groups in the community with different interests in whether and where the fortifications were to be built. From the written sources, it appears that the town council (Danish: byråd) and the Lord of the town was the driving force behind the construction of the walls. But perhaps not everyone with influence was happy about all aspects of the building of the fortification – for instance, where it was to be built. Or perhaps different groups in the community or different individuals were responsible for building different parts of the defences. In this connection, the question of building materials for the fortifications could be of interest. In an official survey of the town of 1496, listing the properties and infrastructure of the town, the word 'mur' (wall) is chosen eleven times to describe the defences in the stretch from Nørreport to Østerport, while in the western part only 'planker' (planks, or fences) are mentioned (Kristiansen 1999a, p. 166, Nielsen 1872, KD 1, p. 234-246).

Thirteenth-century Copenhagen: a large and well-connected town

When Bishop Absalon died in 1201, lordship over Copenhagen was transferred to the diocese of Roskilde; but Copenhagen remained contested for centuries because the Danish kings desired so strongly to possess the town. Evidently Copenhagen was so important that lordship over it was in dispute for centuries (Kjersgaard 1980, p. 63–82, 118–119).

Figure 4. Denmark and Scania, Sweden. The map shows the location of Copenhagen in medieval Denmark. Ill: Ea Rasmussen, Moesgaard Museum and Ann-Lisa Pedersen.

Copenhagen was no small town in the thirteenth century (see Figure 4). Its place in the town hierarchy of Zealand can be assessed from the so-called 'town list', dated to c. 1241. This tax list notes an exact tax amount for each town in Zealand, Lolland-Falster and Møn (Kong Valdemars Jordebog, p. 83, Ulsig and Sørensen 1981). The list contains information about 19 towns, of which the ones giving the highest yield are Roskilde (90 marks), Næstved (40 marks), Kalundborg (33 marks), and Copenhagen (28 marks). Below these, we find a group of nine towns assessed at giving between 5 and 18 marks. It is possible to say that in the mid-thirteenth-century Copenhagen constituted a prosperous town, the fourth largest on the island of Zealand. The prosperity is further supported by the fact that when the wealthy Duchess Ingerd of Regenstein decided to found Franciscan convents, it was precisely these large towns to which she turned.

Thirteenth-century Copenhagen was a well-regulated society. From its town rulers (Danish, byherrer), the Roskilde bishops, it received town laws in 1254 and

1294 (Kroman 1951-61, vol. 3, p. 4f). The town functioned as a bridgehead for traffic crossing from west Denmark to Scania. A fourteenth-century itinerary thus describes a route from the towns of Schleswig and Ribe, across Funen, to Zealand and on to Roskilde-Copenhagen. From Copenhagen the road goes either to Skanør or Malmö, then north via Helsingborg (Paravicini 2000).

Copenhagen was supplied by its fertile hinterland, with which it maintained intense contact. Just one illustration of this is a court case of 1293, which mentions meat imported from the nearby town of Slangerup into Copenhagen (DD 2 ser., vol. 4, no. 95). In 1230, chalk for the building works of the town was brought in from the small island of Saltholm just outside Copenhagen (DD 1. ser., vol. 6, no. 113, 2. ser., vol. 2, no. 396). The town also benefited from the upcoming international markets and fishing centres of Skanør and Falsterbo, and the town law of 1254 notes that the townsmen of Copenhagen are relieved of levies on the Skanør market (Kroman 1951-61, vol. 3, p. 3, § 17). Generally, Copenhagen benefited from the sea trade and communication in the Øresund. In 1275, the ruler of Copenhagen, Bishop Peter Bang, permitted free passage without customs duties between Copenhagen and Malmö (DD 2. ser., vol. 2, no. 252). Ferrying is mentioned in the 1254 town law of Copenhagen, which states that the town is under obligation at any time to ship the town lord, the Bishop of Roskilde, with 12 men to Scania (Kroman 1951-61, vol. 3, no. 1, § 2). That there was a traffic of small boats between the coasts of Zealand and the increasingly prosperous town is shown by a will of 1261 in which the aristocrat Peder Olufsen, owner of the manor of Karise (Stevns), donates all his boats lying at Copenhagen to the Sankt Nicolai Church of that town (DD 2. ser., vol. 1, no. 332). It is tempting to see behind a notice of this kind supplies of grain coming from South Zealand.

Traces of long-distance trade can also be discerned, along with older Nordic trade patterns involving connections to Norway and Iceland, as seen when c. 1242 the Icelandic poet Játgeirr Torfason is said to have been killed by his family in Copenhagen (Mundal 2009). In 1251, we have evidence of English trade when English merchants robbed of their goods in Copenhagen are compensated by Lübeck townsmen who two years earlier had taken part in the plundering of the town (DD 2. ser., vol. 1, no. 43). The connections to England were seemingly not interrupted: in 1329 the Newcastle merchant Robert Musgrave was robbed of his ship and cargo in the harbour of Copenhagen (DD 2. ser., vol. 10, no. 109, 110).

The most important trade partners of Copenhagen were, however, Germans. In 1253, we hear of Bertel 'of Copenhagen' in Dortmund (DD 2. ser., vol. 1, no. 102). Most connections, however, were leading to the emerging German towns on the southern shore of the Baltic. Lübeck certainly interacted with Copenhagen through trade, and imported Lübeck beer (*traveøl*) was widely consumed by the Copenhageners (DD 2. ser., vol. 3, no. 5). We must also assume that people from Lübeck came to fish in the herring fisheries at Copenhagen before Dragør, at Amager, became an international herring market around 1340 (Jahnke 2000, p. 135). Among the other German sea towns, Stralsund interacted a great deal with Copenhagen. Townsmen from Copenhagen are, for instance, mentioned in Stralsund in 1280, 1302 and 1305 (Das älteste Stralsundische Stadtbuch, p. 41, 147, 173). Not surprisingly, there were also connections to Rostock and Greifswald. A number of thirteenth- and fourteenth-century court cases mention townsmen from these towns who have been murdered in Copenhagen (Mecklenburgisches Urkundenbuch, 3, 73, DD 2. ser., vol. 9, no. 109). In 1294 we hear that people from the territory of the German Order (probably from Gdansk) have been robbed in Copenhagen (Nielsen 1872, KD 1, no. 35, p. 60). Some Germans even settled in Copenhagen, such as the two townsmen of Wismar who in 1260 owned a house there (Techen 1912, p. 38). There are enough data to document that thirteenth-century Copenhagen was well integrated into the Baltic trade routes.

Copenhagen before Absalon: previous research

Early theories: 'Historikerfejden', Rosenkjær and Ramsing

From the written sources as well as from archaeology, there is no doubt that Copenhagen was flourishing in the thirteenth century. Historians and archaeologists have striven to throw light on the period before this. It was not until 1982, however, that systematic excavation was to get under way in Copenhagen. The first archaeologist employed at the City Museum was Axel Christophersen, who in 1986 took on the task of summarising and critically assessing all previous theories of the origin of Copenhagen (Christophersen 1986, see below). His interpretation differed substantially from the prevailing theories. Despite – or perhaps because of – the meagre source material on early medieval Copenhagen, extensive theorising about the extent, date and character of the early settlement has been in progress since the late nineteenth century. The so-called 'Historikerfejden' (historians' feud) involved three scholars, each with his own view of where the earliest settlement was situated, which church was the first, and whether Havn had been a rural settlement or had principally been a fishing port. The debate was carried on in the 1870s and 1880s in the journals *Danske Samlinger, Historisk Tidsskrift* and *Aarbøger for Nordisk Oldkyndighed og Historie*. The theories advanced relied on the few written sources, combined with interpretations of ancient maps, place names and contemporary town topography (see Fabricius 1999, p. 45ff for an extensive summary of the theories).

In the first half of the twentieth century, the school teacher H. N. Rosenkjær and Major-General H. U. Ramsing were the two most important figures in research into the early history of Copenhagen. They made extensive documentations of cultural layers and geographical conditions in connection with the large-scale building demolitions that began in the old town in this period. They were the first to use archaeological information as a real basis for their interpretations. While Rosenkjær did pioneer work connecting archaeology with natural science, Ramsing made important contributions in combining archaeology with written sources. Ramsing eventually came up with a theory of the extent of the first town which, with variations, came to last for a long time. It was he who developed the concept Clemensstaden (see discussion below; Ramsing 1908).

Topography of the early town area

It has often been said that Copenhagen's natural topography was marshy and not suited to permanent settlement (El-Sharnouby and Høst-Madsen 2008, p. 148). Therefore, it would at an early stage have been an important task to fill in the areas close to the shore in order to make the site more habitable and stable. Evidence of these types of endeavours exists, among other places in Kompagnistræde (see Figure 3), and the adjacent Løngangstræde and Lille Kirkestræde, where various measures were taken to stop water seeping into the settlement. These activities can be dated to around 1200 and after (Roesdahl 1971, p. 177ff). In the early twentieth century, geological observations were made in many places around the medieval town, principally by Rosenkjær and Ramsing, mapping the early medieval ground level in the respective areas (Ramsing 1940, vol. 1), thus enabling a reconstruction of the early medieval shoreline. The reconstructions were later modified so as to move the early shoreline one block to the north (Skaarup 1999b, Fabricius 1999, p. 75ff). It should be stated that these reconstructions are associated with many uncertainties, and that at this point there is insufficient data to make a detailed reconstruction. Detailed mapping with modern methods remains a vital task for current and future research into the history of the early town.

From the many observations conducted over the years, an approximate idea of the shoreline can nevertheless be obtained (see Figure 9). It is likely that the area along the shore which was between 0 and 1 m above sea level was seasonally flooded, and that it was these areas that were worked upon from no later than c. 1200. The earliest settlement should be seen as located at a higher level. As we shall see below, this fits with the new archaeological information, which indicates that the main settlement was situated in the western part of the town or even further west than the traditionally defined town area, where the ground was higher. It is also likely that the earliest town included small bodies of water such as ponds and wetland areas influencing the placement of streets and buildings. Ramsing's observations on the original ground level around town, combined with the evidence of maps dating from c. 1600, suggest there were several small islands immediately outside the western town area (see Figure 5; Ramsing 1910, p. 506ff, Fabricius 1999, p. 57ff).

'Clemensstaden' and the horseshoe-shaped ditch

The concept of Clemensstaden was first advanced by Ramsing in 1907. It refers to the area in which no bricks have been found in the cultural layers – the area between Vestergade, Gammeltorv/Nytorv, Farvergade, and Rådhuspladsen. Consequently, Ramsing pointed to this area as the extent of the oldest town settlement. Since the church of Sankt Clemens had just been discovered within this area, he named it Clemensstaden

Figure 5. Oldest known map of Copenhagen from c. 1580–1600. North is up. Original from the Royal Danish Library.

(the Clemens town). However, the dominant theory of the town's original extent in the second half of the twentieth century emerged from a series of observations of a ditch managed by Ramsing throughout his active years. Ramsing himself interpreted this ditch as a mill race (Ramsing 1940), but other researchers came to see it as a fortification surrounding the oldest settlement.

The ditch was encountered for the first time in 1900, and then on several occasions leading up to 1912 (see Figure 6). The ditch and fragments of an earthen wall had seemingly enclosed a 2.5 ha area lying between present-day Gammeltorv, Vestergade and Mikkel Bryggers Gade, with its southern edge facing the contemporary waterfront at present-day Farverstræde. In 1940, Ramsing presented the theory that the remains of the feature – a wide ditch (c. 8 m wide and 1.5–2 m deep) and a connected earthen wall (8 m wide and 1.5 m high) that he encountered at several locations within the area – were the fragments of a medieval mill race, connected to a mill pond located to the north (Ramsing 1940, vol. 3, p. 47). He observed that the ditch had been cut through older settlement remains, and that the oldest culture deposits inside the enclosure were without brick inclusions. On the basis of these observations, he concluded that the mill race dated from the period of Absalon (i.e. before c. 1200), but that there had been some activity prior to the cutting of the ditch.

A reconstruction of the course of the ditch and the rampart was consequently made from these observations, and its shape was interpreted as being similar to a horse-shoe (Ramsing 1940). In the 1980s, two further excavations were conducted at locations through which the ditch was predicted to run. In at least one of these, in Vestergade 7, the ditch was seen (marked with 'I' on Figure 6; Skaarup 1988), in the other excavation in Frederiksberggade (marked with 'H' on Figure 6, it is more uncertain (Christophersen 1986, p. 30ff). Deposits which were AMS-dated to the second part of the eleventh century or the first half of the twelfth were seen, but their context was unclear, due to the small excavation area of 6 m^2 (see Table 1; Christophersen 1984).

In 1947, the theory was put forward that the construction could have functioned as the oldest fortification of the town, enclosing the oldest settlement (described in Fabricius 1999, p. 84). This interpretation became the dominant one as the years went by (Stiesdal

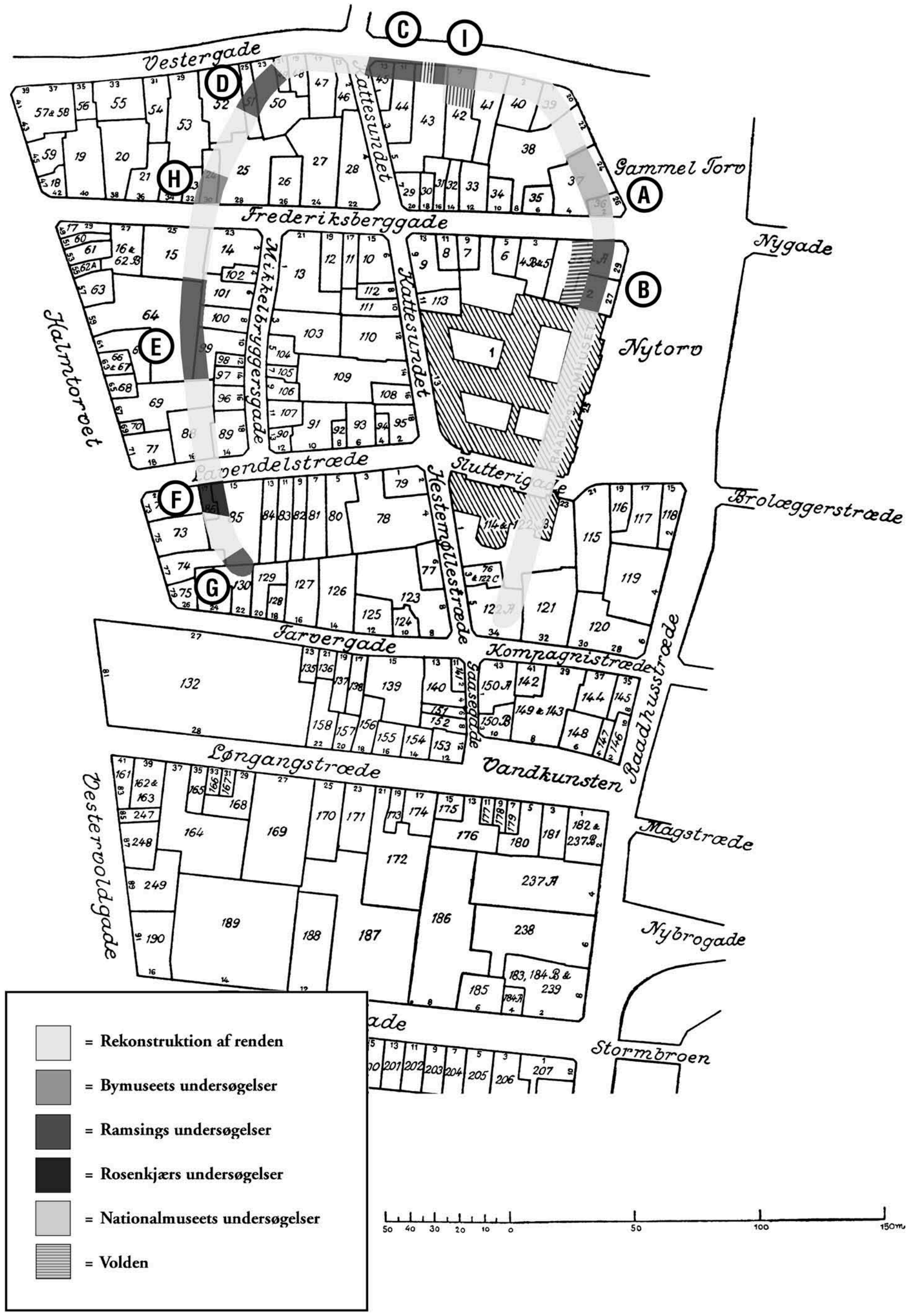

Figure 6. Reconstruction of the horseshoe-shaped ditch, interpreted as the extent of the earliest settlement. The actual sightings of the feature are marked (Danish 'renden' = 'the ditch', seen as light grey; "undersøgelser = 'excavations', seen as darker shades of grey). After Ramsing (1945). The placement of new excavations within the area, mentioned in the text, are marked with a star.

1975). The name 'Clemensstaden' had now come to mean the area within the enclosure. The church of Sankt Clemens came, in this model, to be situated outside the earliest town extent. In the late 1980s, archaeologist Bi Skaarup made new progress with her research concerning the function of the ditch. In 1987 an excavation was undertaken which dismissed the idea of a mill race due to the discovery that there was no difference in height in the ditch, which would have made it impossible for water to run through it. Archaeobotanical analyses of material from the ditch sediments also showed that although the ditch had been a water-logged feature, the water had been still rather than running. This was seen as proof that the ditch had originally been

Table 1. AMS 14C dates mentioned in the text.

Feature type and excavation id	Lab No.	14C year BP	Sigma 2 date	Dated material
Horseshoe shaped ditch? 1984, Frederiksberggade 30, AA 72	K-4543	890±50	1045–1220 AD (sigma 1)	Wood
Horseshoe shaped ditch? 1984, Frederiksberggade 30, AA 72	K-4544	930±50	1030–1180 AD	Animal bone, cattle
Amagertorv 7/Læderstræde 8, KBM 3111			1058–1156 AD	
Oldest ditch KGN 1999, KBM 1410/1910	KIA 6107	937±25	1029–1158 AD	Seed, unknown species
Coffin wood, RHP 2011, KBM 3827	KIA 44,988	1195±20	775–889 AD	Wood, unknown species*
Border ditch cemetery, RHP 2011, KBM 3827	LuS 11,074	920±40	1025–1210	Animal bone, pig
Bulwark KGN 2010, KBM 3829	LuS 9701	835±50	1045–1289 AD	Charcoal, Alder
Bulwark KGN 2010, KBM 3829	LuS 9702	775±50	1155–1295 AD	Charcoal, Alder
Rampart KGN 2010, KBM 3829	LuS 11,347	780±35	1190–1285 AD	Seed, barley
Moat RHP 2016, KBM 3827	LuS 12,015	680±35	1265 – 1395 AD	Bur-reed
Moat RHP 2016, KBM 3827	LuS 12,016	605±35	1290 – 1410 AD	Charcoal, Hazel
High med. building, 2nd floor, RHP 2012, KBM 3827	LuS 10,657	700±45	1220 – 1395 AD	Seed, Goosefoot
High med. building, 4th floor, RHP 2012, KBM 3827	LuS 10,639	645±50	1275–1405 AD	Seed, unknown
Clay lined pit KGN 2010, KBM 3829	LuS 11,364	890±35	1035–1220 AD	Animal bone, horse
Clay lined pit KGN 2010, KBM 3829	LuS 11,363	815±35	1160–1270 AD	Animal bone, sheep

a fortification enclosing the earliest town area (Skaarup 1988, p. 31).

A close dating of the ditch must still be seen as non-existent. We know that it cuts through the oldest settlement traces (see Figure 11), which broadly are dated to the late eleventh century/early twelfth century (Ramsing 1940, p. 81ff, Fabricius 1999, p. 179), and we know that the deposits covering the backfill of the ditch contain finds from before the fourteenth century (Skaarup 1999c, p. 94). AMS dates from the above-mentioned excavation at Frederiksberggade 30 in 1984, together with finds of Baltic Ware pottery, were found by Hoda El-Sharnouby and Lene Høst-Madsen to place the establishment of the ditch and rampart to the later part of the eleventh century or to the first half of the twelfth . This was however based on the assumption that the features dated in the 1984 excavation were parts of the ditch, which it has been argued above are uncertain. This means that the existing dating information for the *construction* of the ditch extends from the late eleventh to the late twelfth century, whereas that for the *backfill* range extends from 1160 (ibid.) to the late thirteenth century. In order to reach plausible and more precise dates for the construction and the falling into disuse for

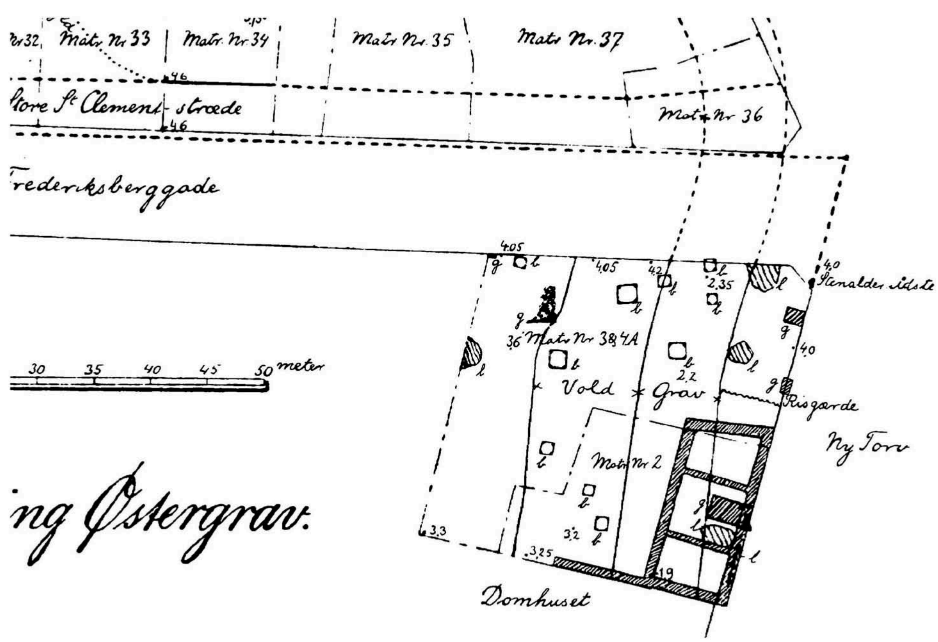

Figure 7. Part of drawing by Ramsing of the north-east corner of the area enclosed by the ditch. It shows remains of ditch (grav), rampart (vold), clay floors (g), wells (b) and pits (l) from the plot Frederiksberggade/Nytorv, excavated in 1909. The drawing shows features encountered below the ditch and rampart (after Ramsing 1909, p. 497; Figure 2).

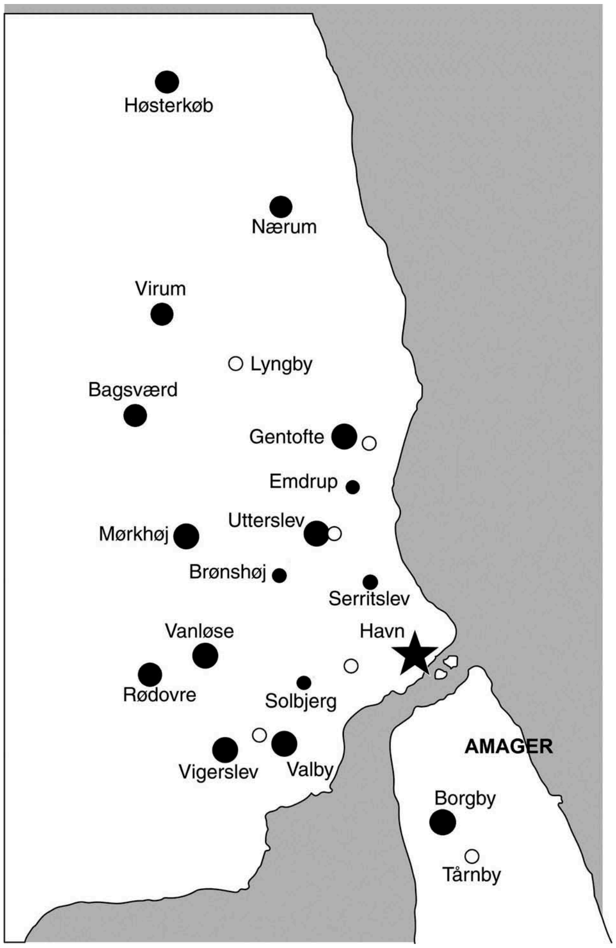

Figure 8. The area around Copenhagen, showing the manors (large filled circles) included in the grant to bishop Absalon 1186. Small filled circles mark villages included in the grant; unfilled circles mark the locations of hoard findings from the eleventh and twelfth century. Adapted from Frandsen *et al.* (1996). Ill: Ea Rasmussen, Moesgaard Museum and Ann-Lisa Pedersen.

the ditch, other information needs to be taken into consideration.

Settlement within 'Clemensstaden'?

Even if settlement indications are strong in the area bounded by the ditch, none of the archaeological evidence encountered in the area shows a spatial connection to the limits of the enclosure. As will be discussed below, this raises questions about what activities should be seen as related to the feature in question. What has been going on inside the (seemingly) enclosed area?

Going back to 1909, in the corner plot of Frederiksberggade and Nytorv, archaeological observations were undertaken of clay floors, wells, pits, and a wicker fence in the brick-free cultural deposits (see Figure 7). Most of the features were situated either outside the ditch or, when it came to wells and pits, below it, which means that they were cut by the ditch and rampart and are therefore older (Fabricius 1999, p. 179f, from Ramsing 1910, p. 497). The settlement remains at this location do not seem to spatially respect or take into account the ditch and rampart structure, but clearly represent an older phase of settlement organisation.

In Vestergade and Frederiksberggade, some remains of clay floors, foundation stones, and finds of what must have been Baltic Ware or Early Greyware pottery were discovered early in the twentieth century (Ramsing 1908). The findings were indications of a settlement, but not enough to try and reconstruct how the settlement might have looked. In the 1980s, small excavations in Mikkel Bryggersgade, Vestergade and Frederiksberggade revealed more of the same types of features. Most important here were perhaps the finds from Mikkel Bryggersgade, with clay floors indicating buildings in several phases, together with finds of Baltic Ware, Pingsdorf ware and, for the first time in Copenhagen, fish bones in large quantities (Skaarup 1999a, 1999b).

Apart from Kattesundet, the street Mikkel Bryggers Gade (which still exists today) and the street Vombadstuestræde (no longer in existence, closed in the eighteenth century) are seen as remains of 'voldgader' (rampart streets) connected to the enclosure (Fabricius 1999, p. 185ff). Furthermore, the streets Store and Lille Sankt Clemens stræde, closed after the fires of the eighteenth century, are seen as part of the infrastructure at the time of the Sankt Clemens church, perhaps going back to the eleventh and twelfth centuries (Store Sankt Clemens stræde is seen on Figure 3).

Streets and settlement east of 'Clemensstaden'

Excavations to the north of Vestergade, which was the main street through the town in the medieval period, have revealed little information about this early period. The remains of a large pond and a ditch running east–west parallel to Vestergade have been documented, but cultural deposits seem to be few in this area. To the east, Vestergade ends in Gammeltorv and Nytorv, where we earlier accounted for remains of early medieval clay floors, wells, pits, and early medieval pottery findings. The street Nørregade, one of two main roads

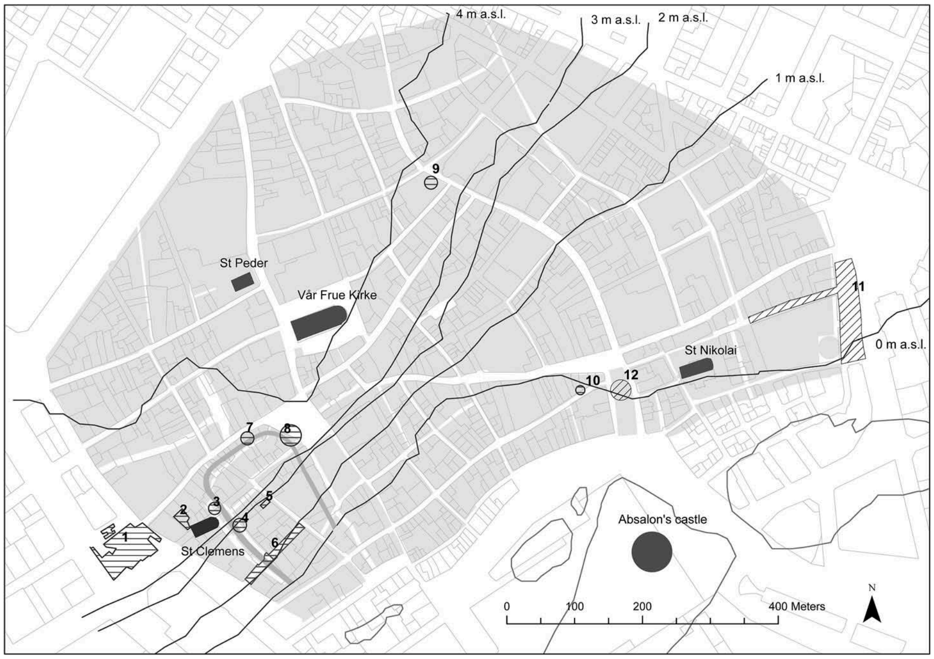

Figure 9. Plan of Copenhagen showing older and newer archaeological sites which have contributed with important information about the town's development before 1200. The contemporary shoreline and topographic levels are marked. Extent of fourteenth-century Copenhagen is seen in shaded grey. A map of modern Copenhagen is used as a background.1: Rådhuspladsen KBM 3827 (2011–12); KBM 4286 (2017–18); 2: Sankt Clemens/Vestergade 29–31 KBM 3621 (2008); 3: Frederiksberggade 30 (AA 72 (1984); 4: Mikkel Bryggers Gade 11–13 KBM 250 (1989); 5: Kattesundet 10 KBM 4088 (2015); 6: Nørregade m.fl (Lavendelstræde).KBM 4022 (2015); 7: Vestergade 7 AA 104 (1987); 8: Gammeltorv/Nytorv/Frederiksberggade. (1909); 9: Regensen KBM 3824 (2012); 10: Amagertorv 7/Læderstræde 8 KBM 2822 (2003); 11: Kongens Nytorv KBM 1410/1910 (1996), KBM 3829 (2010–16), 12: Højbro Plads, KBM 1213 (1994).

entering the medieval town from the north, also opens into Gammeltorv. A little further north, where the ground rises quite steeply, the Church of Our Lady was later built along this same street.

It is quite clear that both Gammeltorv and the eastern Højbro Plads were important locations in the early town, even if at this early point in time they were not open places or squares. Gammeltorv would have had direct access to the waterfront to the south. From here and going east, the street Vimmelskaftet, which is probably medieval in origin, continued into the location of present-day Amagertorv and Højbro Plads. Before the great fires of the late eighteenth century, Højbro Plads was not a square, but a narrow street leading down to the waterfront, where the bridge over to Strandholmen with the castle was situated. The ferry to Amager also went from here (the island Amager is seen on Figure 8; Johansen 1999, p. 133ff). The road leading from the north to Højbro Plads – present-day Købmagergade – is also probably medieval in origin (with its earlier name, Bjørnebrogade; Fabricius 2006, p. 160). Thick cultural deposits containing early medieval finds have been documented at Højbro Plads (KBM 1213). In the excavation the deposits were in the excavation seen to be dumps of household material deriving from nearby settlement. It was concluded that the deposits had been lying below water, preserving organic material such as wooden plates and leather (Johansen 1999, p. 135ff). Noticeable were the finds of a broken bone pin with a runic inscription, and 'spyta' (sticks or spits) typologically dated to late Viking Age, found together with Baltic Ware (ibid.).

We have no archaeological evidence for the earliest harbour, but on the basis of topography and indications of settlement extent and features, the area by and going west from Højbro Plads seems a good location for a harbour (Skaarup 1999b, p. 81). It is also an option that rather than a harbour where the ships docked, this was done in the shallow waters around Strandholmen and the other islands, just south of the waterfront. This was the case in other medieval towns such as Malmö (Reisnert 2006, p. 75f). The above-mentioned written account of 1329 about the robbed English tradesman also speaks of the 'reef' of Copenhagen (DD 2. ser, vol. 10, no. 109).

North of Højbro Plads, material from a street layer at Amagertorv has been AMS-dated to the mid-eleventh to mid-twelfth century (Poulsen 2003, p. 17). It is however not clear if the material that constitutes the road here came from this location or was brought from elsewhere. Going eastwards, the Church of Sankt Nikolai was built in the area between Højbro Plads and Kongens Nytorv in the thirteenth century. Before this there was probably a street running along the contemporary shoreline through to the area of present-day Kongens Nytorv.

In the first Metro excavations of the late 1990s, the only early medieval settlement remains encountered were some ditches with backfill containing large amounts of household waste (animal bones). Bone material from this waste material was AMS-dated to 1029–1158 AD (Table 1). A Viking-style decorated knife-handle made of antler was also found. It is not known where this material came from, but it was probably from close by (Kristiansen 1998). No substantial remains of an eastern manorial property could however be traced through archaeological sources (Frederiksen *et al.* 1999). Having said this, the evidence that does exist shows clearly that much remains to be revealed of the eastern edges of early medieval Copenhagen.

Fortifications

As noted above, the written sources tell of large-scale fortifications being built around Copenhagen in the thirteenth century. The archaeological observations of this fortification stretch back to the first part of the twentieth century, but it was not until the first Metro excavation at Kongens Nytorv in 1996 that solid archaeological material was produced (Kristiansen 1998). In the course of this excavation it was seen that the part of the fortification excavated, which represented the wall and moat south of the eastern gate (Østerport), could be dated through 14C and dendrochronology to the later part of the thirteenth century. For the first time the town wall mentioned in the written sources could be seen, and it could be stated that it had been built at the same time as the rampart rather than as a strengthening of this. On the basis of these dates, together with the information from written sources, the theory was advanced that the building of the fortification had started at the other end, at Vesterport, and finished at Østerport (Kristiansen 1999a, p. 160, 173).

Critique of 'Clemensstaden' and later theories

As early as the 1980s, however, the idea of the ditch as fortifying the oldest area of the town was challenged. In 1986 Axel Christophersen argued for an alternative theory of the earliest town extent, largely based on written accounts of tax zones within the later medieval town, additional written sources, and a dismissal of the theories of Clemensstaden, which he believed were made on insubstantial grounds. Christopherson's idea of the early town was that it had been located along the beach from Gammel Strand to Højbro Plads. This location was connected to the reason Christophersen saw for the origin of Havn: that it had formed as a result of the need for a marketplace for trade in the Øresund region, largely connected to the increasing importance of fishing (Christophersen 1986, p. 22). The emphasis on trade and fishing has been maintained in later research as a prominent explanation for the formation of Havn. Hanne Fabricius (1999) as well as El-Sharnouby and Høst-Madsen (2008) name fishing as an important factor in the early town formation. The idea is based on Copenhagen's location on the Øresund, where, from the late twelfth century, international seasonal fish markets in Skanør and Falsterbo attracted many people to the region. Fishing was an important economic activity in the Øresund area, and the lack of solid evidence for other types of trade in early Copenhagen has made this theory stronger. The first town laws of 1254 mention specific taxes for using nets during the winter herring fishing (Kroman 1951-61, vol. 3, no. 1, p. 3–7), indicating that a part of the population were active seasonal fishermen. Archaeological evidence of fishing to support this theory has however been largely missing. Before the Metro Cityring excavations, possible traces of fish-processing had been found in only one place. In the plot in Mikkel Bryggersgade excavated in 1987, three small holes were excavated in 1986 and 1989 (Skaarup 1993). Here, as mentioned above, large quantities of fish bones were deposited in some of the older layers (Skaarup 1993, p. 23). The dominant species were herring, gadids (from the cod family) and eel. Whether the fish bones had been deposited as production waste or as leftovers from meals is not clear, although the many vertebrae and bones from fish too small to have been eaten have been interpreted as waste from professional fishing. The vertebrae would have come from the gutting of the fish before further processing, and the small bones are regarded as by-catch, small fish caught together with larger ones but thrown away because of their small size (Robinson *et al.* 1991).

In recent years the role of the horse-shoe shaped enclosure has also been questioned. Both Fabricius (1999), El-Sharnouby and Høst-Madsen (2008) and Jane Jark Jensen (forthcoming) see the town as extending further, probably spreading along the coast between Rådhuspladsen and Kongens Nytorv.

On the question of the dating of the oldest settlement, consensus among scholars has for a long time been that the earliest activities, based on the archaeological remains, seem to go back to the eleventh century. The nature and scale of activity has however been highly uncertain, making it impossible to grasp a clear understanding of the site in this period. As we shall see, the possibilities for new knowledge and ideas about the early development of Havn are now considerably improved. Before continuing to these, however, we will move outside Havn and take a look at its place in the landscape and the region.

Situating the town: topography

Copenhagen lies on the eastern coast of Zealand, opposite Scania. Between Zealand and Scania is the Øresund, a strait that today marks the border between Denmark and Sweden, but in the medieval period connected two important Danish regions. The Øresund has historically had great economic importance for Denmark with respect to trade, communication and fishing, but its location on the coast also made it vulnerable to attacks and to plunder. Topographically, Copenhagen was situated in the shelter of a few small islets including Amager, Bremerholm, and Strandholmen, where Bishop Absalon built his castle. The location was very suitable for a port or a landing site, with a deep natural harbour – a rarity on the coast of eastern Zealand (Fabricius 1999, p. 57). The topography of the town area was quite flat along the areas close to the waterfront, with some patches of marshy terrain. The land rose up to six metres above sea level at its highest point, close to where Vor Frue Kirke was constructed around AD 1200. In the western town area, the land rises almost immediately more than a metre above sea level, while the eastern parts closer to present-day Kongens Nytorv included a wide area towards the seafront with much flatter and lower ground (between one and two metres above sea level; see Figure 9). The oldest port, the place where the boats tied up, has not been identified, but the topography means that it was probably located in the area between the Town Hall and Højbro Plads (as discussed above). Due to the extensive landfills/land reclamation from the early thirteenth century, all traces of the original harbour have probably been erased. In the eleventh and twelfth centuries, the waterfront would have been situated along the present-day streets of Farvergade/Kompagnistræde/Læderstræde, across Højbro Plads and the Church of Sankt Nicolai, through Vingårdsstræde to the south end of Kongens Nytorv.

Copenhagen seems to have been the earliest town on the eastern coast of Zealand. We know that a royal castle was built at Vordingborg, in South Zealand, c. 1160, but so far no indications of urban settlement have been localised that date to before the thirteenth century (Wille-Jørgensen 2014).

One reason for Copenhagen's existence and for its formation at this point in time relates to its placement midway between the eleventh-century bishop towns of Roskilde and Lund. Copenhagen has sometimes even been called 'the port of Roskilde'. There has been discussion of whether the deliberate sinking of the Skuldeslevskibene Viking ships in the late eleventh century in the Roskilde fjord may have had a long-term effect on the possibilities for sailing to and from the harbour at Roskilde. This, however, does not seem to be the case, as the disruptive effects of the wreckings seem to have been limited (Fabricius 1999, p. 222, Bill *et al.* 2000). We find it more likely that the flourishing commercial engagement of Havn and the decreasing importance of the Roskilde harbour were associated with the creation of strengthened commercial networks in the Baltic and in the Sound, much to the benefit of Havn.

Either way, relations with Roskilde and Lund probably played an important role in Copenhagen's early history. Other significant partner towns probably include the Zealandic towns of Ringsted, Slagelse and Næstved, all established as towns in the eleventh century (Kristensen and Poulsen 2016, p. 68). They had seemingly mostly non-commercial roles, with Slagelse and Ringsted being sites for royal minting, and Ringsted also functioning as the site where the central court, the *landsting* of Zealand, was held. Næstved, on the other hand, has a long history as a settlement, growing from a port and trading centre from the Iron Age (Hansen 1994). Another town of interest when discussing the formation of Copenhagen is Helsingborg, on the other side of the Øresund and on Scania's west coast. The town goes back to the eleventh century (Weidhagen-Hallerdt 2009). Its strategic location on the inlet to the Øresund, together with the relative height of the early town settlement, was perfect for the control of ships coming into and leaving the strait. Large-scale herring fishing is documented here in the twelfth century (Saxo 2005, p. 411). South of Helsingborg is the Viking Age trading centre of Löddeköpinge, close to the settlement and castle of Borgeby (with an eleventh-century mint) and the small eleventh-century town of Lomma. This conglomerate of places related to the royal and clerical authorities as well as commercial interests are certainly relevant in a discussion of the formation of Havn.

So how should we picture the origin and formation of Havn among these towns and centres in the Øresund area? What role could Havn have had in relation to these other centres? Part of the answer, we believe, is to be found in the area surrounding Copenhagen.

The fertile area around early Copenhagen was densely populated by rural settlement as early as the Late Iron Age, as indicated by place names (Jørgensen 2006). We know of several medieval villages in the immediate surrounding landscape; on the island of Amager, the closely situated Sundbyvester and Sundbyøster, both on the main road towards Havn, are mentioned in written sources in 1085 (DD 1 ser., vol. 2, no. 21). In the 1186 charter mentioned above, we hear that in addition to Havn, Archbishop Absalon owned manors in Utterslev, Gentofte, Mørkhøj and a large number of villages in the vicinity of Copenhagen (see Figure 8; DD 1 ser., vol. 3, no. 137). These were presumably given to him together with Havn, suggesting that they formed parts of a network of royal manors in the region around the emerging town (Frandsen *et al.* 1996, p. 106f, Ulsig 2000, p. 89ff).

Almost no archaeological observations, however, have been made of these or other rural settlements. One exception is the village Tårnby on the island Amager, where a large-scale excavation took place in 1993–1994, yielding evidence of a medieval settlement with a Viking Age predecessor (Kristiansen (ed.) 2005). The areas where these settlements were located are today integrated into the city of Copenhagen and their medieval history is largely lost. Their relevance to the emerging town settlement of Copenhagen should however not be overlooked as we seek networks of trade and migration between town and hinterland. The nearby manors owned by Absalon (and before him by the King) must be seen as active partners with others in the town's early development. Something that could be seen as an indication of close contact between the town and the rural settlements are the treasure finds made in the areas surrounding Copenhagen (National Museum of Denmark, archive). Very few eleventh- and twelfth-century coins have been found in Copenhagen itself, but in the medieval rural areas such as Emdrup, Frederiksberg, Gentofte, Lyngby, Valby and Tårnby,

Figure 10. Air-raid shelters from World War II at Rådhuspladsen. Photo from 1944. Photographer unknown. Copenhagen City Archive.

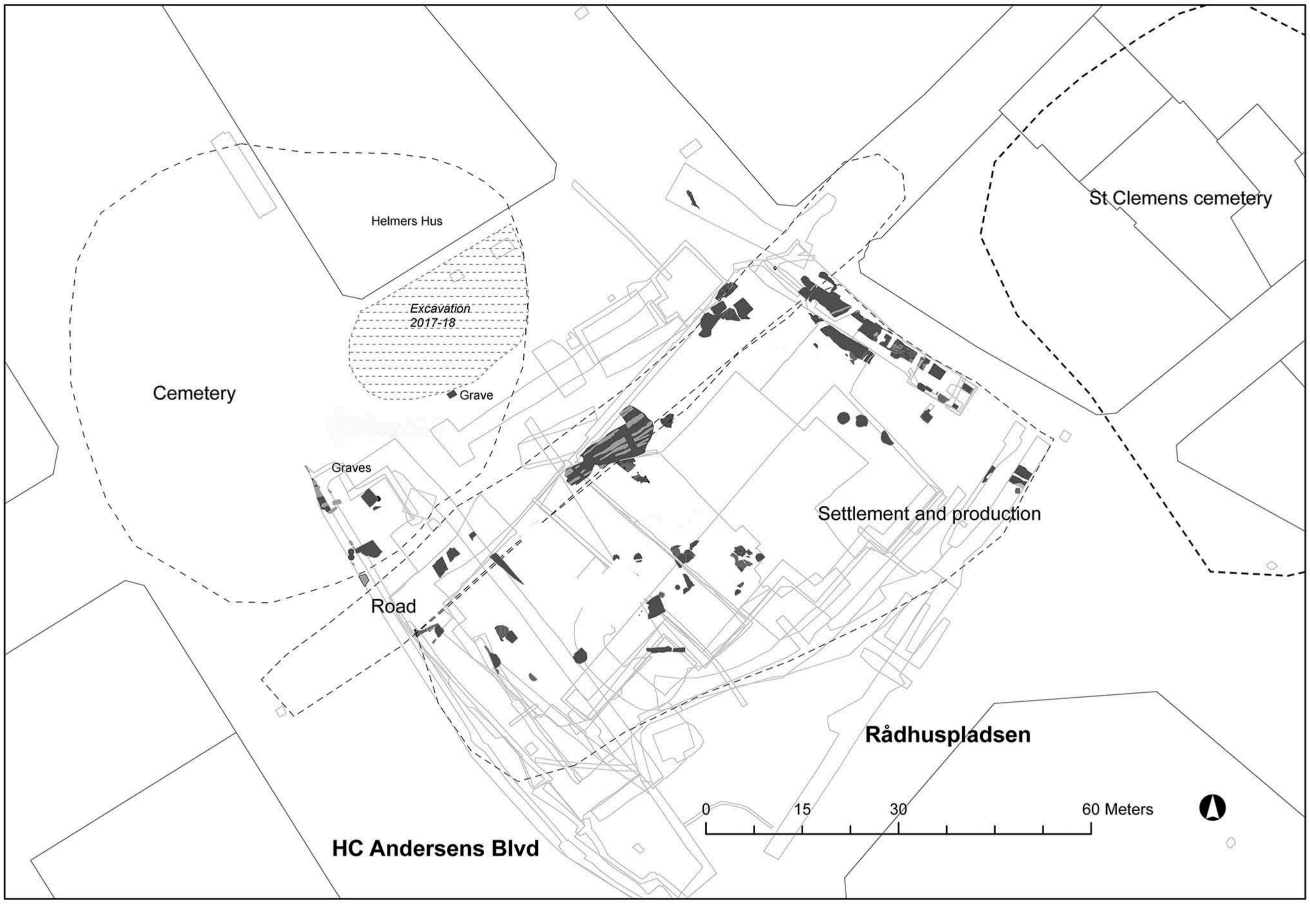

Figure 11. Area of Rådhuspladsen with medieval features revealed at the excavation in 2011–12 (KBM 3827). Areas of different functions are marked within dashed lines. Note – the dashed area within the 'Cemetery' marks the area where additional graves presently are being excavated (Dec. 2017–spring 2018; KBM 4286). Seen on the plan is also Helmers Hus, outside of which the findings of human bones were made in 1954. To the right is the presumed extent of St Clemens cemetery shown.

treasure finds both small and large of Danish, English and German coins are not uncommon (National Museum of Denmark, archive). The quite numerous finds of Arabic (kufic) tenth-century coins found in the Copenhagen region as well as in western Zealand and across the Øresund in Scania (Heijne 2004) indicates that Copenhagen was a part of an older trade network in this area.

New discoveries: early Copenhagen in a new light

During the last ten years, a number of excavations at interesting locations have produced substantial new knowledge on the medieval town (Figure 9). In addition to this, the detailed documentation methods and extensive scientific sampling undertaken at some of these excavations now enable us to ask more exact questions about chronology, activities and actors related to the material culture. Having said this, the archaeological source situation compared to some other towns is still quite modest, as most of the large-scale excavations that have taken place have been located in the outskirts of the medieval town of Copenhagen. They have also taken place in areas intensely used from the sixteenth century onwards, which has led to a high degree of interference in the form of large post-medieval truncations. This is especially the case for the Metro Cityring site at Rådhuspladsen. During World War II, many air-raid shelters were constructed on this square and these substantially damaged the medieval remains (Figure 10).

In spite of these limitations, information has come to light during this period on many aspects of the early town. Some of the new data challenges what has

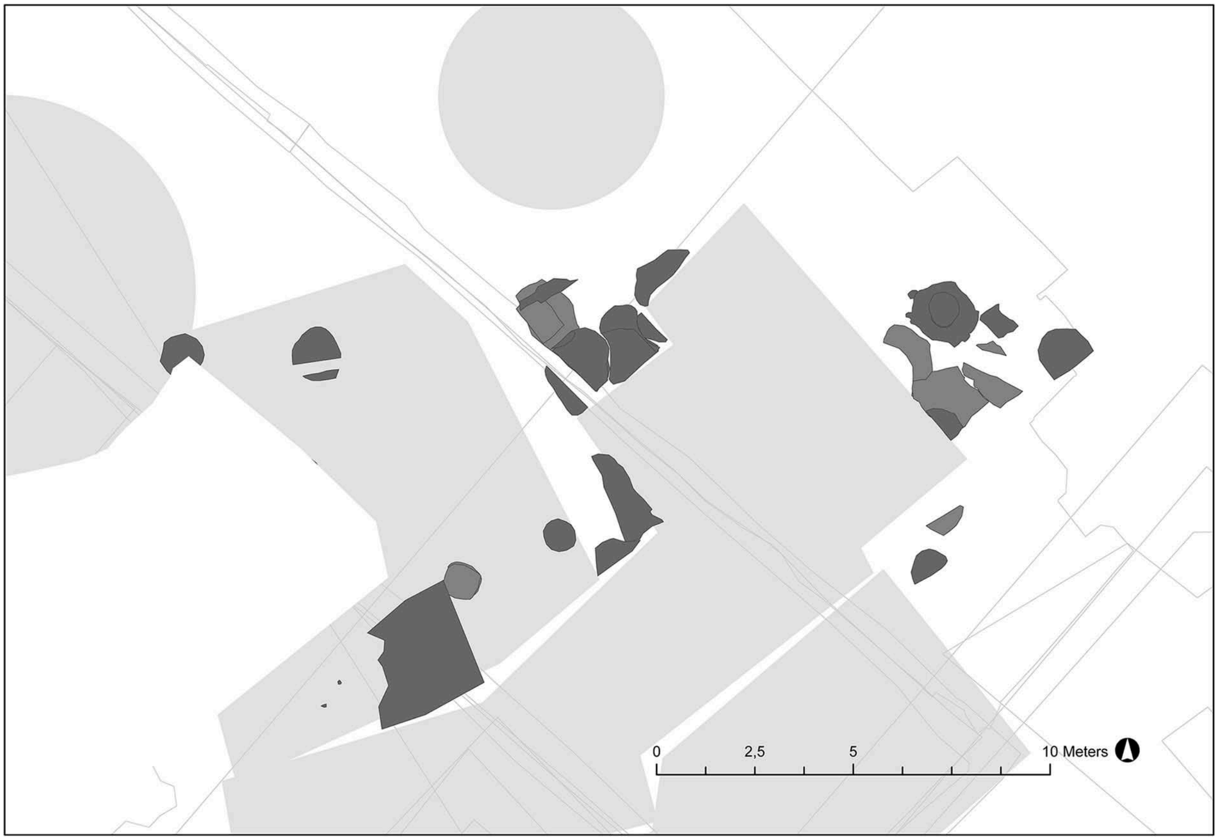

Figure 12. Area at the centre of Rådhuspladsen (KBM 3827) with several phases of early and high medieval pits.

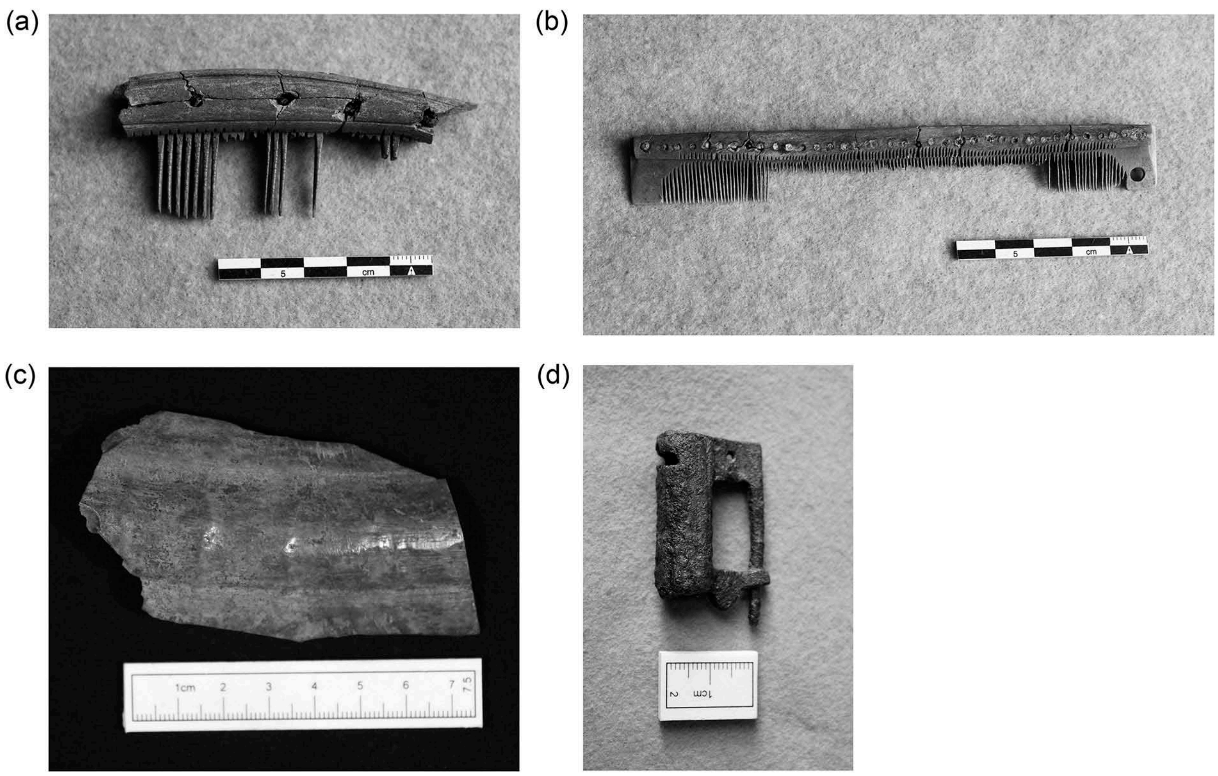

Figure 13. Some of the early medieval finds from the Metro Cityring excavation at Rådhuspladsen 2011–12. a: single-sided composite comb (FO 220,702; from pit Group 399), type dated to late tenth to eleventh century (App. 24 in Lyne and Dahlström, 2015); b: single-sided composite comb (FO 220,696; from pit Group 399), type dated to late tenth to eleventh century (ibid.); c: off-cut from walrus tooth (FO 200,988; from pit Group 104; ibid, App. 1); d: Cu Alloy padlock (FO 201,314; from pit Group 61) Photos: Museum of Copenhagen and National Museum.

previously been believed about the early town, some fills important gaps in prior knowledge, and some raises new questions. In what follows we will present the new archaeological evidence that forms the new basis for knowledge of the town development leading up to the thirteenth century. This will enable us to deal with the proposed questions of how we should understand the formation and early development of the town, who was involved in these processes, and what their motivations were. Below we will revisit earlier described knowledge and theories related to the extent of the early town, church topography, the fortifications, and the town functions or activities. We will start in the west, presenting the evidence for a new town area by Rådhuspladsen, then move eastwards in the town, discussing the previously debated concept of 'Clemensstaden'. Moving further on, we will then touch upon the question of a possible eastern settlement around Kongens Nytorv, then take a closer look at what the new evidence says about the early churches of the town. We will then make some brief points regarding the medieval fortifications, and finally we will examine the evidence for activities in the early town.

The basis for the discussion is the results of the Metro Cityring excavations between 2011 and 2016, together with a few other important excavations conducted in the city centre from 2008 to 2017. As we will see, at the time of writing (January 2018) an excavation at Rådhuspladsen is still ongoing which is yielding important new information related to the findings in the Metro excavation in 2011–2012. This underlines the fact that there is still much information about medieval Copenhagen which has yet to be revealed.

An unknown part of the early town: Rådhuspladsen and the Metro Cityring excavations

The Metro Cityring excavation at Rådhuspladsen in 2011–2012 revealed surprising finds in a previously unknown part of the early medieval settlement, including evidence for dwelling, workshops and a cemetery (Figure 11). The findings changed what we thought we knew about the earliest extent of the town, early church topography, and the medieval fortifications. They also provided us with information about early medieval activities and offered new possibilities for dating the earliest phase of settlement (Dahlström 2014, Lyne and Dahlström 2015).

The excavation, covering c. 4800 m^2, was located in the northern half of Rådhuspladsen. Here, the remains of a settlement and a workshop area dating from the late eleventh to fourteenth century were discovered. In the north-west corner, the outer parts of a cemetery were found (see description and discussion later in the text). No limits to the settlement and workshop area were found, but due to later truncations and the limited excavation area, the further extent is unknown.

The remains from the settlement area show intense activity, with several reorganisations of the area. They consist of fragments of buildings in the shape of postholes, clay floors, hearths, beam slots and demolished clay walls, storage and refuse pits, wells, levelling layers, roads made of pebbles, slag, and large animal bones, as well as a paved street. The presence of these features and finds undoubtedly speak of a busy area of a mixed dwelling and workshop character, but the fragmentation of the remains limits the detail of the information that can be gleaned. Spatial analysis of the features, combined with contextual and quantitative analyses of the refuse material recovered from the many waste pits spread over the area, will hopefully yield a more detailed picture of how the different parts of the area have been used (see Figure 12; Dahlström, forthcoming).

The find categories contain, among other things, large amounts of iron-working residue, animal bones, Early Greyware and Baltic Ware, but also bone combs and bone-working residue, tools, and building debris such as nails and daub (see Figure 13; Lyne and Dahlström, 2015). There is clear evidence of several reorganisations of the settlement area. While the remains of a road running through the area from east-south-east to west-north-west (Figure 11) seem consistent through the whole period in question, fragments of streets and open areas come and go, giving valuable information about the spatial organisation of the activities and the area's relation to activities previously documented to the east of Rådhuspladsen. Placements of pits and wells are fairly consistent, but the features have been relocated within smaller areas several times in the usage period. No detailed information can be gained from the building fragments, but here too it is evident that there are several phases of buildings, and that there was a need for rearrangement of activities within the area.

No plot borders have been established, but this could be due to the fragmentary preservation on the site.

Even though the remains are fragmentary, the area emerges as a busy site with a wide range of activities at the time. Five main phases of activity can be recognised between the late eleventh and the fourteenth century. The first, starting in the late eleventh century and ending in the early twelfth, has the character of a newly established area, with a lower density of features (Lyne and Dahlström, 2015). During the twelfth century, all activities intensify – refuse from households and also iron-working both increase, as does the number of features in the area (Dahlström, forthcoming).

With the information from the excavation at Rådhuspladsen, a plan of the western part of the early town settlement starts to form. Given that the

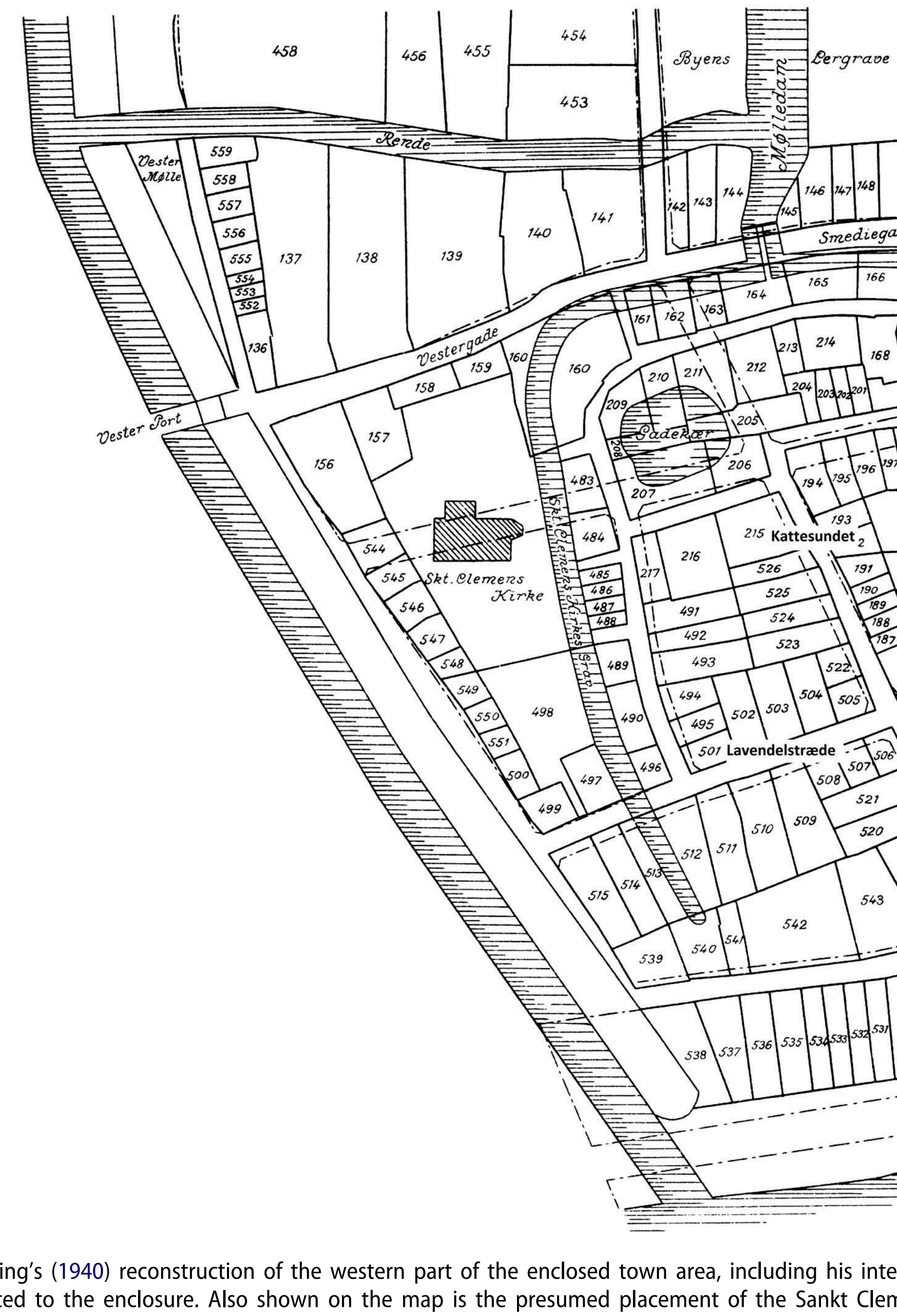

Figure 14. Ramsing's (1940) reconstruction of the western part of the enclosed town area, including his interpretations of ponds and ditches related to the enclosure. Also shown on the map is the presumed placement of the Sankt Clemens church and the present-day streets of Vestergade, Kattesundet and Lavendelstræde. Information on plots and streets from the Bishop of Roskilde's cadaster (in Danish, jordebog) from 1377 is used for Ramsing's background map.

early medieval shoreline was probably located quite near this area and also that the height above sea level rises quite fast on this part of the coastline, the area where Rådhuspladsen is situated today seems like a very good choice of location for settlement. It should again be pointed out that no limit to the settlement or to the cemetery remains towards the west was identified at Rådhuspladsen, so that it is quite possible that it continued even further outside the known later medieval town area.

It was clear from the excavation of 2011–2012 that the area has been dry since it was first settled (Hald *et al.*, 2015, p. 5). There were no traces of seasonal flooding or marshy areas such as are seen on sites further to the east. As part of the post-excavation analyses from Rådhuspladsen, microfossils retrieved from the older features were analysed in order to gather information about the general environment. The analyses showed that the collection of plants present before AD 1250 characterised a newly established environment, while the later flora to a large extent reflected a more mature urban environment. The archaeobotanical evidence further showed that its source was mainly household and workshop activities (Hald *et al.*, 2015).

Clemensstaden: a new take

The long-standing idea that the first town was limited to the so-called 'Clemensstaden' area now seems increasingly less plausible as a consequence of recent archaeological findings, primarily at Rådhuspladsen. Even if archaeologists have, as noted above, questioned this idea for some time, there has been little solid source material that might entirely dismiss the theory (El-Sharnouby and Høst-Madsen, 2008). The archaeological material encountered at Rådhuspladsen provides new data, which has enabled a clearer alternative to the traditional interpretations of the town's extent, disqualifying Clemensstaden as the site of the earliest town.

The new archaeological data requires us to go back to the enclosed area of 'Clemensstaden' and see it in a new way. If it did not frame the earliest town, what then was its function? A few recent archaeological excavations raise new questions, but perhaps also help us to think about the enclosure in a new way. In 2015, parts of a plot in Kattesundet (KBM 4088) and an area along Lavendelstræde (KBM 4022) were investigated due to upcoming commercial building development. Kattesundet is a north–south-orientated street running centrally through the Clemensstaden area (see Figure 14). In the course of construction of a new cellar in a building at Kattesundet 10, cultural layers containing early medieval finds in the shape of Early Greyware and a late Viking Age-style comb case were collected. An area of c. 10 m^2 was excavated. The cultural deposits were very homogenous: there were no marked features, but the deposits were undisturbed by later activity and showed a clear lower interface into the underlying late mesolithic culture-horizon. Above the early medieval horizon, a disturbed deposit with both later medieval and post-medieval finds was collected (KBM 4088, Ruter, 2016). Whether the lack of clearly defined features was the result of extensive bioturbation or simply marked an area that has only been little used, we know too little to say for sure. But the question does arise of what activities went on inside the early ditch and rampart if so few material traces are left. The overall impression of the remains within the enclosure is not what one would expect in a core settlement area in an early medieval town or settlement. If we look back in time, it is noticeable that all earlier observations of early settlement connected to the area of Clemensstaden derive from peripheral parts, or even from areas just outside it. If this area did not function as the core of the early medieval town of Copenhagen, what could its function have been? Before we continue with that discussion, the above-mentioned street of Kattesundet deserves a few words in connection with this discussion.

The age of this street is not known, but it appears on the oldest maps of the town (see Fabricius, 1999, p. 31ff), and the name Kattesundet appears in a number of other medieval towns in Denmark such as Lund, Malmö, Horsens, Schleswig and Svendborg (Fleischer, 1985). The meaning of the name is not completely clear, but it is believed to refer to a narrow stream or canal in the town connected to a larger body of water such as a pond, stream or the sea. In the Copenhagen case this is interesting, because the northern extension of the street beyond the presumed rampart and ditch is spatially connected to an earlier-observed pond with an east–west connected ditch (Rosenkjær, 1906, p. 36, Ramsing, 1940, bd. III, p. 47). The observations of the connecting ditch are of older date. Parts of the pond were observed again in 1987, when it was determined that the horseshoe-shaped ditch and pond could not have been part of a mill (see above; Skaarup, 1988, p. 29.) Might there have been a narrow stream running along the Kattesundet street down to the seashore, then later redirected in the twelfth century when the ditch and rampart were built and the water directed into the enclosing ditch instead? This might be a topographical situation we should bear in mind when picturing the earliest phase of the settlement in Copenhagen.

The other excavation in 2015 that produced information relevant to the enclosure was situated in Lavendelstræde, where the south-west end of the ditch and rampart were predicted to run through (Figure 14). The area in question was excavated down to 4.5 m below present street level, and at that depth natural clay was encountered. No traces were seen of either the ditch or the rampart. Instead, the deposits found were dark and very homogenous, similar to other excavated parts along Lavendelstræde that had been excavated to a depth of 2.5 m. Post-excavation analysis of the material is still undergoing, but it seems the area this close to the original waterfront had been landfilled before it was taken into use later on in the medieval period (KBM 4022). The results of this investigation must however be seen as inconclusive, adding to the scepticism about the solidity of the evidence previously regarded as fact.

It is therefore evident that at some point in the early medieval period there was some kind of ditch surrounding the whole or part of the appointed area. The archaeological evidence for the rampart which has been said to accompany the ditch is however weak, although it is likely that it existed in some form. The only solid observation was made in 1909 at the corner of Frederiksberggade/Nytorv, and to say that it has continued all the way along the ditch is, we believe, to say too much. Additionally, some of the observations of the ditch itself should be regarded with some scepticism. Most of these are very old, and the interpretations are sometimes too imaginative. Of the three excavations conducted since 1912, only one produced clear evidence of the ditch. This therefore brings us back to the question: if not a fortification, and not a mill race, what was the function of the ditch? If we move outside Copenhagen and look at other towns in Denmark, we find a couple of early fortifications that could be compared with the enclosure in Copenhagen but still show crucial differences. In Aarhus, Jutland, the first fortification, dating from the late tenth century, had a similar shape and topographical placement facing the waterfront. It is however much more robust, with a ditch 30 m wide and 3.6 m deep, and a rampart 6 m high and 18 m wide. The area it enclosed was also substantially larger (Skov, 2008, p. 222). One similarity might be that there was settlement outside the fortifications and that this was seen as a sort of suburb (Poulsen, 2011). The most relevant comparison is with Horsens, Jutland, where a similar small enclosure from the eleventh to twelfth century has been documented and interpreted as a fortification. Yet the traces of substantial settlement activity outside the enclosure in Horsens (Kristensen and Poulsen, 2016, p. 69f, 206f), again raise the question whether it is the town itself which was fortified, or a specific element of the town. Going back to Copenhagen, there is, as already mentioned, intensive settlement activity in a quite large area to the west of the enclosure. The enclosure cut through older settlement activity to both east and west, in this way marking a considerable reorganisation rather, evidently, than the first settlement area. The enclosed area is also too small to be regarded as a town – especially if the settled area outside it is larger than the alleged town itself. There are several reasons why the enclosure should not be seen as a fortification – at least not for the whole town. Against this background, we suggest that it could represent a demarcation of a royal manor predating Absalon's castle, comparable with the other rural manors around Copenhagen mentioned in Absalon's grant. The size of the enclosure could be said to fit a large manorial property better than an entire town. The back-filling of the ditch could, as previously seen, be dated to the late twelfth to early thirteenth century, which could be seen as connected to the date of the construction of Absalon's castle at a time when the manor would no longer have a function. There is at this point, however, insufficient information to conclude more definitely on this question, especially as so little is known of the activities inside the enclosure.

A settlement in the east?

Only a few minor archaeological investigations have in the last few years been undertaken in the area

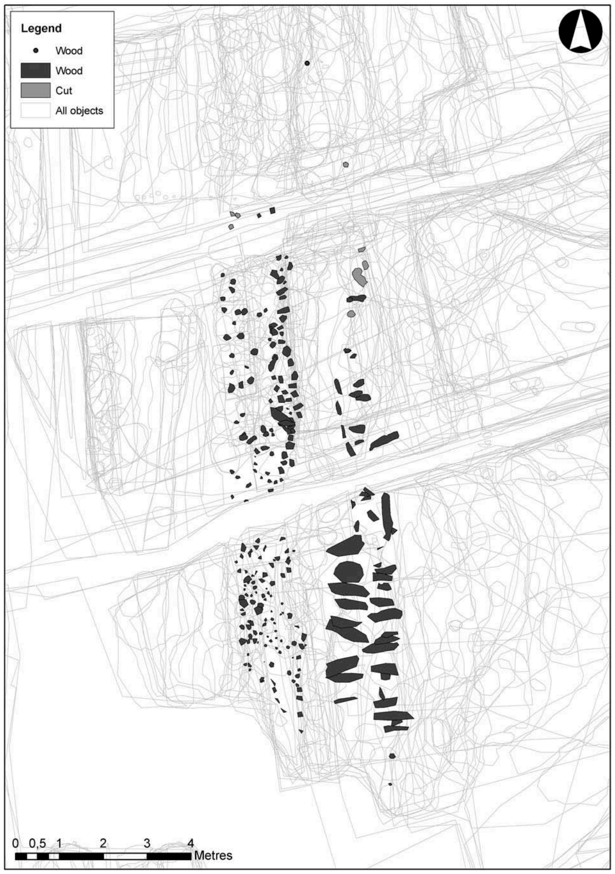

Figure 15. Bulwark related to the medieval rampart at Østerport, dated by dendrochronology to the early thirteenth century (KBM 3829). Ill: Museum of Copenhagen.

between Gammeltorv and Kongens Nytorv, and no evidence of early medieval activity was encountered in connection with these. At the other end of the medieval town, in the area of present-day Kongens Nytorv, some early remains of activity were documented at the Metro Cityring excavation in 2010–2016 (KBM 3829). In Lille Kongensgade, extensive findings of plot borders indicate a strict organisation of the area prior to 1200 (Jensen, forthcoming, Steineke and Jensen, 2017). No clear settlement indications from before AD 1200 have been found, except for the earlier findings of animal bones in backfills of ditches, telling of animal husbandry in the vicinity (Kristiansen, 1999b). The lack of settlement finds is perhaps not surprising in view of the topography, as the whole area moving east from Højbro Plads to Kongens Nytorv is very low above sea level (0–1 m). The findings of clay-lined pits and a smithy from the thirteenth to fourteenth century, telling of blacksmithing and fish handling, indicate the types of activities going on in this area early on (Steineke and Jensen, 2017). In view of its topography, the area around Kongens Nytorv should perhaps be seen to a large extent as an area utilised for less permanent activities in the early phase of the urban settlement. These might have included various different types of production, workshops and activities related to the fishing that was without a doubt so important for the economy of the town. Long-term speculations about an early eastern centre in Copenhagen, perhaps even a manor, remain unsolved in the light of the newest findings.

Medieval fortifications: a reinterpretation

In the Metro Cityring excavations of 2010–2012 in Kongens Nytorv and Rådhuspladsen, substantial new evidence from the medieval fortifications was encountered. Both the Østerport and Vesterport areas were excavated, comprising the remains of moats, gates, bridges, revetments, a wall and a rampart from the high medieval period, together with subsequent renovations and, finally, demolition in connection with the new fortifications built by King Christian IV in the mid-seventeenth century (Lyne and Dahlström, 2015, Steineke and Jensen, 2017).

At Kongens Nytorv, remains of the rampart, bulwark, and moat were preserved from the original phase of the fortifications (Figure 15). AMS and dendrochronological analyses both indicate a date for the first phase of the fortification in the early thirteenth century. The bulwark consisted of wooden stakes and planks, which were found running in parallel lines north–south and could be followed for c. 15 m. The wooden components were dated by dendrochronology as well as 14C. In total, 29 samples were analysed by dendrochronology, and the collective result shows the first construction to have taken place in the late twelfth or early thirteenth century (Steineke and Jensen, 2017). This dating span was supported by two AMS dates (ibid.). The wooden stakes are not likely to have been 'the town's planks', as rather than being placed on top of a rampart, they were driven down directly into the natural clay. The oldest rampart was seen to have been 7.6 m wide, while its height is not known due to later truncations. It was dated by one AMS sample to the early thirteenth century (Steineke and Jensen, 2017). The remains of the moat were too fragmentary to give an idea of its shape and dimensions. Solid information of the size and location of the moat were however recovered earlier, at the excavation KBM 1410 (Kristiansen, 1998).

The eastern gate building was also encountered during the excavation of 2010–2011. The remains of a massive stone foundation, with traces of brickwork attached, gave the impression of an impressive eastern entrance to the high medieval town. A road with wheel ruts was preserved running through the gate building (Steineke and Jensen, 2017).

The difference in dates compared to those revealed by the first Metro excavation further south may be explained by the different source materials and dating methods used. It could also be that the remains found at the southern end represented a renovation rather than the earliest phase. The dendrochronological dates for the bulwarks found in the 2010–2011 excavation are very solid, and must mean that the earliest phase of fortification on the eastern side of the town should be dated to the first decades of the thirteenth century.

In contrast to the early dates for Kongens Nytorv, the Rådhuspladsen dates proved to be very late. The remains of a western gate consisted of a gate building, moat, rampart, and three consecutive bridges crossing the moat (Lyne and Dahlström, 2015, p. 170ff). No evidence of a brick wall was found, and only the lower parts of earthen ramparts. Nor was a wooden post structure found comparable to that at Kongens Nytorv. The medieval moat had been partly destroyed by later moat expansions, showing that the moat was remodelled several times up to about AD 1600, when a mill was constructed south of the gate and the area thoroughly reconstructed. The remains indicate that the medieval moat was 22 m wide and 6 m deep at the western gate area (Lyne and Dahlström, 2015, p. 172). The most reliable date for the oldest phase of the fortifications at the western gate area comes from the bridge across the moat. Deep down a timber structure was found, which had been functioning as the foundation of what seems to have been the oldest bridge across the moat, leading traffic in and out of the western

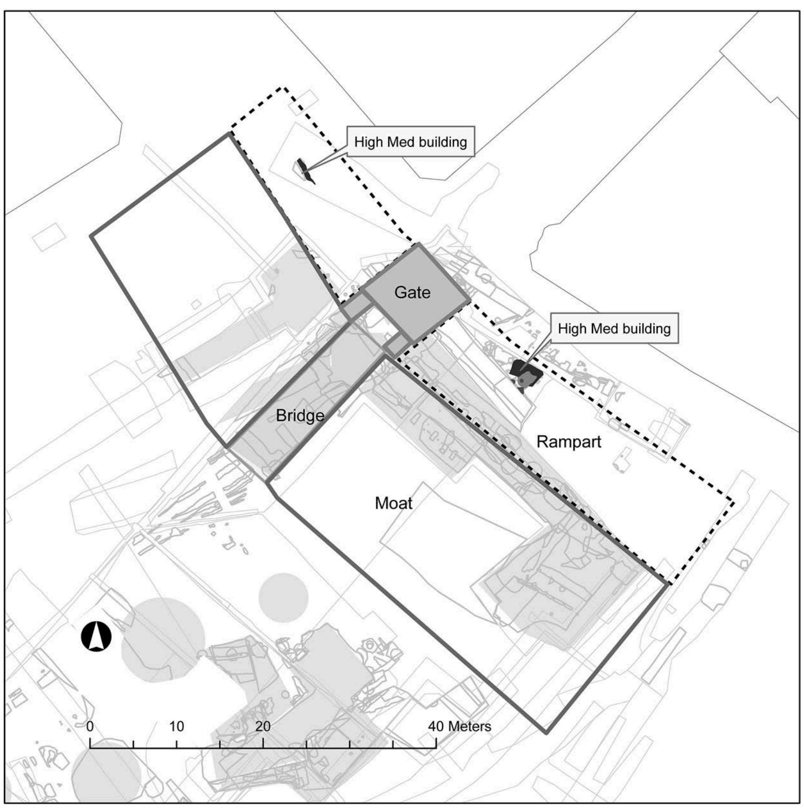

Figure 16. Reconstruction of the area around the medieval western gate according to information from the 2011–2012 and the 2016 excavations (KBM 3827). Archaeological remains of thirteenth/fourteenth-century building fragments covered by the rampart are shown in black. Reconstruction of the placement of the rampart is seen as a dashed line. Reconstruction of the placement of the moat is seen as a solid line.

parts of town. The timbers were dated by dendrochronological analysis to AD 1361, 1370/71, 1371/72 and 1406 (±7; ibid. p. 174ff and Appendix 4). The 1406 date probably represents a later repair, but the other dates quite clearly indicate a date for the oldest preserved bridge to around AD 1372. Nothing seen during fieldwork in the character of the cuts, cultural deposits, or general stratigraphic situation suggested the removal of a large older structure at this location. It is of course a possibility that there had been an older wooden bridge, which was replaced by that of c. 1372. In 2016, an addition to the large excavation field of 2011–2012 was excavated, and this time the original moat cut and the undisturbed primary deposits at the very bottom of the moat could be sampled for 14C analysis. A thistle head lying at the very base of the moat cut was AMS-dated to the most likely date of the mid-to-late-fourteenth century (Lyne and Dahlström, 2016, p. 45). In view of the date from the bottom of the oldest moat on site, together with the results of the dendrochronological analysis of the bridge foundation, a date of c. AD 1372 seems likely (ibid.). In relation to this date, the 1368 attack on Copenhagen by Lübeck should be mentioned. The town is said in the written sources to have been completely devastated (Kjersgaard, 1980, p. 100f). Could the date of the bridge at Vesterport be related to this attack? Was it after this that the fortifications around Copenhagen were finally completed, or does the date from the bridge merely represent a new bridge, rebuilt after the attack?

Of interest when speaking of a date for the oldest western fortification is the extent of the high medieval remains encountered at Rådhuspladsen in 2011–2012. Here, substantial high medieval settlement remains were found very close to the post-medieval moat cut (see Figure 16). Spatially, they must at one point have been covered by the rampart. Remains of buildings with clay floors, a cellar, and demolished walls of wattle and daub were seen to continue all the way towards a spot where they would have been either truncated by the moat cut or covered by the rampart. One building fragment was preserved with six phases of floor constructions: of these, the second level was AMS-dated to the late-thirteenth century, and the fourth to the fourteenth century (Lyne and Dahlström, 2015, p. 140). In another building, pottery finds consisting of Early Redware, Late Greyware and German Stoneware date the usage phase to the thirteenth/fourteenth century (ibid. p. 138). The late dating for

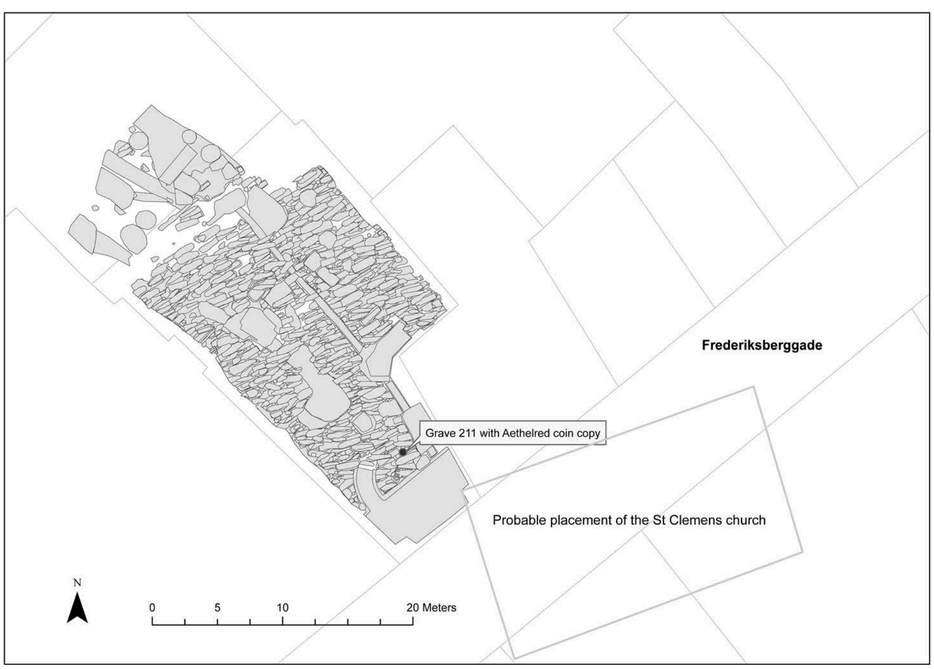

Figure 17. Plan of all graves and other features excavated at Sankt Clemens cemetery in 2008 (KBM 3621).

(a) (b)

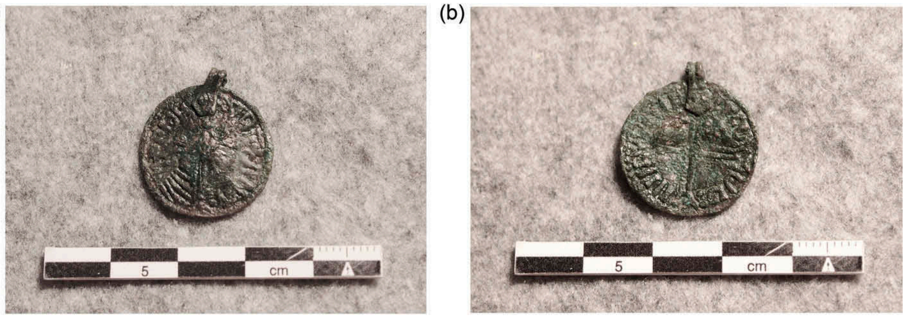

Figure 18. a-b. Pendant made of Cu-Alloy imitating a coin (diameter 23 mm; KBM 3621:×496) from a grave at Sankt Clemens cemetery. There is a loop attached to the edge to fit with a string or chain. Averse (a) with portrait of a king in profile. That the king depicted is the English King Aethelred 2. (r. 1013–1016) is made clear by the legend referring to Aethelred king of the Englishmen. The reverse (b) bears a double cross surrounded by an inscription with letters that can be seen as a corruption of LUND. The pendant was found on top of the chest of the buried individual, who was a child. According to stratigraphy, the grave belonged to the oldest usage phase of the cemetery. The pendant is manufactured in Lund and can be dated to the first half of the eleventh century. It is difficult to find exact parallels, but in the village Örja close to Helsingborg, Scania, a similar pendant was found in 2010, imitating a Magnus den Gode (1042–47) penny from Lund (information by Gitte Ingvardsen, Historical Museum in Lund; (Sabo (ed) 2013)); and in the village Hyllie outside of Malmö, Scania, a silver penny imitating an Aethelred coin) was found in 2000 (Falk *et al.*, 2007, p. 40). Photos: Museum of Copenhagen.

these buildings, located so close to the moat cut, makes it unlikely that an earlier defence structure was located here. The defence structure of which the primary moat fill and the bridge foundation were part had clearly disturbed the western part of the town settlement, and this probably took place some time in the fourteenth century. If there was an earlier defence crossing the eastern parts of Rådhuspladsen, its remains are totally lost. Even if it could be argued that it has been dug away by later moats, the fact remains that settlement remains from the fourteenth century (and at least from the thirteenth century) probably lay in the path of an earlier moat and rampart. The indications for a scenario in which the western parts of the town's defences were not finalised until 1372 must be seen as strong.

Taken together, the findings from Kongens Nytorv and Rådhuspladsen show a very different picture of the character and the date of the remains, indicating that the process of construction was very extended and perhaps marked by conflict. Given that the area where the western part of the fortifications were to be built was at the time an integrated part of the town area, it could be this situation that lay behind the previously mentioned law of 1254 and the letter of 1289.

Contrary to previous theories, all evidence now points to the eastern part of the fortifications being built first, at the start of the thirteenth century, and reaching completion in the western part possibly as late as 1372. The difference in construction elements also indicates that there were different requirements for the eastern and western parts of the fortification. It seems likely that a town wall did not extend all the way around; earthworks and planks have covered parts of the stretch. The very long construction period suggested is noteworthy, and indicates circumstances which we do not know about at this point. This will be further discussed below.

The earliest churches of the town

The cemetery of Sankt Clemens

In 2008, a large excavation in the northern part of the cemetery belonging to the church of Sankt Clemens confirmed earlier theories of an early date for this church. Within an area of 700 m^2 a total of 1048 graves were documented, some of which contained more than one individual (see Figure 17; Jensen and Dahlström, 2009, Jensen, 2017). Most of the graves were lying in stratigraphical sequences of up to seven layers, and the majority of the burials were more or less truncated by younger graves (Jensen and Dahlström, 2009). It was very clear that the cemetery, or at least this part of it, had been densely used for a long time. No traces of the church itself were found, but on several occasions throughout the twentieth-century parts of the stone foundation has been encountered (Rosenkjær 1910, p. 4, Ramsing, 1940, p. 31, Hansen 1991 (KBM 589)).

A number of the oldest grave cuts in the 2008 excavation had an alignment separating them from the rest, indicating that they were orientated towards an older church than the rest of the graves. Based on the arm positions of the individuals buried, as well as a pendant belonging to a child found in one of the graves, a preliminary oldest date of the cemetery to the second part of the eleventh century was made (Jensen and Dahlström, 2009, p. 23, 56). The pendant was made as an imitation of an Aethelred II penny (AD 978–1016; Jensen and Dahlström, 2009, p. 56; see Figure 18(a,b)). Such pendants imitating coins are known to have been struck in Lund during the early part of the eleventh century (Märcher, 2010, p. 203, Kristensen 2009, p. 5). The proposed eleventh-century date of this part of the cemetery is considerably earlier than that previously suggested for the oldest church in Copenhagen (see above). The suggested date, together with different orientation of the oldest graves, is a strong indication of an earlier church, rebuilt already in the twelfth century in stone and brick. It seems very likely that the older church was a wooden church, although no archaeological remains of one have yet been found. Observations of oak posts found within the stone foundation discovered in 1906 are due to their placement among the stones, more likely to belong to the construction of the stone church itself (Jensen and Dahlström, 2009, p. 15).

A date in the eleventh century for the oldest Sankt Clemens church has implications for who could have been behind its construction. If the second part of the twelfth century had seemed likely, Bishop Absalon would naturally be a plausible candidate; but if the eleventh century is more likely following the results of the 2008 excavation, that would suggest a different scenario. It would mean that the construction of the wooden church would have been one of the earliest activities in Copenhagen, and that it should be seen in relation to the very first step in the town formation process. The general history of the churches of Sankt Clemens has been investigated by various scholars (i.e. Cinthio, 1968, Crawford, 2006). There were 21 known Sankt Clemens churches in the Danish territory of Canute the Great (king of Denmark 1018–1035), as well as 40 in the south-east of England, mostly in the Danelagen area. The large number of Danish Sankt Clemens churches is clearly a consequence of the connection between Denmark and England stemming from the Viking Age, which is also seen in the influence from England in the early phase of the Christianisation of Scandinavia. The Sankt Clemens churches in Denmark are believed to have been instigated by the king or members of his retinue in the eleventh century, and there are several examples of the churches being situated in close proximity to a royal manor, for example in Roskilde and Horsens (Nyborg, 2004, p. 127ff). What we know about the Sankt Clemens churches makes an eleventh-century

Figure 19. (a) Plan of the burials, including burial id's, found at the excavation at Rådhuspladsen in 2011, together with the presumed border ditch to the south. Reconstructed orientation of the ditch is shown with dashed lines. (b) Plan of the burials and border ditch from 2011 seen together with burials recorded so far (February 2018) from ongoing excavation (KBM 4286) of what is interpreted as another part of the same cemetery.

Figure 20. Grave of a child with an estimated age of five (G 117, skeleton id: SB8025). Traces of a decayed coffin are seen around the body. The grave had been truncated from above by an infant's grave and had a piece of human bone found in its fill, indicating the presence of yet older graves. Photo: Museum of Copenhagen 2011.

date for the Copenhagen church even more likely, and as a consequence, also for the early town settlement. As discussed above, if we are to look for a royal manor in eleventh-century Copenhagen, the enclosed area immediately to the east of Sankt Clemens church may be where we should turn. The dating of the construction phase as well as the disuse phase of the horseshoe-shaped structure would support this theory.

The cemetery at Rådhuspladsen

Our understanding of the early church topography of Copenhagen changed profoundly in 2011 when the remains of another cemetery were discovered at the north-west corner of Rådhuspladsen. The findings were a complete surprise, as there was no previous knowledge of this cemetery either in written sources or in archaeological records. A total of 17 *in situ* graves, most of which were severely truncated, were seen (see Figure 19(a,b)) . The burials were placed evenly distanced from one another, revealing a structure and organisation of the cemetery rather like that of a permanent parish cemetery (as opposed to a more temporary burial ground such as a plague cemetery). In some instances the burials were on two stratigraphical levels, this also pointing to more than a very short-lived feature. In 10 graves *in situ* skeletons were found, and in most of the graves there were also disarticulated bones. The individuals were women, men and children, the youngest individual among them a 3-month-old infant, while the oldest was a man of 50–60 years of age (see Figure 20). Nothing particular was noted about their health condition, with the exception perhaps of two individuals who were unusually tall – 170 cm for a female and 179 cm for a male. With all the bone material seen together, the skeletal material made up a total MNI (Minimal Number of Individuals) of 21 (Lynnerup, 2011). To the south of the graves was a ditch, interpreted as a boundary ditch and AMS-dated to AD 1025–1210 (Cal 2 sigma) and AD 980–1155 (Cal 2 sigma; see Table 2, Lyne and Dahlström, 2015). AMS dating of the coffin wood and the skeletal material confirmed the suspicions of an early date, and a *weighted mean* of the calibrated AMS dates from the skeletons gave the result AD 1026–1155 (Cal 2 sigma; Kanstrup and Heinemeier, 2013).

The organisation of the graves in the very small area excavated, about 35 m^2, showed that the graves continued towards the west, east, and north, and that grave density increased towards the north. This, together with the possible border ditch, was a strong indication that this was just the outer part of a possibly considerably larger burial ground with its centre towards the north (Dahlström, 2014, p. 140f). In addition to this, parts of another burial had earlier in the excavation been documented 20 m to the east of the cemetery. At that time, a pair of shin bones were collected from a very small trench, 0.5 × 0.5 m and c. 1.5 m deep (see Figure 11). Since no knowledge of the cemetery existed at the time of the find, it was considered as being without further context. This was probably the reason why these bones were later lost, and they were unfortunately not AMS-dated. Yet another observation of human bones in the immediate area supports the theory of a substantially larger cemetery. In the Museum of Copenhagen's archive there is a note of human

Table 2. Radiocarbon sample from Sankt Clemens and Rådhuspladsen. AAR samples are analysed at Aarhus AMS Centre, Aarhus University, Denmark and LuS samples are analysed at SSAMS Radiocarbon dating laboratory, University of Lund, Sweden.

Lab ID	Material	$\delta^{13}C$ (‰ VPDB)	$\delta^{15}N$ (‰ VPDB)	F_{marine} (%)	^{14}C Age (^{14}C years BP)	Calibrated age, AD, (unmodelled) 68.2% conf. interval (1σ)	Calibrated age, AD, (unmodelled) 68.2% conf. interval (2σ)	Calibrated age, AD, (modelled) 68.2% conf. interval (1σ)	Calibrated age, AD, (modelled) 68.2% conf. interval (2σ)	A
St. Clements (start)								1005–1099 [68.2%]	940–1129 [95.4%]	
AAR-25,565	Human	−19.6	12.9	4%	951 ± 34	1037–1057 [13.8%] 1077–1154 [54.4%]	1021–1183 [95.4%]	1045–1055 [7.4%] 1063–1123 [60.8%]	1028–1144 [95.4%]	107.0%
AAR-25,556	Human	−19.7	11.0	3%	1097 ± 26	985–1021 [68.2%]	903–921 [4.8%] 951–1033 [90.6%]	985–1022 [68.2%]	903–921 [4.5%] 950–1034 [90.9%]	99.5%
AAR-25,564	Human	−19.1	12.8	9%	1006 ± 37	993–1047 [48.5%] 1095–1121 [16.8%] 1142–1147 [2.8%]	981–1155 [95.4%]	1101–1128 [37.6%] 1133–1153 [30.6%]	1040–1052 [2.0%] 1068–1164 [93.4%]	70.5%
AAR-25,562	Human	−17.7	14.6	23%	909 ± 28	1054–1081 [18.3%] 1152–1212 [49.9%]	1042–1110 [29.9%] 1116–1222 [65.5%]	1155–1206 [68.2%]	1116–1245 [95.4%]	112.0%
AAR-25,561	Human	−19.2	11.5	8%	1009 ± 26	1018–1049 [38.3%] 1091–1122 [25.3%] 1141–1148 [4.7%]	996–1069 [49.8%] 1076–1154 [45.6%]	1028–1038 [7.2%] 1088–1127 [45.8%] 1136–1151 [15.2%]	1017–1056 [20.3%] 1071–1157 [75.1%]	86.2%
AAR-25,560	Human	−19.3	12.2	7%	789 ± 36	1225–1235 [11.5%] 1242–1280 [56.7%]	1192–1294 [95.4%]	1218–1258 [68.2%]	1183–1274 [95.4%]	82.1%
AAR-25,559	Human	−18.8	12.9	12%	831 ± 29	1224–1267 [68.2%]	1191–1282 [95.4%]	1244–1276 [68.2%]	1224–1283 [95.4%]	105.3%
AAR-25,558	Human	−19.6	12.9	4%	1007 ± 35	995–1047 [48.3%] 1095–1120 [17.5%] 1143–1147 [2.4%]	986–1155 [95.4%]	1028–1034 [3.7%] 1087–1152 [64.5%]	1014–1159 [95.4%]	83.8%
AAR-25,557	Human	−18.5	12.9	15%	972 ± 36	1061–1080 [8.0%] 1127–1137 [4.4%] 1150–1223 [55.8%]	1048–1110 [19.9%] 1115–1253 [75.5%]			
AAR-25,563	Human	−17.3	13.4	28%	931 ± 30	1162–1227 [68.2%]	1056–1082 [4.0%] 1126–1138 [1.6%] 1150–1265 [89.7%]	1179–1242 [68.2%]	1159–1263 [95.4%]	105.2%
AAR-25,555	Human	−19.3	12.1	7%	699 ± 30	1283–1311 [38.1%] 1363–1386 [30.1%]	1275–1327 [51.4%] 1346–1394 [44.0%]	1278–1305 [68.2%]	1264–1326 [92.1%] 1361–1381 [3.3%]	101.7%
St. Clements (end)								1283–1336 [68.2%]	1271–1416 [95.4%]	
LuS-10,810 (90)	Soil				1115 ± 35	894–976 [68.2%]	778–791 [2.0%] 827–841 [1.6%] 864–1016 [91.8%]	894–975 [68.2%]	778–791 [1.8%] 811–818 [0.7%] 825–842 [1.8%] 863–1015 [91.1%]	
Rådhuspladsen (start)								1016–1036 [68.2%]	995–1044 [90.5%] 1090–1113 [4.9%]	
LuS-10,400 (35)	Human	−18.0	13.3	20%	1045 ± 50	1018–1060 [26.9%] 1079–1152 [41.3%]	978–1187 [95.4%]	1024–1042 [68.2%]	1013–1060 [88.0%] 1091–1124 [7.4%]	136.2%
LuS-10,401 (117)	Human	−19.5	11.0	5%	1030 ± 50	975–1048 [52.4%] 1091–1122 [13.1%] 1141 – 1148 [2.7%]	900–924 [4.8%] 946–1157 [90.6%]	1021–1039 [68.2%]	1007–1050 [89.5%] 1094–1119 [5.9%]	139.0%
LuS-10,405 (72)	Human	−17.4	15.5	26%	1080 ± 50	995–1059 [38.9%] 1081–1126 [23.6%] 1138–1150 [5.7%]	910–915 [0.4%] 964–1181 [95.0%]	1026–1045 [68.2%]	1017–1062 [87.6%] 1093–1126 [7.8%]	146.9%
LuS-10,404 (24–216,231)	Human	−18.3	12.5	17%	1045 ± 50	997–1056 [35.1%] 1081–1128 [25.7%] 1136–1151 [7.4%]	967–1185 [95.4%]	1023–1040 [68.2%]	1011–1055 [88.7%] 1090–1120 [6.7%]	148.0%
LuS-10,399 (89)	Human	−19.3	10.8	7%	995 ± 50	1019–1055 [23.7%] 1080–1153 [44.5%]	981–1189 [95.4%]	1023–1040 [68.2%]	1012–1055 [88.5%] 1089–1120 [6.9%]	132.3%

(*Continued*)

Table 2. (Continued).

Lab ID	Material	$\delta^{13}C$ (‰ VPDB)	$\delta^{15}N$ (‰ VPDB)	F_{marine} (%)	^{14}C Age (^{14}C years BP)	Calibrated age, AD, (unmodelled) 68.2% conf. interval (1σ)	Calibrated age, AD, (unmodelled) 68.2% conf. interval (2σ)	Calibrated age, AD, (modelled) 68.2% conf. interval (1σ)	Calibrated age, AD, (modelled) 68.2% conf. interval (2σ)	A
LuS-10,403 (23)	Human	−18.7	13.5	13%	1040 ± 50	990–1053 [41.1%] 1084–1125 [21.5%] 1138–1150 [5.5%]	903–921 [1.7%] 954–1166 [93.7%]	1027–1046 [68.2%]	1021–1065 [86.2%] 1090–1130 [9.2%]	138.3%
LuS-10,398 (68)	Human	−18.6	13.0	14%	1065 ± 50	971–1050 [54.4%] 1090–1122 [12.0%] 1142–1147 [1.8%]	899–926 [5.4%] 943–1156 [90.0%]	1023–1042 [68.2%]	1010–1055 [88.6%] 1094–1122 [6.8%]	129.3%
LuS-10,457 (13–216,240)	Human	−18.8	12.3	12%	1070 ± 45	906–917 [3.7%] 966–1045 [63.2%] 1111–1115 [1.3%]	895–1056 [81.6%] 1080–1152 [13.8%]	1021–1039 [68.2%]	1008–1049 [89.7%] 1096–1118 [5.7%]	104.5%
LuS-10,401 (13–216,228)	Human	−18.7	11.9	13%	990 ± 50	1033–1070 [21.2%] 1076–1153 [47.0%]	1013–1212 [95.4%]	1026–1046 [68.2%]	1019–1064 [87.8%] 1095–1126 [7.6%]	108.8%
LuS-10,397 (29)	Human	−18.8	12.0	12%	1010 ± 50	1021–1056 [23.5%] 1079–1152 [44.7%]	984–1189 [95.4%]	1024–1042 [68.2%]	1014–1061 [87.9%] 1091–1124 [7.5%]	129.5%
LuS-10,458 (180–216,242)	Human	−19.4	12.0	6%	985 ± 45	1022–1054 [21.8%] 1081–1152 [46.4%]	989–1170 [94.9%] 1177–1182 [0.5%]	1025–1042 [68.2%]	1015–1060 [87.9%] 1091–1124 [7.5%]	125.2%
LuS-10,459 (180–216,243)	Human	−19.0	10.0	10%	965 ± 45	1045–1154 [68.2%]	1022–1209 [95.4%]	1025–1043 [68.2%]	1017–1065 [88.0%] 1090 – 1124 [7.4%]	89.0%
LuS-10,455 (476/180)	Human	−17.3	13.7	27%	1075 ± 45	1017–1065 [32.3%] 1079–1128 [28.7%] 1137–1151 [7.2%]	979–1168 [95.4%]	1024–1042 [68.2%]	1013–1059 [88.2%] 1092–1123 [7.2%]	143.1%
LuS-10,464 (88)	Human	−18.9	12.7	11%	1005 ± 45	1022–1055 [22.9%] 1080–1152 [45.3%]	988–1171 [95.0%] 1178–1181 [0.4%]	1025–1042 [68.2%]	1015–1060 [87.9%] 1091–1124 [7.5%]	127.5%
LuS-10,463 (127	Human	−18.9	12.9	11%	990 ± 45	1029–1056 [18.4%] 1079–1153 [49.8%]	998–1191 [95.4%]	1025–1042 [68.2%]	1016–1062 [87.8%] 1090–1124 [7.6%]	110.0%
LuS-10,456 (122)	Human	−19.1	12.3	9%	1015 ± 40	1014–1053 [32.1%] 1083–1126 [28.0%] 1137–1151 [8.1%]	989–1158 [95.4%]	1024–1041 [68.2%]	1013–1056 [88.1%] 1093–1123 [7.3%]	147.6%
LuS-10,819 (22–10,353)	Non specified				995 ± 35	993–1045 [50.5%] 1097–1120 [15.4%] 1143–1147 [2.3%]	983–1059 [58.7%] 1068–1155 [36.7%]	1023–1040 [68.2%]	1013–1052 [88.6%] 1096–1121 [6.8%]	143.9%
LuS-11,074 (22–241,748)	Pig bone				920 ± 40	1043–1107 [41.6%] 1118–1159 [26.6%]	1026–1206 [95.4%]	1025–1044 [68.2%]	1018–1066 [88.2%] 1091–1124 [7.2%]	77.9%
Rådhuspladsen (end)								1030–1051 [68.2%]	1022–1072 [85.3%] 1102–1154 [10.1%]	

All δ13C and δ15N values are measured at Aarhus AMS Centre, Aarhus University, Denmark. Radiocarbon ages are reported as conventional 14C dates in 14C yr BP based on the measured 14C/12C ratio corrected for the natural isotopic fractionation by normalising the result to the standard δ13C value of −25‰ VPDB (Stuiver and Polach, 1977). The 14C age of the humans are reservoir corrected using the measured δ13C values with a terrestrial and marine isotopic endpoints of δ13Cterrestrial = −20‰ and δ13Cmarine = −10‰, respectively. The resulting marine diet fraction is shown as Fmarine with an estimated error of 4%. The soil sample is calibrated with IntCal13 (Reimer *et al.*, 2013) using OxCal 4.3 (Bronk Ramsey, 2009). The humans are calibrated using the mixed curve approach with the estimated Fmarine to determine the mixture between the atmospheric (IntCal13) and the marine (Marine13) calibration curves using OxCal 4.3. A Bayesian model (implemented with OxCal using the sequence method) is used to estimate the start and end date for each locality constrained using stratigraphical information (see Figure 21).

bones being found in 1954 outside the building Helmers Hus, about 30 m north-east of the graves found in 2011. At the time it was not known if the bones were old or recent, so the police had been contacted (Museum of Copenhagen archive, unnumbered case, Rådhuspladsen 1954, Lyne and Dahlström, 2015, p. 28). It was later confirmed through contact with the police that there was no record of this resulting in a police case. Thus the bones located outside Helmers Hus' were probably of older date, and it seems a likely possibility that these bones were connected to the cemetery found in 2011.

The observations gathered surrounding the burials at the edge of Rådhuspladsen strongly indicate that these should be seen as the southern edge of a larger cemetery, most likely connected to a church which was taken out of use early on and was not mentioned in written sources. The presumed church would have been placed to the north, which would thus extend the early settlement area of Copenhagen even further. Also, encountering two stratigraphical levels (plus disarticulated bones, suggesting additional destroyed burials) at the edge of the cemetery suggests that a denser use might be imagined further in towards the presumed centre. Very recent events have confirmed the theory of the cemetery extending towards the north and the north-east. At a presently ongoing excavation (February 2018; KBM 4286) in the northernmost part of Rådhuspladsen, close to Helmers Hus, the cuts for c. 25 graves have so far been uncovered. It is clear that they are part of the same cemetery as the one excavated in 2011. If the same grave density and stratigraphic circumstances are to be expected for the new graves, there could be as many as 50 new graves to add to the 17 found in 2011.

With the information we have so far about this cemetery, it could have been a quite substantial one with many burials. The early date, combined with the fact that the cemetery (and the presumed church) seem to have been taken out of use before long, speak for it having been a wooden church, built on private initiative. Eleventh-century Northern Europe was characterised by proprietary churches, built by lords. Many of these churches were taken out of use once the parish system was fully established, one to two hundred years later. These early churches functioned as 'neighbourhood churches' or 'proto-parish' churches, gathering the people who in some way were connected to the church builder (Nyborg, 2004, p. 137f, Wood, 2008). We would like to interpret the Rådhuspladsen church as such a proprietary church. It is likely, that a manor belonging to the church builder was located close to the cemetery. No archaeological evidence of such a feature has yet been found, but a logical place to search for it would be further to the west, north or north-east.

Discussing the background to the church, the Sankt Olav church of 1261, mentioned earlier, comes to mind. Sankt Olav churches are common in Scandinavia, and often date from the eleventh century. However, if the Rådhuspladsen church was the Sankt Olav church, either it was moved already in the twelfth century, or the extent of the cemetery had been made smaller, or changed. As we will see below, none of the existing AMS-dated graves are as young as the thirteenth century.

Chronological discussion

If Copenhagen seems to have had two churches already in the eleventh century, this has implications for the discussion of who played a role in the early development of the town, the type of place that developed, and the groups of people who might have lived there. The dates for the Sankt Clemens church and the presumed church north of Rådhuspladsen so far suggest that they were at least partly contemporary. As a way to narrow the dating spans for the two cemeteries, more radiocarbon samples, including stable isotope analyses and Bayesian statistic modelling of the data, have been undertaken. The main objectives of the analyses were to determine which cemetery was the oldest and if they existed at the same time. No AMS dates existed prior to this for the Sankt Clemens material, and for the Rådhuspladsen material additional statistical modelling work was required to interpret the isotopic information, correcting the 14C ages by taking the reservoir effect into consideration, because of fish consumption by the sampled individuals as indicated by the stable isotope values. In the Bayesian modelling, the stratigraphic position of the graves is considered as an additional (relative) dating information, which is put into the models to help constrain the modelled age range (Bronk Ramsey, 2009).

For Sankt Clemens cemetery, a total of ten skeletons belonging to three individual, stratigraphical strands were sampled (see Figure 21(a,c)). Each of

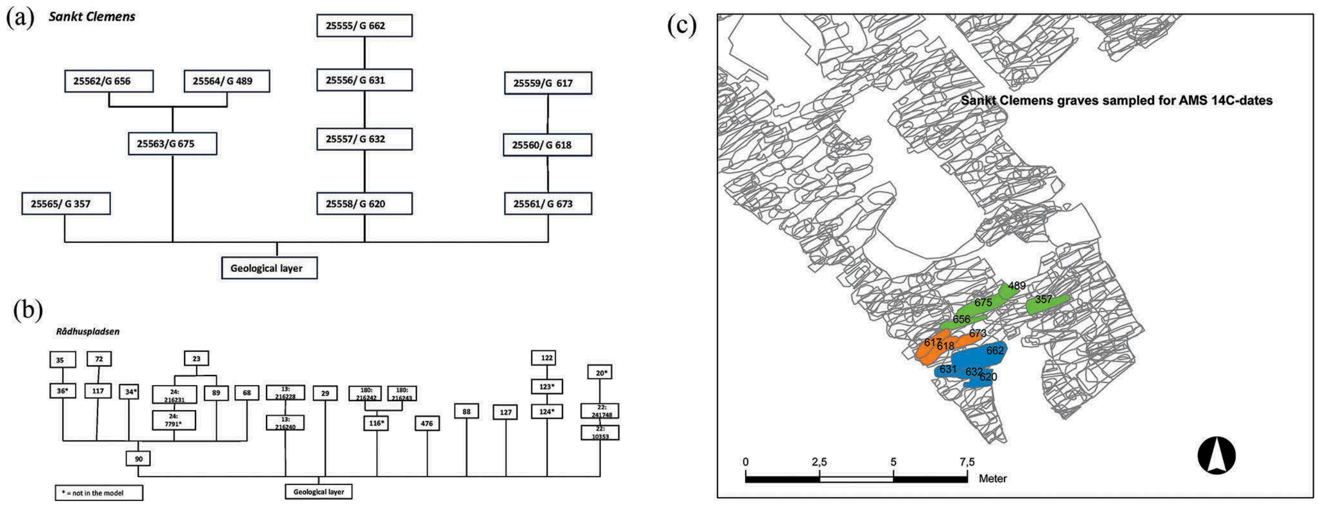

Figure 21. (a) Harris matrix showing the stratigraphical positions and relations between the features included in the St Clemens model shown in Figure 21. (b) Harris matrix showing the stratigraphical positions and relations between the features included in the Rådhuspladsen model shown in Figure 22. (c) Close-up of part of Sankt Clemens cemetery with sampled graves marked. See Figure 19 a for id:s of the sampled graves from Rådhuspladsen.

these strands consisted of three or four skeletons with direct physical, stratigraphical relations to the others in the same strand. One sample is a singular unit with no direct stratigraphical relations to the other graves. For the Rådhuspladsen cemetery, nine *in situ* skeletons in up to two stratigraphical levels, plus disarticulated bones found in one of the graves were put into the model (Figure 21(b)). The disarticulated bones were found in the grave fill and in the model considered as belonging to an older, disturbed grave. In addition to the skeletal material, charcoal (unspec. species) from the cultural layer which the graves were dug through was put into the model as being older than eight of the graves. Lastly, human bone and animal bone from ditches directly related to the cemetery are also included.

After Bayesian modelling of the data, the usage period for the Sankt Clemens cemetery seems to have started between 940 and 1129 (2 sigma) while all graves from the Rådhuspladsen cemetery in the model are dated to between 1010 and 1060 (see Figure 22 and Table 2).

The narrow date span suggested by the statistical model for Rådhuspladsen requires some explanation. The reason for the statistical model to choose the earliest possible date for a large part of the graves is due to the information put into the model, which says that all the graves belong to a continuous usage phase, but graves with a direct physical, stratigraphical relation to older or younger graves are younger or older than these. The individual dates for graves which have a stratigraphic relation are similar, which restrains the date in the specific sub-sequence of those graves and consequently (since they are considered belonging to a continuous usage phase) affects the whole model. This is also the reason for the very tight date range of c. 50 years for all graves. Moreover, the calibration curve for the eleventh century is steep, and enables a short dating span under the right circumstances (Reimer *et al.*, 2013).

The Sankt Clemens model presented here is much more ambiguous. This has several reasons. First, the amount of data used to model the dates is much smaller. A further complication is, that the sample with the oldest date, 25,557, was not the oldest in its stratigraphical sequence, but second after grave 620, here represented by sample 25,558. The stratigraphy and documentation from the excavation has been checked for possible mistakes, but the interpretation seems solid. As a result, sample 25,557 was taken out of the model, and is not regarded when dating the onset of the cemetery, but is seen as an outlier.

According to the Bayesian modelling of the two cemetery materials, the onset of the two cemeteries could be seen as almost parallel in time, happening in the first part of the eleventh century, even if the dates from St Clemens are much more uncertain. Judging only from the current statistical model, it is

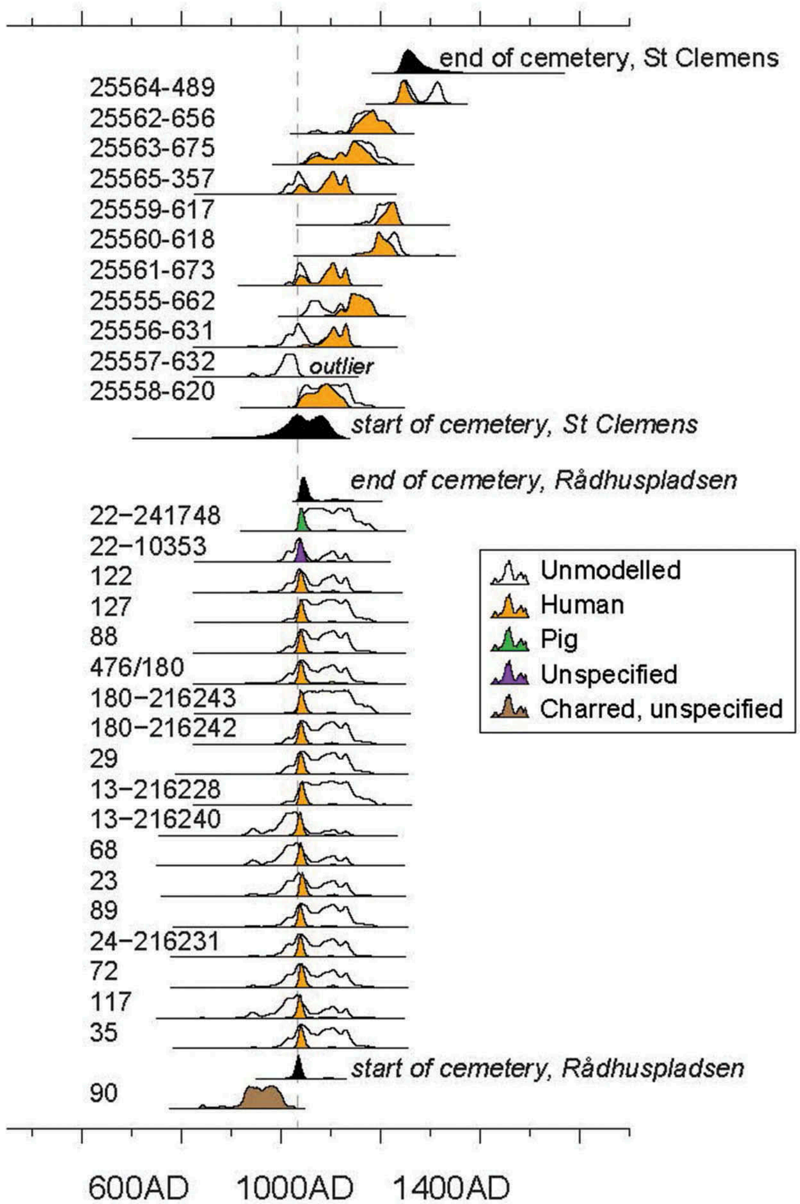

Figure 22. 14C models of the skeletal material from Rådhuspladsen and Sankt Clemens. See note 3 and Table 2 for more information. Colour signatures can be seen in the web version of the article.

more likely that the Rådhuspladsen cemetery came first. The alternatives will be further discussed later in the text. Either way the dates suggested by the model, at least for Rådhuspladsen, are surprisingly early. In the process of modelling the data, the robustness of the models have been tested and uncertain elements have been taken out. For instance, the initial idea of treating disarticulated bones found in the grave fill of an *in situ* grave as being older, was abandoned for Rådhuspladsen since this specific stratigraphical relation seemed to influence the whole model in a disproportional way. We have also tested the model with and without the cemetery soil (90) as an older restrain, but did not found the difference vital for the model. To eliminate the 'weak links' we chose in the end to present the model without the cemetery soil and without a restrain of the disarticulated bones as being older than the *in situ* skeleton. For the Sankt Clemens model, the situation with sample 25,557 as described above resulted in a less precise, but more solid model. The models presented here we believe is the best possible ones, with current available data and knowledge. This does not mean that the dates will not change with more information put into the models – something which hopefully will be tried on a later point. For Sankt Clemens, it seems vital to include more samples to reach a tighter date range. It will also be an important task to date the graves currently being excavated at Rådhuspladsen, to see if they align with the present early dates, or if they change the picture.

A relevant question to ask now is of course – how does this dating information relate to the rest of the archaeological record from the early medieval period? As mentioned above, the Aethelred coin imitations were struck in the first half of the eleventh century, something adding to the possibility of an early onset of the Sankt Clemens cemetery. At the Rådhuspladsen excavation in 2011–2012, a few finds with a clear eleventh-century dating were recovered, foremost a number of combs of types dated to the tenth to eleventh century, but also a fragment of a finger ring made of jet-stone or jet-like material, a rare find mostly belonging to Viking Age contexts (Gjøstein Resi, 2011, Dahlström and Ashby, 2015). The pottery material found at the Metro Cityring excavation at Rådhuspladsen could, based on the rim forms present, indicate settlement activity from 1000–1150 (Langkilde, 2015, p. 16). The early dating based on rim forms are however not conclusive, but needs to be put in context with other dating criteria. The relative low fragmentation of sherds combined with the presence of contexts containing exclusively Baltic Ware, strongly indicate actual *on site* activity, as opposed to redeposited and residual waste material (ibid, p. 17). It should also be mentioned that the same type of modelling for radiocarbon dates from one of the other excavated areas at Rådhuspladsen shows a similar date (from c. 1020) for the earliest phase of settlement activity. The processing of this data is still ongoing. The method of Bayesian modelling of radiocarbon data and what the results mean for our understanding of early Copenhagen will be assessed more in depth in coming research.[1]

The result from the modelling of the two cemetery materials certainly opens up for some interesting scenarios concerning the oldest settlement. Even without Bayesian modelling, the radiocarbon dates seen together with archaeological evidence securely place both cemeteries in the period before 1150. The probability of two contemporary churches in the early medieval period has consequences for how we should understand Copenhagen in its earliest phase. We will return to this question below.

Town activities and town people

The Metro Cityring excavations at Rådhuspladsen have added considerably to what we know of the economic activities in the early medieval town. Apart from household activities related to food preparation and construction/repair, primarily blacksmithing, but also comb-making, tanning and

Figure 23. Profile of clay-lined pits SG-366 (younger) and SG-370 (older) encountered at the Metro Cityring excavation at Kongens Nytorv (KBM 3829). Photo: Museum of Copenhagen.

textile working have been established (Lyne and Dahlström, 2015). At Kongens Nytorv, remains of fish handling and blacksmithing have been encountered, but dating mostly to the early thirteenth century (Steineke and Jensen, 2017). The clay-lined pits (*lerbottnar*, see Figure 23) discovered both in 1999 and in 2010 at Kongens Nytorv represent a phase in the sorting or processing of fish before selling it on the market. These feature types are known from coastal towns in Scania, as well as Dragør, south of Copenhagen, and thus emphasise similarities in the case of Copenhagen to other Øresund and Scanian towns (Ersgård, 2006, p. 48ff, Mårald, 2006). The shallow pits have been AMS-dated to the late twelfth to early thirteenth century, and were found in an area with workshop remains, close to the seashore (Steineke and Jensen, 2017, p. 127ff). In one of these, two whole herrings were still preserved, their tails tied together (Figure 24). Other features in the vicinity – a pit house and a few pits containing deposits with fish bones – were seen to be related to fish-preparing activities. The fish handling seems to have been separated from the salty marsh area closest to the shore by boundary ditches (ibid). This is something also seen in Scanian towns such as Malmö (Larsson and Balic, 2006, p.124f).

At Rådhuspladsen, on the other side of the extended town area, no such features clearly linked to fish handling on a large scale were encountered, although large quantities of fish bones were recovered from some of the pits (Enghoff, 2015, p. 107ff, Lyne and Dahlström, 2015). In some cases, it could be argued that their presence might have been due to some special function. As nothing in the osteological analyses of early medieval features points to fish-processing, the large quantities of fish bones from many species could be seen merely as evidence of a variety of fish being on the menu of the Copenhageners. From the analyses we know that at least 22 species of fish were found in the early deposits, of which the absolute majority were salt-water fish or fish found in brackish water. Herring, gadids and flatfish were dominant (Enghoff, 2015, p. 107). To conclude, though it is likely that fishing was an important economic activity for the early town population, archaeological remains of large-scale fish handling on a professional basis are still lacking.

The remains from Kongens Nytorv, even if on a small scale, have given the first solid evidence of fish handling in what is now central Copenhagen. Some of the early fish handling may have taken place outside Havn: there is room for discussion of whether the town was mainly used for the trading of fish. The island of Amager, just opposite the early settlement, could have had this function. We know that Dragør was established as a fish market by the fourteenth century, but it is likely that the Copenhageners also used places at Amager in the centuries leading up to its establishment.

As discussed previously, the name Copenhagen is in itself a resource for identifying town activities. 'Købmannahafn' should logically refer to some type of trading activity, which speaks for the original function of the site being a trading centre. The fact that the town is sometimes called only Havn is somewhat puzzling, but probably points to its early functions as a place for landing activities. As with the fishing evidence, there is nothing in the

Figure 24. Herrings found in one of the clay-lined pits at Kongens Nytorv in 2011 (KBM 3829). Photo: Museum of Copenhagen.

archaeological material to indicate Købmannahafn as a centre for long-distance trade or trade with specialised goods before the thirteenth century.

Some rare examples of early finds of import in Copenhagen include an offcut from walrus tusk, a finger-ring of jet, and a few sherds of Pingsdorf ware (Lyne and Dahlström, 2015, Whatley and Hansen 2016). Apart from this, imported pottery is scarce. The evidence – or lack of evidence – points to eleventh/twelfth-century Havn being a trading place of local character, where everyday goods were exchanged. This scenario places Copenhagen within the general course of development of Danish trading. If luxury goods were frequently traded in the towns of the eleventh century, in the twelfth century there was a general shift to goods of everyday character – goods that may not leave many traces in the archaeological record (Kristensen and Poulsen, 2016, p. 91f). The types of goods that may have been traded are closely linked to the types of crafts present in the town. Judging from the findings from the Metro Cityring excavations, they could have been products such as fish, leather and skins, iron objects, combs, and livestock.

Before the Metro Cityring excavations, almost nothing was known in terms of archaeological source material about production carried out in the early town. At this point we know more, but the information is still fragmentary, mostly due to the lack of *in situ* workshops. On the Rådhuspladsen, extensive remains of iron-working dating from the late eleventh century to the abandonment of the area in the fourteenth century have been found in the whole area south of the road leading east–west and continuing into present-day Vestergade. Later in the medieval period, Vestergade is known as Smedegade (Smith's street; Fabricius, 2006, p. 51) and as an area where blacksmiths lived (Kristensen and Poulsen, 2016, p. 228). That blacksmithing was an important activity is underlined by early medieval remains of iron-working on the Sankt Clemens cemetery in 2008 (Jensen and Dahlström, 2009, p. 61). The iron-working at Rådhuspladsen up to c. 1150 was medium or small scale, producing everyday objects such as nails and fittings. A total of 50 kg of slag was collected from the period up to c. 1150, plus hammer scales, slag spheres, and the remains of demolished furnace walls (Jouttijärvi, 2014). In this first phase, mainly secondary smithing was performed: no specialised skills were required for this type of work. However, already by c. 1150 the scale of activity increases, and specialised smithing as well as primary smithing becomes more common (ibid., Lyne and Dahlström, 2015). This is interesting, because the move of primary smithing to the towns could point to town authorities wanting more control over the iron production. Instead of the original custom of having the iron initially prepared close to the source, which was more practical, the raw iron was transported to the towns for processing (Andersson, 2015). Another probable aspect of this phenomenon was increasing specialisation among craftsmen, the town smiths probably being more skilled. The area of Rådhuspladsen and Vestergade probably specialised in blacksmithing in view of its location, which was probably towards the outskirts of the town. The area was, however, not used solely for iron-working, as the workshop remains are mixed with those of household activities and other workshop activity. Primary smithing in the thirteenth and fourteenth centuries has also been found on the other edge of the town, in the remains of a smithy just inside the high medieval rampart at Kongen Nytorv (Steineke and Jensen, 2017).

Apart from blacksmithing, workshop residue from comb-making and possibly tanning has been found in deposits in this period at Rådhuspladsen. Semi-manufactures, bone and antler offcuts, and other bone residue were thrown away in refuse pits, together with household refuse and slag material. Skinning marks on toe bones from cattle, metatarsi and metacarpi, found in refuse deposits are indicative of a tannery workshop close by (Enghoff, 2015, p. 109f, 114, 122). The remains were on a quite modest scale. The details of how the different craft and production activities and household activities were distributed in the area are not known at this point, but preliminary studies indicate that there may have been a difference, with more household remains deposited in the eastern part, closer to the town, and more workshop waste, primarily iron-working residue, towards the west, further out on the periphery. Yet the material clearly indicates an environment with different sorts of craft production being undertaken close to the living quarters. This is typical of early phases in towns, and could also be a sign of craft production that is not yet performed on a very specialised level (Carelli, 2001, p. 141f).

There is little, if any, evidence of craft production in other parts of Copenhagen at this time. This is probably due to the lack of large and coherent excavation areas, combined with differing prioritisations in earlier years' excavations, which perhaps may have been more likely to discard finds such as worked bone waste or iron slag.

We should not forget that farming and animal husbandry certainly played a role in the townspeople's economy. It is well known from other towns of this period that agricultural activity also took place inside the town, and that the built environment was characterised by large plots without high building density (Carelli, 2001, p. 106ff). The fragmentary remains of buildings and other plot activity in Copenhagen confirm this settlement pattern (Lyne and Dahlström, 2015). Archaeobotanical material from Lille Kirkestræde, east of Højbro Plads, found in the same layers as wood dated by dendrochronology to around AD 1220 (KBM 775, NNU rapport nr 18, 1992, AUD 1993:303) showed this area to have been used for grazing for quite a long time. The types of plants identified made it clear that the area, even if it was marshy, had been 'domesticated' by grazing animals affecting the flora (Kristiansen, 1999b, Skaarup, 1999b, p. 74f). It seems likely that the marshy areas close to the water, especially in the eastern part of the town area, were used for this purpose.

The people of early Copenhagen occupied themselves with trades such as blacksmithing, fishing, comb-making, leather-working and, most likely, others of which we do not have traces. Sailing the strait for different purposes could have been a semi-professional occupation. Farming and animal husbandry probably were important parts of their economy, as the sale of various different foods and drinks may also have been, as well as putting up lodgers.

Town formation and development until AD 1200: the birth of a medieval town

The development towards the medieval town of Copenhagen seems to have started in the late Viking Age. The name 'Købmannahafn' is related to the history of købinger/köpingar in eastern Denmark, sites of mostly local and regional trade known in the tenth/eleventh century. The topographical location of Copenhagen, on the coast in an area with rich agricultural assets, is also concordant with other købinger. The surrounding countryside displays wealth, with numerous treasure finds from the tenth to twelfth centuries, and in the written sources, some of the villages around Copenhagen are mentioned in the eleventh century. The donation granted to Bishop Absalon by the King before 1186 comprised a good part of the manors in the area surrounding Copenhagen, in addition to the town itself. The gift is an indication of the value of the land around Copenhagen, but possibly also of a long-standing coherence between the town and the manors. It is likely that the manors comprising the gift had been in the royal possession for some time previously, and that they had a history going back to the Late Iron Age. Of special interest is the royal manor and administrative centre of Borgby, on Amager. Viewed together with the aristocratic church at Tårnby and in Købmannahafn, it shows similarities with the Borgeby/Löddeköpinge/Lomma area of western Scania. At a general level, parallels like these set the early development of Købmannahafn against a larger context relating to the political and economic processes in play in eastern Denmark in the eleventh century. The new archaeological evidence at hand draws our attention to the earliest mention of Havn. The above-mentioned story in the *Knýtlingasaga*, of King Sven being attacked outside a place called Höfn (Havn) on Zealand, should at this point perhaps be reconsidered and given more credit than usual. It may be taken as an indication that a settlement named Havn existed as early as the first half of the eleventh century.

Eleventh century

Taking all the archaeological and historical information into account, how can we imagine Købmannahafn in the eleventh century? Who lived there, and what did they occupy themselves with? Where was the first settlement located, and why were there at one point two churches in this small settlement?

The archaeological findings tell the story of a settlement extending at least from the Rådhuspladsen in the west to Gammeltorv in the east (Figure 25(a)). Apart from the newly discovered remains at Rådhuspladsen, earlier observations at Mikkel Bryggers Gade and Gammeltorv, with clay floors, pits, and wells older than the first late eleventh/early twelfth-century enclosure, add to the picture of the extent of the first settlement. The

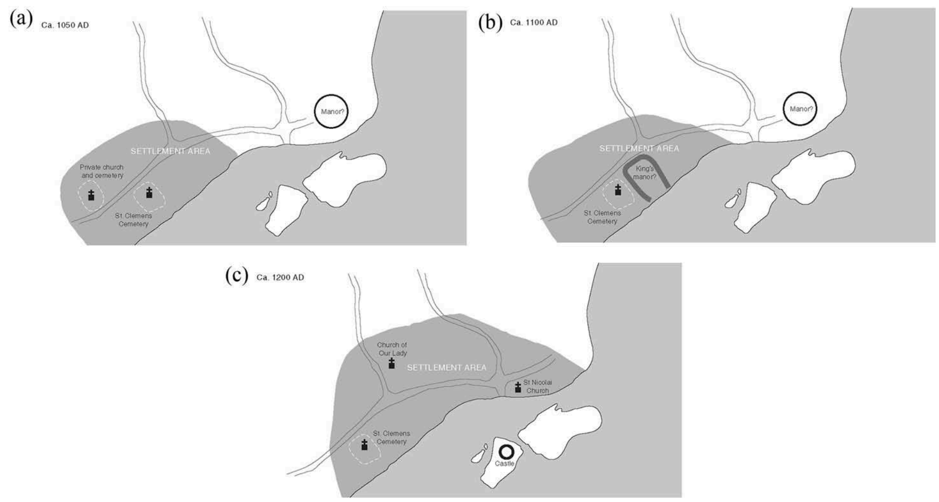

Figure 25. (a–c.) Our interpretation of the three main development phases of Copenhagen until c. 1200. Ill: Hanna Dahlström and Ea Rasmussen, Moesgaard Museum.

remains of a cemetery north of Rådhuspladsen belonging to the first phase of activity open the possibility that the settlement extended further to north and west. By means of AMS dates of the graves belonging to the cemetery it can be dated to the early-to-mid-eleventh century. Taking the indications of the very early date into consideration, it is a possibility that the cemetery was not connected to a church. This is seen in eleventh-century Sigtuna, Sweden, where several burial grounds were placed on the outskirts of the town. However, since the political situation in Denmark and Sweden was different at the time, with a much stronger royal influence in Denmark, it is difficult to compare something like early church topography which is tightly linked to the organisation of the central authorities (Tesch, 2014, p. 107ff). We find it after all more likely that the burials have belonged to a church that has not yet been discovered.

The buried individuals were likely people living in the first settlement of Havn. The cemetery could also have served surrounding rural areas, especially at this possibly early date when not all areas had churches. The ongoing excavation revealing more graves c. 20 m north-west from the graves discovered in 2011, proves that the cemetery has been of a good size, which is another indication of a permanent settlement of some proportion, or an indication of serving a wider geographic area. The graves containing women, men and children indicate a demography fitting a 'normal' population rather than speaking of groups of people like traders or fishermen visiting temporarily.

As discussed in relation to the dating models, the graves belonging to the church of St Clemens could also be placed in the early-to-mid-eleventh century. The possible early date produced by the 14C-modelling can be said to be corroborated by the find of a coin imitation whose original was in production between 997 and 1003. If we choose to rely on the early date alternative shown by the 14C-dates, this means a very early settlement with two cemeteries (and churches) some time in the first half of the eleventh century.

The other possibility is that Sankt Clemens church was established later in the eleventh century. If we look at this scenario, it seems like the cemetery at Rådhuspladsen is taken out of use fairly soon after the establishment of Sankt Clemens. Both scenarios can be taken into consideration. The choice has implications for how we should understand the site Havn in the early-to-mid-eleventh century, who might have been behind it and why it was established.

If we look at the general character of the archaeological material of the eleventh century for clues, the activity seems quite sparse and there is nothing that stands out as remains of specialised activities which could be behind the establishment. Household refuse and small-scale production waste from smithing, comb-making as well as fishing should be seen more as a consequence of there being a settlement rather than the reason for it.

The information from written sources, taken together with the archaeological records, points to an original function for Købmannahafn as a port and local trading centre, used by the local estate-owners and farmers as a landing site and trading centre mainly for their agricultural products (Dahlström et. al., 2017). As stated earlier, Valdemar's gift to Absalon around 1160, in which 'Haffn' together with the manors and villages was granted to the Bishop, points to a close relation between the port and the surrounding estates and rural settlements. The character of the early archaeological remains, indicating the dominance of trade in local, non-specialised products rather than more specialised exotic goods, supports the idea that the oldest settlement in Copenhagen grew out of a need to support the local manors and villages and supply them with goods from outside, as well as offering possibilities for the sale of their own commodities. The first phase of Copenhagen can on this line of argument be characterised as a port and meeting place, primarily for local people and local goods. However, it seems likely that the strategic location very early on had caught royal interest, resulting in the presence of the king in the form of the Sankt Clemens church. The church was a symbol for power, showing the king's alliance with the growing ecclesiastic authorities. We believe it to be reasonable, that the port in the early eleventh century was controlled by the king in collaboration with one or more local lords, one of which was behind the construction of the presumed church at Rådhuspladsen. Therefore we suggest a scenario where the first Sankt Clemens church (a wooden church) and the presumed church at Rådhuspladsen were built close to each other in time, during the first half of the eleventh century. Manors held by local lords or the king were likely placed close to the churches. From the fragmentary material indicating early activity in the east, it is also possible, that the location of present-day Kongens Nytorv/Magasin was the location for one of these manors.

If we see a possible early start for the settlement and port Havn in a wider perspective, it could be compared to the early phase of a town like Lund. Lund is believed to have been established by the royal authorities in the last years of the tenth century. The date is foremost based on graves from what is said to have been the earliest burial ground in Lund (Johansson Hervén, 2008, p. 263ff). The establishment of Lund was part of a strengthening of royal power in Denmark and for this the Christian mission and the building of churches was important. Svend Tveskæg is the king who is now thought to have been behind the first Lund (ibid.). But it was not until the early eleventh century that the real establishment of the settlement and craft production took off. This may be seen in relation to King Canut's return from England around 1020 (Blomqvist, 1951, p. 33). Around this time, it is likely that the need for communication between Scania and the rest of Denmark increased considerably. Perhaps we should see the first establishment of Havn, with two early churches, in this light? The long-standing idea of a primary function for Havn as a port between the towns Lund and Roskilde, a town also established as a royal and episcopal centre form the first years of the eleventh century, should be taken into the scenario. Even if the size of the settlement in Havn must have been small at this point, it was, due to its location, seen as a strategic point to claim a stake in.

Finally, we wish to emphasise that the interpretation of an early eleventh-century settlement structure in Copenhagen presented here, to a large degree rests on dates suggested by the new statistical modelling of the Rådhuspladsen graves. However, even if the proposed datings should be revised, all evidence clearly points to the emergence of Købmannahavn in the eleventh century. The factors involved in the creation of the town which are sketched here do not change even if somewhat later datings should be established, only the names of the main agents involved.

Twelfth century

Around the start of the twelfth century, changes took place in Købmannahafn that manifested themselves in large building projects – the construction of the enclosure surrounding a 2.5 ha area between Rådhuspladsen and Gammeltorv (Figure 25(b)), and the Sankt Clemens stone and brick church. We do not know exactly when the Sankt Clemens stone church was built, but the time of construction should likely be placed in the twelfth century. This could correlate to possible dates for the enclosure which was interpreted above as the first town fortification. It seems likely that the two constructions were undertaken close to one another in time, and that they were built on the initiative of the same town ruler.

The scale of the constructions indicates that they were built by someone with the resources and power to organise and implement large building projects like these. This makes it likely that the king was behind the constructions. As already noted, Sankt Clemens churches are commonly seen as being built by the king, or members of his retinue. The presence of the church can be said to give a clue to the function of the adjacent enclosure. In several towns, such as Roskilde and Horsens, royal manors were placed next to Sankt Clemens churches. We suggest that the ditch (and possibly a rampart) enclosed a royal manor, built in the late eleventh century or early twelfth and taken out of use in the late twelfth century in connection with the construction of Absalon's castle on Strandholmen. Perhaps the building of the Sankt Clemens church and the suggested manor was a part of the king's wish to mark himself as powerful town authority, maybe aimed towards local aristocrats. By this time, it seems like the cemetery at Rådhuspladsen had been taken out of use. The patron of the first church, which was probably a wooden church, was no longer motivated to keep the church in shape, and therefore it was taken out of use at a time when most other town churches in southern Scandinavia were either rebuilt in stone or, like this one, abandoned. These actions probably had symbolic value, as they involved a centralisation of activities away from the site of the first church (and probably a manor that we have not yet seen). The enclosure disrupted earlier settlement, causing the people using those areas for dwelling or working to move and adjust to a new town structure and a new town authority. It was also a signal of who was in charge, directed at local lords, who were probably still active in the town, but on a lower level.

The archaeological settlement evidence of the twelfth century shows increased activity, as well as its spread to a larger area, more in line with the later fortified town area as we know it from the thirteenth and fourteenth centuries (Figure 25(c)). Remains dated to the twelfth century are found in an area extending from Rådhuspladsen in the west to Kongens Nytorv in the east, with the emphasis on the western part. The archaeological remains at Rådhuspladsen clearly show an intensified activity at this period in time.

The mention of a Sankt Olav church in the thirteenth-century written records is interesting. The Sankt Olav church could, as we have noted, date back to the twelfth century, as is also known from other towns. Early Danish towns such as Aarhus, Lund, Kalundborg and Schleswig all had Sankt Olav churches dating from the twelfth to thirteenth century (Jørgensen, 1909, p. 153f, DK 16.1). The possibility of up to three contemporary churches in early Copenhagen is in line with the situation in other Danish towns in the eleventh century. This suggests that the church building took place in the period before the parish system was fully in place (Kristensen and Poulsen, 2016, p. 75). In Copenhagen at the end of the twelfth century the construction of a new, large parish church commenced – the Church of Our Lady (Vor Frue Kirke). At approximately the same time, the ditch surrounding the enclosure, which we suggest may have belonged to a royal manor, was backfilled. These actions should be seen in relation to the shift in the power of the town lords that took place when Absalon gained control over Købmannahafn some time in the mid-twelfth century. The new town ruler wished to leave his mark on the town, and with the church building project, together with the construction of the castle on Strandholmen, he certainly contributed to the town topography and changed the town's character to match a more ambitious town with future aspirations. In connection with the construction of the castle, the functions of the old enclosure and the suggested manor no longer existed, and they were taken out of use. It is also likely that the Bishop, together with the emerging town council, was a force behind the planning of the great wall upon which work was started in the early years of the thirteenth century, only a few years after Absalon's death in 1201.

If we look for Danish towns with which to compare Copenhagen in the mid-twelfth century, Kalundborg is a good example. The town here is believed to have started as a fishing site, and in the twelfth century grown into a town. In the old part of the town there was a Sankt Oluf (Olav) church. Towards the end of the twelfth century, a new town area emerged and here a large church was erected, as well as fortifications surrounding the new town area. This building initiative was taken by Absalon's brother, Lord Esbern Snare, or his daughter (Nyborg 2004, p. 141, Sass Jensen and Roesdahl, 2013). The example shows some of the dynamics of the growth of town government and of institutional and topographical development in this early part of the medieval period.

Around 1200

Returning to Copenhagen, with the physical and structural changes in the town topography dating from c. 1200, it was beginning to resemble the town that we know later in the medieval period (Figure 25(c)). A residue of the older town structure, its centre focused more towards the west, was the settlement area at present-day Rådhuspladsen. Here the same activities as accounted for in the late-eleventh to twelfth centuries were still ongoing – the archaeological record speaks of households and iron-working activity present in the area all the way into the fourteenth century, when the fortification constructions reached the area and it was abandoned for all activity. The fact that the western town area was in use for so long, even though it was in the way of the moat and rampart, can be interpreted as indications of conflicts between people in the town. While most people had good reasons to be in favour of the fortification, it seems that the plot owners in the western town area may have resisted moving for a long time. The latest AMS dates from the excavations at Kongens Nytorv and Rådhuspladsen suggest that the construction process lasted 150 years from the start in the east to completion in the west. While probably not the main reason for the delay in completing the constructions, conflicting interests among the townspeople may have played a role in this development. Could it be a possibility that those who owned plots in the western part of town were related to those families that had interests in this part of the settlement already in the eleventh/twelfth centuries? Resistance could also be seen as an expression of the dynamic development in the early phases of towns like Copenhagen, where changes were decided from above and not always in favour of the town inhabitants.

The way in which the small port of Havn grew into the rich merchant town and the capital of the kingdom in the late medieval period is naturally quite complex. It is related to a general economic and political development, both in the region and across the whole of Denmark. Havn's strongest feature was its communicative value. Its location – on the coast of the Øresund, in a sheltered harbour and surrounded by fertile land – was unique in Zealand. The fertile land offered excellent economic outcomes, producing goods that were brought to Havn and traded on a local and regional level. Economic and political development in the eleventh/twelfth centuries led the royal powers to take an interest in Købmannahafn, and with the backing of the king, the town began to develop into something more than a small port for agrarian trade. Trade, fishing, production, transport, church building and the administration of kings and bishops attracted people to the town, offering a variety of people ways of making a living. The growing importance of Baltic Sea trade with the rise of the German traders, as well as the increasing economic role of herring fishing in the Øresund, only added to the town's strategic and economic value.

The journey that Copenhagen took is not exactly like that of any other Danish town. In the beginning, Copenhagen can in some ways be compared to the köpingar around the Øresund coast. The early church development is however more resembling early town formations as individually different as Lund and Hjørring. In the twelfth and thirteenth century, Copenhagen resembles towns like Kalundborg. Around 1240, Kalundborg was Zealand's third largest town, while Copenhagen was only the fourth. Copenhagen, however, eventually outgrew all the Danish towns, with Malmö its only rival as it reached the fifteenth century. Copenhagen flourished as it did because of the way it managed to attract the interest of people from all levels of society – both the governing strata in society (king, bishop, lords, wealthy tradesmen) and the vast majority of people (farmers looking for a better life, seafarers, paupers, artisans). All made their living in various ways in Copenhagen, and in so doing, all contributed to the town's success.

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ORCID

Jesper Olsen http://orcid.org/0000-0002-4445-5520

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Editorial

Welcome to the second issue of DJA volume 7. The most important news announced in this editorial is that from 2019 onwards we will no longer be publishing under the Taylor & Francis publishing house. For eight years we have teamed up with T&F, but all good things come to an end. From now on we will be a fully Open Access journal joining the OA journal platform at https://tidsskrift.dk, hosted by The Royal Danish Library. The good news for readers of *Danish Journal of Archaeology* is that there will of course no longer be any payment required to access the published articles. We certainly hope that this financial incentive will enable a wider group of readers to follow us. Furthermore, the new publishing format will comply with the increasing demands of funding bodies with regard to publishing the research they support under Open Access.

Authors and their manuscripts will be subject to very similar procedures as those used in the previous six volumes. Accordingly, before being published papers will go through a rigorous single-blind peer review, as well as a critical editorial assessment of the quality of the incoming manuscripts. Once an article has been accepted for publication, a professional proofing and lay-out will follow; and we also aim to pass on the system of rolling publication from previous volumes and therefore upload the individual articles as soon as they are finalised. All the required standard features of DOI registration, OrcID and CrossRef citation are still to be found on the new site (https://tidsskrift.dk).

The change of publishing platform is also the right time to make some changes to the editorial group. Replacing members encourages dynamic relationships and brings new networks into the team. This has been a stated objective from the beginning of our collaboration, and will continue to be an objective in the future. We are therefore pleased to welcome two additional members to the editorial team, both from the National Museum of Denmark: Lasse Sørensen, Head of the Department of Ancient Cultures of Denmark and the Mediterranean; and Thomas Grane, Research Coordinator. Previous to his current position, Lasse did research into a diverse range of topics ranging from jade axes to rock festival campsites, but focused mainly on the Mesolithic/Neolithic transition and in particular on how changes in the subsistence economy owing to the introduction of farming might have occurred. As a classically educated archaeologist, Thomas has firm roots in Roman studies – especially research concerning contact and exchange between Rome and its Germanic neighbours, particularly in the North during the Roman Iron Age and Late Antiquity. In this field he has, for example, studied the value and meaning that imported goods gained in their new cultural setting. Both new editors have several publications under their belts, and are well versed in consulting and administering archaeological research in all shapes and sizes; so rest assured that you will be given strong editorial support by both Lasse and Thomas. In the wake of the arrival of the new editors, Mads Dengsø Jessen will withdraw from the editorial board at the end of 2018. He has been involved in the revitalisation of the journal since the tentative beginnings in late 2009; and during this nine-year spell he has seen more than 70 articles pass through the editorial structure and be published in the journal. On behalf of the new editorial team, we would like to thank Mads warmly for his great efforts for DJA.

The number of full-text downloads for the first half year of 2018 seems to have settled at a stable level (about 7000), and abstract page views are still rising (more than 8000 views). The journal has a reach far beyond Northern and Central Europe, with more than half its readers coming from the rest of the world (in particular from the USA, Australia and China). We aim to maintain high standards in the articles we publish, as we seek to present current Danish and Scandinavian archaeological research and debate to a widespread national and international readership.

Whereas volume 7, issue 1 was a special issue devoted to the presentation of the most recent research relating to the two important Danish cities of Odense and Copenhagen, issue 2 is characterised by a great variety of topics and the presentation of novel methods. The common denominator is high-quality research based on Scandinavian cases, which characterises DJA in its present form and will continue to be our lodestar for the forthcoming volumes. We are delighted to offer empirical, methodological and original research articles as well as discussion papers commenting on articles published in DJA. Characteristic of the methodologically focused papers is the combination of archaeology and various scientific disciplines. Chronologically, issue 2 covers subjects ranging from the Palaeolithic and Mesolithic through the Neolithic, Bronze Age and Iron Age to the Viking Age and the Middle Ages. We wish you happy reading.

Finally, we want to thank all the authors who have trusted us with the results of their research, the increasing number of readers, and all the peer reviewers that have helped us to live up to the high academic standards of *Danish Journal of Archaeology*. We very much hope that you will all follow us to the new Open Access platform, and that the new easy and free access will attract new readers and even more contributions.

Mads Dengsø Jessen
National Museum of Denmark, Ancient Cultures of Denmark and the Mediterranean
Mads.Dengsoe.Jessen@natmus.dk

Mette Svart Kristiansen
Department of Archaeology and Heritage Studies, Aarhus University

Rune Iversen
Saxo Institute, Department of Archaeology, University of Copenhagen

Thomas Grane
National Museum of Denmark, Research, Collections & Conservation

Lasse Sørensen
National Museum of Denmark, Ancient Cultures of Denmark and the Mediterranean

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Roads to complexity: Hawaiians and Vikings compared

Mads Ravn [a,b]

[a]Department of research and collections, Vejle Museums, Vejle, Denmark; [b]Kon-Tiki Museum, Oslo, Norway

ABSTRACT
The purpose of this paper is to analyse roads to complexity and societal development. By comparing the processes leading to complexity in Late Iron Age and early Viking society in South Scandinavia with the pre-contact Hawaiian state, I set the framework for a comparative archaeology and suggest that society in the Viking Age was not a state. I reach this conclusion within a comparative framework, by looking at comparable but also *different* processes in both places over time between the subject and source, in Scandinavia and Hawaii. I estimate how important geographic, cultural, technological, ideological, and ecological factors were for the development and change in both places in general and for the advent of the complexity in particular. I suggest that the analogical approach gives us a less biased perspective in both places, because we avoid partial metanarratives, such as for example teleological, nationalist narratives. Using this approach, we will discover new aspects that cannot be identified in isolation.

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Introduction

Comparisons between contemporary societies studied by anthropologists and prehistoric societies studied by archaeologists, the so-called analogies, have long been used (Wylie 1985, Ravn 1993, for an overview). While many such comparisons have been called hypotheses or theories, this makes them no less subject to the logic of analogical reasoning (Wylie 1982, Ravn 2011). But the archaeological data have not always been able to 'answer' correctly the convincing models developed from analogy. According to Spriggs:

'Ever-more Pacific-looking European pasts are being constructed by European… archaeologists. Melanesian anthropology is being continuously mined for supposed ethnographic parallels to elucidate the European Neolithic with its "Big Man" societies…. And the Bronze Age of Europe and the Levant is also looking increasingly suspiciously like a series of Polynesian chiefdoms minus the coconut trees and the surf and transported to less balmy climes' (Spriggs 2008, p. 538–39).

The main criticism from researchers of the Pacific (Roscoe 2009, Ravn 2011) is that European archaeologists have seen only 'snapshots' of a society where the population, and thus the social organisations have often been affected by new, decimating diseases after contact with Europeans. Following Spriggs:

What I find most remarkable about this Melanesian and Polynesian turn in European prehistory is that, although it is fuelled by a detailed poring over the detail of Pacific and other Third and Fourth World ethnographies, it manages to ignore totally the results of the archaeology of these ethnography-rich regions (Spriggs 2008, p. 539).

In other words, the uses of those analogies have not included the *longue durée*, (Braudel 1980) of the societies compared. Because I suggest that analogies are useful for applying a more balanced comparative archaeology, modelling the roads to complexity, we need to briefly discuss the definition of analogy.

The definition of analogy and its recent use

The comparisons presented above are, according to Wylie, formal analogies. They have been based on simple: 'point for point assessment of similarities or differences in the properties of source and subject' (Wylie 1985, p. 94). Unlike a relational analogy that is: *'a function of knowledge about underlying "principles of connection" that structure source and subject and that assure, on that basis, the existence of specific further similarities between them'* (Wylie 1985, p. 95).

CONTACT Mads Ravn marav@vejle.dk Spinderigade 11E, 7100 Vejle.

The lack of awareness of the definition of relational analogies has made archaeologists cautious, especially because analogies contain an element of subjectivity. Positivist and post-positivist archaeologists especially, were, and to a certain degree still are, sceptical to analogies (Kristiansen 2017, Sørensen 2017), although they also are used in many other positivist-oriented disciplines, including the natural sciences. The scientific philosopher Susan Sterrett stresses, for example, Ernst Mach, who developed the analogy that both light and sound are waves. This is based on the *Doppler Effect*, assuming that the same laws applied to sound as to light (Sterrett 1998, 2017, p. 866). Based on this analogy, one is able to calculate the size of the universe and find out that it expands. Stephen Hawking also used analogical reasoning for understanding how black holes emit very little light, the so-called Hawking radiation (Hawking 1974, see also Visser 2003), the assumption being that waves work in the same way everywhere in the universe (Rousseaux 2013).

The simplistic definition of analogy and the phenomenon of equifinality (Ravn 2011): that vastly different behaviour patterns can lead to the same material patterning has also been seen as problematic. With the advent of numerous multi-proxy methods that are applied in manifold ways on 'bigger' data, this phenomenon, although still present, has waned (Grabowski 2014).

Regarding the definition, if analogy is defined as: *'the selective transposition of information from source to subject on the basis of a comparison that, fully developed, specifies how the terms are compared to similar, different, or of unknown likeness*' (Wylie 1985, p. 93), the concept is less controversial because it involves understanding the processes behind the similarities and differences. Only multiple lines of circumstantial evidence can substantiate the strength of the analogue and make it a stronger 'cable' (Wylie 1989, Sterrett 2017, p. 870).

Analogical cables with a longue durée on both the source and the subject side

The way forward with the use of analogies in archaeology is to compare the *longue durée* at both the source and subject side of the analogy, as emphasised recently (Spriggs 2008). In this way, we may better assess different historical, cultural and ecological trajectories and reasons for various phenomena over time and understand whether they mattered in this particular process or region. We not only learn more about the culture we compare (the subject side of the analogy). We also improve our knowledge of the culture that we use as a source of comparison (the source side of the analogy). This may involve the use of ethno-archaeology, which links material culture behaviour patterns of the present with material culture behaviour patterns of the past (Ravn 1993, p. 74). Other times we may use analyses of the archaeological material and written sources in a protohistoric society and compare them with the archaeology of a prehistoric society. This is called historical analogy (Ravn 2003, p. 2). Against this background, we can map more solid variables and constants and better understand how they diverge under given circumstances in a society, be they religious, social, cultural, ecological, geographic or climatic.

Competition and bottlenecks: early roads to complexity in a comparative perspective

Before moving on to the discussion of roads to complexity, I need to briefly present the term 'bottlenecks'. Earle and Spriggs (2015) have, in a comparative perspective, defined bottlenecks as: *'constriction points in commodity chains that offer an aspiring leader the opportunity to limit access, thus creating ownership over resources, technologies or knowledge'* (Earle and Spriggs 2015, p. 517). They suggest (Earle and Spriggs 2015, Spriggs *et al.* 2016) that Neolithic economies and early Hawaiian culture in Oceania had economic and geographical settings that were too open for chiefs to monopolise resources and land. Thus, they could not create bottlenecks. On that basis, they conclude that few Neolithic societies developed into complex societies. A prestige goods economy does not emerge before the Bronze Age in Europe and in late precontact Neolithic Oceania, especially in Hawaii (Earle and Spriggs 2015, p. 522).

Roads to complexity in chiefdoms and kingdoms: bronze, iron and Viking Age South Scandinavia and early states in Hawaii

In terms of the *longue durée*, Kristian Kristiansen (2016) has compared the Bronze Age of Scandinavia (ca. 1500–1100 BC) with the Viking Age, concluding that: *'..the Viking Age of Northern Europe shares many of the features we now associate with the Bronze Age'..*

in terms of structure,.. 'but the Viking Age was apparently able to expand on a larger geographical scale due to technological and demographic developments since the Bronze Age' (Kristiansen 2016, p. 181).

Suggesting that Scandinavian Bronze Age and Viking Age societies represent a 'structural "*longue durée*" based on similar structural foundations', Kristiansen (2016, p. 178) outlined several similarities in both the Bronze Age and Viking Age. Important are *symbolic similarities*: burial mounds, strong warrior ethos, expressed with chiefly and functional warrior swords. In addition, both periods share the expressive use of symbolic decoration and decorative style with cosmological meaning. In terms of *communication and transport*, ship burials and seafaring are dominant ways of communication in both periods. Indeed, Glørstad and Melheim (2016, p. 100) drew comparison between seafaring in the Viking Age, the Bronze Age and the rise of the Hellenic power during the Peloponnesian wars in the fifth century BC. *Economically*, in both periods, we find individual farmsteads, which function as the basic economic unit, though in the Iron and Viking Age, there are also villages. *Exchange* is dominant, although in the Viking Age, the emphasis is increasingly on commercial ports of trade. In both periods, we see a decentralised political economy. *Socially*, in both periods, society consisted of free farmers who are represented as the dominant warrior class. *Ritually*, in both periods, we observe that there are ritual meeting places and hoarding of metal valuables in the landscape.

An important difference between Bronze Age and Viking Age society that Kristiansen stresses is a missing social/political level above the chiefly families of free farmers, traders, and warriors in the Northern Bronze Age. That level is the king or paramount and his ability to recruit a proportionally larger military force through vassal chiefs.

Hawaii offers a stronger, structural 'cable' (Wylie 1989), especially if we want to understand the roads to early kingdoms in the Germanic Iron Age and Viking Age South Scandinavia, because paramount chiefs are present in both places. Additionally, comparing two independent societies, separated in both time and space, which ended up with a similar, though not an identical kind of complexity will lead to a better *explanation*, as it requires a more detailed understanding of the prerequisites for the development of these societies.

With the structural *longue durée*, in South Scandinavia emphasised by Kristiansen (2016, p. 178) in mind, this approach differs from traditional neo-evolutionary perspectives, which typically look for normative societal types (Drennan *et al.* 2012, p. 2, Smith and Peregrine 2012, Feinman 2012), disregarding dissimilarities and *the longue durée*, as Spriggs points out above (2008). The analogical approach advocated for here on the other hand, stresses a stronger, processual, 'cabled' (Wylie 1989) and diachronic perspective, equally comparing *both sides* of the analogical 'equation', using similarities and differences as navigation points of reference. Following Wylie: *'…, the model may be a conceptualisation of a context…that is substantially unlike any single accessible…analogy.'* (Wylie 1985, p.106).

Hawaiian society

The chiefdom of the paramount of *Kalaniopu'u*, which James Cook encountered in 1779 in *Kelakekua* Bay in Hawaii (Beaglehole 1967, p. 490, Kirch 2000b, p. 248), numbered at least 60,000 maybe even up to 150,000 people and was one of the most complex communities throughout Oceania (Earle and Spriggs 2015, p. 525) (Figure 1).

Anthropologists have called Hawaiian pre-contact society an advanced chiefdom or even a state. Archaeological research has confirmed this contention (Kirch 2000a, b, Earle and Spriggs 2015). Indeed, Hommon (2013, p. 121) defined a state as a:

> durable, large-scale, territorially-based, autonomous society in which a centralized government, directed by a leader or group of leaders, employs legitimate political power, backed by coercion, to exercise sovereignty

Furthermore:

> *….the leader or leading group, usually of a ruling class, makes decisions regarding – and delegates power to a stratified bureaucracy charged with implementing – certain society-wide tasks, including the colleting of taxes, the conduct of state rituals, the promulgation and enforcement of laws, the development of public works, the maintenance of intrapolity order, and the management of extrapolity relations by means of trade, diplomacy, and war.*

This state developed from a few colonising boats that came from possibly Tahiti in East Polynesia ca.

Figure 1. Overview of the Hawaiian Islands. The yellow spot marks the area where James Cook landed in 1778 and 1779 (Graphics: VejleMuseerne).

4000 km to the south around AD 1000 (Hommon 2013). Important here is that Hawaiian society, unlike the Germanic Iron Age and Viking Age kingdoms of Scandinavia, developed over hundreds of years into a very stratified society *in isolation* from external pressure and external contacts, neither from a German-Roman emperor, nor by monopolising exotic, long-distance trade objects (Ravn 2003). In other words, there was no *centre-periphery* relations in Hawaii, a relation that otherwise has been stressed as important in the formation of early states (Wallerstein 1974, Champion 2005).

Population growth

Apparently, the population of Hawaii was allowed to grow rapidly, probably due to the lack of malaria and other common infectious diseases in this area of the Pacific (Sand 2002). The geologically older islands of *O'ahu* and *Kaua'i*, with their ample water supply, became covered with irrigated pond fields for taro, fishponds and tree grooves of bananas, breadfruit and coconut as well as religious monuments, roads and field walls (Figure 2). All this attests to an intensified use of resources over time, and an increasing population, especially from AD 1200. The younger islands of *Maui* and *Hawai'i* to the east had dry fields that were used for growing sweet potato and raising the pigs that were prestigious ceremonial offerings and gift payments. In time, chiefs came to control the most productive staple-producing lands and, following Earle and Spriggs. *'The ancient lineage system through which commoners claimed rights to the land was supplanted by a feudal-like system in which commoners gave obligated labor and material in return for access'* (Earle and Spriggs 2015, p. 525; see also Hommon 2013, p. 18). A tribute system was introduced (*ahupua'a*) with overarching ownership vested in the paramount chief. The close kin of the paramount received units of fiefs and the commoners received subsistence plots. On the islands of *O'ahu* and *Kaua'i* especially, chiefs divided subsistence plots among farmers under a manager's oversight. The farmers were obliged to work the chief's plots and fishponds, generating surplus to support the chief.

Figure 2. When James Cook on his third sea voyage arrived in 1779 with his majesty's ships resolution and discovery in Oceania at Kealakekua Bay, about 3000 canoes escorted him. Here is a view from a sacred platform. In the background, we see Kealakekua Bay (Photo: Mads Ravn).

A bottleneck

There is here a good example of a bottleneck, as defined by Earle and Spriggs (2015, p. 517). In addition, the extensive terraces that according to Ladefoged and Graves (2006, p. 280) were subdivided over time into smaller units suggest that there was a concept of property rights and increasing pressure on land. Patterns of the intensification of agricultural production makes Hommon suggest a *hard times* hypothesis, where chiefs redefined their roles towards more concentration of power in fewer hands in hard times (Hommon 2013, p. 235). In effect, one paramount king (Hommon 2013, p. 258) slowly replaced a diarchy.

The stratified polities of Hawaii, however, could not grow by compiling surplus for the chiefs alone. Wars against and conquest of other polities increased – a process that depended on warriors and priestly specialists. This process between peer islands can be seen as an ideal example of a peer-polity interaction (Renfrew and Cherry 1986). Internal war also helped to formulate an ideology that emphasised external kings with an exotic background, so-called 'stranger kings', being external to the linage. Unlike family relations they could better suppress their subjects, additionally claiming that they were linked to divine powers (Sahlins 1985). In concert, the development supported by surplus production broke local community ownership rights, thus creating an overarching power for the paramount chief and a new institutional order based on warriors and a priestly class.

Strong aristocracy

In order to institutionalise the regional Hawaiian chiefdoms, social labour was mobilised by chiefs. They raised a hierarchy of temples that marked the landscape and obliged communities to support annual ceremonies. The eventual creation of a divine kingship was dependent on ceremonies, supported by surpluses from the extensive irrigation systems. By the end of the process, a smaller but distinctive class of rulers appeared who asserted ownership over community lands, their facilities and staple production. Following this, an increasing bureaucracy of specialists involved in land management, warrior might, and religious sanctification was established.

Prestige goods

Hawaiian prestige items included feathered cloaks, helmets, and elaborately carved idols and bowls. In addition, an important part of the chiefly and religious material culture was special woven mats, elaborately decorated tapa cloth, weapons and basalt adzes. In contrast to Northern Europe, suitable raw materials were widely available, so it was more the artistry of the highly skilled specialists that made the objects prestigious. These objects were not a part of a large network of long-distance trade. The objects functioned as an extension of staple finance, and the chief received them in an annual collection. The chief's household supported artisans who transformed these materials into symbolic objects and received land in return for their skilled labour.

Feathered cloaks for the paramount chief were distributed to supporting chiefs. These special goods became props in the ceremonies and the dress of high chiefs as god kings. In addition, warrior canoes helped solidify control over the warriors, who were so important for conquest. Although canoes thus were necessary for their ancestors, who arrived on the shores around AD 1000, long-distance voyaging with sails diminished in importance.

Social structure

Just before European contact, there were specialised farmers, fishermen, craftsmen, warriors and priests, chiefs and paramount chiefs and a delegated bureaucracy. The chiefs (*Ali'i*) were masters of tens of thousands of people and were both leaders of the local clan or tribe, and descended directly from the gods. Within the chief group, there were eight subdivisions of up to eight groups. In the end, the paramount chief might marry a sibling to concentrate the bloodline. Chiefs drafted large-scale labour in order to build temples and irrigation channels, but few impressive monuments apart from temples (*Heiau*) and no nucleated villages or towns ever developed (Hommon 2013, p. 260). Tribute consisted of food for the chieftain's household. The common people did not have the right to land, but paid tributes to those whose land they cultivated. Anthropologist Marshall Sahlins (1958) and Irving Goldman (1970) classified the Polynesian chiefdoms into three types, where Type I, of which Hawaii is an example, was the most stratified.

The Viking analogy

The Scandinavian Viking Age (traditionally dated to 793–1050 AD) is a period that due to a nationalist revival in the nineteenth century, has become legendary. I suggest, however, that one is able to find most of the conditions and defining points for the Viking Age in the preceding Roman and Germanic Iron Ages ca. AD 200–800 (Ravn 2003). Extensive seafaring, new boat technology, long-distance exchange, raids in Northern Europe, concentration of power, warrior ideology, socially stratified graves, wars, migrations, ethnogenesis, the development of emporia and formation of kingdoms, all these phenomena were already well under way before the start of the Viking Age proper. Therefore, the Viking Age, in my view, is arbitrarily defined and needs to be extended back in time. This is especially the case when one looks at the development of complexity and concentration of power in this region in a much longer time perspective than many Viking scholars traditionally have done (see also Näsman 2006). I call this analogical subject of investigation the 'Viking analogy', although I extend it further back in time than the usual definition allows.

Sources revealing complexity

It is difficult to measure the degree of stratification within Europe and especially Scandinavia. At this time, Scandinavia was prehistoric, and in many cases, we encounter less source material than from the period of Hawaiian state development. Foreign missionaries and Merovingian, Carolingian and Anglo-Saxon chroniclers are the main sources for the early Danish kingdoms. Thus, it is only by comparing South Scandinavia, where the sources are mainly archaeological, with the rest of Europe, where written accounts and archaeology reveal varying stratified societies according to region, that we may reach an understanding of how and when the formation of stratified kingdoms and complexity of South Scandinavia occurred.

Chris Wickham has discussed the challenges of grasping this complex period, indeed emphasising a *comparative approach*:

> *Historians who study one society alone, never looking at others, lack an essential control mechanism, and not*

> *only risk misunderstanding, of what are real causal elements or turning-points and what are not, but also are in danger of falling into metanarratives of national identity, the teleologies of what makes Us special, which bedevil the historical enterprise (*Wickham 2005, p. 825).

Additionally, his overview of this vast and complex area of Europe, understanding some of the major differences and similarities on a structural basis is interesting. With a quite similar materialist approach to Earle and Spriggs (2015) and Hommon (2013) for Hawaiian society, Wickham defines a number of economic aspects that characterise this diverse period. Here I shall focus on South Scandinavia, the region later to become the kingdom of Denmark.

Roman collapse leads to a weak aristocracy

From the fifth century, according to Wickham, we see a collapse of fiscal structures in the Roman Empire, which leaves the majority of Europe with a relatively weak aristocracy. This is also true of South Scandinavia, which is characterised by a decentralised political system and a number of regional kingdoms until the eighth, or perhaps the tenth century (Wickham 2005, p. 371). Numerous finds of imported glass and metal bowls, as well as coins produced in the late Roman provinces support the interpretation that a prestige economy was well underway already in the first half of the first millennium. Graves attesting to some level of regional hierarchy indicate that it was a ranked prestige, and not a monetary, economy (Hedeager 1992, Ravn 2003). Also, the relative homogeneity of villages points to a peasantry that recognises a leader, not a landlord. In the Western Roman Empire, as the economy partly collapses in the fifth century, a number of Germanic migrations across Europe make it a period of instability. In the written sources, tribes numbering as many as 100.000 appear. The first mention of a tribe known as the Danes appears in the works of Gregory of Tours, who describes a sixth century raid on Paris by the kings of the Danes (Gregory of Tours 1974, III: 2).

Archaeological evidence for social complexity

In the western part of South Scandinavia, we have a settlement pattern, consisting of small villages and hamlet communities of 3–10 farm units. People practiced a plot organisation of land, where farms were founded according to neo-locality and bilateral heritage patterns (Holst 2010). This means that the offspring of a farmer established a new farm within a predefined plot, already belonging to the family. When the parents died, the old farm was demolished, on average about every 30 years. This pattern is clearly observable in Jutland, in the western part of South Scandinavia (Holst 2010, p. 172, 2014). We also see this practice mentioned in the contemporary Germanic *Lex Babarorum*, further south. The subsistence pattern in South Scandinavia at this time is rural. In the western part (Jutland), we have a more scattered settlement pattern, while the magnate farms of the eastern isles and Scania indicate a higher level of coercion and a strata of retinue warriors and specialised craft persons.

Magnate farms

I shall here focus a bit more on the magnate farms in the east. In East and Central Scandinavia the occurrence of large amounts of gold, a metal not found naturally in South Scandinavia, alongside the remains of large sixth century magnate farms, suggests that gold was used as a sign of wealth in a prestige production economy guided by the magnate (Christensen 2015). The magnate farm of *Lejre* where, according to the epic poem Beowulf, the Danish kings ruled and the equally rich manor of *Tissø* (Jørgensen 2010, Christensen 2015) was the central unit that defined the social bond of the 'house' (Figure 3). Levi Strauss defined such a term a '*société* À *maison*' or 'house society' (Gillespie 2000). It was within this house society, which ran beyond genetic relations, that social relations were organised in relation to the magnate. The sacred function was most likely connected to the king or magnate, who acted as an intermediary between the gods and the people. He was also the person who performed the rituals.

This 'eastern' organisation is apparently not as widespread in the egalitarian house structures of Jutland in western Denmark (Jessen and Holst 2008, p. 51, Holst 2014, see however Ravn *et al.* in prep.). Hence, a relatively egalitarian pattern based on genetic relations in the west stands in some contrast to the magnate farms that already from the sixth century appear in Sealand, Scania as well as

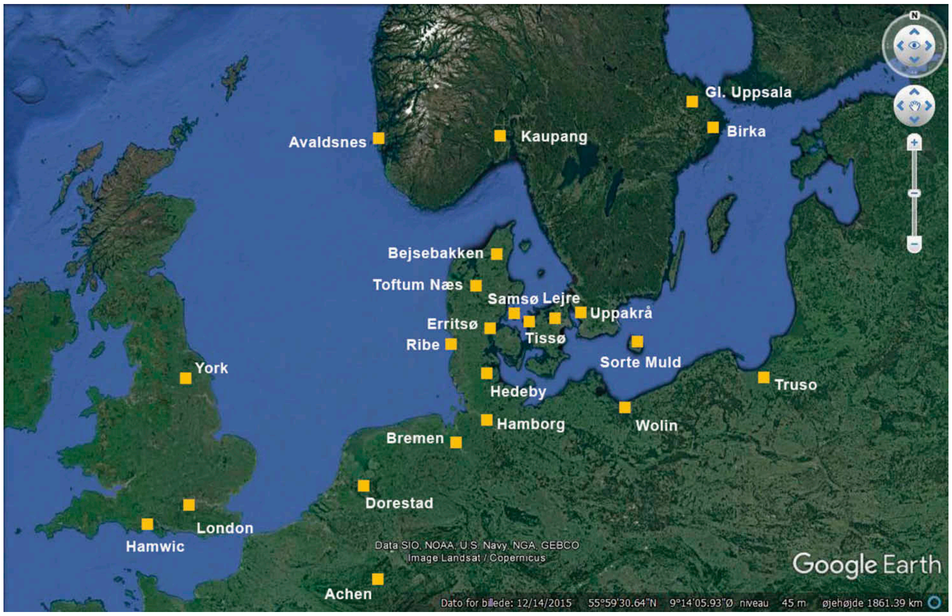

Figure 3. Overview of south and central Scandinavia with a number of important locations from the GERMANIC IRON AGE and early Viking Age. The red spot marks a recently discovered magnate farm in Jutland (graphics: Google Earth and adapted by VejleMuseerne).

in *Gamla Uppsala* in central Sweden (Ljungqvist and Frölund 2015). Still, Wickham suggests: 'that even in the eighth and ninth centuries, and still more in the fifth and sixth, aristocratic economic dominance over peasant neighbours was not established in Denmark'(Wickham 2005, p. 375).

It is possible that the commoners in South Scandinavia paid a kind of tribute, not tax, for protection in recognition of the suzerainty of the lord in the later phases of the Viking Age (Vogt 2017).

What's in a name

Before continuing, a brief discussion of the word 'king' will be worthwhile. The term appears in the Germanic language as far back as the fourth century, amongst the Goths (*Kindins*, in Latin *Judex*). The Goths were the first Germanic people to be admitted into the Roman Empire, in AD 376 (Ravn 2003). *Kindins*, in the ancient Gothic language, refers to an elected person who governs people, but who in general holds more symbolic power (Ravn 2003, p. 8). He is in contrast to a *reiks*, who was a warlord. This duality of power between a symbolic and executive leader is also present in Hawaii prior to the concentration of power and the emergence of the Hawaiian state in the seventeenth and eighteenth centuries. We also see elements of this when the Viking king Hemming dies in AD 812. He was succeeded by kings, Harald and Reginfred. The pattern of dual kings continued throughout the ninth century.

A *kindins* had the juridical ability to judge someone, hence the word *kingdom* (i.e. a king who judges, in Danish a '*dommer*' is a judge), whereas the *reiks* among the Goths were only given power in times of war. In that sense, the presence of the word king does not, in itself, indicate a centralised and stratified state governing a major area of land with a bureaucracy (Näsman 2006). In Scandinavia, we do not see that before possibly the tenth century (Wickham 2005, p. 379), or maybe even later (Bagge 1999).

Towards an explanation of complexity in Viking Age and Hawaiian society

The comparisons so far have been descriptive. In order to reach a deeper understanding of the common drivers of complexity, the first step is to outline the similarities and differences between both places (see Table 1).

Similarities

In terms of *social structure*, both had decentralised individual farmsteads and villages. Initially free farmers represent the dominant warrior class. Over time, a layer of retinues and supervisors, in the Viking age

Table 1. Summarised similarities and differences of complexity between Viking Age society and Hawaiian pre-contact society

Similarities	
Germanic Iron Age/Viking Age (AD 400–ca. 1000)	Hawaiian pre-contact society (AD 1000–1790)
Economy:	**Economy:**
• Decentralised individual farmsteads	• Decentralised individual farmsteads
Social structure:	**Social structure:**
• Patron–client relationship	• Patron–client relationship
• Conspicuous consumption	• Conspicuous consumption
• Moving court?	• Moving court
• Bottleneck situations lead to monopolisation and complexity	• Bottleneck situations lead to monopolisation and complexity
• Internal factors cause change	• Internal factors cause change
• Two leaders, one symbolic and one executive, diarchy.	• Two leaders, one symbolic and one executive, diarchy
• Strong warrior ethos, and elaborate, decorative weapons	• Strong warrior ethos, and elaborate, decorative weapons
• King and/or paramount chief is the intermediary between the gods and the people.	• King and/or paramount chief is the intermediary between the gods and the people.
• Intensified war activities	• Intensified war activities
• Heterarchies	• Heterarchies
Rituals:	**Rituals:**
• Ritual meeting places, things and central places, place names with GUD (i.e. god).	• Ritual meeting places – platforms
• Presence of ship setting burials	• Possible ship setting burials in some instances
Symbols:	**Symbols:**
• Ships symbol of power	• Canoes symbol of power
• Expressive decorative style with cosmological meaning	• Expressive decorative style with cosmological meaning
Differences:	
Germanic Iron Age/Viking Age (AD 400–ca. 1000)	**Hawaiian pre-contact society (AD 1000–1790)**
Economy:	**Economy:**
• Size of land plots grow over time	• Size of land plots diminish over time
• Marine subsistence along farming and herding	• Terrestrial economy along farming and herding
• Free farmers	• Farmers become subjected in late phase
• No extensive pressure on land	• Pressure on land
Social structure:	**Social Structure:**
• Long-distance contacts are present	• Long – distance contacts are not present
• No ownership of land and no taxes	• Ownership of land and taxes
• Emporiums and later towns	• No emporiums and towns
• Weak aristocracy	• Strong chiefs over time
• Centre periphery relations to the south	• Peer polity pressure between islands
• No feudalism before the eleventh century	• Feudalism
• No layer of bureaucracy	• Several layers of bureaucracy
• A decentralised political economy	• A gradual centralised political economy
Symbols:	**Symbols:**
• Presence of conspicuous monumental burial mounds	• No presence of conspicuous monumental burials
Rituals:	**Rituals:**
• Hoarding metal valuables	• No hoarding of valuables in the ground
Transport:	**Transport:**
• Sails on ships important and sailing important driver	• Sails on canoes not important anymore (in late phase)
Geography:	Geography:
• Mainland Europe	• Pacific Ocean
• Temperate climate	• Tropical climate

called *thegns* and *earls*, appear, while in Hawaii the *konohiki*, an individual specialising in creating and collecting surplus, developed. Patron–client relationships, as defined by Sigurdsson (2008. p. 24), are also common to both. Earle and Spriggs (2015, p. 525) called Hawaiian society 'feudal'. In both places, bottleneck situations were created, making monopoly of power possible. In Hawaii it was most likely access to land and prestige goods that caused it. In Scandinavia, it was access to prestigious items, exotics and maybe infanticide and bride wealth (Wicker 1998). Infanticide instigated bands of 'surplus' young men in need of bride-wealth to seek riches and fortune in raiding (Burström 1993, Barrett 2008, p. 680, see also Price 2016).

In both places, the king/paramount most likely was peripatetic. In addition, there were possibly stranger kings in the late phase in both places (Dobat 2009, Hommon 2013). In both places, a heterarchy was most likely present. Heterarchies are where: '*forms of order exist that are not exclusively hierarchical and… interactive elements in complex systems need not be permanently ranked relative to one another*' (Crumley 1995, p. 3).

Also, elaborate *rituals* are present in both places. Initially, it was a *primus inter pares*, but later the king, and even later yet an appointed priest, who conducted the major rituals. In Hawaii and South Scandinavia the king and/or paramount chief was the intermediary between the gods and the people.

In terms of *prestige goods*, there was a strong warrior ethos, as well as elaborate chiefly weapons and functional warrior costumes. In terms of *symbols*, expressive decorative styles with cosmological meanings are present in both Viking society and in Hawaii. Among the Viking warriors, the sword had high prestige. In Hawaii, clubs and adzes and the spiritual armour of feathered helmets and cloaks were prestigious. In addition, conspicuous consumption by elites is a common element.

In terms of *transportation*, seafaring was the dominant method of communication. Possessing a large double canoe in Hawaii was as prestigious as having a ship in Scandinavia. The voyaging canoe in Hawaii, as with the Viking ship, was a means for magnates to grasp power by warfare.

Dissimilarities

In terms of transportation, Sails and sail technology being a techno-deterministic, mono-causal mover for change do not seem likely in a comparative approach, let alone in a long-term perspective, though sailing playing a role in creating a maritime social structure has been presented as a driver in particular cases (Glørstad and Melheim, P. 98–100, Kristiansen 2016, Price 2016). In Hawaii, the presence of sails was not important. Seen in a European context, sailing but not sails were important long before the Viking Age. For example, the Anglo-Saxons arrived in England in large numbers in the fifth century AD, well before the earliest clear evidence for the use of sails in Northern Europe (Figure 4), leaving a larger genetic impact on the present English population than the Vikings (Leslie *et al*. 2015, p. 313). This suggests that the cause for the beginning of the kingdoms of the Viking Age must be found in other *internal, multi-causal and social factors* (see also Näsman 2012, Barrett 2008).

International contacts and exchange were dominant in and before the Viking Age. The emphasis was on commercial ports of trade and later emporia and towns in a centre periphery perspective. This is not the case in Hawaii. This indicates that a peer-polity interaction model is more adequate for explaining the development of stratified societies in Hawaii (Renfrew and Cherry 1986), where towns were not a prime mover (see Näsman 2006, p. 224). International contacts thus are not always essential for the development of complexity.

Figure 4. Details from the *Hunninge* stone from Gotland, Sweden, showing the presence of sails before the Viking Age proper. Although debated this stone dates most likely to the early eighth century. The figures are probably mythological, illustrating the journey by ship by a fallen warrior to the Valhalla of Odin. There a woman with a drinking horn, probably a Valkyrie welcomes the warrior. Under the ship, we probably have the myth about *Sigurd Fafnarsbane* where his brother-in-law *Gunnar* is thrown in the doom of the snakes to die. On show in Gotland Museum (Photo: Mads Ravn).

A large empire to the south, on the other hand, must have been essential for the pressure towards centrality and its collapse towards decentrality in Scandinavia (Wickham 2005, p. 369).

The tradition of *prestige goods*, especially hoarding metal valuables in the landscape, is not present in Hawaii, where public rituals and prestigious artefacts and canoes were used as a means of conspicuous consumption. In terms of *symbols*, there are no monumental burial mounds in Hawaii. Either the Hawaiians buried their dead in caves, sand dunes or the sea; high ranked chiefs were often given hidden burials to avoid the use of their bones as artefacts by those seeking to gain some of the power they had in life.

A major difference to Hawaii is in terms of *subsistence and economy*. In Hawaiian society access to land was much more restricted than in Germanic and early Viking Age society (Wickham 2005, p. 379). It also seems that there was less pressure on land in South Scandinavia than in Hawaii. We see further subdivisions over time within the Hawaiian field systems (Ladefoged and Graves 2006, p. 270) as pressure on land increased (Hommon 2013, p. 232). Indeed the relatively open access to land in Scandinavia, where the farm plots increased in size over time, stands in contrast to Hawaiian society. In the late Germanic Iron Age and early Viking Age society there was a gradual concentration of land where variation in plot size suggests that some individuals were much wealthier than others. This interpretation may be comparable with the concentration of large landowners in Hawaii, but it appears differently in the archaeology and further study is needed (see Holst 2010, p. 169, Løvschal 2017, Vogt 2017). Finally, there is no development of central places with rich metals, towns, numerous monuments and nucleated settlements in Hawaii.

Discussion – a balanced comparative archaeology

The purpose here has been to establish a framework for a more balanced, comparative archaeology in order to understand the development of early complex societies, using two different complex societies as analogy. I argue that such an approach can be productive if we want to understand both the comparative cultures' prerequisites and developments in a long-term perspective (see also Glørstad and Melheim 2016). By looking at similar and different processes over time and across a wider area, we can better isolate how important geographic, cultural, technological, ideological and ecological factors were for the development and change in individual places.

I shall not discuss in detail a volcanic eruption in ca. AD 536, which has been seen by some as leading to hard times and eventually the conversion to a Viking Society (Löwenborg 2012). I consider it a mono-causal, external, and thus a non–explanatory factor (see also comments by Näsman 2012, Gräslund and Price 2012), though it need mentioning, as it is comparable to Hommon's external, hard times hypothesis for the development of complexity in Hawaii.

I prefer the hypothesis that a social bottleneck developed as a result of the selective infanticide of female newborns, leading to too few women (Wicker 1998). This instigated bands of 'surplus' young men in need of bride-wealth who sought riches and fortune in raiding (Barrett 2008, p. 680). This is an internally caused bottleneck. Additionally, an economic bottleneck developed, because access to land was gradually monopolised by stronger magnates who waged war between polities in Scandinavia. Ships made it possible to rally young men that could gain wealth (Price 2016). This happened before the Viking Age. Whatever factor was more important; it was internal social causes and could have meant that Viking Age society also reached its limits for traditional agriculture as people did in Hawaii due to the limited amount of land on these remote islands.

In Europe there was room for emigrating and raiding, which was only the case in Hawaii between a limited numbers of islands. Hence, the Vikings eventually settled in Ireland, Scotland and England in the late ninth century. In Hawaii, land pressure led to wars, which led to centralised state formation that, in terms of complexity, surpasses the Scandinavian Viking society.

Are the Viking kingdoms states?

The comparative approach, adopted in the discussion above, suggests that the Viking Age kingdoms of South Scandinavia were quite different, much less stratified, and much more decentralised than the Hawaiian state. Viking society therefore cannot be called a state. The absence of an advanced bureaucracy and the lack of evidence for the collection of taxes and ownership of land in the Viking Age kingdoms are particularly problematic. Following the definition of Hommon, Viking Age society may be called an advanced chiefdom rather than an archaic state (Hommon 2013, p. 118–122). A state, as defined by Hommon, did not appear in Scandinavia until much later, more likely between the tenth to fourteenth centuries (see Dobat 2009, Roesdahl 2016, p. 175, Bagge 1999). According to Wickham the kingdom societies in South Scandinavia should be called prestate systems (Wickham 2005, p. 56), peasant mode or ranked societies (2005, p. 304). Indeed, it is a question whether the term heterarchy (Crumley 1995, p. 3) is more appropriate to the Scandinavian later Germanic Iron Age and Viking Age, as also suggested indirectly by Holst (2014, p. 181).

Conclusions – comparative archaeology as an exploratory prism

This comparative sketch has presented a 'lens' though which to view the formation of the Viking Age Kingdoms and the Hawaiian state anew. The aim has been to discuss the usefulness of a comparative archaeology without making yet another neo-evolutionist stereotype. One difference from a neo-evolutionist perspective is the focus on differences instead of similarities (Smith 2012, Smith and Peregrine 2012, p. 4). Also, in that perspective, I emphasise a renewed focus on analogy.

The aim here has not been to make the Vikings into Hawaiians as with typical formal analogies. Rather, by playing these two complex societies off against each other, using them not as mirrors, as suggested by Glørstad and Melheim (2016), but more precisely as *dispersive prisms, refracting the light spectre of reflecting images into details*, we learn more about the development of complex societies in general and the two compared societies in particular. According to Smith (2012), and Smith and Peregrine (2012, p. 7), it may be called an *intensive comparative method*, where I expand the comparative frame with a focus on analogy and a perspective that focuses on diverse hierarchical modes (Feinman 2012, p. 29) and heterarchies (Crumley 1995). The relationship between these two latter terms may be the next level to explore, as indeed the relationship between hierarchy and power as problematised by Iteanu (2009, p. 343).

What is common between Earle and Spriggs and Wickham but not Hommon is a materialist focus and a focus on *internal factors*, defined at factors happening within society, as opposed to external influences such a for example natural disasters. Indeed, Wickham writes (Wickham 2005, p. 831): '*social change is overwhelmingly the result of internal factors, not external influences, which has been one of the arguments most often made in this book. Such a recognition is also the best protection against teleological interpretations of history, which are always misleading*'.

In contrast, Hommon sees *hard times* as a defining factor, a situation developed from population pressure and intensification of agriculture.

A common factor in this study is the ability for aspiring leaders to create bottlenecks, as Earle and Spriggs also suggest. These are created in various ways, depending on different geographies, ecologies, social structures and ideologies *in combination* in each place.

The overall preliminary conclusion of a comparative approach in this paper is that there are several roads to complexity. Bottleneck situations appear differently in different regions leading to similar, though not identical results. By comparing different trajectories we may better comprehend specific defining patterns for the development and maintenance of past, present and future complex societies (Turchin *et al.* 2013). In this way, the analogical approach presented here is much more an epistemological *exercise* to think with, than a theoretical *explanation* of how complex societies and states came about.

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ORCID

Mads Ravn http://orcid.org/0000-0002-5657-771X

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ARTICLE

Polynesians of the Atlantic? Precedents, potentials, and pitfalls in Oceanic analogies of the Vikings

Neil Price and John Ljungkvist

Department of Archaeology & Ancient History, University of Uppsala, Uppsala, Sweden

ABSTRACT
Comparisons between Viking-Age Scandinavia and the cultures of Oceania have long antecedents, stretching back at least to the late nineteenth century, with a significant milestone in the first-ever synthesis of Polynesian archaeology – Peter Buck's *Vikings of the Sunrise* published in 1938. This brief contribution offers some critical commentary on a recent example, Mads Ravn's paper in the 2018 volume of this journal, setting it in disciplinary context and also against Hawaiian work on this topic that has been undertaken by the authors since 2013. We consider the very real potential in this kind of comparative research, with some discussion of possible ways forward, and a note on pitfalls that must be avoided. Long sequences of continuous historical data, with a focus on internal social processes in addition to external influences, are at the centre of our approach. Above all, we stress the need for an emphasis on emic perspectives, not only in relation to native Hawaiians and other Pasifika, but also – as far as possible – in the study of the Scandinavian Iron Age.

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Introduction

We are pleased to see Mads Ravn's 2018 paper in this journal, contributing to an important and developing new field in Viking studies – that of comparative archaeology in general, and Oceanic analogy in particular. This is of special interest to us because of our own work in precisely this area, not least on Hawai'i, which has been ongoing since 2013; we thank the editors for the invitation to comment after publication.[1]

Like Ravn, we have been working with issues of state formation and complexity, in the same context of the prehistoric political economy as he takes up, but also addressing the theoretical paradigms constructed around the maritime cultural landscape and the notion of mariculture; issues of voyaging and migration; the entangled nature of cultural encounter; and the notion of prehistoric world systems. For the Scandinavian late Iron Age, we are particularly interested in the intersecting cognitive landscapes of power and ritual, not least in the context of cultural contact and religious change – a topic that has also begun to interest historians of religion (e.g. Schjødt 2017). We have been exploring these in comparative perspective through two reconnaissance surveys on the main island of Hawai'i in 2013 and 2017, with work planned for other regions of Oceania. Our project is introduced more fully elsewhere (Price 2018a), and the purpose of this short contribution is not to take up these ideas in depth. Instead, we wish to briefly discuss three key dimensions of the search for Viking analogies among Hawaiian societies (and those of Polynesia more widely), which we feel would bring useful context to Ravn's analysis. The first of them is precedent.

Precedents: *Vikings of the Pacific*

These comparisons have long histories. Even before more formal academic crossovers, there were interesting connections between the archaeologies of Viking-Age Scandinavia and Oceania. From 1883 to 1885, the Swedish frigate *Vanadis* circumnavigated the world on a voyage of scientific exploration, partially under royal patronage. On board as the official expedition ethnographer was Hjalmar Stolpe (1841–1905), whose work during the mission essentially laid the foundations of

CONTACT Neil Price neil.price@arkeologi.uu.se

professional ethnography in Sweden, with a special emphasis on Oceania. Stolpe's subsequent publications strongly focussed on the arts of the Pacific (e.g. 1892), and he is a well-known figure in the Nordic countries as the founder of the National Museum of Ethnography in Stockholm. However, Stolpe had a prior, and partially parallel, career as a pioneering archaeologist, culminating in his major excavations throughout the 1870s and up to 1882 at the Viking-Age town of Birka in Lake Mälaren (he would also return to excavating the late Iron Age in the 1890s). Two biographies of Stolpe have been written, the first being a collective and highly critical account of the scientists on the *Vanadis* voyage, contextualising their behaviour against contemporary attitudes to racial anthropology (Ljungström 2004, and see our third section below); while following his ethnographic studies in close detail, this otherwise impressive work virtually ignores Stolpe's archaeological experience. A later, full biography (Erikson 2015) gives a more complete picture but strikes an almost hagiographically uncritical tone. Although his archaeological and ethnographic professions are often perceived in isolation, it should be noted that when Stolpe encountered the rich material culture of Oceania on island after island, he was only a year or two out from his Birka excavations and may fairly be described as then being one of the leading Viking specialists in the world. The connections thereby generated are absolutely visible in his subsequent work, and in many ways form the beginning of this kind of comparative study of 'distant Vikings'.

More familiar is of course Peter Buck's *Vikings of the Sunrise* (1938), reissued in 1959 as *Vikings of the Pacific*. Although employed more as metaphor than detailed comparison, it is telling that this title was selected for the first-ever synthesis of Polynesian archaeology, in addition written by a Māori (Buck was the English name of Te Rangi Hīroa) and a Director of the influential Bernice Pauahi Bishop Museum in Hawaii. Although these kinds of comparisons have continued to surface long after (e.g. Kāne 1997, p. 9, another indigenous voice), it may well be more apposite to follow historian Michael King:

> "Peter Buck, the great Maori anthropologist, called his forebears 'Vikings of the Sunrise'. He would have done them, and Northern Europeans, greater honour had he referred to the Vikings as Polynesians" (King 2003, p. 31).

These connections and contradictions are important and resonate throughout a comparativist archaeological endeavour. The title of our commentary is deliberate.

Potentials: internal complexities

In the second of our three points, and the one on which we wish to dwell in critical perspective, it is abundantly clear that the comparative approach has great potential. In his paper, Ravn properly charts the evolution of his own, influential ideas on analogy in Pacific and Scandinavian archaeology (Ravn 1993, 2011). He also brings out the critique raised by Matthew Spriggs, a world-leading Pacific comparativist who early on (2008a) warned that European prehistorians' abundant take-up of Oceanic ethnographies ironically tended to ignore the somewhat contradictory narratives resulting from the actual archaeology of these same regions. Spriggs showed how the material record implied that much of the ethnography was itself a colonial artefact both in its data and conclusions, but – in a work omitted by Ravn – he also explicitly questioned the still-prevalent notion of the 'island as laboratory' (Spriggs 2008b).

In a more recent publication (Spriggs 2016a), a note of renewed optimism is found, but again it is puzzling that Ravn's essay does not take up what we see as a fundamental paper (Spriggs 2016b) in a fundamental book (Melheim *et al.* 2016), since it is here that a Pacific specialist addresses Viking archaeology in a truly comparativist way for the first time. Several prehistorians' papers in that volume use a Bronze Age frame of reference for these analogies, but it is Spriggs' work that brings in Oceania. The theoretical terrain separating these two discussions can also be profitably mapped out through more general comparative works in maritime contexts (e.g. Bentley *et al.* 2007, Anderson *et al.* 2010, the latter including both Polynesian and Viking examples, though unconnected).

A vital element in all this – and in Spriggs' theoretical agenda, which we largely share – must be a focus on *continuous* historical sequences as media of comparison, as opposed to spot analogies with interesting details. Hawaii is a case in point, in that the complex socio-political story of the islands is very much a developing one. Ravn claims to address this by focussing on the *longue durée* and the 'bottlenecks' that he (and others) see within it. However, in practice, this nonetheless still appears to be represented either by selective examples chronologically fixed in place or else by a timeless continuum that is not followed in detail. Spriggs' objections would therefore seem to stand.

Although Ravn sensibly cites the work of Pat Kirch, the doyen of Hawaiian archaeologists, this is restricted to a single paper and his synthesis from 2000 (actually now in a second edition from 2017). This is an important book, and in a sense also a successor to Buck's 1938 volume, but to focus on this alone overlooks precisely the Hawaiian time depth with variation between and within islands that makes such comparisons so productive (e.g. local and archipelagic case studies in Kirch and Sahlins 1992, Kirch 2012, 2014, Bayman and Dye 2013, theoretical treatments in Kirch and Rallu 2007, Kirch 2010).

This leads to another critical aspect of Oceanic analogies, namely the potential for picking up the varying internal dynamics of non-linear socio-political processes. Unlike the existing comparisons with Neolithic and Bronze Age Europe, a focus on the Viking Age brings with it a wealth of external textual sources – it is a proto-historical period, similar in fact to the situation in contact-period Polynesia. What these sources also represent, of course, is a comparable range of external pressures and influences in the form of the European Empires of the early Middle Ages and the eighteenth century. Ravn notes this towards the end of his piece, contrasting the scholars who focus on internal and external forces for change, and using this balance as the central core of his arguments that analogies can provide a means to examine different 'roads to complexity'. However, in all his preceding discussion, he clearly describes the gradual process of state formation in Scandinavia precisely as a result of outside pressures, which he contrasts with the 'isolation' of Hawaii that he sees as lacking the centre–periphery relations of Europe. We must be careful not to miss the subtleties of socio-politics here, in both regions. For example, there was considerable variation and competition among the Hawaiian islands, and even parallel state structures on Hawai'i itself before the rise of Kamehameha. There was fierce inter-island rivalry, which saw competitors driven to the outer regions of the archipelago and perhaps even beyond; Ravn alludes to this, but does not pick up its contradictory implications for the analogies he proposes. Similarly, he treats his focal region of Southern Scandinavia as a single entity, yet it appears to have also contained potential cores and peripheries, such as a bipartite Skåne, Halland, Blekinge, Sjælland, Fyn and a possibly divided Jylland, to name but a few.

Within this southern region, Ravn raises many issues of social structure and land ownership, in particular seemingly rejecting the idea of formalised aristocratic or royal dominance over a notional peasantry. He speaks of leaders rather than landlords, of tribute instead of tax. We would question this terminology, not least in relation to the implications of sites such as Lejre and Tissø, and the realities of 'tribute' from the viewpoint of those providing it. We would also point to the place-name work on administrative landscapes arranged by secular office, military rank, and sacral duty (e.g. Brink 1997, 2014) as evidence of a highly regulated centralising power relatively early on.

Particularly in his tabulated lists, Ravn's assumptions become sharper when compared with the situation in Hawaii. Activities and customs are contrasted directly (the presence/absence of 'monumental' burial mounds, hoarding of prestige goods, etc.) rather than in behavioural terms as signals of special status and difference (as in the private fish ponds, the sponsored *heiau*, and other projects requiring a mobilised workforce). There are also some questionably categorical assertions for the Scandinavian late Iron Age, such as the presence of 'free farmers', the idea that there was no private land ownership, and so on. Nuance is critical here, using solid data to avoid monolithic comparisons of simplistic, transferable templates. We must seek variation *inside* models of, for example, chieftaincies. Our comparisons must not search only for similarities, but also differences: what is the same, what is not, what is missing, is it needed, and why? Above all, how do the comparative studies illuminate the workings of these socio-political structures? Many of the models currently being activated, perhaps especially that of the political economy, present to our eyes generally functionalist interpretations of human culture. This processual, somewhat deterministic emphasis could be modified – not least in the context of the prominent role clearly played by traditional, non-systemic ritual discourse both in Oceania and in the Viking-Age North.

In both regions of comparison, there is a real and long-overlooked legitimacy in the perspectives of the Pasifika and the Iron Age Scandinavians, and it is important to see how this at times conflicts with the imposed viewpoints of respectively the European colonists and the early medieval Christian cultures. We must be careful not to 'primitivise' the Vikings by overly emphasising the external influences at the expense of internal social developments, effectively thereby importing the same biases as afflicted Pacific anthropology for so long.

Pitfalls: against the etic

This brings us to our third point, in that for all the optimistic promise of a comparativist approach, we must also consider possible pitfalls. Perhaps the key concern in following this kind of theoretical path is a failure to contextualise, especially in historical perspective. In the case of both Polynesian anthropology and Viking studies, it is vital to acknowledge the very real traditions of romanticising stereotype (and worse) with which these fields have been infected, and which even now risk seeping into comparative models from one side or another.

For Oceania, the outsider perspective began at least with Bougainville and Cook, continued through later European explorers and missionaries, and achieved fully rounded form in the cultural anthropology of the late nineteenth and early twentieth centuries (a process that has of course been extensively documented, e.g. Thomas 1997, 2010, Smith 2010). If the Pacific embodied the myth of an untouched but highly sexed Paradise (cf. Salmond 2010), for the Vikings the trope was more one of androcentric maritime violence – a different kind of noble savage – coupled with a similarly exciting non-Christian worldview (again, a widely studied field, e.g. Roesdahl and Sørensen 1996, Wawn 2000). Not least, there are also direct links of transferred cultural bias, as in the interesting but compromised work of Thor Heyerdahl, with his fantasies of meeting 'almost Nordic' Polynesians in the Marquesas (1938, a work published in English first in 1974 with the subtitle *Back to Nature*). It is no coincidence that Buck's synthesis (1938) came out the same year, also with problematic connections drawn between the Polynesians and Caucasians.

These tensions have played out in the changing multivocality of both Oceanic studies and our views of the Viking Age. Just as Polynesians and other Pacific Islanders are taking a proper lead in perspectives on their own past, so the multi-ethnic nature of the Viking diaspora (augmented by isotopic and genomic work) has extended to the revelation that many 'Viking' groups were far from entirely Scandinavian in origin. In so many ways, the definitions of the Viking phenomenon itself are open ended as never before (Price 2015, 2018b). This gradual shift from an etic to an emic view is paralleled in the Pacific, typified in the influential work of the Tongan anthropologist Epeli Hau'ofa (e.g. 2008). We discuss his work more fully elsewhere (Price 2018a), but Hau'ofa's concept of the 'sea of islands', a maritime cultural medium that embodied the essence of the Polynesians, is one that we find entirely applicable to Viking-Age Scandinavia. The agency and contribution of indigenous scholars is at last being acknowledged in Oceania: a truly comparative archaeology of the Viking Age must both engage with this and also search for the ancient Scandinavians' own understanding of their world. Though unconnected in time and place, both the Vikings and the Polynesians were changed by their contacts with ultimately the same alien religion and external imperial forces – but they also incorporated and manipulated them to their own ends, and remained uniquely themselves.

Note

1. Our work has been presented at a number of conferences in Scandinavia and the Pacific. Ravn has kindly acknowledged (email pers. comm. 2018–05-31) that one of these papers, at the Viking Congress in the autumn of 2017, in part 'sparked' his own article submitted 3 months later.

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RESEARCH ARTICLE

Species identification using ZooMS, with reference to the exploitation of animal resources in the medieval town of Odense

Luise Ørsted Brandt[a], Kirstine Haase[a,b] and Matthew J. Collins[c,d]

[a]Centre for Urban Network Evolutions, Aarhus University, Aarhus, Denmark; [b]Department of Cultural Heritage, Odense City Museums, Odense, Denmark; [c]EvoGenomics, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark; [d]BioArCh, Department of Archaeology, University of York, York, UK

ABSTRACT

ZooMS (Zooarchaeology by Mass Spectrometry) is increasingly being used as a method for species identification of archaeological and historical remains. The method identifies species from the peptide mass fingerprint of extracted collagen – the principal protein of bone, ivory, dentine, leather, and parchment. ZooMS has the advantages that it is a fast and simple method, that requires only small sample sizes or even non-destructive sampling. The taxonomic resolution of the method varies, but ZooMS is diagnostic for most domesticated animals and for the relatively depauperate Scandinavian fauna, although some groups (seals, martens) cannot be resolved, and it cannot discriminate some domesticates (dog, cattle) from their wild counterparts. In this article, we overview the method and demonstrate the value of ZooMS and illustrate our points via a case study of 20 samples from 12th to 14th century layers in the Danish medieval town of Odense. Four artefacts were tested by a non-destructive eraser technique because of their uniqueness, but only one could be identified. The remaining 16 were identified following destructive analysis of the sample, one sample could not be identified.

Through the identification of a gaming piece as walrus tusk the analysis demonstrated the long distance trade networks of Odense and the pursuit of some inhabitants for luxury products and high living standards. Conversely, the species identification of combs showed that the medieval comb maker would use the resources immediately available to him to create an affordable everyday object rather than rely on imported antler.

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Introduction

The study of animal remains such as bones, skin, and fur in an archaeological context provides insights into past relationships between animals, people, and the environment. Because of the mutual nature of these relationships, animal remains in context have been used to address a wide range of aspects of the human past as amongst many others diet, resource exploitation, animal domestication, economy, environment, trade networks, and cultural identity, and the study is relevant across prehistoric and historic periods, settlement types, and geographical regions (Steele 2015). Identifying the species of animal remains is one of the key prerequisites for discussing such aspects of human culture.

This article explores the protein fingerprinting methodology of ZooMS (Zooarchaeology by Mass Spectrometry, Buckley *et al.* 2009) which uses amino acid sequence variation in the dominant structural protein, type I collagen, which is abundant in bone, skin, and tissue, for species identification in Scandinavian archaeology. Since its introduction, the method has reached maturity and is becoming increasingly popular within archaeology as it is a cheap, easily applicable, and minimally or even non-destructive method for species identification (Fiddyment *et al.* 2015, Coutu *et al.* 2016). Moreover it has been demonstrated to be an excellent method for screening large bone assemblages for specific species (Welker *et al.* 2016).

In this article, we will introduce ZooMS and then present a case study in which the method has been used as part of an analysis of the 12th to 14th century animal resources from the Danish town of Odense.

CONTACT Luise Ørsted Brandt luise.brandt@cas.au.dk Centre for Urban Network Evolutions (UrbNet), Aarhus University, Moesgaard Allé 20, 4230, 2nd floor, DK-8270 Højbjerg

The Scandinavian record

In many sites in Scandinavia, animal bones and skin (rich in collagen) are common finds whereas fur and woollen textiles (rich in keratin) are rare. In fact, animal bones (with waterlogged wood) are the most abundant organic materials that we come across in urban excavations. They are often present in more or less every cultural layer and deposited in every conceivable way; from intact buried animals to fragments in the form of dietary remains, waste from butchering, worked bone or antler, semi-manufactured artefacts and debris from production, finished, discarded or lost artefacts, or reused animal bones in structures as fills.

Because of its abundance and witness of multiple processes, bone holds great interpretive potential, but it is also one of the most challenging to handle. This is not only due to the complicated processes related to its use and deposition but also because of the circumstances that applies to most excavations in Denmark. The majority of the archaeological excavations in Denmark are rescue excavations that are conducted within the framework of the Danish Museum Act part 8.[1] This entails economic restrictions and specific guidelines with regards to the analysis of zooarchaeological material.[2] In practice this implies that it is impossible to collect the preserved bone material in its entirety. The analyses that are carried out are mainly quantitative in nature, where the number of bones, species and sex identification, and their distribution over time are accounted for.

One could argue that collecting all animal bones from a site would be a senseless endeavour, since the excavated material already only represents a part of the original bone assemblage due to selection processes in the past and the following taphonomic processes (Orton 2012). An analysis of the zooarchaeological material from any archaeological site will always have to consider sample bias and fragmented material. This makes it even more important to consider all available information from the archaeological record. Only then it is possible to answer questions such as: What animals provided the raw materials for both food and manufacture of artefacts? Were they local or not? Were some animals preferred over others? And for what purpose? These questions are especially pertinent to the medieval town, since the use of animal resources are part of the economy that sustained life in the town and therefore part of what characterises life in town. Describing these practices on best possible ground will enable us to understand the dynamics that constituted life in the town and ultimately what makes town life different from other forms of existence (Christophersen 2015). In order to answer any of these questions, it is necessary to identify the species of the zooarchaeological material *including* the material that is not identifiable through morphological characteristics. ZooMS offers to do so in a way that is affordable, reliable, and within the scope of the Danish Museum Act.

Species identification of animal remains

Species identification of animal bones has traditionally been performed by osteological examinations of the size, morphological characteristics, and surface features of bones that vary between species (O´Connor 2000). This can lead to the determination of the species of its origin by comparing the observed characteristics with characteristics on bones of known species origin from reference collections or animal bone atlases. These morphological species identification methods are especially valuable in that they often provide additional information to the species, such as the bone element, sex and age of the animal, pathology, traces of wear, and the preservation state of the object (Steele 2015). However, the success of osteological species identification depends on the preservation of the diagnostic characteristics of bones and the opportunity to identify them. Diagnostic characteristics may be lost due to, for instance, processing bones for consumption, working bone into artefacts, taphonomic processes such as weathering and gnawing or diagenetic processes following burial (Lee Lyman 1994). If some animal bones are more heavily processed than others, their importance may be overlooked as their fragments may be less recognisable. Even for well-preserved bones, both wild and domesticated species may display significant variations of bone elements within a species for instance between males and females and between different populations (Hillson 1992). This means that considerable expertise is required for reliable identifications, but also access to reference collections encompassing all such interspecies variations. The last is further a challenge as some species are known to have changed morphologically over the past millennia and during domestication. Examples of this is a great diversity of horns in cattle, sheep, and goat after domestication and a shortening of the face region and jaws seen in for instance domesticated dogs and pigs (Clutton-Brock 1999).

When diagnostic features are not preserved, archaeologists are left with no species identification or identification to a higher taxonomic level, which can lead to large percentages of unidentified bones and bias the interpretations of a bone assemblage (Badenhorst and Plug 2011); indeed archaeologists include the term ovicaprid due to the difficulty of discriminating sheep from goat.

Over the past two decades, developments within biomolecular archaeology have resulted in a range of technologies which are applicable for species identification of archaeological material. Of these, the analysis of ancient DNA is probably the most well-known. DNA from a range of archaeological materials has been successfully extracted and sequenced both targeting short fragments of mitochondrial DNA using PCR (Polymerase Chain Reaction) and larger parts of the genome using Next Generation Sequencing (NGS) technologies. Such studies have provided species identifications of animal bone, skin, and hair (Fiddyment *et al.* 2015, Brown *et al.* 2016, O'Sullivan *et al.* 2016, Welker 2017). The great advantage of DNA studies is the high resolution which allows the distinction between even closely related animal species, and male from female, but also it can discriminate populations, and identify migrations (Cassidy *et al.* 2017, Librado *et al.* 2017). NGS analyses are still relatively expensive and time consuming and the success of aDNA analysis largely depends upon the preservation of DNA, a process which is still poorly understood (Smith *et al.* 2003, Kistler *et al.* 2017). However, materials with no preserved DNA may not be out of reach for species identification.

Over the past years, proteins have been demonstrated to persist for longer than DNA and can be recovered in environments from which DNA cannot be amplified (e.g. eggshell, Demarchi *et al.* 2016, and bone, Welker *et al.* 2015a, Westbury *et al.* 2017). In the case of skin capes from Danish bogs dating to the Iron Age (Schmidt *et al.* 2013), DNA identification failed, whereas a proteomic approach was able to provide species identifications of the skins. More than this, proteins can be tissue and developmentally specific, and the study above provided additional information on the use of young (calf) skin for one of the capes (Brandt *et al.* 2014). Both NGS-based DNA approaches and proteomics methods are however relatively expensive and time consuming. In many cases, merely species identification can be the most relevant information for answering an archaeological question together with traditional zooarchaeological analysis such as quantification, animal size, element processing, etc.

ZooMS – Zooarchaeology by Mass Spectrometry

Whereas shotgun proteomics, as the name suggests, targets all proteins preserved in a sample, ZooMS usually targets the protein collagen, the most abundant protein in animals where it is found in connective tissues, bone, antler, teeth, and skin (Shoulders and Raines 2009). So far, 28 collagen types are described. Of these, type I collagen is the most abundant and found in various tissues including bone, skin, ligament, and tendon. It is a tough, insoluble protein, which is difficult to biodegrade if protected by mineral (bone, dentine, antler) or tanned (leather). Consequently it is the most common protein recovered from archaeological environments. In higher vertebrates, type I collagen consists of three polypeptide chains: two collagen α1 chains and one collagen α2 chain, which are coiled into an extended proline triple helix. Collagen forms a nanorope; the triple helices self assemble into larger collagen microfibrils, which aggregate to form collagen fibres (Shoulders and Raines 2009).

After collagen, the second most widely studied protein from archaeological remains is keratin, found in instance wool, hair, nail, hoof, beak, and feathers (Hollemeyer *et al.* 2002, 2007, 2008, 2012, Solazzo *et al.* 2013, 2014, Solazzo 2017).

Sampling

When analysing archaeological material only small samples are needed. For example, 'empty' tubes used to process collagen for radiocarbon dating (Charlton *et al.* 2016) and eraser rubbings used to clean parchment (Fiddyment *et al.* 2015), have both been used. In the case of archaeological samples, 10-30 mg of

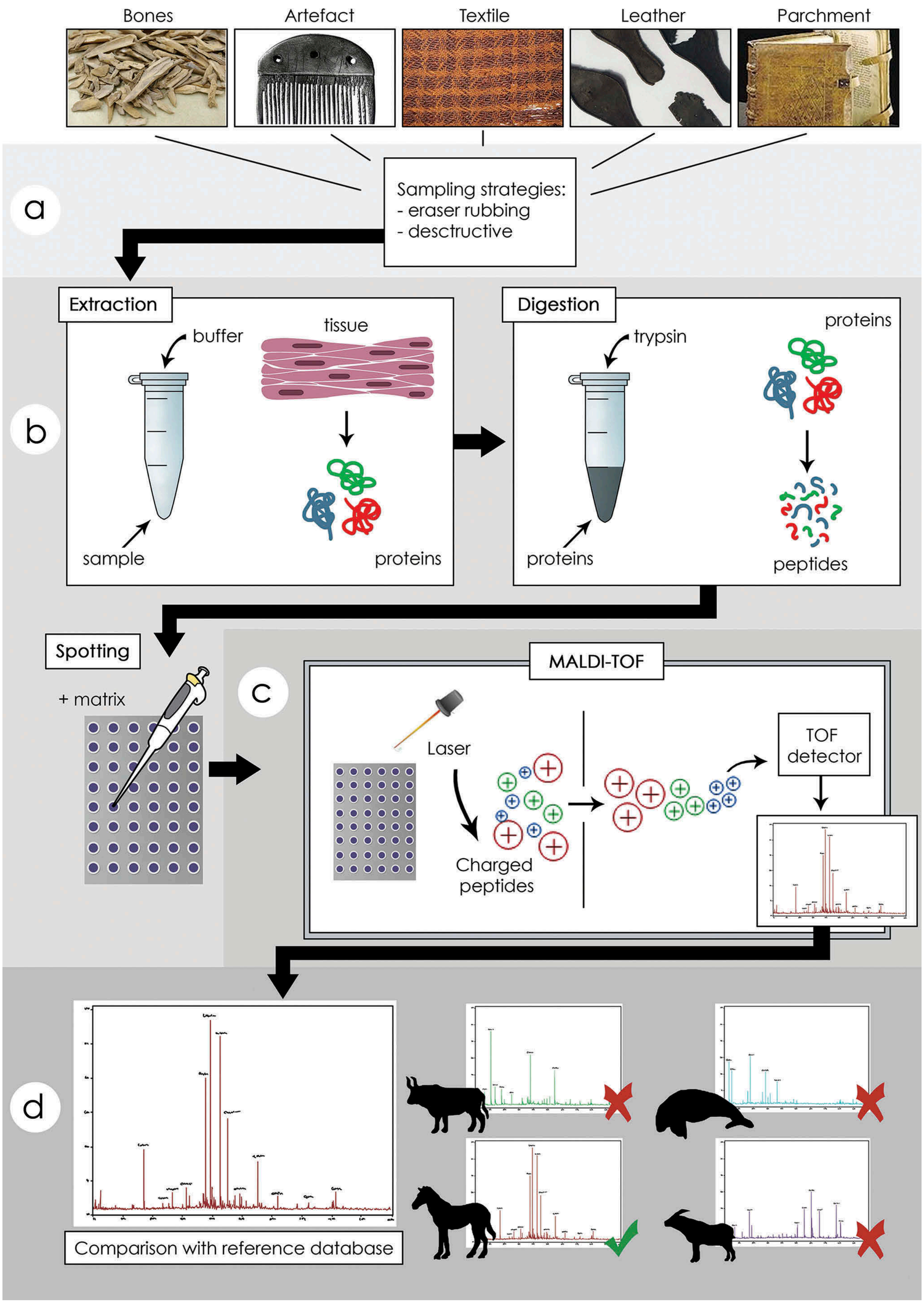

Figure 1. Flow chart of the ZooMS process. Graphics: Sidsel Frisch.

bone (depending on whether bone chips or bone powder is used) or pinhead of skin is sufficient (Figure 1(a)). Being able to sample non-destructively is crucial for getting access to materials from which a sample cannot be spared.

Extraction and digestion of collagen

The extraction protocol varies according to material and strategy (Figure 1(b)). For bone samples, a destructive demineralisation can be applied to dissolve the bones mineral component using hydrochloric acid, which leaves a collagen pellet that can be gelatinised using ammonium bicarbonate (Buckley *et al.* 2009). An alternative and non-destructive approach has been developed (Van Doorn *et al.* 2011), which avoids the demineralisation step, extracts sufficient collagen for ZooMS, and leaves the sample undamaged.

Regardless of the extraction method, the subsequent digestion is usually the same. The solubilised collagen (gelatin) is cleaved using the enzyme trypsin into shorter chains of amino acids (peptides) at lysine and arginine residues. Together lysine and arginine represent about 10% of all the residues in collagen, but they are not evenly distributed over collagen, thus although the average length of a chain will be about 10 residues, resulting peptides will have a varying length, composition, and mass. It is these masses, when known to vary between animal species, due to differences in the amino acid sequence, which enable species identification. However, the low degree of sequence variation in collagen, and the degree of structural constraint means that different peptides can share the same mass. The peptide digests are desalted, typically using C18 columns (ZipTips) and eluted in (TFA) acidified acetonitrile. It is possible to fractionate the eluent from the ZipTip by using different concentrations of solvent. 1 ul of each sample is spotted in triplicate onto a plate (both disposable plastic and reusable stainless steel can be used) to which 1 ul of matrix is added, and the two co-crystallise.

Analysis

The mass of each peptide is measured using Matrix-Assisted Laser Desorption/Ionization Time of Flight Mass Spectrometry (MALDI-TOF) (Figure 1(c)). A laser is targeted at matrix crystals formed as the sample dries on the plate. Using a compatible wavelength to the matrix, the absorbed energy causes the (acidic) crystals to volatilise transferring charge (a single proton) to some of the co-crystallised peptides. An electric field accelerates the volatile charged peptides down a vacuum tube, towards and ion mirror which doubles the length of the flight path and helps focus the ions towards the detector. As all peptides carry a single charge, the smaller and lighter peptides travel faster down the tube than the larger and heavier ones. The time of flight to reach the detector can be used to estimate the mass of the peptide and the resulting peaks generated on a spectrum reflects the mass and the intensity of the detected collagen peptides. Each sample therefore gives a fingerprint of masses of the constituent collagen peptides.

Identification

It is typical to run triplicate spectra, as differences in co-crystallisation impact upon system performance. The three spectra resulting from the triplicate spots of each sample can be averaged and analysed using software tools such as mMass (Strohalm *et al.* 2008).

Masses which represent collagen peptides of different masses are recognised. The masses are then compared to a list of collagen peptide masses from the species that have been analysed, or predicted from sequences. By comparing the masses, it will be possible to rule out species (Figure 1(d)). The more peaks recognised on the spectra, the better the chance for a specific identification. In the ideal situation, the peaks will represent masses that are diagnostic for only one species. Some species are however so closely related that it will not be possible to distinguish them (Buckley *et al.* 2011, Coutu *et al.* 2016). Mammals have been the primary focus for ZooMS identifications, but the reference database also includes markers for fish (Richter *et al.* 2011) and markers for eggshell from birds (Stewart *et al.* 2013, Presslee *et al.* 2018) and is constantly expanding.

Depending on the extraction method, the entire analysis from sampling to analysis can be carried out in few days. Altogether ZooMS therefore represents a minimally or even non-destructive, cheap, easily applicable, and fast method for species identification of archaeological remains rich on collagen or keratin.

Case study: animal remains from medieval Odense

The site

From May 2013 to September 2014 a large rescue excavation prior to construction work took place in Odense; the third largest town in present day Denmark.

Odense is first mentioned in a letter in 988.[3] Also, in the 10th century, a Viking ring fortress was built in Odense, in the 1040s it is possible that minting took place, and in 1086 King Canute (the Holy) was killed before the altar in St. Albany Church and later canonised (Christensen 1988). These events all suggest that Odense was a significant settlement already in the 11th century although it has been difficult to characterise the settlement further through the archaeological record.[4] By the 13th century, Odense acquired market rights and the archaeological and written records testifies to a vibrant and growing town that maintains its position as one of the most important towns in Denmark throughout the Middle Ages.

An area of 2500 m^2 with approximately 4300 m^3 of cultural layers in the central part of the medieval town was excavated. A coherent area of that size and location had prior to this never been excavated in Odense. All though the area had been heavily truncated by modern construction activity the preservation conditions for wood, bone, and other organic material were surprisingly excellent. Both an extensive finds assemblage and well-preserved structures such as stalls, houses, stables, latrines, paths, roads, fences, manure heaps, and much more was brought to light. This presented a unique opportunity to study the period from the 11th to 16th century CE in Odense in detail (Figure 2).

Table 1. Number of animal bone fragments from the 2013–2014 excavation in Odense (OBM9776) and their distribution through time.

Period	No. of fragments
–1100	848
12th Century	12.031
13th Century	30.404
14th Century	31.956
15th Century	8.843
After 1500	100
In total	84.182

Zooarchaeological results

A total of 84,182 fragments of animal bones were recovered from the cultural layers – all as the result of an extensive sieving procedure (Table 1). Of these it was possible to identify the species or family level of 40,913 fragments which illustrates the challenges in

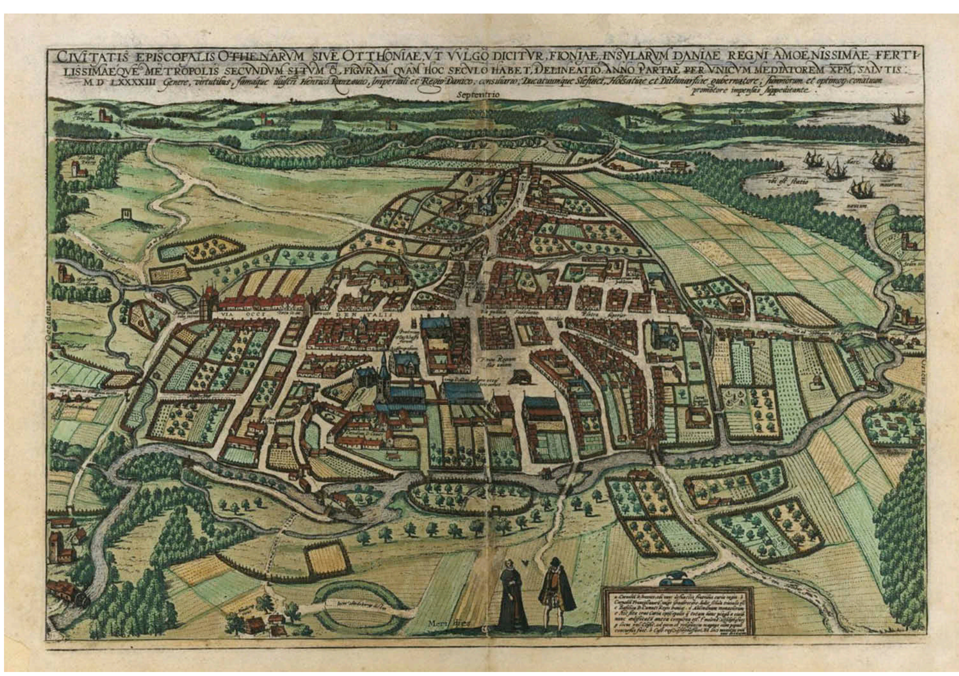

Figure 2. Odense around 1593 AD – Braun & Hogenberg *Civitates orbis terrarum Vol. V.*

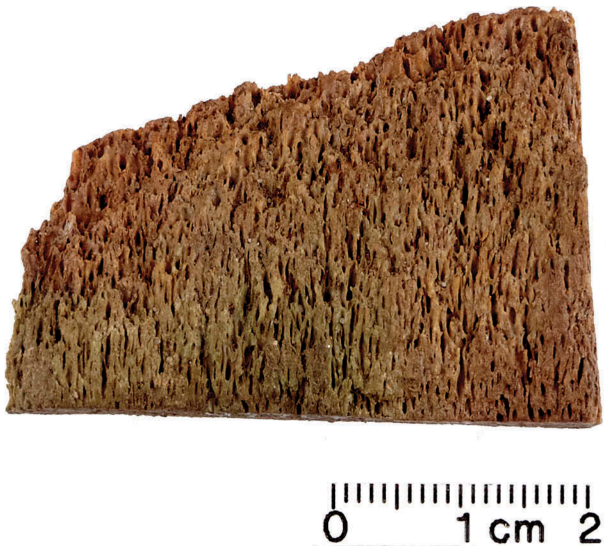

Figure 3. Photo of a piece of worked right whale bone (x5850). Photo: Nermin Hasic, Odense City Museums.

working with this often fragmented material. In spite of only half of the bones being identified, the results of the excavations and the zooarchaeological analysis demonstrate that a wide range of domestic animals such as horse, pig, cattle, sheep, and goat have been an important contribution to life in town from the 11th to 16th centuries (Østergaard 2016). On each stage of their life-history, these animals would be an almost indispensable resource acting as draught animals, providing milk, meat, and raw materials such as leather and bone for manufacturing various objects.

A total of 208 artefacts were produced of either antler or animal bone. Amongst these were semi-manufacture, production waste, needles, dice, combs, mounts, gaming pieces, handles, and a number of artefacts that could not be identified apart from the material; bone or antler. Forty of the 208 artefacts were identified to species level through morphological traits – most of these to red deer antler. 26 artefacts were identified as either a large or a small mammal. Amongst the artefacts for which the raw material could not be identified, 20 were selected for further analysis. These artefacts were chosen because they had a solid relation to an archaeological context and because this context was well-defined both stratigraphically and with regards to their interpretation. In addition, some were selected because of their unusual appearance (e.g. Figure 3). Finally, 13 samples were included because they were interpreted as being either combs, parts of combs, semi-manufacture, or production waste from comb-production. The artefacts were moreover chosen so they spread over the 12th, 13th, and 14th century as one of the research questions was whether the selection of raw material for combs had changed over time. Another question was whether antler used for comb production derived from local animals from medieval Denmark, or from imported raw materials (Roesdahl 1999, Linaa 2015). A recent study of comb making in Viking Age Ribe, Århus and Aggersborg (Denmark) successfully used ZooMS to identify the raw material used as mainly cervid (red deer, roe deer, and reindeer, Ashby *et al.* 2015, 679–704). Also, Von Holstein *et al.* (2014) used ZooMS and DNA to explore evidence of trade with Scandinavia in pre-Viking Scottish combs. The number of samples from Odense was too small to give a representative picture of the development and the characteristics of use of animal resources and the analysis served therefore as a pilot project.

ZooMS analysis

For 16 of 20 bone samples, ZooMS was carried out using demineralisation according to Buckley *et al.* (2009) and for four samples using the non-destructive sampling with eraser (Fiddyment *et al.* 2015). Non-invasive sampling removes collagen using the triboelectric effect and was chosen, because it avoids the need to take a physical sample, when sampling complete or unique artefacts.

Table 2. Results of ZooMS identifications on 20 samples from the 2013–2014 excavation in Odense (OBM9776).

Specimen no.	Sampling technique	
OBM9776	Destructive (Buckley *et al.* 2009), Non-destructive (Fiddyment *et al.* 2015)	Species ID
x1276	Destructive	Cattle
x3025	Destructive	Bovid/cervid
x3116	Non-destructive	No ID
x3595	Non-destructive	No ID
x4685	Destructive	Bovid/cervid
x4715	Destructive	Bovid/cervid
x4974	Non-destructive	Bovid/cervid
x5559	Destructive	Cattle
x5651	Destructive	No ID
x5794	Non-destructive	No ID
x5850	Destructive	Right whale
x5864	Destructive	Cattle
x5875	Destructive	Red deer/fallow deer
x5953	Destructive	No ID
x6732	Destructive	Sperm whale
x7341	Destructive	Atlantic walrus
x7378	Destructive	Pig
x7564	Destructive	Horse
x7576	Destructive	Horse
x852	Destructive	Bovid/cervid

Results

Identification to species was possible for nine of 20 samples. Five samples failed to yield any identifications, while five samples were identified to the level of bovid[5] or cervid[6] and one to red deer or fallow deer (Table 2).

The possibility of identifying a sample depends first of all on the presence of collagen in the sample. It moreover requires that there are known differences between species and that peptides with these diagnostic masses are preserved. Not all the diagnostic peptides are identified in every sample and therefore identification will often be limited to a higher taxonomic level. To illustrate this, we have chosen the example of the whale, for which the 1682 peak is not shared with any other species. This provides a unique identification of the artefact to right whale (Buckley *et al.* 2014) (Figure 3).

Another example is the identification to a larger group of bovids and cervids present in the database. For OBM9776 x852, the presence of the peak 1427 m/z is shared between Bovidae such as sheep, goat, cattle, and gazelle and Cervidae such as reindeer, roe deer, fallow deer, red deer.[7] Therefore, if there are no other peaks present on the spectra that differ between these species, the identification will be bovid/cervid. However, the peptide with the weight of 1427 differs from the peptide found in for instance pig, dog, and marine mammals, which after all excludes a range of species. If no diagnostic peaks are present, the result will be No ID.

The combs

The results of the pilot ZooMS analysis were somewhat surprising. As expected the medieval combs were primarily from animal bone. Generally it is widely accepted that medieval combs or combs manufactured in the 13th century and later are made from bone rather than antler

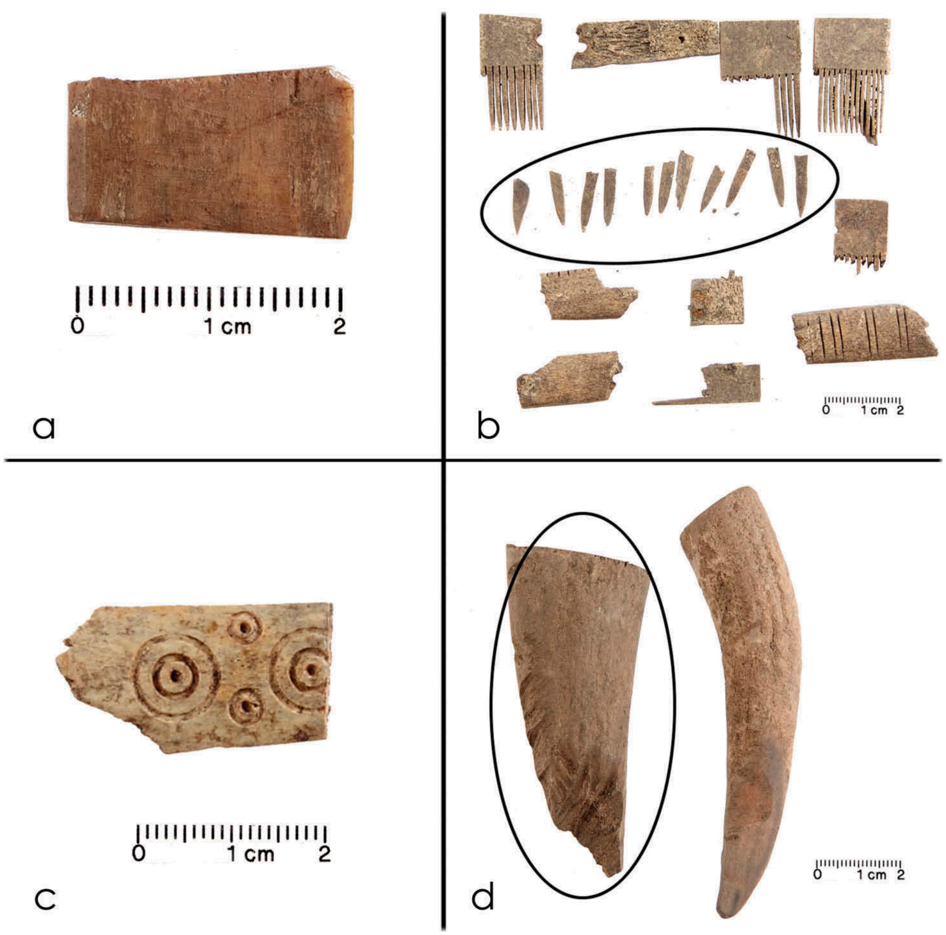

Figure 4. A selection of the analysed items. A: Horse (x7564), B: Pig (x7378), C: Bovid/Cervid (x4715), and D: Red deer/Fallow deer (x5875). Photo: Nermin Hasic, Odense City Museums.

(Øye 2005, Ashby 2009). The surprise was rather the *diversity* in the choice of species used for comb manufacture (Figure 4). For those parts with a positive identification, beyond bovid/cervid, the ZooMS analyses showed that cattle was the primary source for connecting plates (x5559, x1276) whereas horse, pig, cattle, and even bone from sperm whale have been used for making tooth plates (x7378, x7564, x5864, x6732). There was no positive identification for reindeer, roe deer, fallow deer, or red deer in any of the artefacts that with certainty could be related to comb production.

The presence of sperm whale (identified by key marker 2133 (Buckley *et al.* 2014)) was unexpected. Sperm whales are rare guests in the waters around Funen, but in the present day there are regular beachings of sperm whales on the west coast of Jutland, which might also have been the case in the Middle Ages. The beached whale belonged to the king, but locals were allowed some parts of it (Hybel and Poulsen 2007, 55). Maybe this was how the sperm whale bone ended up in Odense, brought there by a visitor or a merchant from Jutland. It does not seem that the comb maker distinguished between raw material from either small (pig) or large (horse, whale) animals. Horse bone was a very rare find amongst the animal bones (0,1%) in Odense and the main part of that material was represented by a complete horse that had been buried in a landfill area sometime during the 14th century (Østergaard 2016). The bones of this horse had cut marks which suggest that it had been skinned. Horses were mainly used for riding or as draught animals in the medieval period, but their skin would be used for leather. Finds of production waste from horse bone in Århus and Ribe suggest that it was not unusual to use horse bone in comb making in the Viking and medieval period (Møhl 1971, Enghoff 2006).[8] In the aforementioned study from 2015, horse was found in a finished comb from Århus (Ashby *et al.* 2015, 690). In spite of the complicated procedure with removal of the flesh, etc. the examples show that horse bone may have played a larger role as raw material than the bone assemblage from Odense alone suggested.

With some precaution in regards to the small number of samples we may conclude that the medieval combs are a product of the town to a much larger degree than the Viking Age comb (Larsen 2005, Frandsen 2006, Ashby *et al.* 2015). It was possible to procure the raw material within the town limits including animals that would probably not be used for dietary purposes – the horse. Antler was still used in comb production, as contemporary antler production waste from the area indicate, but it is most likely only from local red or fallow deer. The analysis suggests that at least half of the objects with relation to comb production were made from different types of animal bone (horse, whale, pig, and cattle) and not antler. This was either because of difficulties in access to antler or a desire to use the raw material available within the town perimeter. A cost-effective method that would make the comb a very affordable product and probably also enable a mass production since the raw material was present in abundance. Instead of being dependant on raw material from outside the town the comb maker would operate within the town limits. Even the copper used for the rivets, that would attach the connecting plates to the tooth plates, may have been made from reused material.

These considerations also leads to the suggestion that using a specific type of antler in Viking Age combs was a very conscious and active choice since the Viking Age comb makers also would have had access to animal bones as raw material. It does not seem to have any functional or visual consequence whether animal bone or antler is used as raw material for the comb. Instead there might be some underlying symbolic meaning in the Viking Age comb makers choice of material (Ashby 2014, 99–121). The change of raw material indicates that the comb changes from being an exclusive product to a more accessible and affordable everyday product (Figure 5).

The exotica

A couple of exotic species turned up amongst the species identifications by ZooMS. One was the Atlantic walrus (Figure 6) and the other was a right whale. The piece identified as walrus was a part of walrus tusk also known as 'the ivory of the north' in the Middle Ages. Walrus tusk was used as gaming pieces, mounts or decorations for caskets or other decorative items. They were highly prestigious items and a luxury good. The piece from Odense may be part of a gaming piece, but it has not been possible to give a positive identification. It was found in the activity layers that had accumulated around a 14th century market stall. It is possible that it was part of what was sold from the stall but it is also possible that it was lost accidentally in the busy crowd by one of the customers.

Figure 5. A small one-piece double-sided comb made from bovid/cervid bone (x3025). Photo: Nermin Hasic, Odense City Museums.

Figure 6. Two small pieces of worked walrus tusk which might have served as gaming pieces. OBM 9776 × 731. Photo: Peter Helles Eriksen.

The Atlantic walrus was traded all over Europe from Iceland and Greenland as early as the 13th century as mentioned in *Kongespejlet (Latin: Speculum regale* c. 1220–30 AD) (Brøgger 1947). They were hunted by the Norse who settled on the south-west coast of Greenland from around 1000 to the early 14th century (Jensen and Østergaard 2017, 178). In 1327 the Greenlandic tithes were paid through sale of walrus tusk (Liebgott 1985, 10–11; Jette Arneborg 2000, 304–305). Findings of walrus skulls in Norse farms show that it was mainly the tusks – and probably also the hide – that was the most desired part of the walrus (Arneborg 1999). Walrus found in Denmark may have been traded through Norway.

The presence of walrus tusk in Odense both evidences the trade connections of the town and also a rise in living standards paralleling trends elsewhere in Europe.

Discussion

The ZooMS analysis of bone artefacts from medieval Odense demonstrates the potential of ZooMS for species identification a group of materials that have until now remained silent: artefacts without recognisable morphological traits. Until now such artefacts have mainly been treated in relation to their function or decoration, but integrating ZooMS, they can also provide us with information of the choice of animal resources for bone artefacts which, as demonstrated, adds to our understanding of their production, use, and interpretation. ZooMS offers the opportunity to obtain a more complete picture of the use of animal resources by allowing us to include not only worked artefacts, but also the large material of unidentified animal bones without diagnostic traits. This not only applies to bone assemblages from medieval towns, but to animal bones across time periods, cultures, and geographical regions.

While other biomolecular methods might be used for species identification, ZooMS is cheaper and faster and more easily applicable than both regular aDNA analysis and shotgun DNA or proteomics methods. This has several advantages; for museums, this means that it is possible to perform large-scale ZooMS analysis of artefacts without over-burdening budgets. Also the species identification is within the guidelines of the Danish Museum Act.[9] Combining traditional zooarchaeological analysis with ZooMS will enhance the outcome of both methods and give more complete data on past animal resources and how they were exploited. With the low costs it is moreover possible to do 'bulk analysis' that will go beyond identifying the species of different looking artefacts in the hope of detecting the presence of exotic and unexpected animals (e.g. 12,317 samples, Buckley *et al.* 2017). Instead, it is possible to ask questions that require a larger body of analysed objects and enable construction of full biographies of the practices related to the use of animal resources and reveal patterns in trade and resource networks on a global, regional, and local scale. ZooMS can even be used as a screening tool and precursor to aDNA analysis. As an example ZooMS has been applied to Palaeolithic bone assemblages to reveal archaic hominins, which could then be subjected to further biomolecular analysis that can provide higher resolution data as aDNA and shotgun proteomics (Brown *et al.* 2016, Welker *et al.* 2016). This means that museums can select for destructive analysis (e.g. isotopes, DNA, radiocarbon dating) samples which have no morphological value instead of artefacts or elements with diagnostic characteristics (e.g. the right humerus of the Neandertal type specimen, Krings *et al.* 1997).

The reliability of ZooMS as a method for species identification has been independently confirmed in several studies (e.g. Von Holstein *et al.* 2014/1; Welker *et al.* 2015b, Evans *et al.* 2016). However there are two further considerations which should be born in mind before considering undertaking a study. Firstly the rate of collagen sequence evolution is relatively slow and consequently there may be instances, such as in the case of Indian/African elephants/mammoth, in which there are no differences within type I collagen (Buckley *et al.* 2011, Coutu *et al.* 2016). This may be particularly problematic if there is a large diversity of closely related species which could be utilised (e.g. Bovidae in Africa), but ZooMS is for instance diagnostic for most domesticated animals in Scandinavia. Secondly the quality of the identification is only as good as the quality of the database against which the samples are searched. Consequently there are cases in which samples could be misidentified, if the relevant species is not available. In these cases, the best match would be a closely related species, and if no unique masses are present, the identification may be mis-called.

The success rate of ZooMS is a function of the amount of collagen present in the sample which itself will decline in older bones, will be low in bones that have been cooked and absent in bones which have been burnt. For unburnt bone, Evans *et al.* (2016) report that 35/38 archaeological whale bones were identified to order, family or genus, and Ashby *et al.* report identifications to species for antler or animal bone for 469 of 705 combs or comb fragments from Danish Viking Age (Ashby *et al.* 2015). However, few studies report clear success rates, perhaps because samples can easily and without great cost be reprocessed. A second factor which may lead to poor results is if the extracts are highly discoloured for instance due to an abundance of humic acids from the soil. This can be a problem in urban deposits, but where this becomes a challenge is the case of tanned leather. It remains unclear as to why tanned leather has sometimes proven problematic for ZooMS (and also for DNA amplification, Vuissoz *et al.* 2007), it may be because the tanning agents interfere with the enzymes used in the assay or it may be that not all of the aromatic compounds are retained in the C_{18} clean up step and they may interfere with the laser ionisation step. For parchment (well preserved processed animal skins) which has never been buried, the eraser method even works better than destructive sampling (Fiddyment *et al.* 2015). However as demonstrated in the case-study from Odense, above, (for which 15 of 16 of the bone samples that had been sampled destructively worked compared to one of four of the ones sampled by eraser) that in order to have a high success rate it is necessary to take a sub-sample of the bone. Although the success rate for the eraser method on worked, bone, ivory and antler, is understandably lower, the lack of a sub-sample has obvious application, not least to portable art (e.g. Coutu *et al.* 2016).

Even where destructive sampling is used, the sample size can be so small that it is still possible to do the sampling in a area where the object can be photographed or put on display in a museum without showing the sample spot.

Although this article has focused on bone, bone assemblages are by no means the only suitable material for ZooMS. Collagen is also the major protein in skin, and the potential for ZooMS has been demonstrated on parchment as well as animal skin and connective tissues (Kirby *et al.* 2013, Fiddyment *et al.* 2015). This opens up for a enormous amount of skin-based materials of archaeological or historical origin including clothing, shoes, leather goods, furnishing, containers, wrappings, book bindings and skin-based glues. The fact that the database for keratin has been expanded (Solazzo *et al.* 2013, 2017, Solazzo 2017) opens up for an array of materials based on hair, feather, nail and baleen, not to mention textiles, for which the identification of fibre is an essential question.

Leather, skin, and hair all face the same issues as bones in terms of species identification, which also for these is based on recognisable morphological traits and differences in the so-called grain pattern of skin, which varies between species, and characteristics of hair as hair diameter, the length of the fibres, and the appearance of the scales and medulla, which also varies between species. Once these morphological features are lost, all will rely upon molecular identification.

Conclusion

The analysis of the 20 samples from medieval Odense showed that there is a great and yet unexplored potential in analysing the artefacts that are made unidentifiable through manufacture. ZooMS will test assumptions on the choice of material for different purpose and enable interpretation that goes beyond the mere species identification. Through a precise and un-debatable species identification, we are able to ask questions regarding intended and unintended actions, identities, practices taking place in the town, etc. For Odense, long distance connections was demonstrated by the find of walrus tusk and the combs showed that the medieval comb maker would use the resources available to him in the town to create an affordable everyday object.

ZooMS is a fast, minimally or even non-destructive, easily applicable method for species identification, which has proven reliable and with a good success rate, and resolution for Scandinavian fauna. The potentials of ZooMS expand beyond animal bones and is for instance applied extensively for species identification of parchment (Fiddyment *et al.* 2015), but its potentials for skin and hair based materials are also great. In medieval Odense, the ongoing species identification of leather objects will enable a cross-correlation with the evidence obtained from the bone assemblage (O´Connor 2003, 3231–3235) and in Odense and in general the identifications of leather can enlighten aspects as skin trade and choices of leather for functional or signalling purposes.

At the moment ZooMS is a research method, but like many technologies before, as the approaches become standardised we are hoping that it is made available to a wider, non-specialised, audience. Like radiocarbon before it, it is hoped that in the future ZooMS will become a routine tool available to local museums conducting contract archaeology within Danish Museums Act part 8.

Notes

1. https://www.retsinformation.dk/Forms/R0710.aspx?id=162504 (visited 21.09.2017).
2. http://slks.dk/fortidsminder-diger/arkaeologi-paa-land/museernes-arkaeologiske-arbejde/vejledning-om-arkaeologiske-undersoegelser/kap-6-konservering-og-naturvidenskab/#c45926 (visited 21.09.2017).
3. Diplomatarium Danicum I, I nr. 343 s. 133–34. http://dendigitalebyport.byhistorie.dk/medieval/item.aspx?itemid=391 (accessed 09–04-2018) .
4. http://museum.odense.dk/forskning/projekter/odenses-opstaaen (accessed 21–09-2017).
5. A biological family of cloven-hoofed ruminant mammals including species such as bison, African buffalo, water buffalo, antelopes, sheep, goats, muskoxen, and domestic cattle.
6. A biological family of hoofed ruminant mammals including species such as elk, reindeer, fallow deer, and roe deer.
7. In theory also with horse, but this species can be eliminated by the peak 2131,1 (bovids/cervids) or 2145,1 (horse/zebra) which is often identified, but not shown in the displayed spectrum.
8. In Århus there was 2,7% horse bone in the 10th-12th century and 1,7% in the 13th −14th century. In Ribe there were 30 fragments of horse from the 8th-9th century.
9. https://slks.dk/fortidsminder-diger/arkaeologi-paa-land/museernes-arkaeologiske-arbejde/vejledning-om-arkaeologiske-undersoegelser/kap-6-konservering-og-naturvidenskab/.

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ORCID

Matthew J. Collins http://orcid.org/0000-0003-4226-5501

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ARTICLE

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Failing arguments for the presence of iron in Denmark during the Bronze Age Period IV. Regarding the razors from Kjeldbymagle and Arnitlund and a knife from Grødby

Henriette Lyngstrøm [a] and Arne Jouttijärvi [b]

[a]Department of Archaeology, SAXO-Institute, University of Copenhagen; [b]Heimdal Archaeometry, Virum

ABSTRACT

The dark squiggly lines of the razors from Kjeldbymagle and Arnitlund are often mentioned, along with the knife from Grødby, as the earliest examples of iron in Denmark. The razors can be dated to the early Late Bronze Age (Period IV) – around 1000 BC – due to their form and ornamentation, while the iron knife from Grødby is reported to have been found in a slightly earlier urn burial.

Recent metallurgical analyses have, however, shown that the squiggly lines are not in fact iron, but rather copper covered by a layer of iron-bearing corrosion, and that the knife's context with the other grave objects must be considered uncertain.

This means that there is no evidence for the presence of iron in Denmark until the very end of the Bronze Age – around 700–500 BC.

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Within the confines of contemporary Denmark, iron and bog iron has been used and produced for two thousand years: from the first furnaces of around 500 BC until sometime in the AD 1500s, when farmers from Mid-Jutland sent self-produced iron to the forges at Bremerholm in Copenhagen for the last time (Nørbach 1998, p. 57f; Buchwald 2008, 113ff). During this long period, several technological changes occurred not only in furnace design, but also in the process and range of iron ore grades (Lyngstrøm 2008, Rundberget *et al.* 2013). Moreover, despite the cessation of production and use of bog iron being explained by mechanisms of market economy alone, explanations for the introduction of iron and iron technology have always been greater in quantity and complexity (Levinsen 1984, 153ff; Hedeager 1988, p. 196; Jensen 1997, p. 203, 2005, p. 172f).

The introduction also marks, perhaps especially for people living in a landscape such as the Danish one, a significant break with the existing knowledge and skills within metal technology. For not only are both ore and the reducing agent (charcoal) found locally, but the iron of the Iron Age differentiates itself from all other metals by remaining solid – actually never becoming a liquid – throughout the entire process. During extraction, liquid slag was smelted from solid iron, and the amount of iron at the forge was increased by welding pieces of metal onto pieces of metal and not, as with copper, tin, lead, gold or silver, by pouring liquid metal together. Thus, the introduction of iron as a material and of iron technology as a process was not only a question of introducing a new metal in line with all others, but of introducing a whole new way of understanding and processing metal.

The pre-Roman Iron Age iron extraction furnaces on the Mid-Jutland farms near Koustrup, Elia and Guldborgvej show with great clarity that some farmers possessed both the knowledge and ability regarding iron-technology processes as early as the earliest Iron Age (Olesen 2010, p. 86ff). Moreover, farmers on the Danish islands also learned it – though perhaps a little later (Lyngstrøm 2016, p. 140f). These early iron extraction furnaces fit in well with the small range of iron in pins and belt hooks from the contemporary southern Jutlandic small burial mounds of

CONTACT Henriette Lyngstrøm lyngst@hum.ku.dk SAXO-institute, University of Copenhagen

*The razor from Kjeldbymagle is museum number NM 18425 and is found in Kjeldby parish, Mønbo Herred. The razor from Arnitlund is museum number NM B 7225 and is found in Vedsted parish, Gram Herred.

Årupgård and Krogslund. They are forged of pure iron; only a few of them have an unevenly distributed carbon content of up to 0.3%. At the same time, the composition of slag inclusions makes it probable that these objects were forged by both imported and self-produced iron (Jouttijärvi 1996, p. 28).

However, there is no doubt that some people, as early as during the earlier Bronze Age Period VI, possessed knowledge of iron as a material without being able to produce it themselves. Grooming sets with Hallstatt-type tweezers, ear spoons and nail cleaners from the rich graves of Håstrup and Høed in southwest Funen (Baudou 1960, p. 44; Thrane 2004, p. 95f and 244), knife blades found in graves in Vesterby and Kvindebjerggård on Langeland (Jensen 1997, p. 251f) and perhaps also the coil-headed pin from the Hellegård cemetery in northern Jutland (Hornstrup *et al.* 2005, p. 93 and Fig. 13:66c) are good examples. However, the question is whether or not knowledge of iron – within the confines of the contemporaneous Denmark – reaches even further back.

Razors from Kjeldbymagle and Arnitlund

Since the beginning of the 1900s, the knife from Grødby and the razors from Kjeldbymagle and Arnitlund have offered three weighty arguments for the presence of iron as early as in the Bronze

Figure 1. The razor from Arnitlund where the dark wire is supplemented with a wire of gold (Photo: The National Museum, København).

Age Period IV (Broholm 1933, p. 223 and 663; Kimmig 1964, p. 278 and 174ff; Levinsen 1984, 154; Pleiner 2000, p. 30 and Fig. 8), and it cannot be made any clearer given that both razors display a distinct Period IV form and what appears as inserted wires of a dark metal. On the razor from Arnitlund, the dark thread is even supplemented with a wire of gold, an expression of the new metal's value and a parallelising with precious metals (***F. Kaul: Jernalderen i* Den Store Danske, *Gyldendal. Hentet 26. oktober 2017 fra http://denstoredanske.dk/index.php?sideId=101227***). (Figures 1 and 2).

The razor from Kjeldbymagle was found in 1858 by a quite young Vilhelm Boye, who was affiliated with the Royal Museum of Nordic Antiquities as one of C.J. Thomsen's protégés at that time. During the excavation of a partially destroyed burial mound, Hvilehøi in Keldby on the island of Møn, he found several urn graves

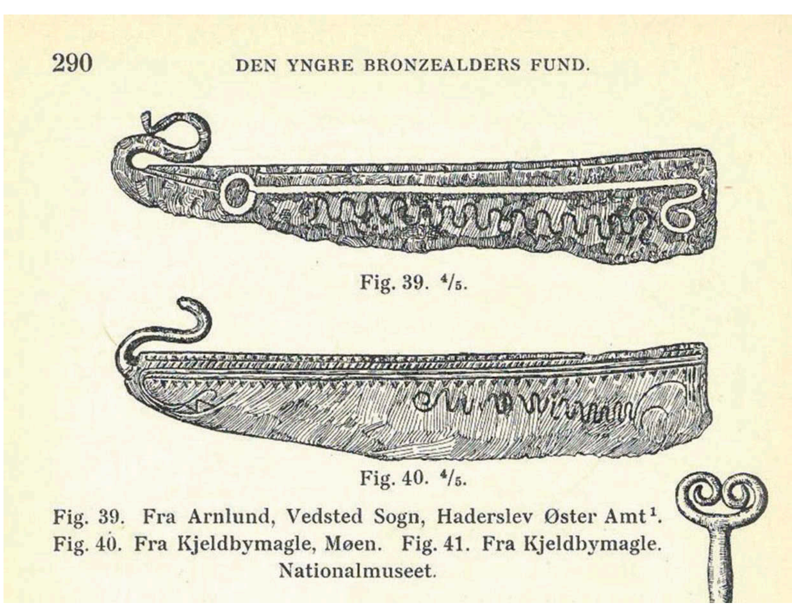

Figure 2. The razors from Kjeldbymagle and Arnitlund compared by Sophus Müller in 1914 (Müller 1914, Figs. 39 and 40).

including one with two clay vessels, tweezers, a miniature sword and '*en smukt forziret Kniv*[1]' (Boye 1858, p. 212; Broholm 1933, nr. 224; Kaul 1998, nr. 88). And in 1900, a somewhat similar razor was handed in to the National Museum by farm owner Chr. Lund from Arnitlund in southern Jutland (Broholm 1933, nr. 663; Kaul 1998, nr. 329). The inlay in this razor is described in the introduction of the museum's protocol as '*en stærkt bugtet Linie af et ligeledes indlagt Stof (Jern?)*'[2]. Some hesitation regarding the nature of the metal can clearly be sensed; a few years later, when Sophus Müller described the meandering line as '*et mørkt Metal, forskjelligt fra Knivens Bronze. Det ser ud som Jern og maa efter en foretagen, dels mikroskopisk, dels chemisk Undersøgelse antages at være dette Metal*'[3]… (Müller 1914, p. 289). The analysis was carried out by the then famous chemist and pharmacist H. Baggesgaard Rasmussen. He concluded that the dark parts of the knife from Arnitlund contained large amounts of iron and a small amount of copper. However, the razors from Arnitlund and Kjeldbymagle were both analysed in 1979 and 1998 too: the first analysis was done by Elmer W. Fabech having been commissioned by curator David Liversage and the second analysis was carried out by Arne Jouttijärvi on the direction of curator Olfert Voss[4].

Since 1914, the claim that the razors from Arnitlund and Kjeldbymagle were both ornamented with a band of iron wire and that iron, therefore, occurred as early as around 1000 BC within the contemporary borders of Denmark has been repeated.

Results: wire of copper

The metallurgical analysis from 1998 was made by Arne Jouttijärvi, Heimdal archaeometry, using a SEM at the Institute of metallurgy at the Technical University of Denmark. As sampling was not allowed, small (1 mm^2) areas of metal were cleaned from corrosion products prior to analysis. The supposed inlay, consisting primarily of oxides, was analysed directly. By the metallurgical analyses, it was found that the blades were cast of light lead-containing bronze with a tin content of 9 and 12%, respectively, with surfaces characterised by a heavy-handed cleaning technique – perhaps with a steel brush, applied after the knives were found (Table 1).

On both sides of the razor blade from Kjeldbymagle is a wire, which in some areas looks black, while it is – on the front in particular – seen as red against the yellowish-brown bronze. A metallurgical analysis of the wire showed that it consists of almost pure copper partly covered by a layer of corrosion, dirt and the remains of an earlier cast of silicone rubber (Fabech 1979). When the front and back of the blade are compared, it can be seen that the two inlays follow the same course, and that when the inlay is missing on one side, it can be seen on the other. Therefore, it is plausible that it is the same wire seen on both sides of the blade and that the wire lies inside the blade. This means that the wire was laid in the mould before the blade was cast – or if the lost wax method was employed that the wire was in the model. By turning the ends of the wire upwards it would have been quite simple to hold it in place in the mould, and the protruding ends could easily be removed when the razor blade was finished. The blade was probably polished and together with the later rough removal of the corrosion, it has left little sign of the casting process. It may be that the bronze caster used the wire as a practical measure to prevent the two sides of the mould from coming too close together, so as to ensure the bronze could flow completely into the thin cast. The coiled end of the copper wire, however, suggests that it was in fact intended for the wire to be seen on the surface of the finished blade.

Table 1. The results of the analysis carried out by A. Jouttijärvi in 1998.

ARNITLUND NM B 7225	Cu	Sn	Pb	Sb	Zn	As	Ag	Fe	S	Si	Au
The razor	80.2	12.1	3.1	2.6	0.3	0.2	0.0	0.5			
The dark line (the material at the top of the groove)	41.2	2.6	5.4	1.9	0.9	0.5	0.4	45.2	0.0	1.3	
The dark line (the material at the bottom of the groove)	95.6	0.4	1.4	0.1	0.0	0.0	0.3	1.5			
The golden line	4.4	2.2	0.0	0.5	0.0	0.2	10.9	0.3			80.0
KJELDBYMAGLE NM 18425											
The razor	82.7	9.1	2.5	2.2	0.3	0.7	0.7	0.0			
The dark line (the material at the bottom of the groove)	96.0	2.2	0.0	0.5	0.3	0.1	0.0	0.2			

The razor from Arnitlund contains two wires, one of which is gold. The gold wire was applied using the tauschierung technique, whereby, in this case, the bronze base was roughed, and the wire was then hammered into place. The other, darker wire however appears to be lying in a groove. The material at the top of the groove contains primarily iron and copper oxides, but also some tin, lead and antimony oxides, and under that – just like in the razor from Kjeldbymagle – is a layer of almost pure copper. Therefore, also in this case, the inlay consists of a copper wire covered by a layer of iron-containing corrosion.

In one of the wire's curves, a 2 mm clear overlap between two copper wires is visible (Figure 3). It is unlikely that such an overlap would occur if the wire had been laid in an engraved groove where it is possible to place two wires precisely as elongations of each other, but it may be due to the fact that the wires in this razor were also placed in the mould before casting. The copper used in the wires is not the only feature that the razors have in common, but also how deeply set in the blades they are.

It is quite likely that the inlays in both razors appear darker today due to corrosion formed when they were lying in the ground, because iron is found in the soil almost everywhere in Denmark, which can be concentrated as iron oxide in corrosion layers – even on bronze objects. The surface of the copper wire might, either during the manufacture of the blade or due to corrosion, be lying slightly deeper than the surface of the blade. During the corrosion of the bronze surface, the slightly recessed groove will also be filled with corrosion. After the knives were found, the heavy-handed cleaning removed most of the corrosion from the surface of the bronze, but left a thin layer in the hollow above the copper wire now resembling a dark inlay.

In the Bronze Age, the copper wires may have stood out distinctly with their red colour from the more yellowish-brown bronze, but it has also been suggested that copper wires may have been darkened using artificial patination (Schwab *et al.* 2010, p. 33). If that has been the case, the current appearance of the razor blades may not be so far from the original.

There are only a few examples of copper inlays in bronze found in northern Europe. An early example is a sword from Nebra, in Central Germany, which has an inlay of gold in the hilt and a copper wire in the blade (Meller 2002, p. 17). Similarly, a sword from the Vreta monastery in Östergötland has an inlay that is probably copper but is severely corroded (Schwab *et al.* 2010, 31f). Both of these finds can be dated to the 17th–16th centuries BC. Apart from these examples, the technique is primarily known from the eastern Mediterranean area.

Figure 3. The 2 mm overlap between two copper wires in the razor from Arnitlund (Photo: A. Jouttijärvi).

From the Late Bronze Age, inlays of iron in bronze are predominantly found in Central Europe and in two cases occur alongside deposits of copper (Berger 2014). In Scandinavia, there is only one example: a sword from Rud, in Värmland, in Sweden, while other examples from Europe include three swords from Witkowo, Czysta and Gamów in Poland, respectively (Berger 2012, p. 11f).

Failing arguments for iron in the Bronze Age period IV

The failing arguments consisting of the razors from Arnitlund and Kjeldbymagle leave us with the knife fragment, the provenance of which county governor Emil Vedel examined during the tender beginnings of his archaeological career (Figure 4). There were a few urn graves from Period III/IV in Grødby, near Aaker on Bornholm, and the objects had already been removed when Vedel arrived at the site one March day in 1869 (Vedel 1886, p. 262; Randsborg 1972, nr. 28 og Pl. VI,4). However, some young boys were able to tell the county governor that in one of the two graves had been a dagger, a knife, a tweezers, a fibula and a spiral ring of bronze as well as a flat piece of metal that was thought to be the remains of a knife blade on which were small rusted pieces of burned bone – or as Vedel himself described in his cover letter to the National Museum: '*et sært Metalstykke som ligner Jern. At det virkelig er fundet i kisten, kan der være nogen Tvivl om*'[5].

The knife is actually made of iron and in this point it differs from the wires in the two razors. If the knife belongs to the grave, it is an important testimony to the presence of iron in the Bronze Age Period III/IV. However, the affiliation to the grave is not secured and if Vedel's claim holds true, then we have no evidence of iron in

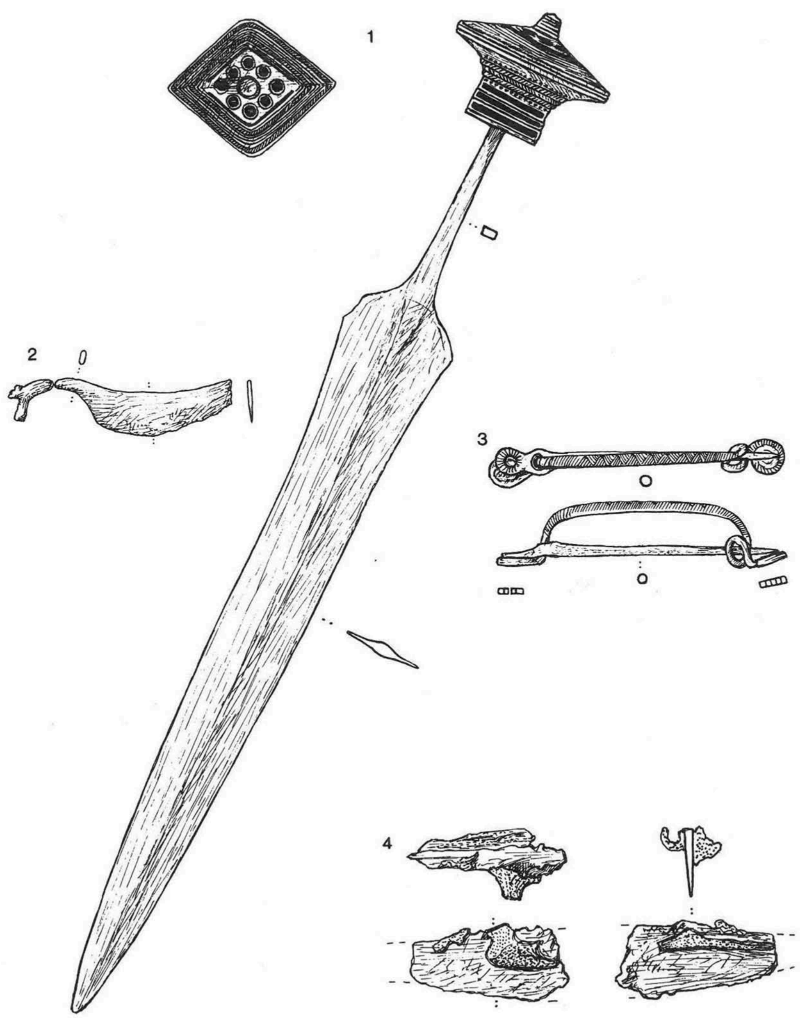

Figure 4. The dagger, knife, tweezers, fibula and spiral ring of bronze – and the iron knife from Grødby (Randsborg 1972, Pl. VI,4).

Denmark during the Bronze Age Period IV. Rather, we are left with a number of pins, rings, grooming sets and knife blades spread across the peninsula of Jutland, Funen and Langeland towards the end of the Bronze Age. Around 500 BC, there is a clear increase in the amount of iron in the graves in Jutland and on the island of Bornholm – often of types forged in iron and cast in bronze: pins, rings and belt buckles while knives made of iron seem to disappear from burials.

Notes

1. 'a beautifully ornamented knife.'
2. 'a strongly meandering line of a likewise inlayed material (iron?).'
3. 'a dark metal, different from the knife's bronze. It looks like iron, and can, after carrying out partly microscopic, partly chemical investigation, be assumed to be that metal.'
4. The razor from Arnitlund was analysed by H. Baggesgård Rasmussen. The analysis is undated, but journalised at the National Museum in 1900 as 715/00. The razors from Arnitlund and Kjeldbymagle were analysed in 1979 and 1998: by Elmer Fabech (dated 19.2.1979) and Arne Jouttijärvi (dated April 1998). All analysis reports are archived at the National Museum.
5. '...a peculiar piece of metal, which resembles iron. Of its being found in the grave there is some doubt.' Excerpts are from the letter of county governor E. Vedel dated 20 March 1869. Antiquities numbers NM B 323–333.

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ORCID

Henriette Lyngstrøm http://orcid.org/0000-0001-7633-753X

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Wool textiles and archaeometry: testing reliability of archaeological wool fibre diameter measurements

Irene Skals[a], Margarita Gleba [b], Michelle Taube [a] and Ulla Mannering [a]

[a]Research, Collection and Conservation, National Museum of Denmark, Copenhagen, Denmark; [b]McDonald Institute for Archaeological Research, University of Cambridge, Cambridge, UK

ABSTRACT

Characterisations of ancient sheep breeds and wool types and theories about wool fibre processing are integral parts of textile archaeology. The studies build on statistical calculations of measurements of wool fibre diameters and reveal characteristics of the yarns that are attributed to the available raw wool and to the production methods of the time. Different microscope types have been used for data collection. Presently digital images from either scanning electron microscopy (SEM) or transmitted light microscopy (TLM) are the preferred methods. The advantage of SEM is the good depth of field at high magnification, while TLM is simpler to use and more readily available. Several classification systems have been developed to facilitate the interpretation of the results. In this article, the comparability of the results from these two methods and from the use of different magnifications in general is examined based on the analyses of a large number of the Danish prehistoric textiles. The results do not indicate superiority of one microscope type in favour of another. Rather, they reveal differences in the calculations that can be ascribed to the diversity of the fibres in the individual yarns as well as to the methodology and the magnification level.

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KEYWORDS
Fibre fineness analysis of ancient wool; compare use of SEM and TLM; fibre type; processing

Introduction

Recent debate in archaeology has focused on the reliability of scientific methods in archaeological research (most recently, Sørensen 2017) and how they influence our interpretations of the past. Textile archaeology utilises a wide gamut of scientific analytical techniques, one of which is wool fibre analysis. The range of the fibre diameters in a yarn affects the appearance of the finished textile, so its understanding is essential for elucidating the development of ancient textile production. Sheep wool has been a major textile material in Scandinavia and Europe at least since the Bronze Age. Selection has been imposed on sheep populations since the domestication process commenced in the Fertile Crescent approximately 10,500 calibrated radiocarbon years BP (Peters *et al.* 2005), resulting in a spectrum of phenotypically distinct breeds, whose fibre is still used for a diverse range of products, from fine clothing to coarse carpets and upholstery. By studying wool fibres on a microscopic level, we can come closer to understanding the issues of selective breeding and fleece processing used to refine the production of wool since it began to be used as a major textile material during the Bronze Age.

Denmark is extremely fortunate in the preservation of wool textiles in bogs and burials, particularly from the Bronze and Iron Ages, providing an unprecedented opportunity to explore wool fibre development. Wool fibre analyses carried out on numerous samples of Danish archaeological textiles by the Danish National Research Foundation's Centre for Textile Research (CTR) have lead us to investigate the reliability of the methods used. This article presents the results of tests carried out to examine the comparability of two different measurement techniques and their effect on the data. The study has important implications not only for the methodology of wool analysis, but also for our understanding of selective breeding and textile production in prehistoric Scandinavia and beyond.

CONTACT Irene Skals irene.skals@natmus.dk

Background: wool and its analysis

In spite of the invention of synthetic textile fibres about 100 years ago and the ongoing research to improve them for human wear, sheep wool continues to be an important material in our modern societies and archaeological textiles document its use for garments as far back in time as the Early Bronze Age (Barber 1991, Ryder 1983a). Today as in the past, the value of wool is determined by its fineness, crimp, yield, colour, and staple strength and length. Fineness is one of the most important parameters in the modern wool industry and is defined by the mean fibre diameter of each individual fleece calculated from numerous diameter measurements made using advanced automatic technology (Qi *et al.* 1994). The fleeces with the finest fibres are valued most and are selected to be used for garments. The fineness of the individual fibres depends on many different factors such as the sex, age, and health of the animal from which they derive, where on the body they have grown, and the time of year they have been harvested. The diameter of each fibre also varies along its length. For these reasons, the modern sheep grown to produce wool for industrial purposes are reared to yield as much and as homogeneous fibre as possible.

The method of measuring fibre diameters was adapted to the study of prehistoric wool textiles and sheep skins during the 1960s to 1970s (Ryder 1964, 1969, 1974, 1981, 1983a, 1983b, 1987, 1988, 1992, 2000, 2005). Comparing the results with fleeces from modern, so-called wild, heritage or 'primitive' sheep breeds which still exist in remote areas of Europe, lead to conclusions about ancient breeds, and an evolutionary model for sheep fleece development was established (Ryder 1969, 1983a).

What distinguishes fleeces of the wild sheep breeds and what makes them comparable to prehistoric wool is that they in general consist of an outer coat of coarse kemp (with diameters from *c.* 60 to more than 100 microns), hair or medium fibres (with diameters from *c.* 25 to 60 microns), and a much finer underwool (with diameters up to *c.* 25 microns) (Ryder 1983a, p. 45, Rast-Eicher 2008, p. 122, Rast-Eicher and Bender Jørgensen 2013, p. 1225). According to the evolutionary model, sheep husbandry and breeding caused the underwool to become less fine over time while the outer coat became less coarse, eventually resulting in the disappearance of kemp and hair at the expense of the extremely fine fibres (Ryder 1983a).

The study of wool fibre fineness by measuring their diameters has since become an integral part of the standard analyses of archaeological wool textiles and consists of diameter measurement of 100 or more fibres per yarn or staple and statistical analyses resulting in distribution histograms. Various scholars have also developed fleece classification systems (see summary in Gleba 2012) and, of the two that will be mentioned here, Ryder's system recognises six fleece types (Table 1).

Wool samples from several of the prehistoric Danish textiles as well as samples of fur from some of the skin capes have previously been studied and the results were used to characterise the fleece types according to Ryder's system (Bender Jørgensen and Walton 1986, p. 177, Walton 1988, p. 144, Ryder 1988, p. 136). As a result, the Danish Bronze and Early Iron Age textiles have been interpreted as being made from fleeces with very fine underwool and a relatively small amount of kemp (1–7%), and the majority of the samples were classified as 'Hairy' or 'Hairy Medium' and coming from a primitive moulting sheep breed.

Table 1. Ryder's classification system recognises six fleece type categories and builds on the methods used in the wool industry to classify the individual fleeces.

Ryder's model of sheep fleece classification			
Wool type	Mode diameter	Maximum diameter	Distribution
Hairy (H)	30–40 microns	>100 microns	Continuous
Hairy medium (HM)	30 microns	>60 < 100 microns	Skewed to fine
Generalised medium (GM)	20 microns	55 microns	Skewed to fine
Medium (M)	30–40 microns	60 microns	Symmetrical
Fine (F)	20 microns	35 microns	Symmetrical
Short (S)	25 microns	40 microns	Symmetrical

In recent years, a new understanding has developed that wool in textiles should be seen as the result of conscious choices and meticulous processing of the material (Good 1999, Christiansen 2004, Rast-Eicher 2008). Analyses of fibre diameters are now interpreted as a way to understand the work involved in the processing of the wool into yarns. Preliminary sorting of the fibres for the intended use may start while plucking or cutting the fleece. Hand spinning is further facilitated by combing and teasing the wool, whereby dirt and tangles are removed (Andersson Strand 2012, p. 31). Through this preparatory work, the coarser fibres may be separated from the finer to achieve more uniform fibre combinations, and fibres from fleeces from different animals may be mixed in this process. The information obtained from diameter measurements of wool from textiles thus does not necessarily represent one single fleece but is an intricate and complex mixture of several different biological, technological, and human factors in the transformation from raw fleece to wool yarn.

Rast-Eicher (2008) proposed a fibre categorisation system addressing the processing specifically. It is derived from one used in the wool industry (Doehner and Reumuth 1964) and assigns single or multiple letters to wool with different percentages of fibres of different diameters (Table 2). The system has 11 categories, taking into account the percentage of fine fibres measuring less than 25 and 30 microns and the number of outliers exceeding 30, 40, and 60 microns in the yarn samples (Rast-Eicher 2008).

Table 2. Rast-Eicher's classification system consists of a flexible letter system of 11 wool quality categories and takes the process from raw wool to yarns into account.

Rast-Eicher's model of wool fibre classification	
Wool quality class	% of fibres of different diameter
AAA	92% < 25 µm, 8% > 25.1 µm, 1% > 30 µm, max 40 µm
AA	85% < 25 µm, 15% > 25.1 µm, 3% > 30 µm, max 60 µm
A	93% < 25 µm, 7% > 30.1 µm, 1% > 40 µm, max 60 µm
AB	80% < 30 µm, 15% > 30.1 µm, 2% > 40 µm, max 60 µm
B	75% < 30 µm, 25% > 30.1 µm, 2% > 40 µm
C	66% < 30 µm, 10% > 45 µm, 1% > 50 µm
CD	80% < 40 µm, 20% > 40.1 µm, 2% > 60 µm
D	66% < 40 µm, 34% > 40.1 µm, 5% > 60 µm
E	60% < 40 µm, 40% > 40.1 µm, 10% > 60 µm
EE	50% < 40 µm, 50% > 40.1 µm, 15% > 60 µm
F	50% < 30 µm, up to 50% > 60 µm

The two mentioned categorisation systems are both based on the width of the uninterrupted range in the histogram which represents the majority of the measurements and the presence, size, and percentage of fibres with diameters larger than 40 microns in any given sample, which represent outliers (Figure 1).

Certain parameters, such as the preservation of the prehistoric fibre material, are beyond the analyst's control, and can make assessment of the original fibres extremely difficult. Little is known about how not only use, but also charring, mineralisation or desiccation of waterlogged textiles has affected the fibre diameters (Mannering and Peacock 1998). Moreover, in the case of textiles that are still in their organic state, it is common practice to take fibre samples where they will cause minimum visual damage, that is, near open edges or holes where degradation is often more advanced and may have influenced the fibre diameter (Figure 2).

The previous analyses of archaeological wool fibre diameters were made using a projection microscope (Bender Jørgensen and Walton 1986, Ryder 1988, Walton 1988). Today, the analyses are typically made on digital images of the fibres and one standard approach has been developed by Rast-Eicher who used scanning electron microscopy (SEM) and based the investigations on analyses of mineralised textile fibres (Rast-Eicher 2008). SEM makes impressive images with a very fine depth of field and has a wide magnification range reaching above 10,000×. However, when the Danish National Research Foundation's CTR initiated a systematic and comprehensive investigation of wool fibres in order to get an understanding of the available wool and the wool production in the prehistoric Danish societies, it was decided to use digital images from transmitted light microscopy (TLM) for the analyses.

Our study included 76 yarn samples from the Danish bog textiles dated to the Early Iron Age (500 BC–AD 375). They were photographed at 40× magnification (low) and the measurements of the fibres were made on the images

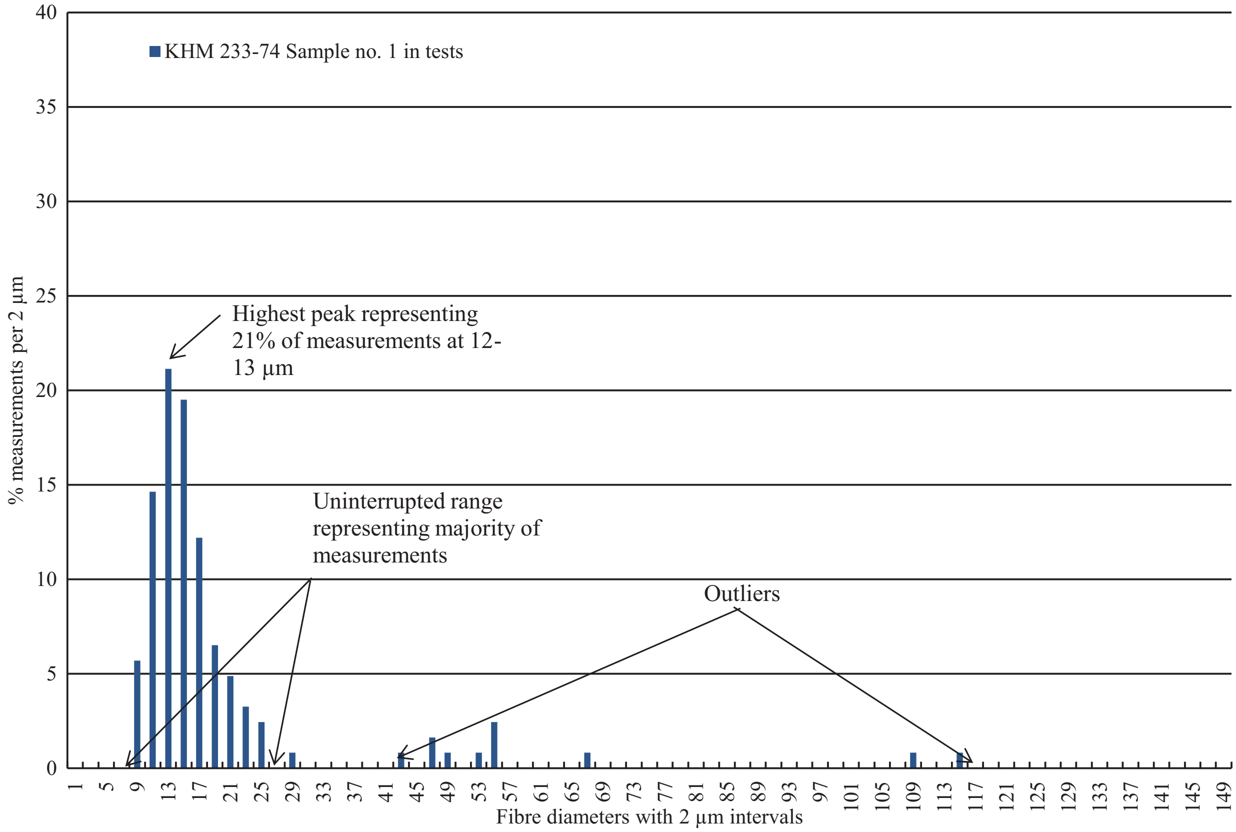

Figure 1. Wool fibre distribution diagram. The important features to look at in a distribution diagram are the width of the uninterrupted range, the position and the height of the peaks, and the position and number of the outliers.

Figure 2. Sampling from textile fragments. Sampling is most often done near open edges or holes where degradation can be more advanced.

(Mannering *et al.* 2010). The results turned out to be 5–16 microns finer than the earlier studies made using a projection microscope at 400× magnification (Bender Jørgensen and Walton 1986, Ryder 1988, Walton 1988). These differences raised questions regarding the accuracy of the measurements at the lower magnification, and reanalysis of a selection of the samples using SEM at 300× magnification was therefore carried out. On evaluating the results from the two analyses of the same yarn samples, we found it necessary to make a thorough investigation of the comparability of the two methods currently used by practitioners in the field. This was carried out on 36 samples from 13 textiles (Table 3) and could document that inherent uncertainties existed in both, independent of the magnification.

Experimental

The comparative study consisted of five tests (labelled Tests 1–5):

Test 1

SEM and TLM were compared by measurements on images of a standard glass stage micrometre

Table 3. Yarn samples from 13 textiles from eight sites dated to the Bronze and Early Iron Ages have been studied in this project. They are listed alphabetically after the sites and numbered consecutively with reference to the specific tests in which they appear.

Yarn type and date of wool fibre samples used in the tests					
Sample no.	Used in Test	Sample ID.	Textile	Date	Yarn type
1	2	166	Auning KHM 233–74	200 BC–AD 110	Sewing
2	2	5	Bredmose C 24624	370 BC–AD 10	Warp
3	3	110	Bredmose C 24527	370 BC–AD 10	Warp
4	3	111	Bredmose C 24527	370 BC–AD 10	Warp
5	3/4	65	Corselitze 7325 b	AD 210–410	Warp
6	2/3/4	66	Corselitze 7325 b	AD 210–410	Warp
7	2/4	67	Corselitze 7325 b	AD 210–410	Weft
8	2/3/4	68	Corselitze 7325 b	AD 210–410	Weft
9	2/4	69	Corselitze 7325 a	AD 210–410	Warp
10	2/4	70	Corselitze 7325 a	AD 210–410	Warp
11	2/4	71	Corselitze 7325 a	AD 210–410	Weft
12	2/4	72	Corselitze 7325 a	AD 210–410	Weft
13	3/5	I warp	Egtved B11834	1370 BC	Warp
14	3/5	I weft	Egtved B11834	1370 BC	Weft
15	2	23	Haralskær 3707 C1	347–42 BC	Light weft
16	2/3/4	57	Huldremose I C 3473	350–41 BC	Dark warp
17	2/3/4	58	Huldremose I C 3473	350–41 BC	Dark warp
18	2/3/4/5	59	Huldremose I C 3473	350–41 BC	Light warp
19	3/4/5	60	Huldremose I C 3473	350–41 BC	Light warp
20	2/4	61	Huldremose I C 3473	350–41 BC	Dark weft
21	4	62	Huldremose I C 3473	350–41 BC	Dark weft
22	2/4	63	Huldremose I C 3473	350–41 BC	Light weft
23	4	64	Huldremose I C 3473	350–41 BC	Light weft
24	2/4	120	Huldremose I C 3474	350–41 BC	Light warp
25	4	121	Huldremose I C 3474	350–41 BC	Light warp
26	2	122	Huldremose I C 3474	350–41 BC	Medium warp
27	2/4	124	Huldremose I C 3474	350–41 BC	Dark warp
28	4	125	Huldremose I C 3474	350–41 BC	Dark warp
29	2	126	Huldremose I C 3474	350–41 BC	Light weft
30	2/4	128	Huldremose I C 3474	350–41 BC	Medium weft
31	4	129	Huldremose I C 3474	350–41 BC	Medium weft
32	2	37	Krogens Mølle D 1310A	399–181 BC	Light weft
33	2	55	Krogens Mølle D 1310E	399–181 BC	Dark weft
34	2	83	Krogens Mølle D1310J-L	399–181 BC	Warp
35	3	9	Ømark C 25182	390–200 BC	Warp
36	3	10	Ømark C 25182	390–200 BC	Weft

acquired by SEM at 100×, 500×, and 1000×magnification and by TLM using 4×, 10×, and 40× objectives.

Test 2

SEM and TLM were compared by measuring the fibre diameters on images of wool fibres from the same samples using SEM at 300× magnification and TLM with a 4× objective.

Test 3

The precision of measurements at different magnifications in TLM was tested by comparing the results from diameter measurements on photographs of wool fibres using a 4× objective and a 10× objective.

Test 4

The statistical significance of the results was tested by analysis of fibres from samples of the same yarn in a textile selected at two different places. The photographs were captured using TLM with a 4× objective.

Test 5

Human and technical factors were tested by an analysis of fibre diameter measurements made on the same photographs on two separate occasions. The photographs were captured using TLM with a 4× objective in four cases and a 10× objective in one case.

The measurements of the fibres in Tests 3–5 were further classified following Rast-Eicher's categorisation system (Rast-Eicher 2008) and the results were analysed.

In the case of TLM, only the objective magnification is listed here. The camera increases the magnification more than tenfold. An Olympus type BH-2 microscope equipped with a Cool Snap digital camera (A99M81023) from RS Photometrics was used for the analyses of fibres using a 4× objective. The measurements in these cases were made in ImageJ, an open-access image processing and analysis program. A Primo Star iLED microscope from Zeiss with 4×, 10×, and 40× objectives and equipped with an AxioCam ERc5s camera was used for the remaining TLM images, and the measurements in these cases were made using the camera software. The cameras were calibrated by a standard method for high-magnification light microscopes with a stage micrometre showing 1 mm divided into 10-micron sections.

The SEM analyses in Test 1 were made using a TD JEOL JSM-5310 LV scanning electron microscope equipped with Oxford Instruments Link ISIS software version 3.35. The images for this test were acquired at two different scanning speeds: (1) Slow, where each pixel is measured four times on average and (2) Kalman, where the images are made by combining the information from several quick scans of the entire viewing area. Kalman is often chosen for acquiring higher magnification images of uncoated textile fibres because the fibres absorb static charge and deteriorate if the electron beam is held in one place for too long, as it is with the Slow method. The measurements on the images were performed in Photoshop.

The SEM analyses in Test 2 were carried out using a Hitachi S 3200N Scanning Electron Microscope and the measurements made directly on the screen using the SEM software after image capture. The images for this test were acquired at slow speed.

Results and discussion

Test 1

In this test, the accuracy of the measurements obtained when using TLM as opposed to SEM at different magnifications was investigated. The embedded scale bars in SEM images acquired using scan speed Kalman at 500× magnification and scan speed Slow at 1000× magnification, respectively, were used for

Table 4. Measurements of distances on a micrometre using the embedded SEM scale marker bars differ depending on the scan speed in SEM: In scan speed Kalman, 100 µm can be both longer and shorter than 0.1 mm. In scan speed Slow, 50 µm is in all cases longer than 0.05 mm.

The impact of the SEM scan speed on measurements with the SEM scale marker	
100 µm scale bar – scan speed Kalman	50 µm scale bar – scan speed Slow
0.1 mm = 92.128 µm	0.05 mm = 52.047 µm
0.1 mm = 93.586 µm	0.05 mm = 52.485 µm
0.1 mm = 95.918 µm	0.05 mm = 52.485 µm
0.1 mm = 97.959 µm	0.05 mm = 52.924 µm
0.1 mm = 98.834 µm	0.05 mm = 52.632 µm
0.1 mm = 99.417 µm	0.05 mm = 52.632 µm
0.1 mm = 99.708 µm	0.05 mm = 52.778 µm
0.1 mm = 100.583 µm	0.05 mm = 52.632 µm
0.1 mm = 100.584 µm	0.05 mm = 52.486 µm
0.1 mm = 101.749 µm	0.05 mm = 52.778 µm
0.1 mm = 102.332 µm	0.05 mm = 52.778 µm
0.1 mm = 102.332 µm	0.05 mm = 52.485 µm
0.1 mm = 103.207 µm	0.05 mm = 52.778 µm
0.1 mm = 103.207 µm	0.05 mm = 52.632 µm

measurements on the image of the stage micrometre (Table 4). On the image acquired at scan speed Kalman, the results varied across the micrograph indicating a slight distortion of the image. The distance of 100 microns (0.1 mm) deviated from 0.6–3.2% longer to 0.3–8% shorter than the stated 100 microns (Table 4, Figures 3 and 4). On the image acquired at scan speed Slow, the results were more uniform across the micrograph, but they were in all cases longer by 4.1–5.8% (Table 4, Figure 4).

Subsequently, measurements were made of the embedded scale bars of lengths 500 microns, 100 microns, and 50 microns on images taken at 100×, 500×, and 1000× magnifications, respectively, with both scan methods using the appropriate distances on the photograph of the stage micrometre as a scale (Table 5). In all cases, the measurements of the SEM scale bars turned out to be from 0.29 to 5.79% shorter than stated and the differences appeared at both scan speeds and all three magnifications. The results from the highest magnification did not appear more accurate than the ones from the lowest magnification.

In the third analysis of the SEM images, different distances on the micrometre itself were made using the same scales as above of 50, 100, and 500 microns on the micrometre at the same three magnifications (Table 6). Six out of the 40

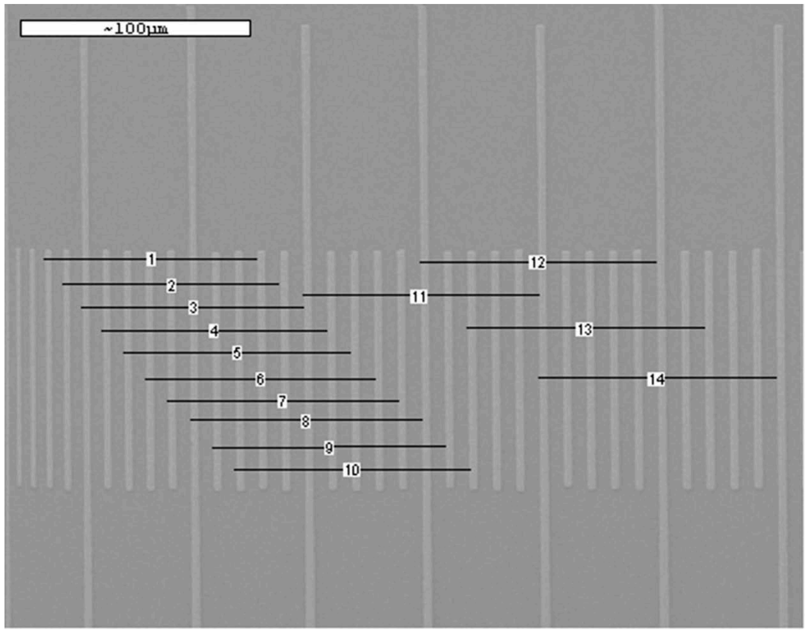

Figure 3. Measurements on images acquired at scan speed Kalman. Using the embedded scale marker bar of 100 microns, measurements of 0.1 mm on the micrometre deviate by plus 0.6–3.2% to minus 0.3–8% across the SEM image acquired at scan speed Kalman at 500× magnification. The exact measurements are listed in Table 4.

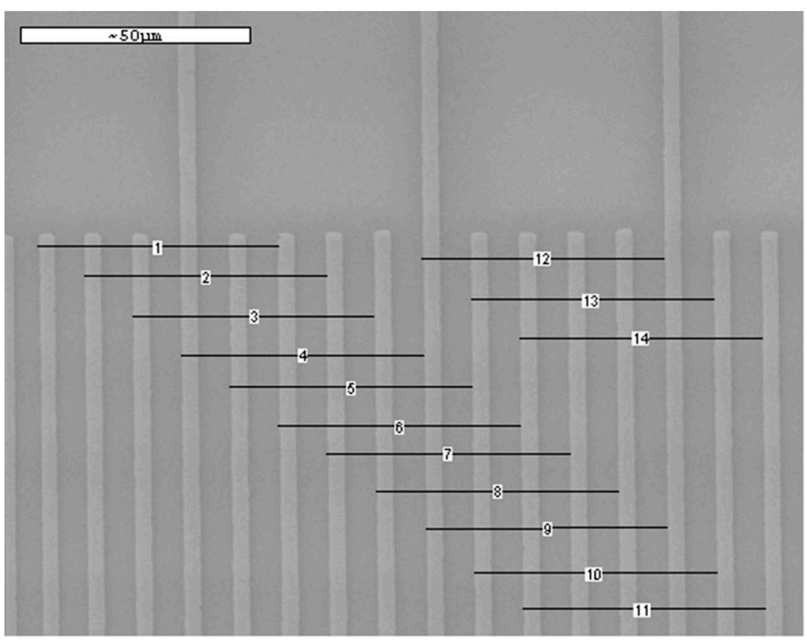

Figure 4. Measurements on images acquired at scan speed Slow. Using the embedded scale marker bar of 50 microns, measurements of 0.05 mm on the micrometre deviates by plus 4.1–5.8% across the SEM image acquired at scan speed Slow at 1000× magnification. The exact measurements are listed in Table 4.

measurements recorded were precisely equal (two at each magnification), whereas the remaining were either shorter up to 7.7% or longer up to 6.1%. The biggest discrepancies were recorded at the highest magnification.

On the TLM images at three different magnifications, distances of 10, 20, 50, and 100 microns on the micrometre were measured using the camera software (Table 7). In the images taken using the 10× objective, two measurements were 1.9%

Table 5. The lengths of 0.5 mm, 0.1 mm, and 0.05 mm on the micrometre can be both shorter and longer than the equivalent distances on the SEM scale bar and differ according to the scan speed.

Known lengths on the micrometre compared to equivalent distances on the SEM scale bar								
50.000 µm SEM scale 1000× magnification			100.000 µm SEM scale 500× magnification			500.000 µm SEM scale 100× magnification		
Calibration	Slow	Kalman	Calibration	Slow	Kalman	Calibration	Slow	Kalman
0.05 mm = 50.000	47.383	47.107	0.1 mm = 100.000	95.000	95.556	0.5 mm = 500.000	472.376	472.376
0.05 mm = 50.000	47.507	47.507	0.1 mm = 99.998	99.710	99.707	0.5 mm = 500.000	472.376	495.665
0.05 mm = 50.000	49.855	49.710	0.1 mm = 99.999	95.265	95.265	-	-	-
0.05 mm = 50.000	47.514	47.376	-	-	-	-	-	-

Table 6. Using 0.5 mm, 0.1 mm, and 0.05 mm on the micrometre as scales for measurements of the micrometre, the results in most cases turn out either shorter or longer by 0.3% to 7.7% depending on the scan speed. Discrepancies are seen at all three magnifications.

Known lengths on the micrometre compared to equivalent distances on the same micrometre in SEM images						
100× magnification						
	50 µm		100 µm		500 µm	
Calibration	Slow	Kalman	Slow	Kalman	Slow	Kalman
0.5 mm = 500.000 µm	49.724 µm	48.343 µm	99.448 µm	95.304 µm	500.000 µm	475.140 µm
0.5 mm = 500.000 µm	50.599 µm	49.133 µm	104.046 µm	99.711 µm	523.121 µm	500.000 µm
500× magnification						
	50 µm		100 µm		-	
Calibration	Slow	Kalman	Slow	Kalman	-	-
0.1 mm = 100.000 µm	49.722 µm	47.222 µm	100.000 µm	95.556 µm	-	-
0.1 mm = 99.998 µm	52.035 µm	50.871 µm	104.651 µm	101.742 µm	-	-
0.1 mm = 99.999 µm	50.140 µm	47.354 µm	100.000 µm	96.100 µm	-	-
1000× magnification						
	10 µm		50 µm		-	
Calibration	Slow	Kalman	Slow	Kalman	-	-
0.05 mm = 50.000 µm	10.055 µm	9.229 µm	49.725 µm	47.521 µm	-	-
0.05 mm = 50.000 µm	10.249 µm	9.418 µm	50.000 µm	47.645 µm	-	-
0.05 mm = 50.000 µm	10.610 µm	10.029 µm	52.326 µm	50.291 µm	-	-
0.05 mm = 50.000 µm	10.083 µm	9.669 µm	50.000 µm	47.790 µm	-	-

longer than 10 and 20 microns, respectively, whereas the deviations in the remaining results were less than 1%. Both the least and the most accurate results were found at the two highest magnifications.

Test 1 demonstrated that measurements made on images from SEM and TLM of the same scale differed. In TLM, the measurements of the scale were shorter by 0.2 and 0.3% in two out of nine cases and in the remaining cases they were longer by 0.1–1.9% (see Table 7). Measurements of the embedded SEM scale marker bars using the micrometre as scale revealed that calibration of the SEM scale bar differed from the standard micrometre (see Table 5). It also became apparent that the results would vary depending on the scan method (see Table 4–6). With the Kalman method, the images got slightly distorted causing the measurements on the micrometre to be either shorter up to 7.9% or longer up to 3.2%. With the Slow method they were in all cases longer by between 4.1 and 5.8%. The different analyses demonstrated that measurements on images from the two different microscope types were not directly comparable due to the different calibration methods. SEM is calibrated by a ratio between the scan area and the ultimate image size while TLM uses a physical calibration tool.

Table 7. Measurements of distances on the micrometre using the camera software in TLM images with three different objectives give variable results and the most accurate measurements as well as biggest discrepancies are found at the two higher magnifications.

Measurements of distances on the micrometre on TLM images		
4× objective	10× objective	40× objective
0.01 mm = 10.06 µm	0.01 mm = 10.19 µm	0.01 mm = 10.03 µm
0.05 mm = 50.28 µm	0.02 mm = 20.38 µm	0.02 mm = 19.96 µm
0.10 mm = 100.56 µm	0.05 mm = 50.07 µm	0.05 mm = 49.83 µm

Test 2

The purpose of Test 2 was to compare the results from TLM and SEM images of diameter measurements of archaeological wool fibres picked

Table 8. The statistical mode calculated from the results from the same yarn samples using different methods is generally higher by a few microns in the SEM results and the finest measurements are generally seen in the TLM results.

Evaluation of results from SEM and TLM images of samples from the same yarn						
Sample	Number of fibres		Mode in μm		Measurements in μm	
No.	SEM	TLM	SEM	TLM	SEM	TLM
1	107	123	17	13	7–24, 27, 36, 43, 52, 54, 57, 60, 76, 100, 111, 122, 147	8–25, 29, 43, 45, 48, 53, 55, 67, 109, 115
2	113	92	15	10	11–21, 27, 63, 75, 79, 113	4–14, 16, 18, 51, 63, 82, 103
6	111	36	18	13	11–30, 33, 41, 51–52	11, 13–20, 23–26
7	114	76	17	15	13–38, 40–43, 46	9, 11, 13–34, 36–37, 43
8	114	145	17	13	11–24, 27–34, 41, 44, 46, 56, 71	7–11, 13–18, 20–23, 27–30, 32
9	103	136	19	15	15–36, 38–30, 43	11, 13 – 23, 25–28, 31, 38, 40
10	102	39	21	18	9, 14–27, 30–32, 34–35, 42, 46, 61	10–11, 13–24, 26–29, 32, 37, 41, 52
11	109	113	23	16	12–35, 38–39, 41, 45–46	10–11, 13–33, 36, 38
12	114	71	23	13	13–29, 31–35, 42, 59	11, 13–28, 30, 32, 34–35
15	106	56	17	9	10–26	6–11, 13–15, 20
16	118	84	19	13	10–23, 25, 28–29	7–11, 13–18, 21–22, 25
17	111	87	17	13	11–23, 25, 82	8–11, 13–20, 29, 81
18	128	94	17	13	10–25, 29, 49, 71	7–18, 20, 25, 046
20	152	91	17	13	7, 9–27, 60, 67, 78, 86	8–11, 13–18, 23, 65
22	106	77	17	11	12–28, 126, 147	8–11, 13–21, 25, 28, 32, 109
24	124	93	13	13	8–22, 29, 83	5–11, 13–16, 18, 20
26	102	130	19	13	10, 12–28, 30–31, 33, 94, 171	8–25, 27–230, 38
27	107	64	19	13	11–26, 29	7–24
29	106	83	19	13	11–25, 28, 30, 57, 60, 82, 156	7–11, 13–18, 20, 22–23, 27, 124
30	103	82	18	13	11–30	6, 8–11, 13–18, 20, 22–24, 27
32	92	72	19	13	13–29	8, 10–11, 13–23, 27
33	86	62	19	15	13–30, 58	8–11, 13–16, 18, 20–21, 23, 25–26
34	113	89	15	13	10–24, 26–27, 29–30, 48, 113	6–11, 13–16, 18, 20

from the same yarn samples. The fibre analyses of the Danish bog textiles were made using TLM with a 4× objective. A selection of the samples was reanalysed using SEM and the results were calculated (Table 8). They showed that the finest fibres recorded generally were finer in the TLM analyses than in the SEM analyses and that the calculations of the statistical modes from the TLM measurements were lower in all cases but one. The differences in the modes were not consistent but varied between 0 and 10 microns, although in most cases they were between 4 and 6 microns. Two different results are illustrated in histograms (Figures 5 and 6). In Figure 5, the shapes of the uninterrupted curves are very similar, but the SEM results are positioned slightly to the right of the TLM results on the *x*-axis (indicative of the slightly coarser range of diameters), while in Figure 6 the two histograms are positioned similarly but the measurements from the SEM analyses have a wider uninterrupted range and a few outliers.

The differences recorded in Test 2 correspond well to the results from Test 1 and can be explained by the different calibration methods. However, the inconsistency of the results is surprising and may be caused by the fact that different parts of the same yarn samples were analysed, a factor which is investigated further in Test 4.

Test 3

This test was made to determine to what extent the use of a 4× objective as opposed to a 10× objective for the TLM analysis would influence the results of the fibre diameter measurements. Nine samples were analysed (Table 9). Here, too, the tests were made on different parts of the same yarn sample.

As in Test 2, the finest diameter measurements were seen in the results from the lowest magnification. The statistical modes at the lower magnification were subsequently lower than at the higher magnification by 2–6 microns except in one case. The shapes of the curves in the histograms were very similar, and differences resulting from the magnifications were not altogether clear. There are examples of histograms positioned almost identically (Figure 7) and of histograms positioned differently (Figure 8) as was also seen in Test 2.

It is generally assumed that higher magnification should enhance the precision, but the results from

Table 9. Results using TLM with the lower magnification appear to be slightly finer giving a lower statistical mode in all cases but one. The results also demonstrate that the same yarn can be attributed two very different categories.

Evaluation of results from TLM images at different magnifications of samples from the same yarn								
Sample	Number of fibres		Mode in µm		Measurements in µm		Category	
No.	4×	10×	4×	10×	4×	10×	4×	10×
3 and 4	160	230	13	15	6–11, 13–16, 18–23, 25, 28–29, 50	8–29, 31–32, 37, 43, 94, 122	AA	B
5 and 6	96	162	18	14	11–26, 28–29, 32–33	9, 11–34, 37, 39, 41	AA	*AB*
8	145	96	13	17	7–11, 13–23, 27–30, 32	14–36, 40, 43, 50, 57	AA	CD
13	266	132	13	16	9–26, 37, 45, 61, 88	9–23, 25, 41, 88, 92, 107	B	D
14	298	127	12	14	5–24, 43, 118, 152	10–25, 161, 210	B	B
16 and 17	171	256	13	17	7–11, 13–22, 25, 29, 81	9–27, 29–30, 69	B	B
18 and 19	181	354	13	17	6–11, 13–20, 23, 25, 46, 57	9–28, 118	AA	B
35	78	305	13	19	8–11, 13–18, 20, 23, 25	11–28, 30–31, 46, 68–69, 116, 143	AAA	B
36	64	407	14	16	6–11, 13–22	10–30, 34, 36, 50, 52, 54, 60, 74, 81, 107, 134, 154	AAA	CD

the lower magnification appeared to be comparable with regard to the fibre composition, as illustrated by the overall shapes of the histograms.

Rast-Eicher's categorisation system (Rast-Eicher 2008) was applied to the results in this test, and it became apparent that even minor differences in the range of measurements caused divergent categorisations. In seven out of nine cases, the categorisation for the two analyses of the same yarn samples differed. The most striking examples were Samples 35 and 36 (see Table 9). Using the 4× objective, no fibres coarser than 30 microns were recorded in these samples, whereas with the 10× objective a significant number were present resulting in the same yarns being attributed Categories AAA and B and AAA and CD, respectively. The uninterrupted ranges in the histograms, however, do not indicate significant differences in the fibre content and it is

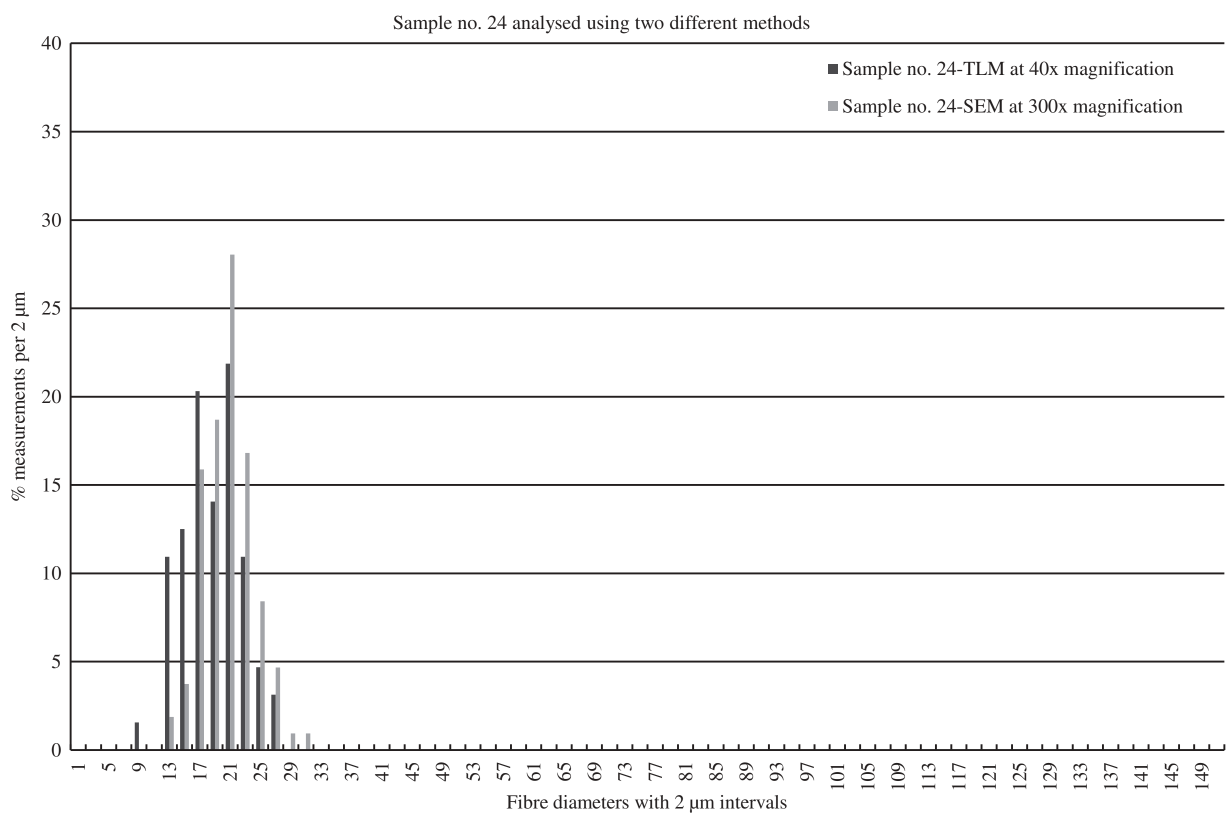

Figure 5. Sample no. 24 analysed using two different methods. Histograms of sample no. 24 has the TLM curve positioned to the left of the SEM curve. TLM produces finer measurements than SEM.

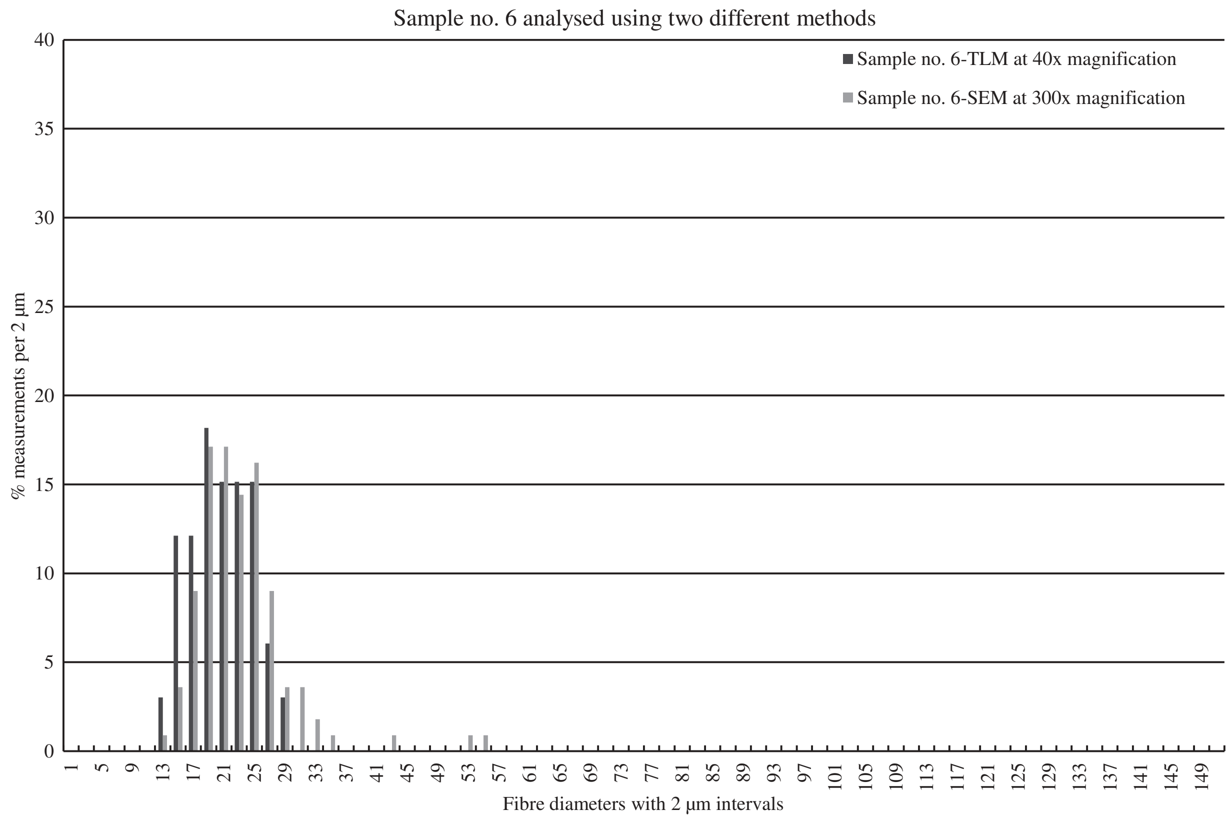

Figure 6. Sample no. 6 analysed using two different methods. In the histograms of sample no. 6, the TLM and the SEM curves appear very similar but a few outliers have been recorded in the SEM analysis.

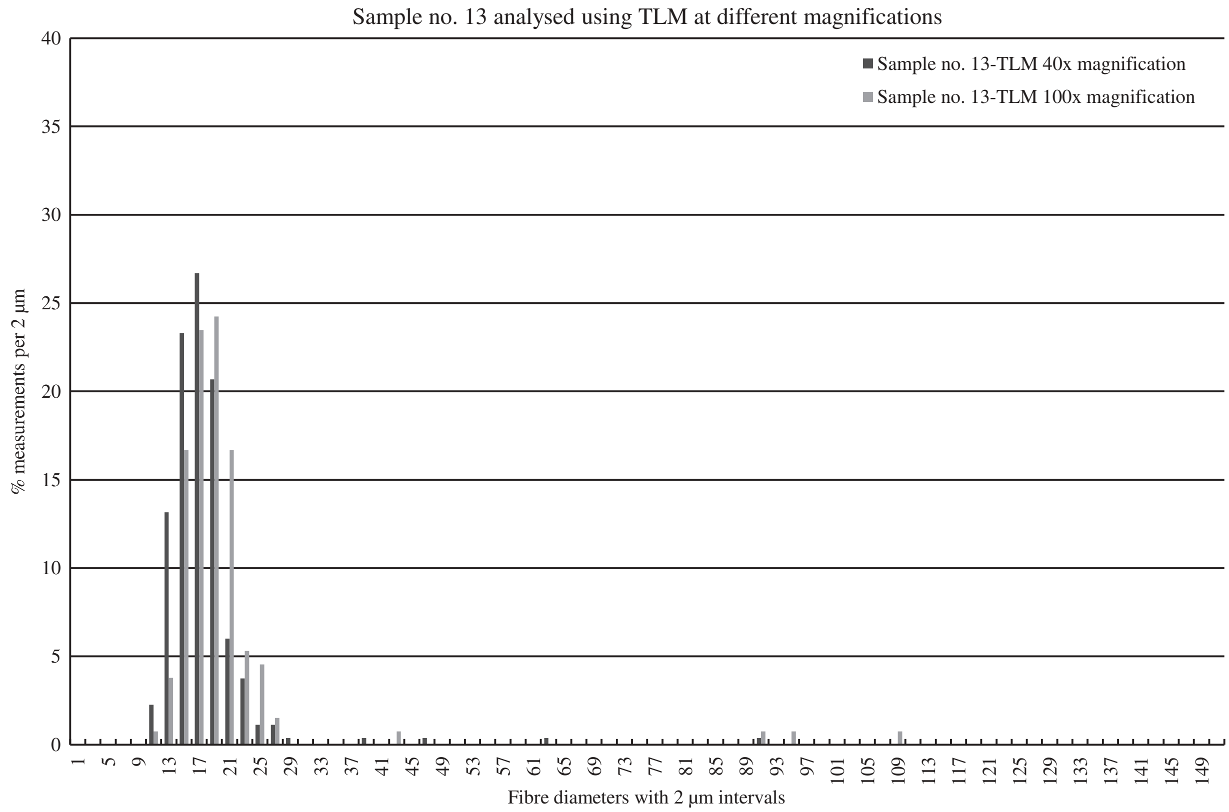

Figure 7. Sample no. 13 analysed using TLM at different magnifications. The two histograms of results from TLM analyses at low and high magnification are positioned similarly and give the same impression of the fibre composition in the yarn.

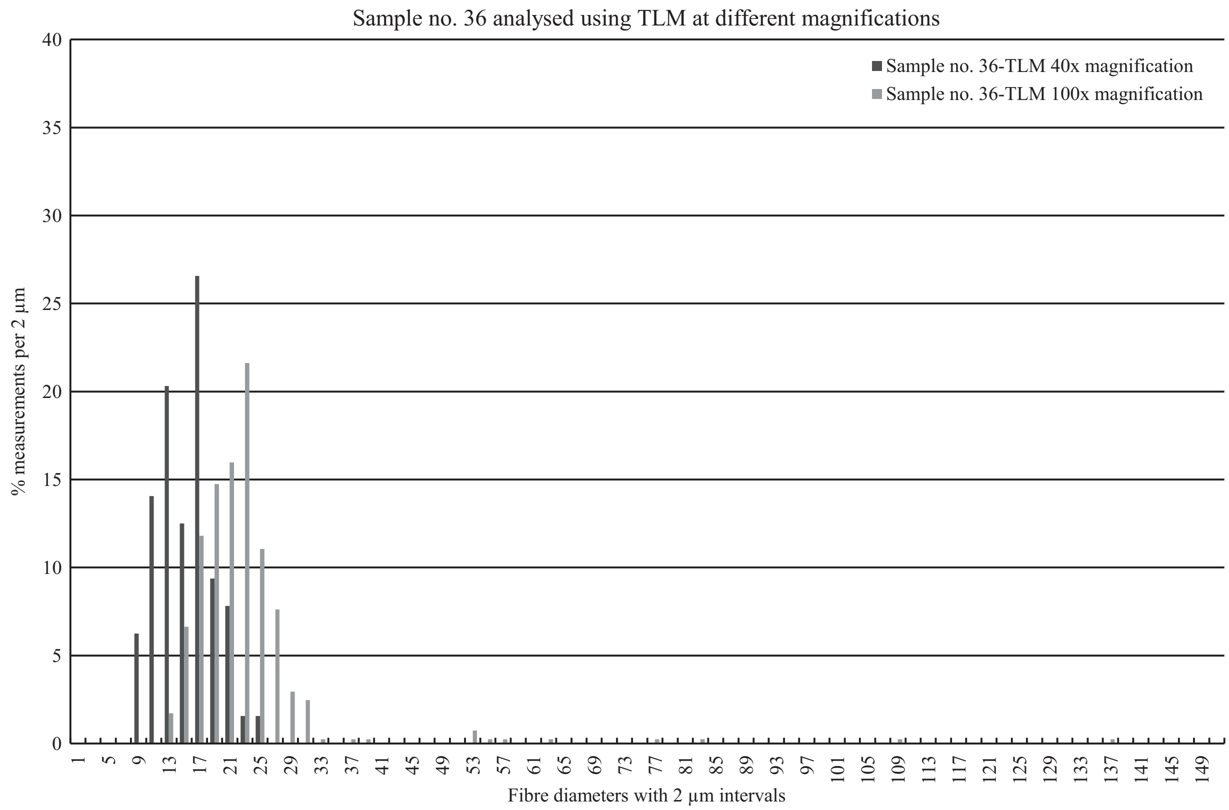

Figure 8. Sample no. 36 analysed using TLM at different magnifications. The two histograms of results from TLM analyses at low and high magnification differ not only in their position on the *x*-axis but also in the widths of the uninterrupted curves and the peak heights.

the number and size of the outliers that determine the categorisation (see Figure 8). Similar to Test 2, the results from Test 3 also indicated that an uneven distribution of the fine and coarser fibres in the yarns is more likely to cause differences in the categorisation than the chosen magnification does.

Test 4

As the results from the two previous tests have suggested, the possibility exists that the fibre compositions vary within the same strand of yarn to such an extent that the same yarn can be attributed two very different categories. To explore this question, two different samples from 11 yarns were analysed at the same magnification (TLM with 4× objective) and the impressions of the fibre combinations in both the categorisations and the histograms were examined closely (Table 10).

The categorisations were identical in four of the 11 cases. In the remaining cases, the most pronounced differences were between categories AAA and B, equivalent to a drop of four steps in the system, which were recorded in sample nos. 16/17 (Figure 9), 20/21, and 22/23, and between categories AA and CD, equivalent to a drop of five steps, which was recorded in sample nos. 9/10 (Figure 10). The former was caused by 1–2% increase in the content of outliers, while the latter was caused by a decrease in the percentage of fine fibre as no fibres above 60 microns were recorded in either of these samples.

The results demonstrated the extent to which small variations in the fibre composition influence the categorisations. The presence of outliers in the yarns is not

Table 10. The categorisations of two samples from the same yarns vary in most cases and the results demonstrate to what extent small variations in the fibre composition influence the categorisations.

Evaluation of Rast-Eicher's classification system				
Sample no.	Number of fibres	Category	% measurements below 25 µm	% measurements above 30 µm
5/6	63/36	A/AAA	86/97	3 (32, 33 µm)/0
7/8	76/145	*AB*/AA	76/90	13 (31–34, 36–37, 43/3 (32 µm)
9/10	136/39	AA/CD	93/77	2 (31, 38, 40)/11 (32, 37, 41, 52 µm)
11/12	113/71	*AB/AB*	81/83	11 (31–33, 36, 38)/8 (32, 34–35 µm)
16/17	84/87	AAA/B	100/97	0/1 (81 µm)
18/19	94/87	AA/AA	99/99	1 (46 µm)/1 (57 µm)
20/21	91/86	B/AAA	99/100	1 (65 µm)/0
22/23	77/90	B/AAA	97/100	3 (32, 109 µm)/0
24/25	93/86	AAA/AAA	100/100	0/0
27/28	64/80	AAA/AA	100/98	0/2 (32.33 µm)
30/31	82/79	AAA/AAA	99/100	0/0

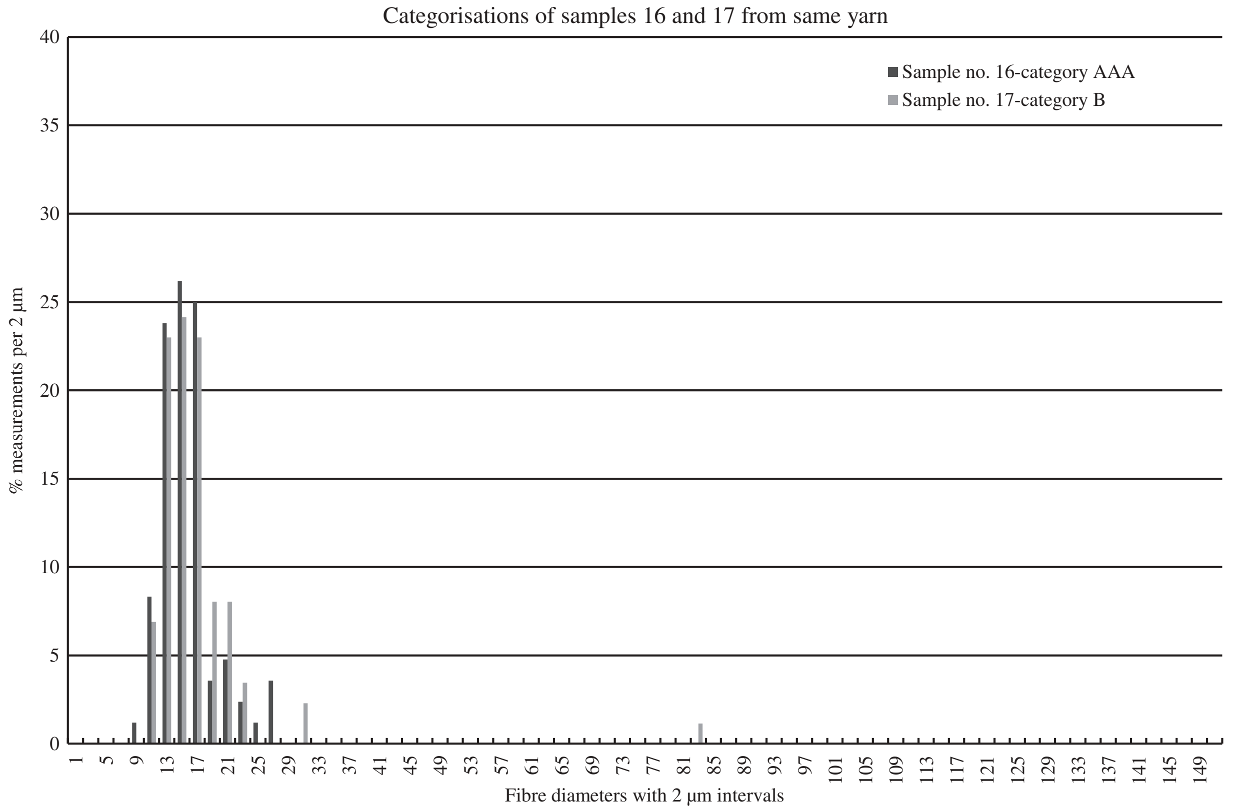

Figure 9. Categorisations of sample nos. 16 and 17 from the same yarn. The TLM analyses of fibres from samples 16 and 17 picked from the same yarn in the textile result in almost identical histograms but very different categorisations due to one measurement of 81 microns in sample 17.

consistent and the analyses of these 11 yarns showed that the fibre compositions in a single yarn can vary to the extent that two parts of it are categorised very differently. The analyses also clarified that the fineness of the fibre combination in some of the yarns is overruled within the categorisation system by the existence of only a few outliers exceeding 60 microns. In these cases, an evaluation and comparison of the histograms, with respect to the uninterrupted ranges and the percentages of fine fibres in our opinion, give a better understanding of the fibre composition than the letter classification by itself.

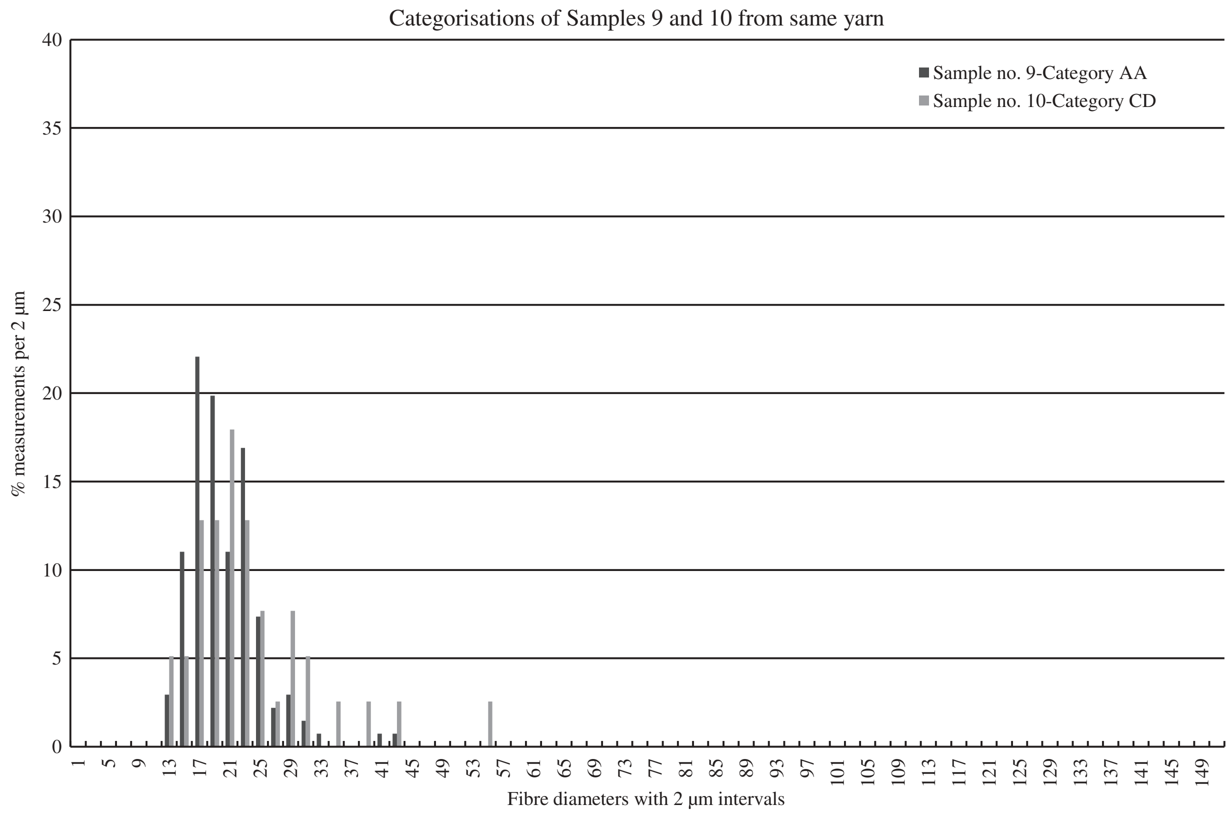

Figure 10. Categorisations of sample nos. 9 and 10 from the same yarn. The histograms of the TLM results from samples 9 and 10 picked from the same yarn in the textile resemble each other and no measurements above 60 microns are recorded. The width of the curve of sample no. 10 is slightly wider and causes the different categorisation.

Test 5

The statistical reliability of the fibre measurements was further examined in a final test where the results from two separate analyses made by the same person on the same photographs were compared. For this test, TLM photographs taken with a 4× objective of four samples and with a 10× objective of one sample were used (Table 11). The statistical modes differed in all cases and although the curves in the histograms appeared similar (Figures 11 and 12) small differences in the fibre measurements again resulted in different categorisations of three of the samples. This illustrated that the human factor also resulted in measurement uncertainty to a degree that caused the calculations to differ.

Manually operating a computer mouse and finding the clearest places to mark the outlines of the fibres can result in size variations ranging to several pixels. This problem may be further influenced by the sharpness of the pictures and the quality of the computer screen. Together with the facts that the fibres are rarely completely round in cross-section and that the width of

Table 11. Two analyses of the same images illustrate the complexity of the material and the difficulties of obtaining identical results. The statistical mode differs in all cases and the categorisations differ in three out of five cases.

Evaluation of results from two analyses of the same TLM images									
Sample	TLM	Number of fibres		Mode in µm		Measurements in µm		Category	
No.	Objective	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
13	4×	266	138	13	16	9–26, 37, 45, 61, 88	10–23, 28, 63, 89	B	B
14	4×	298	140	12	14	5–24, 43, 118, 152	9–26	B	AAA
18	4×	94	78	13	15	7–11, 13–18, 20, 25, 46	7–8, 10–20, 24	AA	AAA
19	4×	87	79	13	14	6–11, 13–20, 23, 57	9–20, 24, 27, 29, 53	AA	AA
18 + 19	10×	354	126	17	16	9–28, 118	9–26	B	AAA

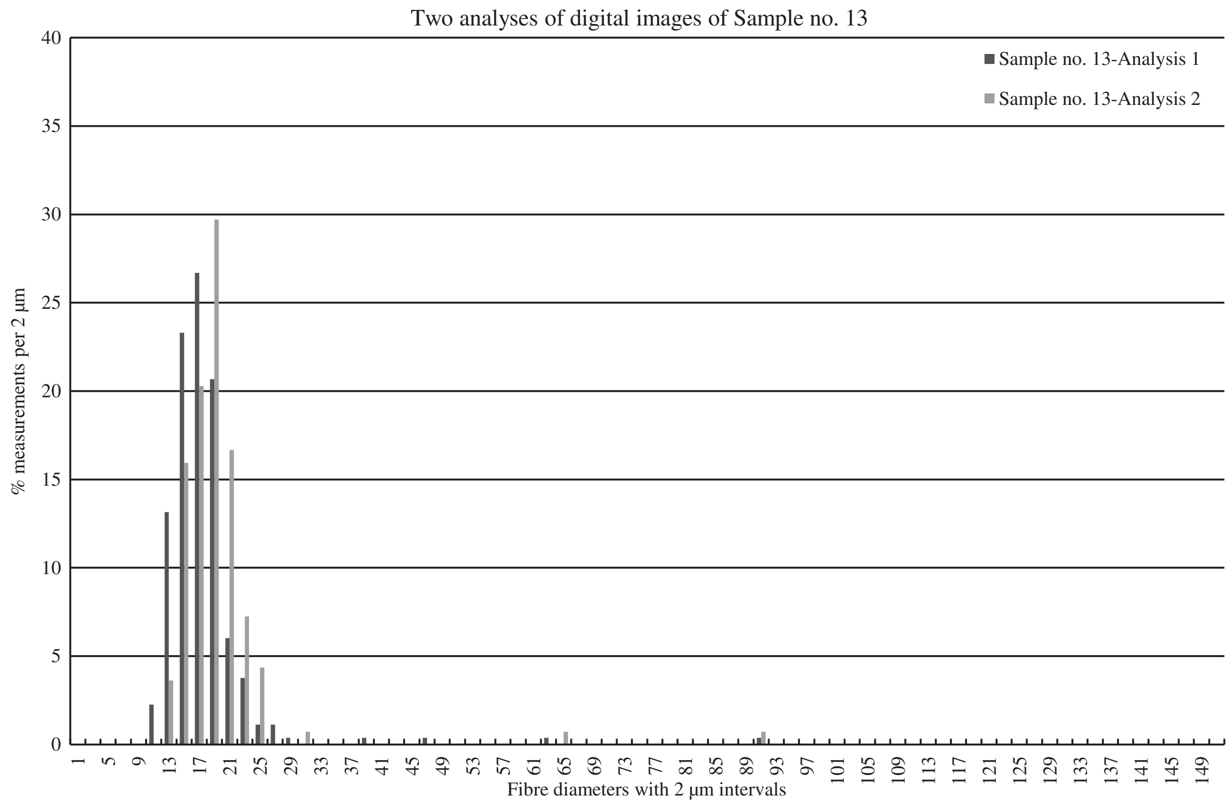

Figure 11. Two TLM analyses of the same digital images of sample no. 13. Two separate analyses of the images of sample no. 13 result in very similar histograms and give the same impression of the fibre content.

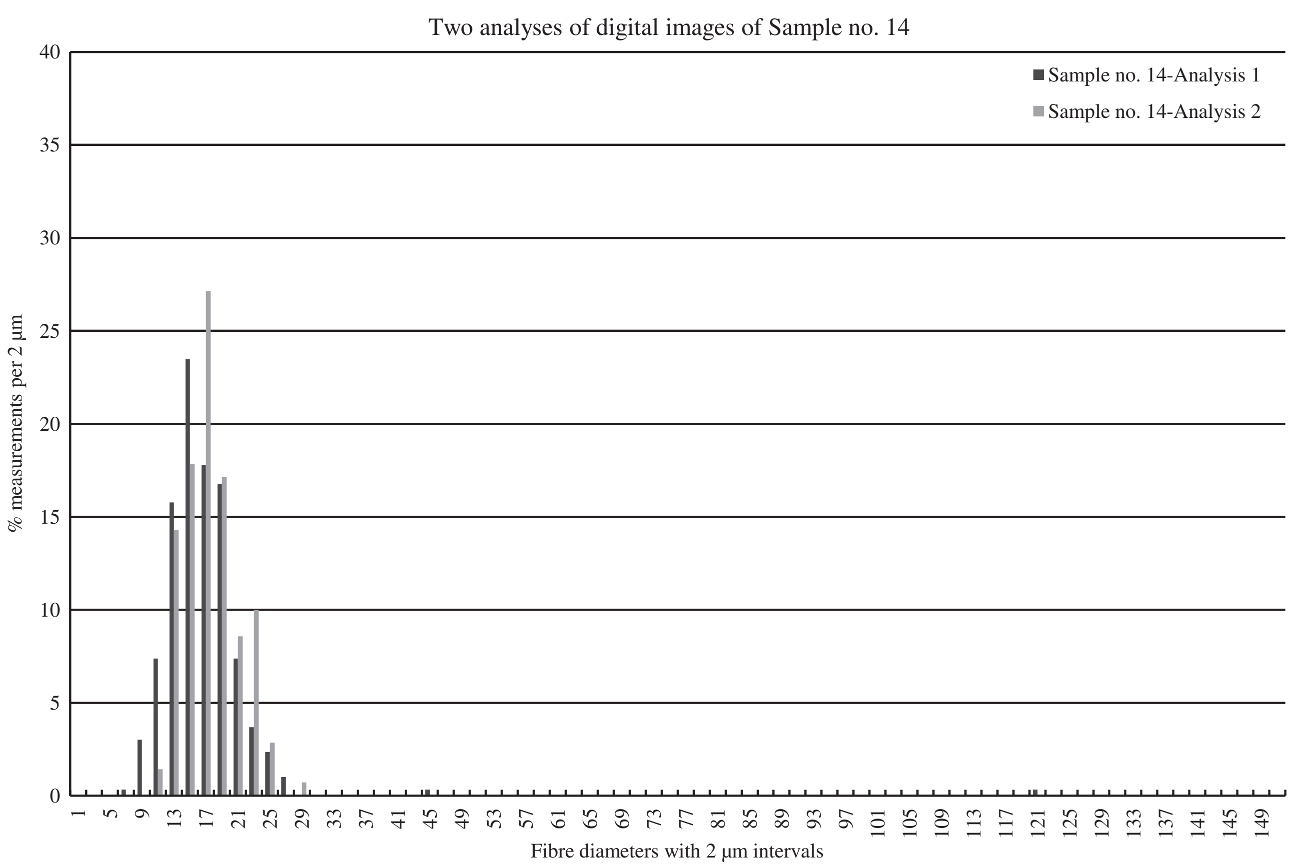

Figure 12. Two TLM analyses of the same digital images of sample no. 14. The recording of two outliers in analysis 1 of sample no. 14 is the major difference between the two analyses of the same images.

a single fibre varies along its length, it must be concluded that it is impossible to fully recreate analyses. It is expected that this problem would be compounded if the fibre diameters were measured by different researchers.

Conclusions

Across time and space, wool fibres of specific qualities such as the ability to insulate for or against heat, to make textiles water repellent, easy to spin, dye or felt, were selected for the production of diverse textiles intended for diverse purposes. Already at the end of the third millennium BC, Near Eastern Ur III archives mention at least five categories of wool quality, with category 1 being the finest and destined for the production of royal garments (Waetzoldt 1972). Two millennia later, Roman encyclopaedian Pliny, 1940 the Elder (*Naturalis Historia* 8, 190) informs us that the most expensive sheep wool of his day (first century AD) came from the Po region, and was valued for its whiteness and fineness. Medieval economies of Europe were built on wool trade, which encouraged the breeding of sheep with specific qualities (Munro 2009, p. 4). Over the last few decades, textile archaeologists have been attempting to identify breeds mentioned in these written sources by measuring the diameters of fibres in extent archaeological wool samples.

Differences between the wools used already during the Bronze Age in Central Europe and Scandinavia have been noted (Rast-Eicher and Bender Jørgensen 2013, Grömer *et al.* 2018, p. 356), with the fine fibres in the Scandinavian wools having on average lower diameters. Understanding such regional variations can in some instances help identifying exotic materials. Thus, some unusual Hallstatt Bronze Age fleeces with dyed, naturally nearly white wool and fibre diameter measurements that did not correspond to the typical Bronze Age fleeces found in the salt mines of Hallstatt in Austria have been interpreted as possible imports (Rast-Eicher and Bender Jørgensen 2013, p. 1234). Such cases are more evident in the material dating to the medieval period, from which many more wool textiles survive. For example, among the over 400 textile fragments recovered from the thirteenth- to fifteenth-century AD Elbing in Poland, many were identified as English or Spanish (merino) imports, based on the comparison of their histograms to the ones of fibres in modern samples from the Shropshire and Merino breeds (Maik 1998, p. 219).

Even within a single textile, different types of wool may be combined to achieve a specific aim: for example, the wool in the warp of the tablet-woven bands from the Iron Age salt mines of Hallstatt was carefully selected and processed, likely in order to withstand abrasion of the tablets (Rast-Eicher and Bender Jørgensen 2013, p. 1232). The warp and weft of the Norse Medieval garments found on Greenland were made of different parts of the sheep fleece, with long and strong hair used for the warp (which needed to withstand the tension on the loom), and shorter and finer underwool used for the weft, which provided insulation (Walton Rogers 2004). These were conscious choices on the part of the craftspeople, who understood the different properties imparted onto textiles by their choice and processing of the specific raw material.

Archaeological data does not permit us to disentangle the complexities of how wool quality was defined by particular cultures during various periods of the past, but it is still possible to see the potential of their available resources and that there were various methods for obtaining the ideal raw material appropriate for the end product. Nor is it possible to deduce the exact fibre composition of prehistoric raw or unprocessed wool directly from the textiles. Prehistoric skins have been considered ideal for this purpose and several analyses have been made of fibres from skin capes from the same contexts as the textiles and interpreted as such (Ryder 1990, Rast-Eicher and Bender Jørgensen 2013). However, our recent analyses of fibres from Danish Early Iron Age skin capes, made of cured but not de-haired sheep skins, seemed to indicate that the skins had also been selected for their special qualities and with specific use in mind, wherefore they do not necessarily represent the raw material used for textile production (Mannering and Gleba Forthcoming).

The extremely good preservation of the Danish prehistoric textiles has enabled the execution of the five tests described above. In most other cases, fibre analyses are carried out on one small sample from one yarn in a textile. Knowing the inherent uncertainties in the analyses that have been highlighted by the tests makes interpretation of the complex mixture of information our measurements provide even more challenging. The results are influenced by the type of microscope (Tests 1 and 2), the magnification (Test 3), the nature of the material, and the restrictions for sampling which make it impossible to measure the exact same fibres at the exact same locations (Tests 2 and 4). The analyst and the resolution of the images can also affect the results (Test 5). However, the results can provide useful information because the uncertainties appear inconsistent and occur regardless of the method and the magnification, and because the histograms obtained from the same samples using either microscope type as well as different magnifications are comparable (Tests 2 and 3).

The differences in the measurements that we observed were either on the micron level which did not influence the overall results or they were in the amount of outliers, usually the fibres with large diameters (see Figure 6, 7, 9, 10, 11), which could have a great impact on the resulting categorisations (Test 3, 4, 5) because it is the number and size of the outliers that define the categorisation of wool in both Ryder's and Rast-Eicher's classification systems. Furthermore, since sorting the wool of a fleece can skew a sample towards the finer end of the distribution in any case, we need to focus on the uninterrupted range and the shape of the histogram rather than the outliers, which do not present the whole picture (as already pointed out by Gleba 2012).

A more nuanced and less rigid approach for interpreting the results can be to study and compare the appearances of the histograms representing the different yarns, to evaluate the uninterrupted ranges and the height of the peaks, and to calculate the percentages of fine, medium, and coarse fibres. This offers the possibility of detecting patterns despite the uncertainties demonstrated by our tests, and an understanding of the fibre compositions in the wool yarns from the Danish prehistoric textiles has been obtained by this method and has revealed interesting details that can be attributed to either the raw material or its processing (Skals and Mannering 2014). This way, too, it is easier to abstain from attributing quality definitions, a risk which is often a consequence of using classification systems.

The methodological refinements allow differentiating important regional as well as chronological patterns in the wool yarn composition, which may be attributed to the work processes of the craftspeople. The characteristic differences between the wool yarns from the Early Bronze Age, the Pre-Roman Iron Age, and the Roman Iron Age in Denmark (Skals and Mannering 2014) are not the only examples. Chronologically, there are also differences between the Bronze Age and Iron Age wool in Hallstatt, Austria (Rast-Eicher and Bender Jørgensen 2013), and in Italy (Gleba 2012). In all cases, Bronze Age wools have very fine underwool and a significant presence of very coarse fibres. Over time, the mean diameter of underwool increases and that of coarse hair fibres decreases, leading towards greater homogeneity of the fleeces. There are also differing wool types contemporaneously present during the Pre-Roman Iron Age in Scandinavia (Mannering and Gleba Forthcoming) and the Iron Age in Italy (Gleba 2012), suggesting either the coexistence of several different sheep varieties and/or differential selection and processing of wool.

The very detailed studies of prehistoric wool are particularly made possible by the large number of wool textiles preserved in Denmark and, to date, only the salt mines in Hallstatt, Austria, have produced a comparable amount of organically preserved wool textiles dating to the European Bronze and Iron Ages (Rast-Eicher 2013, Rast-Eicher and Bender Jørgensen 2013). As more archaeological samples from across Europe and the Near East are analysed, we will be able to accumulate statistically significant amounts of samples for a better understanding of sheep fleece evolution through time and space and contribute new insights into prehistoric consumption and exchange of wool, textiles, and livestock. But we must ensure that our methods are robust and reliable, and we should not be afraid of making more nuanced and subtle interpretations of the archaeological data.

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ORCID

Margarita Gleba http://orcid.org/0000-0001-7729-7795
Michelle Taube http://orcid.org/0000-0002-4414-5602
Ulla Mannering http://orcid.org/0000-0001-8454-9153

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RESEARCH ARTICLE

Hybrid beasts of the Nordic Bronze Age

Laura Ahlqvist and Helle Vandkilde

Department of Archaeology and Heritage Studies, Aarhus University, Aarhus, Denmark

ABSTRACT

During the Nordic Bronze Age (NBA), hybrid beasts contributed to cosmological and mythical narratives on the main media of metal and rock. These hybrids are composed of body parts from particular animals – including bull, bird, snake, horse and human – which entangle with particular objects or images. On metalwork, they appear especially on bronze razors but also on shields, bowls, combs, helmets and in the shape of figurines. Their main occurrence clusters in the later part of the NBA that is characterised by social change. Especially cremation as the total metamorphosis of the human body aligns with a nexus of analogues firmly linking interspecies composites with ideas of bodily fluidity and transformation. Overall, this may be understood as a way of perceiving, and potentially controlling, the world. NBA hybridising art does not indicate that the religion of the era is reducible to mere animism throughout, but society certainly retained and put to use properties of an animistic tradition. Supported by contextual data, the article proposes that the hybrids related to shared NBA myths and religious practices while also legitimising the privilege and leadership of the upper echelons of NBA societies.

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Nordic Bronze Age (NBA); hybrid; cosmology; elite; animism

Introduction

Hybrids composed of different beings formed part of the Nordic Bronze Age (NBA), but have so far merely received sporadic treatment by the archaeological research and have in some cases barely been noticed (e.g. Müller 1921, p. 52, fig. 185). By contrast, Late Iron Age and Viking Period hybridising imagery has been investigated and interpreted in terms of mythical narratives, shamanistic shape-shifting and the religiosity of privileged social groups (notably Price 2002, Hedeager 2010, 2011, p. 59ff, Kristoffersen 2010).

The present contribution aims to clarify the phenomenon of hybrid appearances in the NBA with an emphasis on versions in bronze. Essentially, complex interspecies relationships incorporated animals, humans and objects in a highly selective manner, including the choice of media. A number of questions transpire: which creatures are selected to be combined into hybrids, where is this imagery presented and how should hybrids be understood within the societal context of the NBA? In dialogue with adequate theory, and drawing on later analogies and similar imagery, we propose that NBA hybrids, that is combinations of different animals (including humans) and objects merged together, materialised aspects of animistic beliefs intertwined with the strategic making of identities in the upper societal rung and with particular references to warriorhood.

Previous research in Scandinavia

Different hybrid creatures have been recognised briefly in especially earlier archaeological literature (e.g. Müller 1921, p. 32, p. 52, Brøndsted 1938, p. 28ff, Broholm 1953, p. 19, Glob 1962, 1969), however, the present article represents the first overview of the NBA hybrids, as well as a comprehensive interpretation of the phenomenon.

Various combinations of bulls, people, snakes and horses on various Bronze Age artefacts and rock carvings have been discussed in relation to myths and similar iconography from the Ancient Near East by Kristiansen & Larsson (2005, p. 320ff). Bull's horns are thought to have represented divine rulership referencing Bronze Age mythology, and horses are assumed to function

CONTACT Laura Ahlqvist lauraelisabethsvopahlqvist@gmail.com Department of Archaeology and Heritage Studies, Aarhus University, Moesgård Allé 20, Aarhus 8270, Denmark

as a medium linking the Pantheon of divinities with its human counterparts of leaders and chiefs (Kristiansen & Larsson 2005, p. 320ff).

Kaul (1998a, p. 200ff, 1998b, p. 28, fig. 56, p. 146, fig. 357, 2004, p. 242ff) also employs a religious framework in his interpretation of the hybrid creatures on the Late NBA razors as elements of the great narrative of the sun's journey across the sky (see also Goldhahn 2005). Similarly, the small figurines from Grevensvænge and Fårdal (Figure 1–2) are considered miniature reproductions of religious leaders or 'practitioners of rituals', and the twin helmets from Viksø are also discussed as objects of ritual significance (Kaul 1998a, p. 16ff).

The Viksø helmets (Figure 1a) were recently reexamined from a combined social and religious perspective: they appear as implicitly hybrid, as they incorporate selected animal and material parts and highlight human eyes and brows (Vandkilde 2013, p. 167ff). Vandkilde suggests that the two helmet carriers were meant to internalise the plethora of animal features, the semi-divine warrior twins and their ships, which have a strong bearing on the wider mythical world of the Late NBA with parallels, for example, in the Grevensvænge figurines. Thus, on the one hand, shamanistic or animistic shape-shifting could be involved. On the other hand, rituals revolving around the two well known warrior adventurers may, by the Late NBA, have incorporated aggrandising components reminiscent of Mediterranean post-Bronze Age hero cults, in which gigantic, semi-divine ancestors played a profound role

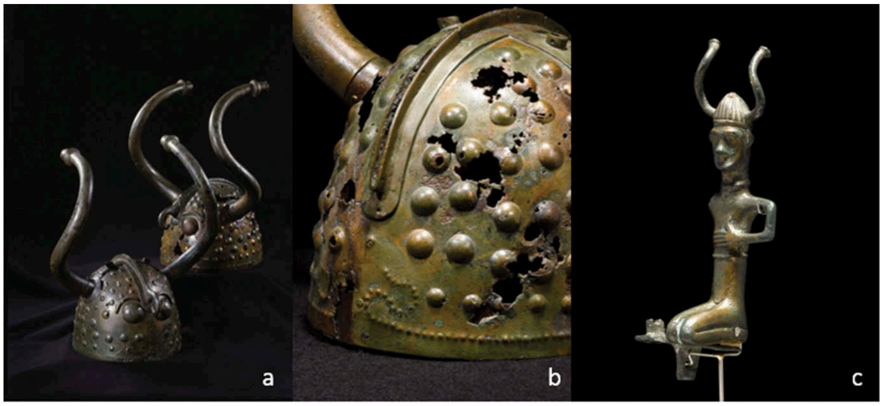

Figure 1. a: Twin bull-horned helmets from Viksø, northeast Zealand (Courtesy of the National Museum of Denmark, photo: Lennart Larsen) and b: a close-up (Courtesy of the National Museum of Denmark, photo: Roberto Fortuna & Kira Ursem) of the swan-headed devices on stern and rear of the encircling longships. NBA IV. The imagery is hybridising on several levels while repeated on the Fogdarp yokes. c: Figurines of bull-horned twins from Grevensvænge, southeast Zealand (Courtesy of the National Museum of Denmark, photo: Roberto Fortuna & Kira Ursem) which might, in conjunction with several rock carvings, suggest hybrids between bull and man or that certain males wore bull-horned helmets on particular occasions such as war – likely the same issue.

Figure 2. Figurines from Fårdal, central Jutland (NBA VI). Four horse heads, each crowned with bull's horns, were probably attached to stern and rear of a longship model. The passengers were figures of a divine golden-eyed female and an animal hybrid merging the head of a bull-horned horse and the wriggling body of a snake (Courtesy of the National Museum of Denmark, photo: Roberto Fortuna & Kira Ursem).

(Vandkilde 2013, p. 171ff). In a similar vein, Vandkilde has explained the emergence of NBA elite weaponry and warriorhood c. 1600–1500 BCE in the light of reformed religious beliefs in a tripartite cosmos: this involved complex human-animal-object relationships but usually without distinct hybridisations at this early point (Vandkilde 2014).

Hybrid creatures from other periods of prehistory have been more widely explored and interpreted, which is in stark contrast to the literature on the NBA hybrids. Often, it is suggested that they refer to ritual specialists or shamans (e.g. Lindstrøm 2012, p. 156ff). Hybrids are especially prominent in Late Iron Age and Viking Age animal styles (Figure 3) (Kristoffersen 2010, p. 263ff). Furthermore, fragmented human and animal remains thought to represent religious practices are found in different contexts during these periods (Hedeager 2011, p. 68ff). The significant role of shape-shifting and shamanism as religion-related practices was established with Price's early work (2001, 2002), and more recently, with Hedeager's comprehensive studies, they have become firmly linked to the hybrid realm of animal styles and the legitimisation of new forms of rulership. Drawing on later written sources about shape-shifting, Hedeager (2011, p. 75ff) perceives hybrids as the expression of a world where boundaries between different bodies – both human and animal – are not sharply drawn. She considers hybrid beings as shape-shifters who possess a fluid identity and body. Warriors, warfare, religion and power constitute entangled domains notably incorporating wolf, eagle and boar warriors (Hedeager 2010, p. 114ff, 2011, p. 75ff).

a

b

Figure 3. Hybrid animal art in the Nordic Late Iron Age and Viking Age often combine parts from different animals including humans. Examples: a: the Torslunda plate, Sweden, b: mounting from Söderby Karl, Sweden (a: drawing by Bengt Händel in Arbman 1980, p. 25, b: drawing by Harald Faith-Ell after Holmqvist 1951, Figure 7).

To use written and material sources as a direct basis for interpretations of iconography several centuries older may be a dubious endeavour. However, as a relational analogue (Wylie 1985), the contemporary interpretations of these earlier sources may work far better, especially because of the structural resemblance between NBA and Viking Age societies pointed out in recent years (e.g. Kristiansen 2016). Research in NBA hybrids is a new field and will benefit from the mentioned Iron Age studies.

Interspecies entanglements in premodern human beliefs

The NBA hybrid beings might be discussed in relation to various theoretical frameworks that concern transition, iconography and, above all, transformation. The most appropriate of theories to improve knowledge of the subject area are rooted in ethnographic examples from all over the world. Most notably, animism is relevant as metamorphosis between not only people and animals but also between different animals and between people and objects is a key element in societies with animistic traits (Ingold 2011, p. 123).

Animism, first described by Tylor (1871), or perhaps more appropriately, animistic notions should not be viewed as a religion with dogmas, but rather as a way of viewing the world, deeply embedded in everyday life and permeating through every sphere of society (Insoll 2011, p.

1004f). Post-Tylor, animism has nevertheless often been conceptualised as the original form of religion, a research position which has been much debated (e.g. Stringer 1999), and in current research, there is a growing awareness of the changing nature of animism. Thus, animistic perceptions of the world may take different forms in different societies and are not solely tied to a hunter-gatherer way of life; in fact, they might combine with other belief traditions and cosmologies (e.g. Ingold 2011, p. 77ff). Rather than perceiving animism as the belief that people, animals and objects have similar souls, we might view it as the notion that a mighty force created and permeates the world and now inhabits all the creatures in it (Insoll 2011, p. 1004f, Peoples *et al.* 2016, p. 274f). This means that no shapes and bodies are stable but in constant flux, ever-changing and hybridising (Ingold 2011, p. 113). Communication with the spirits, animals and humans is essentially social and ensures the continued balance in the world as ritualised actions such as gift-giving/votive depositions, while permitting the giver to enter into a reciprocal relationship with nature and supernatural beings (Mauss 1990, p. 14ff, Jordan 2003, p. 137).

Animism is closely associated with shamanistic practices and its inherent idea of shape-shifting and hybrid existences between animals, humans and objects. Voluntary transformation in animistic societies is generally performed by the shaman, who leaves the human body and takes the shape of helping spirits to travel through different realms (Hultkrantz 1978, p. 12, Ingold 2011, p. 123). These helping spirits often have animal form and so the transformation can be achieved by wearing feathers or antlers as well as other animal parts (Hultkrantz 1978, p. 16, Niekum 2008, p. 157f). Interestingly, some NBA finds such as the Viksø helmets and potentially even the Hagendrup find do, in fact, seem to combine multiple parts of animals with human features whilst likely being worn by humans (Vandkilde 2013). Ethnographically the shaman's body is also known to merge with other bodies as he/she rides the animals, which move through air, water and on the ground, such as Odin's Sleipnir (Hultkrantz 1978, p. 16ff). In addition, the shaman has the power to transform completely into one of the helping animal spirits (Hultkrantz 1978, p 18), which would align more with the NBA solar myth (Kaul 1998a) and the sacred role of the NBA horse as a boundary crosser (Vandkilde 2014, Kveiborg 2017).

Alternatively, non-shamans might also achieve the power of transformation through the use of masks and costumes (Conneller 2004, 42ff), as the human physical appearance is altered, and the person appears animal. This phenomenon is known from several contemporary societies with animistic notions, for example in Siberia and Mongolia (Niekum 2008, p. 157f, Little *et al.* 2016, p. 2f). Masks should not be seen as a means of hiding the carrier's identity, but rather as a means of exposing the spirits and animals that live within the human bearer, in other words, the carrier's true identity and face. Some masks, in fact, have a hybrid identity themselves; a mask viewed from one angle could resemble an animal and, from another, a human (Ingold 2011, p. 123ff). The mask-like Viksø helmets carry all these qualities (Figure 1a).

Animistic beliefs may manifest themselves in art and iconography, which are used as physical manifestations depicting the dialogue between people, animals and objects (Ingold 2011, p. 121ff), as well as transformations or the mere possibility of transformation (Hedeager 2011, p. 66ff). Iconographic representation of transformation has also been known to illustrate myths and cosmology, for example the myth of Odin, master of disguise, who is associated with animals (two birds and two wolves) as well as objects (a spear and a ring). The possibility of existence beyond the body is also seen in animal style, where people and animals are interwoven (Hedeager 2011, p. 7ff) (Figure 3). This same animal style, which often has religious connotations, can also be linked to a range of non-religious myths and social identities, for example warriors and kings who turn into animals (Hedeager 2011, p. 84). This recalls the warriors entwined with features from bird and bull in NBA imagery.

On the categorisation of NBA hybrids

Figurative Bronze Age art is often abstract and stylised, which can complicate defining what is a hybrid and what is just stylisation. The distinction between hybrids and stylised animals and the potential challenges linked to this is worthy of a nuanced discussion, which is outside the scope of the present pilot. However, we argue that some creatures are simply too surreal to be considered animals with merely stylised or overaccentuated features. Furthermore, some of the hybrids discussed in the present article appear next to non-fantastical looking animals (see Figure 4c), thus solidifying the interpretation that these are, in fact, something other than animals.

Another grey zone concerns the many instances in which whole or partial animals combine with certain objects. Items incorporating a single animal include, for example, the horse-headed belt-hooks (Figure 5), numerous razors with horse, swan or snake-headed handle (Kaul 1998a, 1998b), the Trundholm sun chariot, and Late NBA bronze vessels displaying the sun-bird-ship motif (e.g. the vessel on Figure 6). Razors may themselves symbolise the vessel transporting the sun (Kaul 2004). If all these objects and images merging with parts from one animal – usually its head and often all together referencing the transport of the sun – are categorised as true hybrids, the phenomenon is very comprehensive. This is a possibility though, and it is interesting that such simple crossbreeds between object and animal appear in art already with the breakthrough of the NBA c. 1600 BCE and continue throughout the era, hence emphasising the significance of specific animals in specific NBA life worlds, which also embraced hybrids per se.

To keep the analysis concise, only creatures combining attributes from more than one animal (counting humans) are included below. This aligns with Hedeager's statement that hybridity concerns porous boundaries between different bodies – both human and animal – and that this state of being characterises the art world as well as certain social practices (Hedeager 2010, p. 114ff, 2011, p. 75ff). The hybridising objects and images themselves with their source material (bronze, gold, rock, clay) can be considered primary contexts of importance for the interpretation, while it is without doubt significant that they often originate from extraordinary burials and votive deposits. As shown by Kaul (1998a, 2004) and others (e.g. Felding 2015), there is, furthermore, a level of consistency between scenery on rock and metalwork, which should be considered in the interpretive undertaking.

The canon of hybrids on NBA metalwork

Based on the above criteria, it appears that the hybrids follow a prescribed canon. Hybrid imagery pertains to razors in addition to notably shields, drinking vessels, combs and helmets, and in the shape of figurines. Alongside humans, the animals comprise horse, serpent, bird, bull, fish and a single dog. The entities of suns and water currents may be added. The preferred body parts comprise human face (including beard and accentuated eyes), bird of prey beak, bull's horns, horse head, serpent

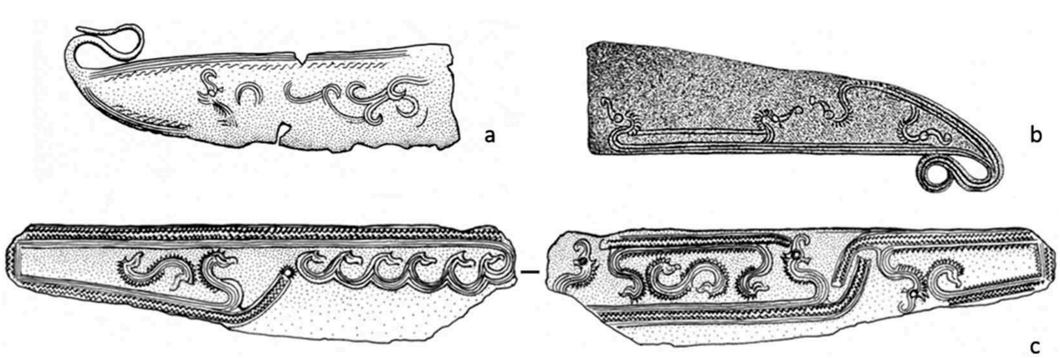

Figure 4. Repeated representations of the hybridised creature on Late NBA razors. Even though there are slight variations to the motif, the overall image appears the same, which is further underlined by the similarity in posture. The hybridised creature is clearly distinguishable from a horse on c, where it co-appears with more natural-looking horses without the oversized eye, the beard and the beak. (after Kaul 1998b: a: Figure 1, b: fig. 203, c: fig. 313).

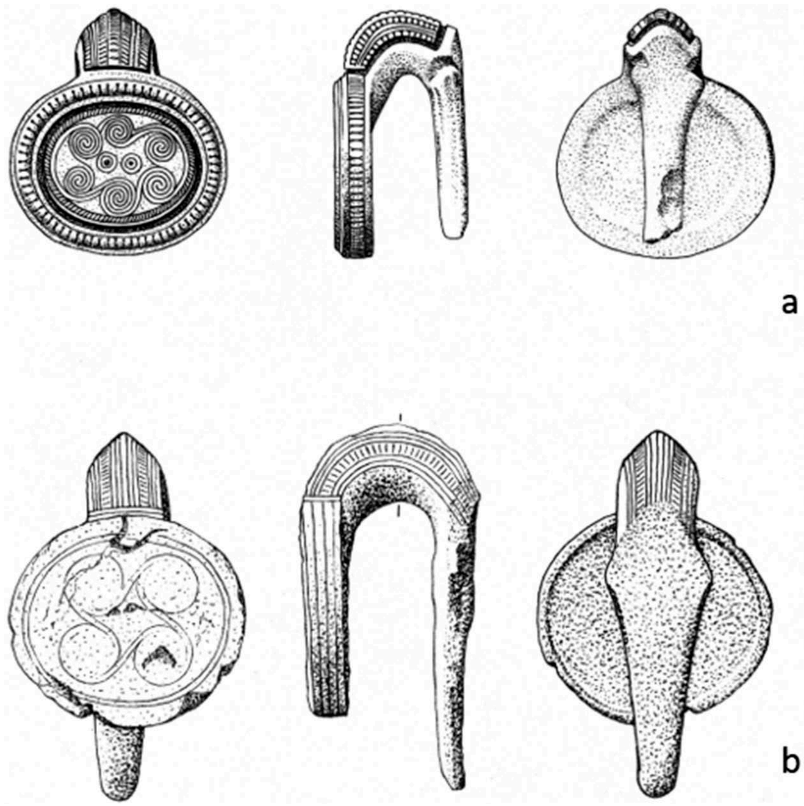

Figure 5. Examples of horse-headed belt hooks from Fredensborg and Copenhagen counties, Zealand (after Aner and Kersten 1973: a: Ke 364, b: 518N). The earliest have a straight arm that develops into a sun-disc pulled by the horse. The horse heads range from stylised to naturalistic. The belt hooks are not categorised as full interspecies hybrids here but relate to these: the horse's head entangles with material parts: firstly, the practical belt fastener and, secondly, the symbolic-religious reference to the sun horse. Belt hooks often occur in rich male burials below mounds. They date from NBA IB to NBA II early (c. 1600–1400 BCE).

Figure 6. Late NBA bronze amphora adorned with sun-bird-ship motif and originally containing the 11 gold bowls adorned with solar symbols and handle composed of a swan's neck terminating in the head of a bull-horned horse. Connection with transitory solar rites and drinking rituals to support social cohesion in the warrior fellowship might be suggested. Mariesminde Mose, Funen (Courtesy of the National Museum of Denmark, photo: Roberto Fortuna & Kira Ursem).

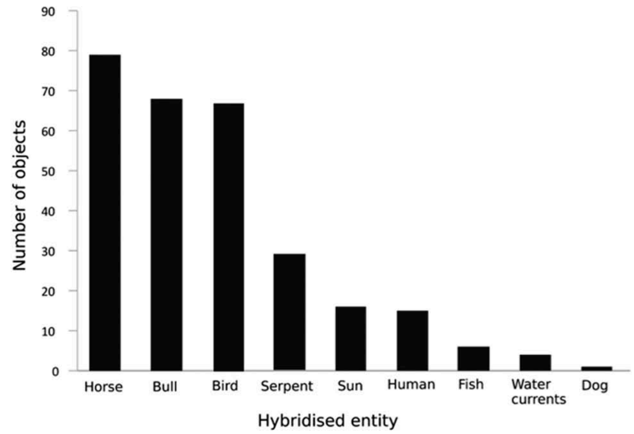

Figure 7. Frequency of different entities on 107 metal objects (83 razors, 9 figurines, 5 pieces of jewellery, 2 helmets/masks, 2 vases/amphoras, 2 shields, 1 comb, 1 tweezer, 1 spearhead, 1 drinking vessel) (Müller 1921, Brøndsted 1938, Broholm 1952, 1953, Kaul 1998a, 1998b, Sommerfeld 2010). Based on prior analysis in Ahlqvist 2016 (unpublished).

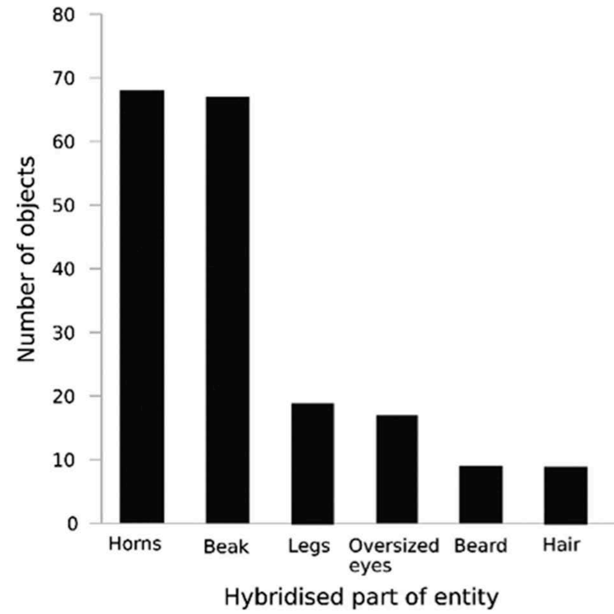

Figure 8. Frequency of the hybridised elements from different entities on 107 metal objects (83 razors, 9 figurines, 5 pieces of jewellery, 2 helmets/masks, 2 vases/amphoras, 2 shields, 1 comb, 1 tweezer, 1 spearhead, 1 drinking vessel) (Müller 1921, Brøndsted 1938, Broholm 1952, 1953, Kaul 1998a, 1998b, Sommerfeld 2010). Based on prior analysis in Ahlqvist 2016 (unpublished).

body, swan neck and head and, more anonymously, legs, tail and hair.

Some of these entities (animals, water currents, sun) and parts of them are more often hybridised than others. Horses, bulls and birds form part of the hybrid on the far majority of objects, whereas serpents, humans and suns are underrepresented (see Figure 7). It should, however, be noted that even though horse, bull and bird all appear on a large number of objects, these hybrids are mainly horse bodies or horse heads combined with beaks and horns, not bulls with horsetails etc. Additionally, the individual animal parts that feature most often are the components of beak and horns. Legs and oversized, round eyes are the second-most common parts (Figure 8). Hair, i.e. manes and beards, are much less common, but these parts may well have existed as real world additions that could be worn, which might be evident from the remains of bird's feathers in the small holes on either side of the crest on the helmets from Viksø (cf. Vandkilde 2013).

Some creatures look so strange and stylised that it cannot be clearly determined which animals or parts of animals they might represent. At times, it appears that one angle resembles one animal while a different angle resembles another. This is potentially an analytical problem; however, it may be intentional and interpreted as evidence of fluidity between different animals and other beings.

Razors with images on the blade are by far the most common space for hybrid figuration involving both anthropomorphic and, particularly, zoomorphic iconography (Figure 9). The razor and its find contexts of burial or sacrifice in sacred places link variously with rites of passage, hence transformation from one stage of being to another. Shaving might even be seen as a rite of passage in itself (Leach 1958, p. 149ff). This said, razors are very particular objects in the NBA as they routinely combine with other tools used to groom the body of the beautiful warrior in the higher echelons of NBA society (Treherne 1995, Vandkilde 2017, 2018). This is similarly signified by the presence of hybrids on *combs and some tweezers* also belonging in the domain of male body grooming. The hybrid motifs on razors often signify different stages in the sun's travel between and across the spheres of cosmos (Kaul 1998a, 1998b). Hybrid creatures enable the journey while transforming when entering different realms of the cosmos.

Figure 9. Late NBA razor with hybrid imagery on the blade. The creature, which appears on the prow and stern of a ship next to an apparent 'sun-horse' seems to be a combination of a horse with horns, a beak, an accentuated eye and a triangular beard (Courtesy of the National Museum of Denmark, photo: John Lee).

Hybrids on *shields and the helmets* from Viksø also broadly link with warfare and warriorhood (see above) but simultaneously with certain reiterated rituals associated with the solar myth or other central myths. Hybrids on *bronze and gold drinking vessels* are situated in a similar intersection in which the consumption of beverages may have served double purposes by maintaining certain cosmological myths as well as social cohesion among groups of high-ranking warriors. The golden bowls with solar symbols and handles terminating in bull-horned horse heads illustrate the exquisiteness of the endeavour (Figure 6). *Figurines* form another space in which hybridity is played out (Figure 2). Such bronze miniatures, not all distinctly hybrid, were probably attached to models of vehicles, in particular ships, as has been suggested for Grevensvænge and Fårdal (Glob 1962). The entire scenery was likely meant to evoke and circulate crucial mythical events among the people participating in the ritual.

In summary, interspecies hybridity on NBA metalwork follows a prescribed canon with preference for certain animals and combinations of these. The canon involves redundancy in terms of the select material media disseminating the hybrids. The preferred range of amalgamations and their contexts align well with the above ideas of bodily transformation in an animistic worldview and, overall, with the transmission of ritual knowledge among privileged peers (see Larsson 2002).

The chronology of hybrid imagery

The far majority of metal items with hybrids belong in the Late NBA c. 1100–500 BCE. However, the question of their beginning is not clear-cut, and hybrids seem to have existed in the Early NBA as well. One clue to this is the bull-horned device from Hagendrup in North Zealand made of gold plated bronze and, based on the spiral decoration, clearly dating to NBA II. It has been interpreted as a horse's mask (Kaul 1998a, p. 30, fig. 23) in anticipation of the later bull-horned horses known from the gold bowls and the Fårdal figurines (Figure 2, 8). Still, it is uncertain whether Hagendrup should count as a hybrid or not (cf. Kaul 1998a, p. 29f, Kristiansen and Larsson 2005, p. 333).

The Kivik cist with the processions of bird-like humans (or human-like birds) on two of the carved slabs make a very plausible hybrid dating to early NBA II c. 1500–1400 BCE (Figure 9a). These strange human-animals have been compared to the Glasbacka celt (Figure 9d), often dated typologically to the final NBA and, recently by Goldhahn, categorised as a hybrid between bird and human (2013, p. 530f). In terms of the framework of the present study, this 7 cm long celt-like item (Figure 10a) combines the beak of a falcon (or other bird of prey) with a human face with one eye blind and the other seeing. The resemblance to Kivik is striking.

Bird-humans depicted on rock panels also sometimes appear very early. Not far from Kivik, on the Simrishamn panel, bird-faced males – apparently

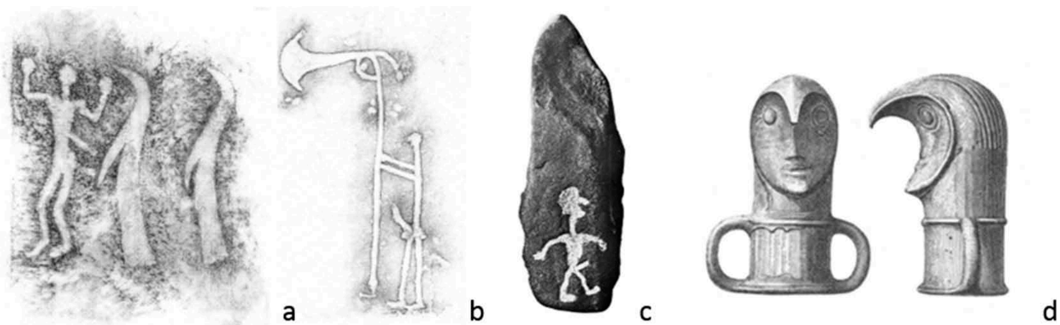

Figure 10. Early NBA bird-humans: a: Kivik cist (NBA II), b: Simris rock panel (NBA IA) on the coast of southeast Scania and c: a slab from Truehøjgård, Jutland, (NBA I-II) compared with d: NBA falcon-human from Glasbacka, Halland (NBA V?), which may have adorned the prow of a ship model. Shape, eyelets and socket suggest axe-like qualities on top of bird-human traits, also reminiscent of the imagery found at Viksø, Fogdarp and Grevensvænge. (a and b after Skoglund 2016, fig. 2.8, Evers Dietrich 1970: Source SHFA (www.shfa.se), fig. 2.1, Evers Dietrich 1970: Source SHFA (www.shfa.se), c after Glob 1969, fig. 18, d after Montelius 1922, fig. 1476 a, b).

warriors – wield huge axes (Skoglund 2016) (Figure 10b). The particular shape and size of the axes and the procession character of the Simrishamn scenery clearly match the oversized, flanged axes with half-circular cutting edge, deposited at the lengthy palisade of multiple posts at Arildshov-Boest in central Jutland. Simrishamn and Arildskov both date to NBA IA 1700–1600 BCE, based on axe typology and 14^{c} (cf. Vandkilde 1996, p. 97ff, 211ff, Rassmann 2015).

Dating on the basis of rock art may be deemed problematic (Brøndsted 1938, p. 12, Horn and Potter 2017). Recent advances in this respect are due to the quite detailed chronology of ships and comparisons with bronze object typology (Kaul 2004, Ling 2008, Skoglund 2016). NBA II and NBA V are floruit periods regarding imagery on both bronze and rock, and it would seem strange if especially the prominent bird-humans on Kivik and Simrishamn did not have counterparts in contemporaneous rock art.

In summary, a practice of hybridisation emerged immediately prior to the breakthrough of the NBA and probably developed further during NBA II. However, the mature phenomenon of hybrids associates with Late NBA. Major socio-cultural changes took form already during the transition 1300–1100 BCE, notably in burial practises where the flames of cremation offered full bodily fluidity and transformation, but also in material culture and depositional rituals (Fokkens 1997, p. 360ff, Kaul 2004, p. 232f, Kristiansen and Larsson 2005, p. 318, fig. 146), and it is interesting that the mature hybrid phenomenon co-occurs with these. Nevertheless, it is worth repeating that simple crossbreeds occurred throughout the NBA, like the ones found early on in the ship-formed scimitars (e.g. Vandkilde 2014), animal-headed devices (e.g. Figure 5) and animal-adorned ships on rocks. While change and transformation in social order and beliefs can be posited, it is also true that a quintessential cultural tradition characterised the entire epoch.

What does the repetitive order of hybrids in metal mean?

Analysis of NBA hybridising iconography revealed preference for particular hybrids appearing in metalwork. This systematisation may be interpreted as a belief that some animals and objects had a special meaning or status: there are several possibilities, which do not exclude one another, and which involve transformation one way or the other. The apparent preference for combinations of human and animal body parts likely suggests that bodies and identities were generally perceived as fluid and unstable in the NBA. The hybrids are generally highly varied, though with some exceptions (see below), perhaps indicating that any being, human, animal or object could transform into another and back again. Thus, the hybrids most often co-appear with different hybrids on the same objects, and only relatively rarely are hybrids depicted with non-hybrids. Such liberal views on body and identity as well as of the boundaries between animals and humans are very much in line with key perceptions in various societies with animistic notions (Ingold 2011, p. 113f). In addition, some of the objects discussed here bear close resemblance to shamanic equipment, i.e. the Viksø helmets and perhaps even the Hagendrup find, which would mean that we can identify the shaman, another central feature in animistic communities (see Price 2002), in NBA society as well.

Hybrids may well connect to rituals (cf. Kaul 1998a, p. 20ff, 2004, p. 342f), which would entail that some animals and objects had ritual significance alongside a greater social importance. This is underpinned by the fact that the vast majority of animal hybrids on bronzes are found on razors from urn burials, an inherently ritualised context (Bradley 2006, p. 375) in which bodily transformation is key. Death and the transition from one state of being to another is linked to rituals concerning the liminal phase in many societies, which, coupled with the 'monstrous images' on the razors, does suggest a ritual nature of the hybrids. However, these rituals do not necessarily have to be exclusively religious (i.e. tied to the belief system, cf. Garwood 2011, p. 261ff).

Additionally, the systematisation of the hybrid motifs could be viewed as evident of a universal cosmology of NBA myths and narratives – an association hard to reject in the light of much recent research by Kaul and others. By way of analogy, similar hybrid iconography on Iron Age objects has been interpreted as depicting Norse mythology as known from written sources (Figure 3). The key mythical and boundary-crossing role of the NBA horse highlights this because of its clear parallel in Norse mythology through the sky horses of *Skinfaxi and Hrymfaxi* and Odin's eight-legged horse Sleipnir, able to cross between worlds (cf. Hedeager 2011, p. 7f, p. 75). With the recognition of the hybrid phenomenon already in the Bronze Age we potentially see a continuous iconographic tradition of hybridising art in Scandinavia from the Bronze Age throughout the Iron and Viking ages and finally ending with the consolidation of Christianity in the thirteenth century (Hedeager 2011, p. 96ff, cf. Andrén 2014, p. 117ff). Perhaps this could be indicative of a continuous animistic tradition that terminated with the full adoption of a Christian worldview? This is an intriguing thought that would be worth pursuing in the future.

In augmentation of the above, we can identify the outline of a particular narrative or myth in Bronze Age imagery in the most common hybrid. This creature has a horse's head, bull horns, a beak, a triangular beard and oversized round eyes (see Figure 9). This composite being is almost always placed on the prow of a ship and in slightly different versions of the same posture, i.e. the chest is pushed forward, and the head tilted back, its nose pointing slightly upwards. The creature even features in relation to other non-hybrid animals, thus solidifying the idea that it is something more than merely a horse's head on a ship's prow (Figure 4). Furthermore, the creature is so widespread, both temporally and regionally, that it is very likely to have had large-scale interlinking importance. There are other examples of repetition in the hybridisations, albeit none were present on as many objects as the horned-beaked creature described above. Birds with horse manes and hooked beaks connected to the prows of ships, and humans with horns were also present on several objects.

In further support of a cosmological communality or identity, the same oversized round eyes feature in other hybridisations, although the aforementioned creature seems to be the only example of such a widespread, repeated combination of strictly selected traits. Notably, the oversized round eyes occur on bronze figurines such as the ones from Fogdarp (Kaul 1998a, p. 28, fig. 21) and Fårdal (Broholm 1953, p. 42f) and on the famed Viksø helmets (Broholm 1953, p. 24, Vandkilde 2013, p. 167ff). Given that this attribute seems to be a signifier of hybrids, it could be suggested that a creature with oversized round eyes perhaps should be considered a hybrid even if no other obvious hybrid features are present. Only one such object is known, i.e. the bronze figurine from Fårdal depicting a kneeling woman (e.g. Broholm 1953, fig. 317) (see Figure 2).

Fabulous animals such as the hybrids are, however, not necessarily linked solely to religion and cosmology – hence recognising that religion may intersect with other social issues and is ethnographically seen as deeply embedded in everyday practices in, for example, animistic societies. For example Julius Caesar's mentioning of monsters roaming the Gallic areas may have been war-related political rhetoric to justify Roman expansion policy (Caesar 1869). Above, we have seen how hybridity and animal art in the NBA connected to the gear of war and the grooming of the bodies of high-ranking warriors, even if undoubtedly also carrying mythical and religious connotations. Bird-faced and bull-horned warriors of the NBA, usually shown with swords or other weapons, recall the animal warriors of the Norse Late Iron Age who signified the quality of being able to transform during war into eagle, boar or wolf, as the most prominent forms (cf. Hedeager 2011). Especially in the Late NBA, the bull-horned humans seem significant. Not only do they appear on one razor (Kaul 1998b, p. 86f, fig. 210), bronze figurines (Kaul 1998a, p. 28, fig. 21, Broholm 1953, p. 24, fig. 105, fig. 105a) and on the bronze helmets from Viksø (Vandkilde 2013), they are also a common motif in rock art (Kristiansen and Larsson 2005, p. 333). This repetition suggests that horned humans played an important role in Bronze Age iconography and cosmology, while it also implies that horned creatures may have been of overriding significance. A key example is the curious bronze figurine from Maribo, which even has three horns (Müller 1921, p. 52, fig. 185). This prevalence of horned humans further supports that the horns on horses are in fact horns and not just ears.

In summary, the systematisation of hybrids on/in bronze points in the direction of a complex world of transformations in several intersecting domains of NBA society, while contributing immensely to a paramount cosmology of NBA mythical narratives, likely with commemorative and possibly socially unifying effects. The level on which this worked is not entirely clear albeit there is a link to the upper social ranks and perhaps especially males.

Hybrids on rock and other media

The hybrid creatures on bronze often find matches or deviations on rock art panels. Some degree of thematic congruence between rock and metal is generally recognised, as some similarities are too conspicuous to be mere coincidence: the horned or beaked humans, already discussed above, appear frequently on rock panels (Kristiansen and Larsson 2005, p. 333f) as well as on a single razor (Kaul 1998b, p. 86, fig. 210). These animal-humans also inhabit several other bronzes, such as the Viksø helmets (Vandkilde 2013), the Grevensvænge figurines (Broholm 1953, p. 24, fig. 105, fig. 105a) and the Fogdarp yokes (Kaul 1998a, p. 28, fig. 21).

Nevertheless, there are also clear discrepancies between the depictions in rock art and metal objects. Human-like figures are notably much more frequently carved in rock (Brøndsted 1938, p. 10, Bradley 2006, p. 375ff), especially the above somewhat stereotypic animal-humans. In addition, some of the same animals occur on rock, but not as hybrids and not in relation to ships. Rock art animals may have horns while other hybrid characteristics such as oversized round eyes seem absent.

The sun, commonly cross-breeding with other features on bronze items, is frequently shown in full and in companionship with humans on rock panels (Kjellén 1976, p. 125, p. 137, Kaul 2004, p. 345ff). The sun is also often placed in different positions than on the razors, for example between the horns of an ox/bull, hovering above groups of animals, etc. (Kjellén 1976, p. 129). Besides, hybrids on rock feature other hybridisations than metalwork. For example, men with bird's wings and beaks as well as a man with two bird's heads are known from Kallsängen in Bohuslän (Aldhouse-Green & Aldhouse-Green 2005, p. 95), and on a rock carving from Hällby in Litslena a man appears with a tree for a head (Kjellén 1976, p. 172). Such hybrid figures lack parallels on the bronze objects. The human/tree combination sometimes appears on clay pots, e.g. one from Haderslev (Broholm 1953, p. 269). However, on a similar pot from Føvling (Müller 1921, p. 34f) in Jutland, tree-like hands translate much better as humans with oversized hands, as the hand motif is frequent on rock and also occurs on the backside of Late NBA 'eyeglass' fibulae and on the Sandagergård cult house (Kaul 1985). Four-legged birds, also counting as hybrids, are engraved on the aforementioned clay pot from Føvling: this recalls another NBA bird-shaped urn with four legs (Broholm 1953, p. 50). More broadly, the fascination with waterfowl in the later NBA likely connects to ideas and beliefs circulating within a wider Bronze Age world, cremation practices and hence bodily transformation.

In summary, most Bronze Age hybrids adorn bronze razors and rock panels, respectively. Whilst razor hybrids mainly comprise a few selected animals and their parts (horse, bull, bird, snake), rock art shows a wider range of animal species and the hybrids are often humans combined with other animals and even plants (for example bull/human, bird/human and human/tree). The disparity is surely rooted in the different possibilities offered by each of these media, such as obviously the large spaces of rock. As emphasised by Kaul (1998a, 2004), rock art and bronzes represent partly different properties of the same cosmology. Following this line of thought, hybrids on bronze often appear as 'snapshots' of particularly significant mythical scenes or condensations of these into symbols. By comparison, rock art motifs with hybrids are in some cases quite action-oriented, showing shamanistic solar rituals of transformation, while in other cases they depict excerpts from adventurous narratives implicating bird-warriors or bull-warriors on board or near longships.

Conclusions

This article has highlighted hybridisation in NBA imagery with the aim of clarifying this phenomenon, its background and role. NBA material culture is rich in simple crossbreeds such as between sword/ship and horse/ship occurring throughout the era, but full hybrids articulate compositions of body parts from two or more animals, including humans, and entangle with particular objects or images. Repeated combinations of animals notably comprise horse, bird, bull, snake and human. The rendering of hybrids follows a certain syntax, and the beasts occur with other images on metalwork and on rock as the primary media, but also sometimes show on funerary urns of clay. In terms of metalwork, hybrids occur especially on bronze razors but also on shields, helmets, bowls and combs, and in the shape of figurines: materials, forms and contexts suggest sacred rituals among an upper social rung with some particular reference to male warriors. Interspecies creatures occur ordered within each medium but also synchronised across media, and moreover cover a wide Southern Scandinavian geography. This may suggest that the phenomenon was socially and culturally embedded and, at least to some extent, shared. A strong presence of mythical narratives, and even an epic cycle pertaining to a gallery of celebrities, transpire (cf. Jensen 1990, Kristiansen and Larsson 2005, Vandkilde 2013).

Albeit appearing immediately prior to the breakthrough of the NBA c. 1700 BCE, the phenomenon of hybrids especially associates with the Late NBA, which saw somewhat opposing developments towards strong communality but also marked hierarchy. The belief system – perhaps mostly a way of perceiving, and enabling connectivity between, realms of the cosmos – seems geared to support both these trends. The numerous cremations testify to common beliefs in metamorphosis of the human body, and this aligns with the nexus of ethnographic and early historical analogues cited above. Interspecies composites, as manifested in the often socially elevated setting of NBA imagery, correspond equally well with ideas of bodily fluidity and transformation, in terms of critical transitions, or journeys, between the realms of the cosmos in some sort of eternal cycle (cf. Holst and Rasmussen 2015). The hybrids and their setting of social exclusivity may reveal a perceived ability to control such critical transitions through elaborate shape-shifting rituals. Social power is otherwise present in the clear link to warriorhood among an elite group.

References to warriorhood in relation to the in-between imagery are, as mentioned, evident as they are especially prevalent on razors, shields, helmets and drinking vessels, and recall later accounts of warriors transforming into wolves, eagles and bears (Hedeager 2010, 2011). This resonates well with the ubiquitous possibility of transformation within animistic worldviews. Beaked and horned warriors are also displayed in rock art, thus indicating coherence between these and the hybrids in metal. Clear differences in hybridisation on rock art and metals are also present; however, bull-horned humans, appear in both media, and must have been of special importance.

The interspecies hybrids stemming from burials, votive offerings and rock panels overall point to a ritually significant transformative iconography active in NBA religious practices and beliefs. Thus, the hybridised miniature figurines as well as the therianthropes and other apparent shamanistic solar rituals depicted on rock panels indicate that certain animistic traits were incorporated within NBA cosmology. However, NBA hybridising imagery does not indicate that the religion of the era is reducible to mere animism throughout, but that society certainly retained and put to use properties of an animistic tradition.

In summary and conclusion, the figuration and context of hybrids reveal properties of animistic beliefs in the NBA, probably intertwined with the strategies of an upper social rung among whom warriors, through their bodies and doings, were rendered prominent. The imagery of hybrids covers the NBA as a culture-geographical zone. This may suggest that the notion of shape-shifting, and the perceived transition between states of being, were also widespread. Furthermore, this belief, or aspects of it, served to mythologise and legitimise ambitions, leadership and privilege among certain social groups who clearly networked with one another.

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ORCID

Helle Vandkilde http://orcid.org/0000-0001-9326-7633

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RESEARCH ARTICLE

Hjarnø Sund – all year, all inclusive. A submerged Late Mesolithic coastal site with organic remains

Claus Skriver[a], Peter M. Astrup[a] and Per Borup[b]

[a]Archaeological Department, Moesgaard Museum, Højbjerg, Denmark; [b]Archaeological Department, Horsens Museum, Horsens, Denmark

ABSTRACT
Between 2009 and 2016, a series of investigations were undertaken at a submerged settlement of the island of Hjarnø in Horsens Fjord, Denmark. The work was prompted by the discovery in 2008 that heavy erosion of a gyttja deposit containing archaeological remains had resulted in artefacts of bone, antler and, not least, wood becoming exposed on the seabed. The investigations revealed that occupation of the site, with a few exceptions, dates to the first half of the Ertebølle culture (5400–4700 BC). In addition to numerous well-preserved artefacts made of organic materials, several areas were found to contain intact shell layers from submerged kitchen middens. Deposits of this kind have not previously been demonstrated in Denmark.

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1. Introduction

Marine archaeological investigations of Mesolithic settlements have been undertaken in Denmark and northern Germany since the 1970s (Andersen 1985, 2009, 2013, Skaarup and Grøn 2004, Lübke *et al.* 2011, Glykou 2016). Due to the exceptionally favourable conditions for the preservation of organic materials, these investigations have resulted in a broader and more nuanced picture of Mesolithic society. For example, through the discovery of new tool and implement types made of organic materials (Skaarup and Grøn 2004, Andersen 2009, 2013, Kloos 2015), as well as the aspects of the contemporaneous diet that are reflected in preserved seeds, fruits and other plant remains. The investigations at the 'Hjarnø Sund' settlement are the latest in this series of marine archaeological investigations in Denmark.

The Hjarnø Sund settlement is situated in shallow water on the southwestern side of the small island of Hjarnø at the mouth of Horsens Fjord (Figure 1). Due to its richness in finds, the locality has for many years attracted amateur archaeologists from both Denmark and abroad.

The finds collected from the sandy seabed at Hjarnø over the years mainly comprise flint tools, but artefacts of bone and antler have also occasionally been encountered. In 2008 it was observed that, in an area previously covered by sand, a layer of dark gyttja had become exposed, and from this, numerous wooden artefacts, several antler axes and the skull of a dog were recovered (Skriver *et al.* 2017). The finds were, in the first instance, handed over to Horsens Museum, but they subsequently formed the basis for a research collaboration between Moesgaard Museum, Horsens Museum and Aarhus University. In 2010 this partnership received funding from the Danish Agency for Culture and Palaces for a minor investigation at Hjarnø. The results from this led to five further minor excavations, funded by the same authority; the last of which was undertaken in 2016.[1] In parallel with these investigations, diver reconnaissance was undertaken during the entire period, aimed at picking up the artefacts that were continuously being eroded out of the gyttja by the sea.

As at many other submerged prehistoric settlements, favourable conditions for the preservation of organic materials have resulted in the 'dump' deposits at Hjarnø having a substantial content of

CONTACT Claus Skriver cs@moesgaardmuseum.dk Archaeological Department, Moesgaard Museum, Højbjerg, Denmark

Figure 1. Horsens Fjord with the islands of Hjarnø, Alrø and Vorsø.

worked and unworked objects of bone, antler and wood (Skriver and Borup, 2012). It was therefore clear from the outset that the site had major scientific research potential, and this was further underlined by the finds of completely new tool types and large assemblages of preserved faunal and botanical remains. One of the project's major aims was therefore to collect and preserve a selection of the organic objects that were being continually eroded out from their original context on the seabed (Skriver *et al.* 2018, p. 126). During successive site visits, several areas were observed where dense shell layers (possible shell mounds) were suffering heavy erosion. There was therefore a need to clarify whether these shell deposits represented natural shell banks or human refuse dumps, or whether they could be the remains of actual kitchen middens formed along the contemporaneous shoreline. A further major task was to evaluate the level of threat to the various areas of the settlement in relation to marine erosion and, at the same time, attempt to find ways to protect these areas in the future.

The aim of this paper is to present the preliminary results of these investigations which, due primarily to the exceptional preservation of organic materials at the site, have provided new information on the characteristic coastal settlement of the Ertebølle culture.[2]

After outlining the formation history of Horsens Fjord, the objectives and methods employed in the investigations are described. Then, based on the investigation findings, a picture is drawn of the local coastal environment and its development during Atlantic times. This includes an evaluation of the contemporaneous sea level, with direct reference to the archaeological evidence. There then follows a description of the investigated shell deposits which, together with the substantial faunal assemblage and the various tool types made of organic materials, provide the basis for a preliminary insight into the subsistence economy of the settlement. The paper concludes with a short description of the methods involved in the planned future protection of the locality.

2. The formation and development of the fjord in prehistoric times

Horsens Fjord is a predominantly shallow fjord, with a length of *c.* 20 km and a width that increases from *c.* 2 km at its head to 6–7 km at its mouth. At its entrance lie the two largest of the fjord's three islands – Alrø and Hjarnø – from where there is a clear view inland to the head of the fjord. The third and smallest island – Vorsø – lies about halfway along the fjord, close to its northern shore (Figure 1). The date of formation of Horsens Fjord is still unclear, but the sea probably penetrated a pre-existing valley in Early Atlantic times (Borup 2003). This took place via a deep old river channel running through the strait of Hjarnø Sund, from where there was unhindered access to the innermost part of the valley. The sea relatively quickly flooded the entire valley, which at the beginning of the High Atlantic transgression became transformed into a fjord with a fully developed marine environment and a water level that lay close to that of the present day (see later).

Information on the development of the sea level through both the remainder of the Atlantic period and in subsequent Subboreal times is still limited, and current knowledge is based primarily on some archaeological investigations (Borup 1993, 2003). The position of the coastal settlements of the time suggests that the sea level remained below that of the present until the end of the Atlantic period (*c.* 4000 BC), when it apparently fluctuated with an overall amplitude of only about 1 m. Consequently, all the settlements from the Ertebølle culture in Horsens Fjord lie between 1 and 0.5 m below current mean sea level. At the end of the Ertebølle culture, there was apparently a marked rise in sea level such that, for the first time, it exceeded that of today, and here it remained throughout the Subboreal. This explains why all the Neolithic coastal settlements are found today up in the fields, often directly above the submerged settlements of the Ertebølle culture. Investigations of fossil beach ridges in the area show that a Postglacial maximum of 1–1.5 m above mean sea level was reached in Subboreal times (Mertz 1924).

3. Methods

Between 2008 and 2018, a large number of methods have been employed in the investigations at the Hjarnø Sund settlement. The choice of methods was influenced to a major extent by the rapid degradation of the exposed dump deposit: There was a special focus on regular recording of the changes in the gyttja layer, as well as collecting and recording the finds eroded out from it. The deposit lies today in the littoral zone, extending out to a depth of 1–1.5 m, which gave various advantages and disadvantages with respect to the investigation.

Even though the actual excavation was undertaken by divers, it was sometimes necessary to carry out the work in such shallow water that the divers lay virtually on the seabed with their air tanks above water (Figure 2). Conversely, the shallow water also made it possible for a person wearing waders to take core samples and undertake survey work using a high-precision GPS.

3.1. Excavation techniques

The excavations were carried out using an ejector pump (Figure 3). In technical terms, this was accomplished as follows: A Honda pump fitted with a suction dredge was installed on the work dinghy and a net with a mesh size of 10 mm was fitted over the exit port. The drawn-up sediment passed through the net, which was subsequently examined for artefacts and plant macro-remains such as hazelnut shells, buds and charcoal. Sorting took place partly on the boat and partly on land, where amateur archaeologists provided assistance (Figure 4).[3] This method resulted in the recovery of a diverse and representative archaeological

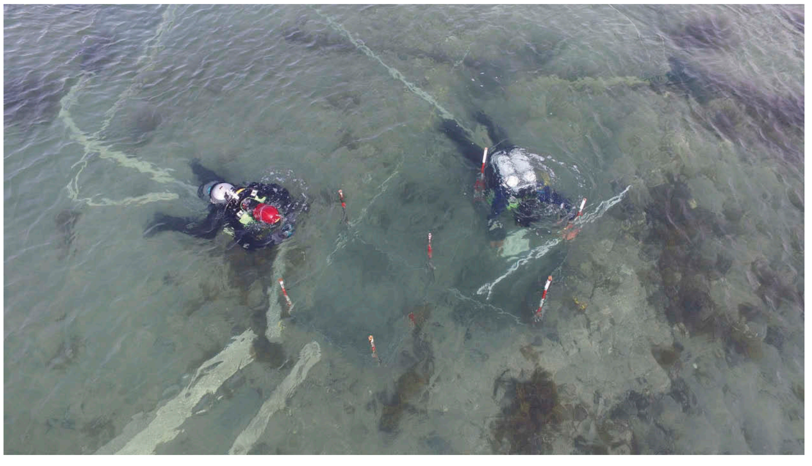


Figure 2. Divers working in shallow water. Photo: M. Hamberg.

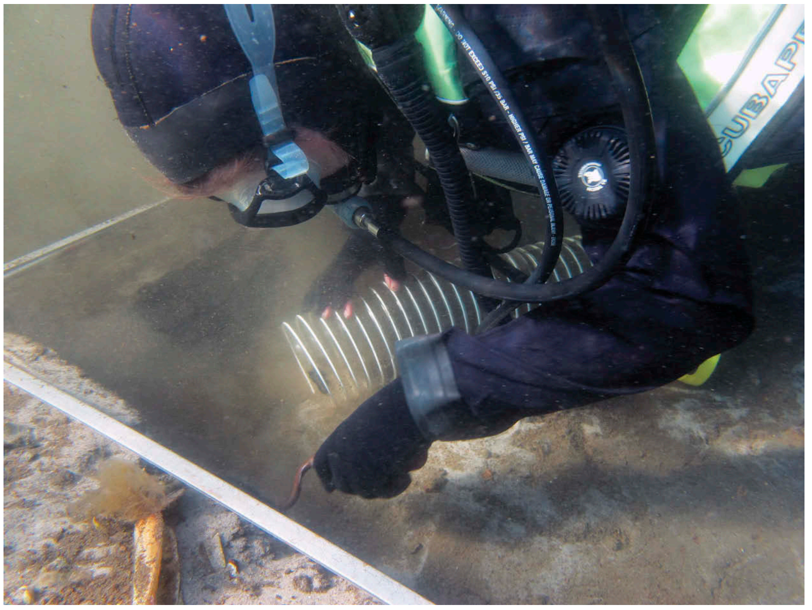


Figure 3. Excavating with an ejector pump and a straightedge. Photo: C. Skriver.

Figure 4. Some of the sorting work was undertaken by enthusiastic amateur archaeologists. Photo: C. Skriver.

assemblage consisting of bones, charcoal, plant macro-remains and flint from the individual excavated squares.

The gyttja was first carefully excavated with a trowel and then directed into the inlet of the ejector pump. The aim was to excavate the trenches in 25 cm layers. Each suction bag was marked with the layer from which its contents came, so there is a precise stratigraphic 'address' for all the artefacts recovered in this way. Larger finds and all wooden artefacts were surveyed and drawn in the field as follows: Ranging rods were used to mark each corner of an excavated square and an excavating frame measuring 1 × 1 m was lowered over these, so the 1 m^2 square was clearly marked. A holder on which a straightedge could be laid was then mounted on the ranging rods, and the level of this holder was determined by GPS. A spirit level could then be laid out across the square from the straightedge so that the level of the surface and the recovered finds could be measured. These levels were then transferred to drawings on plastic foil sheets. The finds were given x-numbers with prenumbered labels and

Figure 5. Overview of the Hjarnø settlement showing the locations of the excavated squares (white) and the core samples (red stars).

taken up into the boat, where the boatman entered them on the finds forms.

In the case of special finds (such as bows, paddles and fish weirs), photos were taken for 3D recording. This method, whereby the artefact is photographed from different angles with defined coordinates, made it possible subsequently to recreate detailed 3D scale georeferenced models of complex artefacts on the computer.

During the first excavation campaign, 1 × 1 m squares were excavated to a depth of up to 60 cm. This gave a good understanding of the individual layers and their contents but was, however, very time-consuming and meant that only very few square metres could be excavated during a season. In 2014 it was decided to excavate a surface of 18 m^2 to a reduced depth of 20 cm, with the aim of obtaining a better overview of the gyttja layer and making it possible to excavate a larger part of the area, which would otherwise be eroded away within a relatively short time. Based on the good results obtained in this way, it was decided to employ the same approach in the following year, when a shell mound was similarly excavated over an 18 m^2 area. Using this method, two divers could excavate side by side, each in their own square, while working together in setting up the excavation grid, surveying, etc. A total area of 48 m^2 has been excavated across the entire settlement area, and the distribution of the excavated squares is shown in Figure 5.

3.2. Reconnaissance

In parallel with the archaeological and geological investigations, regular reconnaissance surveys were also undertaken of the seabed. The aim was to do these surveys on a monthly basis, through the involvement of a local scuba (sports) diver. The finds recovered as a result included numerous wooden artefacts, several of which represented previously unknown types of tools and implements. All the finds were plotted in by the finder using a handheld GPS and then covered with sandbags until they could be excavated and recovered in cooperation with Moesgaard Museum.

3.3. Coring

In parallel with the excavations, a series of cores were taken in the area. The aim was, in the first instance, to obtain an overview of the extent of the exposed gyttja deposit and an idea of the depth of the sand cover in the areas where the gyttja was not visible. The latter was to evaluate the degree to which further areas were potentially threatened by future marine erosion. As new questions and problems arose during the excavation, the aims and

Figure 6. Core sample with alternating layers of dark organic gyttja, sterile pale gyttja and coarse sand. Photo: P. Borup.

objectives of the coring activities were adjusted accordingly to give a better understanding of the overall settlement area, the contemporaneous coastal environment and the influence of sea-level change upon this.

Initially, 42 core samples were taken, all 20 m apart, on a grid system. A so-called Russian corer with a diameter of 5 cm was used to take the samples. The cores were photographed and described on specially produced sample sheets (Figure 6). A few cores were retained for later analysis at Moesgaard Museum's Department of Environmental Archaeology and Conservation. In subsequent years, the network of core samples was refined and the spacing between the individual sampling points was reduced to only 2 m. At the same time, the diameter of the corer employed was reduced to 3 cm, making it possible to take a greater number of cores and to a greater depth. A total of 259 core samples were taken during the entire period of the investigation (see Figure 5).

As it was important to be able to fix the positions of all the recorded finds and levels precisely, all cores, sections recorded in the excavated squares holes, fix points and significant finds were surveyed and plotted using RTK precision GPS.

3.4. Sampling and scientific analysis

A large number of scientific analyses have so far been performed on material recovered from the site. These include a total of 50 radiocarbon dates for finds and samples taken from sections, identification of the wood used for almost all the wooden artefacts, analysis of plant macro-remains and faunal remains and identification of various species of molluscs. In addition, ongoing lipid analyses of samples taken from potsherds are expected to reveal the composition of some conspicuous food crusts. Unless otherwise stated, all the radiocarbon dates listed in the text are presented as calibrated using OxCal V 4.3 and are quoted with two standard deviations (2 σ). Marine samples have been corrected for the reservoir effect using the Marine 13 calibration dataset (Reimer *et al.* 2013) (see also the description in Table 1).

4. Results of the investigations

Based partly on the excavation and core samples, and partly on the observations that were possible on the seabed, a general impression can be gained of the stratigraphy within the excavated area. Erosion in modern times has apparently resulted in cultural deposits from the later part of the Ertebølle culture being completely removed from the area. A general picture of the stratigraphy in the northern part of the area is shown in Figure 8. From this it is evident that over the subsoil there was a layer of oyster shells (K19), which was overlain by a layer of cockle shells (K18) and a sand layer containing finds (K17). Gyttja layer K1 was formed on top of the latter.

4.1. Dates and cultural environments

About 50 radiocarbon dates are available from the Hjarnø locality. Those mentioned in this paper are shown in Table 1. The dates have helped to fix the habitations in absolute calendar years.

Table 1. Radiocarbon dating of samples from the Hjarnø midden site. Results are presented in stratigraphic sequence for each of the 2013, 2015 and 2016 excavations. Radiocarbon ages were calibrated using OxCal 4.3 (Bronk Ramsey 2009). Shell samples were calibrated using the Marine13 calibration dataset (Reimer *et al.* 2013). Charcoal and bone samples were calibrated with the IntCal13 calibration dataset (Reimer *et al.* 2013). All calibrated ages are quoted at the 95.4% probability range.

Lab No.	Trench–Sample–Layer	Material	Species	^{14}C Age (years BP)	Calibrated Age BC	Median Calibrated Age BC
AAR-16958	2013–X119–K10	Charcoal	?	6396 ± 27	5468–5320‡	5379
AAR-16959	2013–X112–K10	Bone	Roe deer	6426 ± 28	5474–5340	5414
AAR-24753	2015–P4–K1	Charcoal	Hazel	6130 ± 48	5214–4947	5077
AAR-24756	2015–P7–K21	Shell	Cockle	6515 ± 34	5275–4955	5116
AAR-24751	2015–P2–K21	Shell	Cockle	6538 ± 39	5296–4976	5140
AAR-24754	2015–P5–K19	Shell	Oyster	6588 ± 38	5341–5022	5200
AAR-24755	2015–P6–K19	Shell	Oyster	6492 ± 48	5270–4910	5090
AAR-24750	2015–P1–K19	Shell	Oyster	6617 ± 36	5367–5051	5233
AAR-24752	2015–P3–K20	Charcoal	Hazel	6162 ± 34	5215–5011	5122
AAR-26593	2016–P1–K22	Charcoal	Hazel	6390 ± 49	5477–5299	5378
AAR-26592	2016–P2–K23	Shell	Cockle	6515 ± 27	5271–4961	5116
AAR-26591	2016–P3–K19	Shell	Oyster	6637 ± 35	5395–5072	5254
AAR-26594	2016–P4–K9	Charcoal	Hazel	6285 ± 40	5365–5082	5266
AAR-16090	Bow – X144 – K1	Wood	Elm	6136 ± 30	5209–4998	5089
AAR-12641	Brakør	Wood	Stump	6225 ± 55	5315–5040	5177
AAR-23271	K1	Wood	Hazel	5691 ± 27	4593–4458	4520
K-1222	Stensballe Sund	Shell	Oyster	6340 ± 130	5557–5003	5319

Most of the archaeological finds encountered at Hjarnø are types that are familiar from many other Ertebølle settlements in southern Scandinavia and northern Germany (Skaarup and Grøn 2004, Andersen 2009, 2013, Klooss 2015): Flint flakes, blades and both flake and core axes have been found in large numbers scattered across the seabed. The abundance of finds reflects long-term occupation, and the initial radiocarbon dates show that there was activity at the site from around 5400 BC until some time after 4600 BC. This time frame is underlined by the typological dating of the artefacts, although the majority of these fall primarily within the first half of the Ertebølle culture. Most of the collected and excavated artefacts come from well-defined and well-dated shell mounds and gyttja layers, representing the settlement's kitchen midden and dump deposits. Many of the finds can consequently also be assigned to specific phases or 'cultural environments' within this particular period.

The earliest traces of human activity at the site were found in a shell deposit (Figure 9, section 2013), which contained a very small, but culturally well-delimited, finds assemblage, including a good number of arrowheads that are all of the oblique transverse type. This shell mound has been radiocarbon dated to the very earliest part of the Ertebølle culture 5474–5340 cal BC (AAR-16959) and 5468–5320 (AAR-16958).

The majority of the finds derive from the exposed gyttja layer (K1) which, despite a degree of homogeneity and a generally modest thickness, has been radiocarbon dated to an extended period of several hundred years (from 5214–4947 cal BC (AAR-24753) to 4593–4458 cal BC (AAR-23271)). It could therefore have been formed during horizontal displacement. Characteristic finds from K1 include several antler axes, all of the type with the shaft hole by the burr, which is normally diagnostic for the early part of the Ertebølle culture (Andersen 2001, p. 168). However, the gyttja was also found to contain large sherds of Ertebølle pottery, normally dated to the later part of the period, after *c.* 4600 BC (Andersen 2013). Overall, the gyttja layer must, in archaeological terms, be seen as representing both the Early and the beginning of the Late Ertebølle culture.

4.2. Shell mounds – natural or man-made?

As mentioned above, the remains of several shell heaps were found during the investigations. Denmark has a long tradition of investigating shell mounds and kitchen middens which extends back to the mid-nineteenth century (Madsen *et al.* 1900, Andersen and Johansen 1986, Andersen 1995). Most middens have been encountered in northern parts of the country, where they all lie above present sea level. It therefore aroused considerable interest when oyster shells were found in several of the core samples at Hjarnø in 2012 (Figure 9). These could represent the first submerged kitchen midden ever found in Denmark. A small investigation was launched in the following year (2013) to establish whether the layer had been formed naturally or could possibly represent an inundated, perhaps redeposited, kitchen midden. A small trench of 2 m^2 was excavated, and in this it could be seen that the shell layer was 10–12 cm thick and consisted predominantly of oyster shells. It also contained large quantities of charcoal, flint, fishbones and other bones, including whales and roe deer (Figure 7). More than *c*. 4600 fishbones were recorded during the excavation, as well as 600 fragments of mammal bones and *c*. 2500 pieces of worked flint. Given the quantity of cultural remains, and the fact that the shells did not lie in pairs, it was concluded that the shell layer had not formed naturally. It was less certain whether the layer had been formed as a kitchen midden on the contemporaneous shore or whether the shells and the cultural remains were embedded in a submarine dump deposit. A sample from the top of the shell layer has been radiocarbon dated to 5469–5319 cal BC (AAR-16958), while a sample from the base (x119) gave a date of 5474–5341 cal BC (AAR-16959). The shell layer can therefore be said to be coeval with the earliest shell layers in southern Scandinavia, for example, that at Brovst in northern Jutland (Andersen 1969). The feature lies relatively well protected and has therefore been given a lower archaeological priority in favour of more exposed areas that are suffering rapid degradation.

A new area containing shells was discovered in 2015, but here they were freely exposed on the seabed and, like the gyttja layer, were subject to heavy erosion (Figure 9). An investigation was therefore launched to clarify whether this shell deposit could also represent a kitchen midden. A 9 × 2 m N-S trench was excavated on the seabed where the shells lay exposed. The excavation revealed that a compact shell layer, comprised

Figure 7. Whale bone under excavation in the shell layer. Photo: J. Frederiksen.

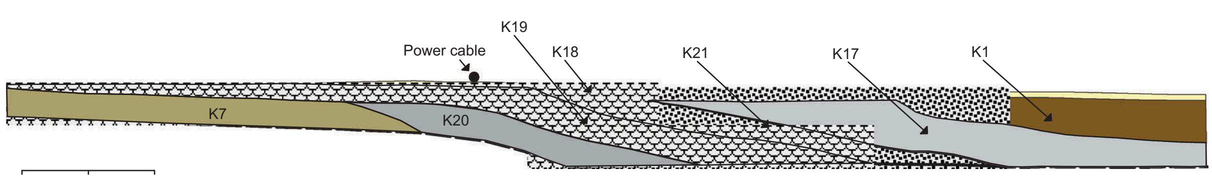


Figure 8. Section through shell heap 2 excavated in 2015. K1: brown gyttja, K7: subsoil, K17: grey sand, K18: modern sand layer, K19: compact layer of oyster shells, K20: grey gyttja, K21: cockle shells (*Cerastoderma edule*). Digitalisation: P.M. Astrup.

Figure 9. Reconstruction of the local environment, gyttja deposits (dark brown), coastline (light brown), shell midden (grey), core with shells (green stars) core with gyttja (red stars) and excavated squares (white). The dates mark the area excavated in that particular year. Photo: Geodatastyrelsen, orto_foraar, WMS-tjeneste. Drawing: Ea Rasmussen.

mostly of oysters but with a minor content of cockles, lay partly over the subsoil (sand and glacial sediments) K7 and partly over gyttja layer K20 (Figure 8). The presence of terrestrial snails among the marine shells indicates that at least parts of the shell heap developed on dry land and should therefore be seen as a result of human activity, i.e. a shell midden. The shell deposit had undoubtedly been larger – both horizontally and vertically – extending up towards the former shore, until it was exposed to erosion by the sea.

The compact layer of oyster shells (K19) was directly overlain by another shell layer consisting primarily of cockle shells (K21). Even though the two shell layers appeared clearly discrete and separate, they both contained large quantities of charcoal, flint and fishbones resulting from human activities. In the cockle layer (K21), a large proportion of the shells also showed signs of having been exposed to heat, and there were charcoal remains on their inner surfaces. This not only indicates that the shells were deposited after having been on a fire, but also that this took place without subsequent redeposition by the sea. The cockle layer (K21) probably originally extended over a larger part of the oyster layer (K19), before it subsequently became inundated and covered by sand (K17) due to a rise in sea level. The sand layer similarly contained large quantities of cultural remains in the form of bones and flint.

Final clarification of the origins of the shell deposits came in 2016, when a 4 × 1 m trench was dug at right angles to the trench cut in 2015. In the resulting section, remains were observed of an *in-situ* hearth with fire-brittled stones and charcoal fragments. Several lines of evidence therefore suggest that the two shell layers, K19 and K21, represent a kitchen midden formed above the contemporaneous shoreline.

The shell deposits that were investigated possibly constitute only a minor part of a much larger shell midden, the existence of which was demonstrated in a series of cores taken along the contemporaneous coast to the north. The shell layers here had a thickness of up to 40 cm. However, the degree to which they represent a single large shell midden, with a length of at least 80 m, or several smaller discrete shell deposits, remains to be clarified.

Samples were taken for radiocarbon dating from all the layers in section 2015, and the resulting dates are rather surprising as they show that the sequence of deposits was formed over less than 50–100 years. With reservations for the uncertainty inherent in radiocarbon dates, the ages of the lowest (oldest) and the uppermost samples in trench 2015 are almost identical: Like the intervening stratigraphy, they are dated to the time around 5100 BC. The fact that the gyttja overlies the shell midden indicates that there was a marked rise in sea level around 5100 BC. It is unclear why an almost homogeneous layer of cockle shells was deposited on top of an almost equally homogeneous layer of oyster shells. It could reflect changes in the local marine environment towards poorer conditions for oysters but could also simply be due to a change in human behaviour (Larsen et al. 2018).

4.3. Reconstruction of the local environment in Ertebølle times

Hjarnø is surrounded by channels with a minimum depth of 4–5 m, and it was probably cut off from the mainland, i.e. became an island, as early as some time in the Atlantic period. The investigations have shown that Hjarnø achieved its current approximate size and extent at the beginning of the Ertebølle culture. The largest channel follows the former course of a late glacial river, which now constitutes the major part of the *c.* 700 m wide and up to more than 20 m deep Hjarnø Sund, running between Hjarnø and the mainland at Snaptun. Like the archaeological investigations, the geological investigations were undertaken at depths of less than 1 m below current sea level – limited by the length of the coring equipment. Consequently, this depth also marks the lower chronological boundary for the investigations of the contemporaneous sea level. The results of the various investigations have enabled a picture to be drawn of some contemporaneous cultural and coastal environments, whereby the relationship between well-dated cultural layers and coeval coastal formations has formed the basis for an evaluation of the contemporaneous sea level. Whereas the marine deposits are, in this respect, able to give a minimum value for the contemporaneous sea level, some of the terrestrial cultural layers define a maximum level. It has also been possible in several cases to undertake an evaluation based on several different deposits and events. The investigations have, furthermore, shown how the rise in sea level in the later part of the Atlantic period created variable and, at times, complicated sedimentary conditions at one of the coastal settlements of this time.

During the Atlantic transgression phases, the coast was subjected to major marine influences and, as a consequence, apparently changed character over a very short time span. This is reflected in core samples taken from the seabed offshore from the contemporaneous coastline. These contained alternating and, at times, sharply delineated layers of marine sediments, which varied from thick uniform deposits to horizons of only a few centimetres (Figure 6). Some striking boundaries are evident between layers of coarse sand and fine clay gyttja: two sediment types that normally reflect widely differing sedimentary conditions.

Fine gyttja is deposited in calm waters, which explains why this kind of sediment is not found on the exposed present-day coasts, where wave action deposits sand and forms beach ridges instead.

The gyttja deposits therefore reveal a coastal morphology which, at the time of their formation, was very different to that of today. Only the uppermost and partially exposed gyttja layer K1 has been securely dated at present, but other thick gyttja deposits below this suggest that the area was characterised by calm depositional conditions, not only during most of the Early Ertebølle culture but also in earlier periods.

The gyttja layers are not homogeneous but vary in both consistency and colour. Greyish, virtually sterile layers, with no conspicuous content of organic material, are, accordingly, found embedded between dark-brown layers of detritus gyttja with a major content of worked and unworked wood. These variations reflect changes in the contemporaneous sedimentary conditions and in the vegetation and cultural environment of the immediate surroundings.

The archaeological remains encountered at Hjarnø cover a period of just less than 1000 years (*c.* 5400–4600 BC), corresponding to the Early and Middle Ertebølle culture. At the beginning of this period, the area around the central gyttja deposit K1 was occupied by a small bay which extended more than 60 m inland from the contemporaneous coastline to a position close to the present-day shore. A small, *c.* 20 m wide point formed the southern boundary of the bay, which had a *c.* 40 m opening out towards the sea.

There was a steep-sided basin here in which gyttja could accumulate in deep water. Already at the beginning of the Ertebølle culture, the bay appears to have been completely levelled and, at this time, a minor shell midden (shell midden 1) was formed on the small point to the south (Figure 9). The finds from here show that the shell deposit was formed as a kitchen midden close to the contemporaneous shoreline and, consequently, some of the shells became embedded in dark-green gyttja. The shell deposit has been dated to 5470–5330 BC cal BC (AAR-16958) and 5474–5340 cal BC (AAR-16959), and its position indicates a contemporaneous sea level about 1 m below that of the present. An almost completely identical situation is evident at Brakør, on the north side of the fjord, where a tree stump was inundated at 0.9 m below mean sea level this has been radiocarbon dated to 5315–5040 cal BC (AAR-12641).

Shell midden 1 represents not only one of the earliest known kitchen middens in Denmark, but also the earliest evidence so far of the presence of oysters in Horsens Fjord. Some oyster shells from the lower layers of an up to 9 m thick shell deposit in the narrow Stensballe Sund, innermost in the fjord, have previously been radiocarbon dated to *c.* 5557–5003 cal BC (K-1222; Tauber 1968). Given the special conditions required in the local marine environment for oysters to thrive (Aaris-Sørensen 1988), the shell deposit at Hjarnø shows that there was already both a relatively strong water flow and high salinity here prior to the Ertebølle culture.

Like the kitchen midden, most of the actual point itself was subsequently inundated by a transgression which also removed the final remnants of the small bay. This could be the same rise in sea level that deposited the greyish gyttja layer K20 on the north side of the former bay and which is dated to 5215–5011 BC (AAR-24752). Around this time, a new kitchen midden was formed here (shell midden 2), comprised of two different shell layers, K19 and K21 (see later). It lay on the contemporaneous shore around 0.6–0.8 m below current mean sea level, and over older marine deposits (K20) in the apparently earlier seabed beyond this. There were no indications of redeposition of the shells, suggesting that the sea had receded somewhat by this time.

In the excavated longitudinal section in midden 2 (Figure 8), the shell layers were overlain first by the thick sand layer K17, then by the dark-brown gyttja layer K1, which here constitutes the northern edge of this gyttja deposit. These two sediments were laid down under widely differing conditions, but during the same transgression, when the sea reached a level that then appears to have remained relatively constant in subsequent centuries. The height of this sea level is uncertain, but it probably did not exceed 0.5 m below current mean sea level. Virtually identical dates for the earliest gyttja layer K20, the latest layer K1 and the intervening shell layers K19 and K21 to *c.* 5200–5000 BC reflect repeated and significant changes in the local coastal environment within this relatively short period of time. Collectively, the heterogeneous sequence of sediments probably represents various phases of the same transgression, i.e. the High Atlantic transgression, which characterised the shores of the fjord in Early Ertebølle times at the beginning of the 6th millennium BC. When sand layer K17 was deposited, this took place on an open coast, where the former bay was also exposed to marine wave action. During the phases of the Atlantic transgression, the advancing sea caused heavy coastal erosion, and some of the sand removed from the coastal slopes was redeposited close by as extended reefs and spits along the coast. Small sand spits could, with time, develop into large curved spits or enclosed lagoons, within which fine sand and clay particles could be deposited in a calm environment, shielded from marine waves. With continued sedimentation, the further development of the lagoon could lead to the formation of a new shore meadow, that is if a new transgression had not already flooded and eroded away the protective sand spits. These fossil sand formations can rarely be demonstrated directly, but sand layer K17 shows that the conditions necessary for the spit formation existed here at this time.

The process that led to the formation of sand spits can also be observed today along the shallow coasts of the fjord, where new sand formations continue to display the various phases in the development of new lagoons (Borup 2015). Some fine examples of these large developed lagoons are found on both the southern and northern coasts of Hjarnø, where only a narrow opening now hinders complete exclusion of the sea. A small lagoon has been formed in a similar fashion in recent years by some exposed sand spits on the northwest coast of the island (Figure 10).

It was presumably the development of a protective curved spit that enabled the accumulation of brown detritus gyttja layer K1 at Hjarnø, and the extent of this layer suggests that the size of the lagoon was at times considerable. But the protective sand barriers were not permanent features, and the core samples revealed thick sand layers embedded in the gyttja, showing that it had been inundated on several occasions and perhaps also partially eroded by the sea. Several thinner sand layers are presumably the result of brief transgressions caused by local weather phenomena.

During both Late Atlantic and Subboreal times, further rises in sea level led to not only the lagoon but also the activity areas on the nearby shore being inundated and exposed to incipient erosion. The reason we do not find preserved cultural layers from the Late Ertebølle culture at the site today could therefore be because the original cultural layers from this period have been removed by erosion in

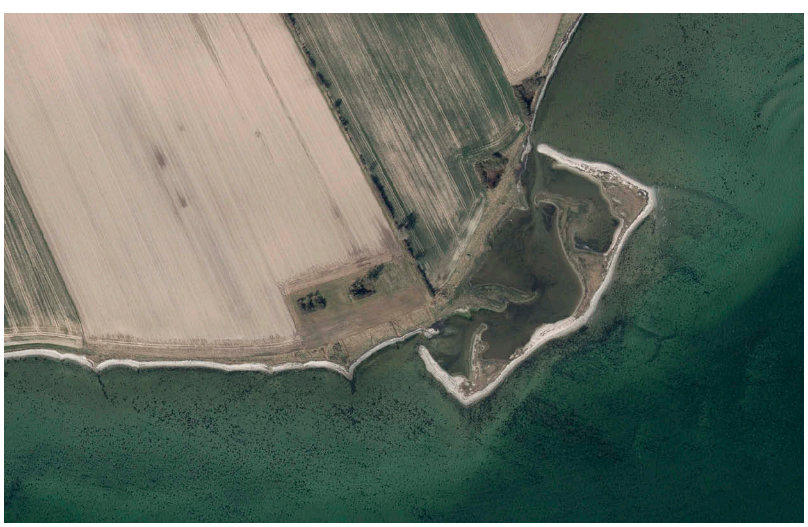


Figure 10. An example of a developed lagoon as formed in many places in Horsens Fjord today. This lagoon is on the south coast of Alrø. Photo: Geodatastyrelsen, orto_foraar, WMS-tjeneste.

more recent times. Numerous artefacts dating from this period have been collected in the area previously.

4.4. Subsistence economy

4.4.1. Hunting

The subsistence economy of the Ertebølle culture was characterised by hunting, fishing and gathering and, as testified by various categories of finds recovered from the site, the Hjarnø Sund settlement was no different in this respect.

The faunal remains constitute an important component of the finds assemblage. From these it is evident that large game animals were commonly hunted for their meat. Analyses of the bones show that red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), elk (*Alces alces*), aurochs (*Bos primigenius*) and wild boar (*Sus scrofa*) were all killed. In addition, both cast and sawn-off antlers of red deer and a single sawn-off antler of roe deer have been found. Large terrestrial game was probably not hunted on Hjarnø itself, as the island's area was too small to support a population of these animals. We must therefore imagine that the hunters travelled the short distance to the mainland by boat to hunt in the extensive forests there. Water transport on the fjord has been demonstrated at Hjarnø by the finding of a fragmented dug-out boat in the seabed just offshore from the settlement. The dimensions of this boat are unknown, as it remains '*in situ*' just below the surface of the seabed, covered by sand. An analysis of the wood shows – very characteristically for Late Mesolithic dug-out boats – that it is made of lime wood (Andersen 2011). Propulsion was by paddle, of which four more or less preserved examples have been found at Hjarnø (see Section 'Wooden Artefacts').

Hunting of large game animals was undertaken primarily with bows and arrows, and fragments of a total of seven bows have been found, all in the settlement's dump deposit. None is complete, but five are so well preserved that it is possible to calculate their approximate original length, which varies from 123 to 166 cm. This variation could be due to the bows being intended for different kinds of hunting, but it is also possible that the smaller examples were used by children. S.H. Andersen reports that the characteristic bows from Funen were between 150 and 160 cm in length (1985, p. 64, 2009, p. 102), though one found at Tybrind Vig had a length of 167 cm (2013, p. 142).

Two main bow types can be identified at Hjarnø: (1) examples with flattened oval limbs, (2) flatbows which taper from the grip towards the ends. The first type has a possible parallel in the form of a bow fragment found at the settlement at Møllegabet (Skaarup and Grøn 2004, p. 89). This type is represented at Hjarnø by two relatively well-preserved examples (Figure 11). The longest of the bows measured 135 cm on recovery but had originally had a length of *c.* 166 cm. The grip measures *c.* 12 cm, and the bow has *c.* 5.5 cm wide flattened oval limbs, which terminate in 26 cm long tips. There is no trace of an attachment or nock for the bowstring.

Figure 11. Examples of well-preserved bows with flattened oval limbs. Photos: D. Butler and J.G. Due, Photo/media Moesgaard museum.

The bow has been radiocarbon dated to *c.* 5209–4998 cal BC (AAR-16090). The second bow of this type had an original length of *c.* 140 cm, of which only a few centimetres were missing when it was recovered. The other five bows are of the more common flatbow type, with limbs tapering evenly towards each end. Common to both bow types is that they are made of elm wood (*Ulmus*).

No definite examples of wooden arrow shafts have been found at Hjarnø, but a total of 30 transverse arrowheads were recovered. A possibly unique find from the Danish Mesolithic is a harpoon-like implement made of wood of Pomoideae (apple, hawthorn, Rowan etc. subfamily) (Figure 12). The implement has a preserved length of 27 cm, but the tip has been broken off and its original length is estimated to have been *c.* 30 cm. About 7 cm from the tip there is a 2.5 cm long barb, and in the middle a small groove has been carved – possibly so a stone weight could be lashed in place. The side from which the barb projects is a few centimetres wide and carved flat. It is unlikely that the implement functioned as a harpoon as these are normally made of antler or bone, because a wooden version would break more easily when impacting large animals. The implement could possibly be a so-called 'atlatl' or spear-thrower, as known both from ethnographic parallels, including the Greenland Inuit, where it is known as 'norsaq' (Jensen 1975, Petersen 1997), from Palaeo-Eskimo contexts (Gotfredsen and Møbjerg 2004) and from Palaeolithic contexts in Europe (Stodiek 1993). S.H. Andersen, in his publication of the Ronæs Skov settlement (2009), has suggested that spear-like objects found there could have been launched with 'atlatls' of this kind.

Figure 12. Possible spear-thrower ('atlatl'). Photo: R.N. Johansen, Photo/media Moesgaard museum.

In addition to hunting large terrestrial game animals, seal bones (*phocidea*) in the faunal assemblage show that marine mammals were also hunted. Seal bones are very common archaeological finds in Horsens Fjord, where seal hunting appears to have played a particularly important role at coastal settlements. A whale rib bone (Figure 13) and the tooth of a killer whale could similarly result from marine hunting. These large whales are, however, more likely to have stranded in the shallow fjord, after which they would have been butchered so their bones could be used for tools and their blubber for small oil lamps. Hunting of marine mammals was presumably undertaken with some of the same hunting weapons used for large terrestrial mammals, including 'atlatls': The latter are known to have been employed in this way by the Greenland Inuit (Petersen 1997). We know from many other settlements that harpoons were used to hunt marine mammals, but only one harpoon was found during the present investigations. Another example has though been found in the area previously (Andersen 1997), and harpoons have also been recorded at other settlements on the fjord. Pieces of antler with burin furrows are interpreted as characteristic waste products from harpoon manufacture (Andersen 2009), and antler artefacts of this kind have been found during the investigations at Hjarnø.

Hunting of fur animals is indicated by bones of animals such as otter (*Lutra lutra*), water rat (*Arvicola terrestris*), fox (*Vulpes vulpes*) and wild

Figure 13. Whale bone found during reconnaissance on the settlement area. Photo: C. Skriver.

cat (*Felis sylvestris*). These four species were also found at the settlements of Ronæs Skov (Andersen 2009) and Tybrind Vig (Andersen 2013). Birds are represented at Hjarnø by a few bones of large waterfowl, such as mute swan (*Cygnus olor*), cormorant (*Phalacrocorax carbo*) and red-necked grebe (*Podiceps grisegena*).

4.4.2. Fishing

Fish made up a very large part of the diet, and it was presumably fishing that had the crucial role in determining the settlement's almost permanent location close to the channel. The archaeozoological analyses reveal that a wide variety of species were fished for, including cod family (*Gadidae*), flatfish (*Pleuronectidae)* and mackerel (*Scomber scombrus*) as well as eel (*Anguilla anguilla*), herring (*Clupea harengus*), bull-rout (*Myoxocephalus scorpius*), spiny dogfish (*Squalus acanthias*) and garfish (*Belone belone*). Viviparous eelpout (*Zoarces viviparus*) and salmon family (Salmonidae) also feature in the assemblage, but only to a limited extent. No remains have been found of freshwater fish, and all the species represented appear to have been caught close to the actual settlement.

The archaeological finds show that two kinds of fishing were practised:

(1) Active fishing with hook/line and leister

(2) Passive fishing with fish weir and fish trap

The active fishing is documented by finds of fragments of leisters and a single fish hook. Fragments were found of a total of nine leister prongs (Figure 14). These occur as two variants: one consists of a single complete piece of wood, while the other type was made by cleaving a piece of wood to produce two exact mirror images for the two wooden leister prongs.

A fish hook of bone was found during reconnaissance near the settlement area (Figure 15).

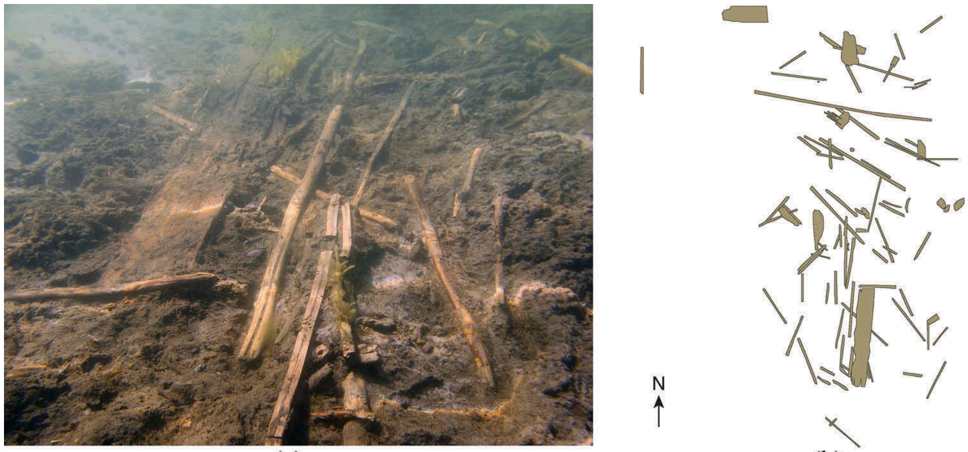
Passive fishing is documented by the widespread occurrence in the gyttja layer of hazel rods and stakes with sharpened ends, the latter in some cases still standing in a vertical position. Similar rods and stakes have been found at sites such as Tybrind Vig (Andersen 2013, p. 59–62) and Ronæs Skov (Andersen 2009, p. 42–44). It is usually assumed that sharpened rods and stakes of this kind, which occur very frequently in the dump deposits associated with the settlements, constitute remains of fish weirs, which had the function of directing fish into a fish trap (Andersen 2013). A damaged panel presumed to be from a fish weir was encountered in 2014, during the establishment of the coordinate system (grid) for the site. The panel's orientation was approximately N-S, and a section of measuring 6 × 2.8 m was visible.

(a) (b)

Figure 14. (a-b). Examples of leister prongs. Photos: R.N. Johansen, Photo/media Moesgaard museum.

Figure 15. Bone fish hook found during reconnaissance. Photo: R.N. Johansen, Photo/media Moesgaard museum.

The fish weir was made of hazel rods of various sizes, with and without bark, as well as some sheets of bark which lay approximately across the longitudinal orientation of the rods (Figure 16). Even though this structure was not intact, it was evident that several of the long stakes that had originally stood vertically in the weir now lay on the seabed, parallel to the rods which originally were at right angles to them, i.e. they ran horizontally in the panel. In addition, several vertical stakes were recorded around the structure. It is still unclear, however, whether the latter were part of the fish weir or whether the current had carried the preserved part of the fish weir away from its original position more or less intact. The individual stakes had lengths of up to 2.7 m, and the average diameter of the vertical stakes was 2.65 cm (11.5 years/tree rings), while the average for the horizontal examples was 1.96 cm (7.8 years/tree rings). Of the 15 rods that have been identified to species, 12 are of hazel, while the other 3 are of elm, willow and oak, respectively. Based on the cessation of tree-ring formation, it seems the hazel rods



(a) (b)

Figure 16. (a) Underwater photograph of part of a fish weir under excavation. Photo: P.M. Astrup. (b) Plan of the structure. Drawing: P.M. Astrup.

were cut in the middle or at the end of the growing season.

4.4.3 Gathering

Gathering of food is reflected by the presence of hazelnut shell fragments, as well as the previously mentioned shell layers containing oysters and cockles with an admixture of other marine molluscs, which show that this food source also constituted an excellent supplement to meat and fish. From other sites with preserved organic materials, we know that sea beet (*Beta vulgaris* ssp. *maritima*) and acorns (*Quercus* sp.) were also gathered during this period (Andersen 2013).

4.5 Archaeological finds

4.5.1 Artefacts of antler, bone and tooth/tusk

Ten antler axes have been found at the site. In all cases, the shaft hole is located at one end of the axe, near the burr, which dates the axes typologically to the early part of the Ertebølle culture (Andersen 2001). Several of them have a length of 25–30 cm, and they are therefore relatively large compared to the modest diameter of their shafts. Four of the axes were found with an intact wooden (hazel) shaft. A conically shaped shaft hole prevented the axe's head from falling off during use. The shafts are just less than 50 cm in length (Figure 17).

Just like several of the paddles, four (i.e. almost half) of the antler axes are ornamented (Figure 18). Two of them have some quite small areas on their sides with a few fine incised criss-cross lines. On the third, fine lines form a larger and more regular pattern resembling a chequered motif. On the fourth axe, traces are evident of a more finely composed pattern incised with broader and deeper lines. Unfortunately, this is only preserved as a large fragment. Two of the axes also have parallel lines running around the shaft hole and the place where a tine has been sawn off. None of the ornamented objects has been radiocarbon dated, but their finds contexts indicate that they all date from an early part of the Ertebølle culture, corresponding to the picture previously presented for ornamented artefacts (Andersen 1981).

In terms of artefact type, given the widely varying nature and extent of their motifs, the ornamented artefacts constitute a very heterogeneous group. In some cases, these objects appear to have had a special symbolic or prestigious value, being the preserve of the few, while others seem more ordinary and could represent everyday objects. Frequent examples of edge damage suggest that the ornamented antler axes were also used as working tools. More exquisitely composed, almost surface-covering patterns are, for example, evident on some special, long antler shafts that were presumably only owned by a select few members of society. Three ornamented shafts of this type have

Figure 17. Antler axe head with wooden shaft, lying on the gyttja layer. Photo: P.M. Astrup.

Figure 18. Example of ornamented antler axe. Photo: M. Johansen, Photo/media Moesgaard museum.

been found previously in Horsens Fjord: one on the beach at Hjarnø, the second at Snaptun on the opposite side of the sound and the third at a locality innermost in the fjord (Andersen 1981).

In general, there appears to have been a special predilection at the settlements in Horsens Fjord during this period for decorating or ornamenting personal artefacts. Numerous ornamented objects of this kind have been found, primarily of bone and antler (Andersen 1981), but there are also some of amber, a single piece of limestone (Borup 2008) and now also some of wood.

4.5.2 Wooden artefacts

A total of 75 wooden artefacts have been recovered, in addition to the artefacts already mentioned above in the section on hunting and gathering (4.4.1 and 4.4.3). They include axe handles and other types of shafts, as well as various rods and stakes, etc. Special mention should be made of ‘axe sockets’, of which a total of six have been found. Some of these are very finely shaped, while others appear simpler and without ‘finish’. The species of wood used has been identified in five cases: Four are of Pomoideae (apple, hawthorn, rowan, etc. subfamily), while one is of oak. This artefact type has also been found at Ronæs Skov and Flynderhage (Andersen 2009, 2013), as well as at Margrethes Næs (Myrhøj and Willemoes 1997); a single example was recorded in each case. The socket from Ronæs Skov is, like the majority of those from Hjarnø, made of wood of Pomoideae (Andersen 2009), while the socket from Margrethes Næs is of hazel (Myrhøj and Willemoes 1997). These sockets have previously been described as being hafts or mounts for a flint axe on a shaft, where the shaft comprised the lower part and the socket the upper part of the composite hafting (Myrhøj and Willemoes 1997, Andersen 2009). A rare find of a hafted core axe shows, however, that there may also be two socket pieces forming the actual haft, which was then mounted on a shaft (Figure 19). This suggests, in turn, that there were two types of hafting devices or sockets, one of which has a knob at one end, while the other is more pointed oval or rounded. The knobbed examples are possibly associated with the latter type of hafting, as seen in the axes from Hjarnø.

Four fragments of paddles were found during the investigations, and paddles have also been found previously at Tybrind Vig (Andersen 2013). Even though the number of paddles found at Ertebølle sites remains modest relative to other artefact types, they are now seen as one of the characteristic implements at the coastal settlements. They are typically made of ash wood and this is also the case for the examples found at Hjarnø. Of the four fragments recovered there, two stand out, because, despite some degradation of the wood, traces of preserved paint are evident on the actual blades. The applied motifs on the two paddles are not quite identical, but in general terms they represent the same composition. Both have a surface-covering black substance (pigment) on the lower half of the blade, and above this are three parallel, horizontal lines. On one paddle, these lines are 6 mm wide and curve upwards in the middle from both sides, while the other blade appears to have three separate distinct groups of *c.* 1.3 cm wide bands (Figure 20). The painted pattern has only been demonstrated on one side of the paddle blades, but this could be because the other side is, in both instances, less well preserved. It is consequently unclear whether the paddles were originally painted on both sides. Interestingly, a paddle found next to a kitchen midden some years ago at Flynderhage in Norsminde Fjord, just less than 25 km north of Horsens Fjord, has decoration which is very similar to that evident on one of the paddles from Horsens Fjord (Andersen 2013, p. 182, fig. 3.83). On the Flynderhage example, black paint has been

Figure 19. Hafting device consisting of two socket components between which a core axe was placed. Photo: R.N. Johansen, Photo/media Moesgaard museum.

(a) (b)

Figure 20. (a-b). Painted paddle blades. Photo: M. Dalegaard, Photo/media Moesgaard museum.

used to draw four narrow lines, arched in the middle, over a similarly fully blackened lower half. The two motifs therefore show a close resemblance. Only the number of lines appears to vary in the motifs on the two paddles. This could indicate a certain degree of symbolic symbiosis and consequently a relationship between the populations of the two areas.

Ornamented paddles have also been found at a very few other Danish Ertebølle settlements. The best known of these are the ornamented paddle blades from Tybrind Vig in western Funen, mentioned above, where 4 of the 13 paddle components recovered were decorated in various ways (Andersen 2013 p. 175–184). The motifs comprise exquisite patterns formed of dots and lines executed in sunken relief; the presence of black pigment has also been demonstrated here. Clear differences are though evident between the paddles from Horsens Fjord and those from Tybrind Vig, both with respect to their motifs and the technique employed.

4.5.3 Flint artefacts

An actual analysis of the flint assemblage recovered from Hjarnø has not yet been undertaken. As for the total numbers of flint artefacts, it must be noted that only actual tools were picked up from the seabed and recorded, while this was not the case for the many waste flakes, because this would have rendered the flint assemblage almost unmanageably large. Conversely, all the flakes encountered during the excavations on the seabed were retained, including those from all the excavated squares.

The flint assemblage comprises both patinated flint from the seabed and unpatinated flint recovered during the excavations. Microscopic examination of a handful of the tools shows that the unpatinated flint is well suited to wear-trace analysis.

A total of 4435 pieces of flint were recovered during the investigations, of which 4213 are flakes. The remainder comprises axes, unmodified blades and blade tools such as scrapers, knives, truncated pieces, etc. A total of 33 flake and core axes were found. The flake axes are in the majority with 20 examples, or rather more than 60% of the total number. Thirty-one transverse arrowheads were recovered. These vary typologically from oblique examples of varying size to transverse examples with a flared edge; there are also a few with a narrow edge and parallel sides. During the investigation of the earliest shell mound (K10) in 2013, 11 oblique transverse arrowheads were recovered from a trench of only 2 m^2 in area. This presumably represents a specialised functional area.

4.5.4 Artefacts of other stone types

4.5.4.1 Greenstone axes. Three greenstone (diabase) axes were recovered. Two were located in the dump layer, while the third was found washed up on the beach (Figure 21). One of the axes is virtually round in cross-section with a maximum diameter of 4 cm, while another is more oval and has a maximum diameter of 4.5 cm. Two of the

Figure 21. Greenstone axe found on the shore at low tide. Photo: P.M. Astrup.

axes are broken in the edge region but have had a ground/polished facet on one side, running towards the edge.

4.5.4.2 Flat stones. Three special stones were found which differ in several ways from all the natural stones evident on the seabed. They are completely flat and have one or both sides smoothly polished. One is fragmented and probably only represents a quarter of its original size. It consists of a 1.5 cm thick slab of sandstone, the edge of which has also clearly been rounded or polished. The other is an intact, approximately oval stone slab measuring 14 × 11 cm. The stone itself is almost black with a shiny black residue over a large part of one side. It also has a ground rounded edge. The third stone has one flat side too, a small part of which appears to be covered with black 'paint' or 'pigment'. The function of these three stone objects remains unknown, but one cautious interpretation could be that they were used as 'palette stones' employed in the painting of special objects, for example, the paddle blades found at Hjarnø.

5. The future

An important reason for the Hjarnø settlement being subjected to heavy erosion today is that the eelgrass which previously covered large areas of the seabed has disappeared from the site. Eelgrass normally forms a carpet of roots which protects the underlying sediments. With the disappearance of eelgrass from the area, the site's cultural deposits are no longer protected from wave erosion and the destructive activities of marine organisms such as crabs, piddocks (*Barnea candida*) and shipworms (*Terodo navalis*), which bore deep into the wood to reach the cellulose. As early as 1936, a school teacher from Hjarnø reported that: In recent years, as the seaweed disappeared from the waters, the sea has washed a quantity of stone tools up, and more than 20 a day can be found. This suggests that there has been habitation out where there now is sand. The seaweed referred to here is eelgrass which, due to a global epidemic – or 'wasting disease' (Rasmussen 1977) – had disappeared from major parts of inner Danish waters a few years previously. The submarine cultural layers at Hjarnø appear therefore to have been subject to erosion, presumably to a varying extent, for more than 80 years.

In 2016 the Hjarnø project received funding from the Danish Agency for Culture and Palaces to facilitate protective covering of the locality. An application was approved by the Danish Coastal Authority that permitted covering of the area in 2017, after which the site's scientific potential will hopefully be secured for posterity. Protection will be achieved by adding a protective layer of sand. Seeds of eelgrass will then be sown in this sand, and eelgrass plants will also be planted. The expectation is that eelgrass will again form a mat of roots which will be able to protect the underlying deposits against erosion.

6. Conclusion

The investigations in Hjarnø Sund have yielded several new and exciting results. For example, the numerous artefacts of organic materials include completely new types, as well new variants of already known tools and implements, thereby shedding important light on their use and function. The 75 wooden artefacts recovered from the site also demonstrate the great archaeological potential of submerged early prehistoric settlements, as well as the importance of undertaking investigations and of preserving these localities. Ornamented artefacts constitute a special and important element of the archaeological finds assemblage from Hjarnø. The ornamentation on the paddle blades, in particular, is interesting, seen in relation to that on the paddle blades from other Ertebølle sites. It is possible that these can form the foundation for future studies of the territories of the Ertebølle culture (Skriver *et al.* 2017).

The discovery of several submerged shell mounds is also intriguing, not least because these include the first recorded example of a submerged kitchen midden in Denmark. Moreover, the intact cultural deposits are much better able to fix and date the levels of the coeval coastlines than corresponding marine dump deposits. The oldest shell mound also represents one of the earliest known kitchen middens yet found in Denmark.

The broad nature of the settlement's subsistence economy is evident from the bones found in both the shell mounds and the dump deposits. Given the presence of a range of seasonal indicators which collectively cover the entire year (catching of mackerel and garfish, gathering of shed antlers, hunting fur animals, presence of hazelnuts, etc.), the site was probably occupied all year round. Its position was likely determined primarily by fishing, such that this could be undertaken using both active and passive techniques.

In addition to the purely archaeological observations, the investigations have made it possible to draw up a picture of the relationship between well-dated cultural deposits and the contemporaneous coastal topography. They have also enabled an assessment of the contemporaneous sea level and provided an insight into the local sedimentary conditions associated with the various phases of the Atlantic transgression.

Notes

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ARTICLE

A short comment on the early development of Odense

Olav Elias Gundersen and Johan Sandvang Larsen

Centre for Urban Network Evolutions (UrbNet), Aarhus University, Højbjerg, Denmark

ABSTRACT
In a recent overview of the material from eighth to twelfth century Odense, Runge and Henriksen propose to move the date of the town's foundation by a hundred years, to the early tenth century. In this brief comment we challenge their interpretation of the earliest Odense, and point to some problems with their definition of what constitutes towns and proto-towns, as well as the analysis of the material they present.

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Mads Runge and Mogens Bo Henriksen's article 'The origins of Odense – new aspects of early urbanisation in southern Scandinavia' in the latest issue of the Danish Journal of Archaeology contains an analysis of the material from the earliest phases of Odense, along with an eminently useful overview of the material in the form of an extensive appendix. There are, however, several propositions in the article that warrants further discussion.

Terms such as urban, urbanity, urban factors, emporia, early towns, towns and 'proto-towns' appear frequently in the article, though only town and proto-town are attempted defined. The definition of proto-town proposed by Runge and Henriksen is, except for some very slight alterations, quite conventional for medieval towns. In their paper, the following criteria are considered to be important: towns should have a certain population density, a permanent settlement of a certain size, and a majority of the population subsisting by trade and craft production (Runge and Henriksen 2018, p. 12, 17). This fits well with both medieval towns and the earlier emporia – though it is naturally an arbitrary definition where one can debate what a 'certain size' indicates, as well as what constitutes a sufficiently high population density. In this regard the last criterion is the least ambiguous of the three, as it is difficult to establish a threshold for when the other two describe a town rather than a village. The differences they seize upon between towns and proto-towns are the necessity of towns having two or more churches (following Andrén (1985), though this is less of a universal town marker than a way to quantitatively evaluate the hierarchy of settlements within the specific socio-economic context of the Middle Ages), a different fiscal structure, and the presence of minting (Runge and Henriksen 2018, p. 11, 17). As only a minority of the medieval Danish towns actually had a mint – and then often only for a limited period – it hardly seems to be a defining criterion, nor are different fiscal structures always easy to prove even in the Middle Ages.

After chastising researchers for focusing on the year 1000 as a turning point in the history of urbanisation, when Christianity seriously begins to 'define the king's position, both mentally and physically, in the urban space, and urban characteristics consequently become clearer and more -numerous', Runge and Henriksen claim that 'it is obvious that if the definition of a town is to be based on these factors, then no settlement predating AD 1000 – apart from emporia such as Ribe, Haithabu, Kaupang and Birka – will be able to meet these requirements' (Runge and Henriksen 2018, p. 21). There are two problems with this. First, if researchers were so

CONTACT Olav Elias Gundersen olav.elias.gundersen@cas.au.dk Centre for Urban Network Evolutions (UrbNet), Aarhus University, Højbjerg, Denmark

blinded by Christianity and all that brought with it – especially churches, which Runge and Henriksen describe as 'crucial' (Runge and Henriksen 2018, p. 12, 17) – it is difficult to understand how they have identified Ribe, Haithabu, Kaupang and Birka as towns (and some researchers have been careful to not label them towns, and rather use the term emporia to signify precisely that these differ from the later medieval towns). In their critique of the 'inflexible professional preconceptions and traditions' (Runge and Henriksen 2018, p. 20), they seem to have forgotten that neither Olaf Olsen nor Susan Reynolds – whose research they base their definitions on – seem to consider churches crucial in their definition of what a medieval town is, and the more recent and updated *Danmarks byer i middelalderen* (2016) considers it an indicator rather than criterion – and not something that is useful before the medieval period in Scandinavia (Poulsen and Kristensen 2016, p. 15). Second, Runge and Henriksen seem to forget that the function of these definitions is to do precisely what they accuse them of doing: helping researchers separate sites that do not match the proposed criteria from sites that do, in order to consistently analyse both the sites and the society in which they existed. Interestingly, herein lies the greatest potential for the study: to bring to our attention a new type of sites that can meaningfully be examined through the lens of urbanisation.

The question remains, however, whether the material supports the idea that Odense in the tenth century can be characterised as a proto-town according to Runge and Henriksen's definition. As noted earlier, the strength of the article lies in the comprehensive overview of the material; however, this also makes it easy to spot just how little there is. From phases 1 and 2 there are four pit-houses, a possible dwelling house, a pit, two to three longhouses, either a house or a fence, and possibly a house (Runge and Henriksen 2018, p. 12–14). Some structures are dated to the older phase (700–900), others to the younger (900–1000) and some are broadly placed between 700 and 1000. The data is – as they acknowledge – limited and it is fair to question what it really represents. Particularly interesting are the longhouses which are also commonly associated with contemporary rural settlements. Unfortunately, they do not discuss this in depth, simply mentioning that similar longhouses in agrarian settlements are classified as permanent structures (Runge and Henriksen 2018, p. 17). With regard to how the data is used and held up against their previously discussed definition of proto-towns there are several problems.

First, there is the question of population density. Either there is a misunderstanding of what the term means or the study attempts to use the size of the settlement as a stand-in for density without explaining the relevance. Runge and Henriksen estimate that the proto-town of Odense covered *c.* $500 \times 100\ m^2$ in phases 1 and 2, but there is no discussion of how they arrived at said estimate (Runge and Henriksen 2018, p. 17). In the appendix, they refer to a hypothesis of the placement of a Viking Age ditch, which they subsequently admit has never been shown archaeologically despite a small excavation in the relevant area (Runge and Henriksen 2018, p. 46). A better approach would perhaps have been to ignore population density, as there are simply too many issues when it comes to measuring this. Second, there is the issue of what constitutes a permanent settlement of a 'certain size'. In the paper, no indication is given of how many people would presumably live in Odense at around, say, the year 900. This is fair enough as population size is generally difficult to establish, though of course this means that it is not a criterion that can be examined in this context. Since both of these criteria are difficult to investigate based on the archaeological record, and as both size and population have been considered arbitrary terms when defining urbanity (Wirth 1938, p. 4), the argument hinges on whether the third and most important criterion – that the majority of the population subsist by trade and crafts – can be established. Unfortunately, it quickly becomes confusing, and at one point they instead pose the question of 'whether *any form of trade* took place in Odense in the centuries prior to AD 1000' (Runge and Henriksen 2018, p. 17, our italics). This – which does not satisfy the criterion of a majority of the population subsisting by trade and crafts outlined above – is left uncertain, though they argue that the pit-houses at Mageløs/Klaregade and Vestergade 70–74 are indications of some form of trade, finding that 'the finds assemblages from the pit-houses at Mageløs/Klaregade and Vestergade 70–74 is of an extent and a character that make it seem likely that these items were not exclusively intended for self-sufficiency', and goes on to state that ‘there are no other known indications that, in phases 1 and 2, the inhabitants subsisted primarily by craft production – and perhaps trade’ (Runge and Henriksen 2018, p. 17).

There is, in other words, no compelling argument to be made that this site fulfils any of the criteria they themselves list for what a proto-town should look like. Nonetheless, the most significant lack is their failure to specify what separates a proto-town, such as they observe in Odense, from a village. This becomes obvious in their conclusion when they write that 'the hiatus in the finds and the sporadic archaeological record should perhaps not be interpreted as a break in development but more an indication that towns from the ninth and tenth centuries *cannot be expected to stand out and differ markedly from agrarian settlements'*. (Runge and Henriksen 2018, p. 23, our italics)

If the material remains cannot be distinguished from those of an agrarian settlement, then is it not likely that what we are looking at is a village rather than a town, as it is continually alluded to throughout the article? Similarities with villages are referred to with regard to the estimated settlement size and the placement of the church (Runge and Henriksen 2018, p. 17, 20), and the evidence they present (longhouses, pit-houses, production debris), seems similar in nature to what is found on contemporary rural settlements, such as the latest phases of Vorbasse (Hvass 1979, pp. 381–91). Odense should perhaps be seen in connection to the stationary villages which were established on Funen from the 7th century onwards (Hansen 2011). The decision to call the settlement a proto-town seems to come about because it is located in the same place which later became a medieval town – not surprisingly the same area which defines the geographical boundaries of the study (Runge and Henriksen 2018, p. 3).

While Runge and Henriksen’s study contains an impressive overview of both the material from Odense and the landscape it was situated in, it fails to provide a convincing argument that what we are looking at in the ninth and tenth century is an urban site. A discussion not of criteria but of what makes a place urban might have led to a more nuanced view of Odense in the ninth and tenth centuries, as would an open discussion of the possibility that it can be classified as a village rather than a town.

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RESEARCH ARTICLE

Neolithic transverse arrowheads – a great misunderstanding

Andreas Valentin Wadskjær

SAXO-Institute, Copenhagen University, Copenhagen, Denmark

ABSTRACT
One of the most debated subjects in archaeology is the transition between the Mesolithic and the Neolithic period. A missing piece in this debate has been the transverse arrowhead, which is a relic from the hunting and gathering society but still has its place in the new agrarian societies. What we think we know about transverse arrowheads from Southern Scandinavia is based on a more than 75 years old theory, which hypothesises that Neolithic arrowheads were manufactured from irregular or polished flakes. This article offers a critical review of research so far into transverse arrowheads in Southern Scandinavia. It does so by proposing a new typo-chronology of Neolithic arrowheads from this region, which demonstrates how the transverse arrowhead developed from the Late Mesolithic to the Middle Neolithic, and it is actually the first study with the main focus on this subject. The study is concluded with a discussion that argues the empirical basis for the typological restructuring and highlights the implications of the study for the broader debate on Neolithisation.

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Transverse arrowheads; neolithisation; flint; neolithic; transition; typo-chronology; creolisation

1. Introduction

The transition from hunter-gatherer to agricultural societies is one of the most debated topics in archeology (e.g. L. Sørensen 2014, p. 1), but for long the transverse arrowhead have been left out of the discussion. In Southern Scandinavia, we have been satisfied with the claim that Neolithic transverse arrowheads were manufactured from flakes instead of blades, as they were in the Mesolithic (e.g. Ebbesen 2011, 99ff). This aspect is basically the only thing that concerns us when we are dealing with a Neolithic arrowhead material, but why is that? I have two suggestions: Firstly, with the introduction of agriculture, archaeological interest in hunting-gathering traditions diminishes significantly due to the introduction of new technologies and the fundamental changes taking place in society. Secondly, with the introduction of especially new ceramic styles and polished flint, find groups that we are already familiar with are quickly overshadowed. One sees a similar tendency when we reach the Bronze Age, where the role played by flint is almost completely ignored, despite the fact that it still must have played an important role in the everyday economy due to the easy access of it compared to bronze (Högberg 2009). This article is an attempt to begin rectifying this neglect of certain find categories by offering new perspectives on the transverse arrowheads from the Late Mesolithic to the Middle Neolithic (4500–2800 BC).

The aim is to construct a useful and reliable dating tool in the form of a typo-chronology for the transverse arrowheads from the aforementioned time horizon to use them to tentatively date Neolithic contexts. The objective is to define some primary and secondary types for the transition to the Neolithic and for the Early and Middle Neolithic. In doing so, the following issues will be addressed:

- Is it possible to create a typo-chronology for the Neolithic transverse arrowheads? And on the basis of which criteria can such a typo-chronology be designed?
- Can the development of transverse arrowheads contribute to the Neolitisation debate in regard to processes of migration, exchange and adaptation?

By elucidating the above questions, the article strives to bring into the limelight an overlooked issue in the Neolitisation debate. At the same time, it will be an important dating tool for archaeologists working in the relevant periods.

CONTACT Andreas Valentin Wadskjær Andreas.vwp@gmail.com Bobakken 2, 3. Mf. 2720 Vanløse, Denmark

1.1. Research history

Overviews of types and chronologies have always been popular in archeology (Eriksen 2009a, 7ff). As for arrowheads, the most acknowledged typo-chronology for the Southern Scandinavian material is the one proposed by Peter Vang Petersen (1979, 2008b)). His typology focuses on the Mesolithic arrowheads and provides a fine chronological division of types from the beginning of the Kongemose culture (6400 BC) until the end of the Ertebølle culture (4000 BC). However, when it comes to the Neolithic transverse arrowheads, Vang Petersen's analysis becomes a bit vague (Petersen 2008b, 90).

Petersen identified five distinct Neolithic transverse arrowheads, but did not provide any indications of chronology. Petersen's types are defined as: 1) With convex sides; 2) With biconvex broadsides; 3) Extremely large; 4) From polished flakes; and 5) with polished sides. In general, he describes them as often manufactured from small flakes (type 1) and many from biconvex flakes (type 2) or flakes from polished flint axes (type 4). According to Petersen the retouche is often shaped from the dorsal surface and the polished arrows are rare (Type 5).

Petersen, however, is not the first to have attempted to construct a Neolithic typology of the transverse arrowheads. Carl Johan Becker reviewed Neolithic transverse arrowheads 40 years before Petersen's thesis (Becker 1940, 253ff). This study was most of all a comparison with the arrowheads from the Ertebølle culture, and two of Becker's Ertebølle types dominate the Neolithic material: 1) straight edge with concave sides & 2) Straight edge and convex sides. In addition, he described minor nuances, for example that the Neolithic arrowheads often are manufactured from flakes of polished axes. Furthermore, the biconvex flakes are used, and the Neolithic transverse arrowheads are larger and less elegant than the Mesolithic ones (Becker 1940, 253ff). Unlike Petersen, Becker does not distinguish the types from which type of blank the arrowhead is manufactured, be it a polished, a biconvex or a normal flake. Anders Jæger has also discussed a typology before Petersen's typology (Jæger 1976, 2ff), he suggested that the main difference from the Mesolithic to the Neolithic is that the Neolithic arrowheads often are manufactured from polished or unpolished flakes. However, later in the article he states that there is a domination of blade produced arrowheads compared to flakes, and that the polished flakes only are represented by 2% in the finds from Tornhøj II. Jæger also thinks that the Mesolithic arrowheads are more elegant because of their concave sides, while the Neolithic ones have straight or convex sides. He concludes that in the Neolithic, the transverse arrowhead is already fully developed and therefore does not change significantly over time. Jæger's arrowhead typology is designed with a focus on the arrowheads neck.

On the contrary, Klaus Ebbesen believes that neither Becker's nor Jæger's typologies are applicable, since Neolithic transverse arrowheads morphologically are very uniform (Ebbesen 2011, 99ff). Instead, he believes that a typology must be constructed on the basis of the different type of retouche. Ebbesen claims that Neolithic tranverse arrowheads are always manufactured from flakes, making them easy to distinguish from Mesolithic ones. Ebbesen states that there are no chronological, geographical or functional differences between the arrowheads, with the exception of the polished ones. According to Ebbesen, the Early Neolithic arrowheads are larger than the later ones (Ebbesen 2011, 435ff). He furthermore suggests that all the Neolithic transverse arrowheads have straight edges, the sides are either straight or slightly convex, there are only a few oversized ones, and they generally have a triangular or trapezoidal outline.

To sum up, there has been suggested six different types earlier, of which two are based on their flint blank, and one by size only. It has also been suggested that a typology should be based on the retouche or the neck of the arrowhead. There has generally been a consensus that most to all of the arrowheads were manufactured from flakes and polished flakes. Yet this too has been met with evidence that points in other directions. Finally, none of all these remarks have any chronological structure.

2. Methodology

I have reviewed and analysed 391 transverse arrowheads, from sites on Zealand and Lolland (Figure 1) with secure contexts dating to the Ålekistebro phase (4500–4000 BC), Early Neolithic Ia (ENIa: 4000–3800

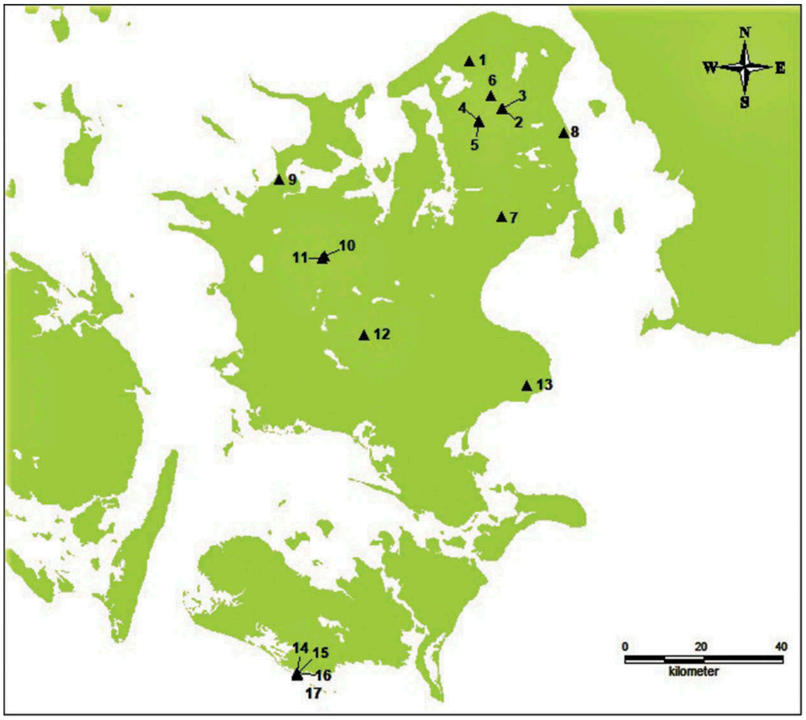

Figure 1. Map of Zealand and Lolland-Falster with the different sites. 1) Bryggergården IV, 2) Salpetermosen Syd 11, 3) Salpetermosen Syd 1, 4) Orebjerg Enge, 5) Orebjerg Agre, 6) Ullerødgård, 7) Helgeshøj, 8) Maglemosegård, 9) Dragsholm, 10) Præstelyngen, 11) Muldbjerg I, 12) Sigersted III, 13) Havnelev, 14) Syltholm II, 15) Syltholm XIV, 16) Syltholm XIII, 17) Syltholm IX. (Bredsdorffs map from Settlement and Landscape).

BC), Early Neolithic Ib (ENIb: 3800–3500 BC), Early Neolithic II (ENII: 3500–3300 BC), Middle Neolithic I (MNI: 3300–3100 BC) and Middle Neolithic V (MNV: 2900–2800 BC). Vang Petersen's flint typo-chronology (Petersen 1979, 2008b) of the Mesolithic arrowheads constitutes the basis for many observations and decisions made in this process.

The material came from the National Museum, Museum Nordsjælland, Kroppedal Museum and Museum Lolland-Falster. The material from Zealand includes 010106–59 Bryggergården IV, 010301–55 Salpetermosen Syd 11, 010301–163, Salpetermosen Syd 1, 010304–66 Orebjerg Enge, 010304–67 Orebjerg Agre, 010508–21 Ullerødgård, 020310–153 Maglemosegård, 030403–503 Dragsholm, 040112–229 Muldbjerg I, 040214–34 Sigersted III and 050602-14a Havnelev. The Mesolithic side of the transition is represented by secondary material from 030318–454 Præstelyngen. The aforementioned cover every phase from the Ålekistebro phase to the MNI. Primary material from the site 020211–71 Helgeshøj was subsequently included in my statistics and covers MNV. Unfortunately, the intermediate phases in the MN still need to be investigated due to lack of material included in this study. Primary material from Lolland has subsequently been added to the study for a regional comparison. The sites consist of 070314–58 Syltholm II, 070314–77 Syltholm XIV, 070314–80 Syltholm XIII and 070314–91 Syltholm IX.

Since this work is a geographic case study, there are of course limitations in what material that could be involved and as the number of arrowheads included in the analysis precludes this study from broader statistical validity, it is possible that complimentary studies in the future may cause the implications of this analysis to be modified.

It has previously been proposed to operate with two different regional chronological systems, respectively, east and west of Store Bælt (SH. Andersen 1979, 91ff). By focusing on Zealand, it is likely that there will be no major regional differences; furthermore, this study can be used in comparison and addition to Vang Petersen's arrowhead typo-chronology.

The period from the Late Mesolithic to the Middle Neolithic has been chosen for illuminating an unexamined perspective in the Neolithisation debate. Furthermore, this will complement the Petersen's typo-chronology and will be the first major attempt to create a typo-chronology of transverse arrowheads in the Neolithic.

The definition of a transverse arrowhead that will be used in this work is that the piece can be manufactured from either a flint blade or flake. The piece has a sharp edge, instead of a point. The edge is formed when the piece is knapped off of the core. The neck may be shaped similarly or by the retouche. Both of the piece's sides must be shaped by retouche, otherwise the piece is considered unfinished.

The result of the first review was to maintain some of Vang Petersen's definitions (Petersen 1979, 2008b), while other definitions had to be altered partly because of the diversity of the materials, but also simply because a better definition had been reached (Figure 2). I have added an aspect to the calculation of whether a transverse arrowhead is broad- or narrow-edged: I have defined an edge as being broad when the relative edge-width (the average of the long diagonal divided by the edge-width and the median divided by the edge-width) is less than 1.75 or if the edge-width is at least 1.75 times larger than the mid-width. Since it only affects about 10% of the total material, and since these would all be classified as broad-edged based on a quick subjective review rather than a metric analysis, it justifies the change of the definition. Another important definition that required a reassessment was the calculation of the arrowhead's size; here I use the formula edge-width multiplied by the median (figs. 3 & 4).

2.1. Theoretical and methodological considerations

As in Vang Petersen's arrowhead typology (Petersen 1979, 2008b), it has been important for this work that the types and their characteristics can be defined based on objective measurements. However, it is also important that the objective measurements are essentially consistent with subjective classifications, since there are rarely resources for a larger metrical review of a whole material at the museums after completion of excavation. Most often, it will be a subjective assessment of a material that will classify the types, so it is important that the objectivity match the visual appearance.

Being exclusively subjective to a material is problematic, as it lacks consistency. Objectivity, on the other hand, will overlook some types and include others that should not be included, but if the definitions are well-considered and constructed while

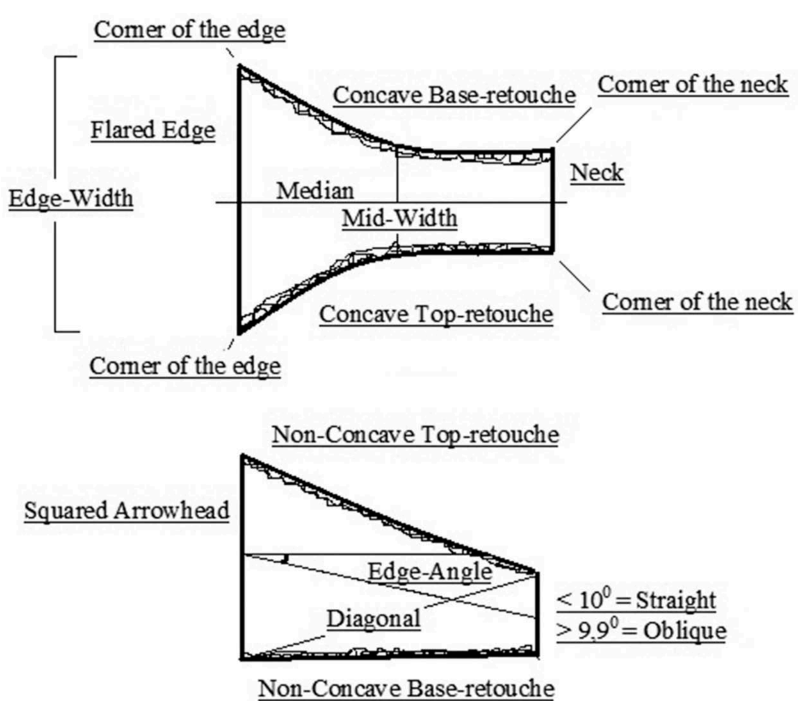

Figure 2. The definitions of the transverse arrowhead.

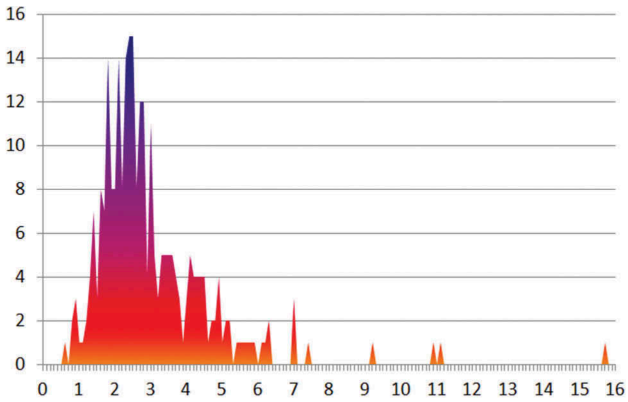

Figure 3. Graph showing the frequencies of the sizes of the arrowheads from Zealand. The sizes vary from 0.6 to 15.75 with 0.1 between each interval.

incorporating the relevant material, the overall picture of a well-represented material will still be clear (Albert 1985, 93ff; Weber 2009, 142ff; Van Gijn 2010, 35ff).

Another important consideration is how one defines whether an arrowhead is manufactured from a blade or a flake. It can be extremely difficult to assess as we are left with a relatively small product compared to the preform (Eriksen 2009b, 2009c). In addition, we see a tendency for Neolithic blades to become shorter and broader over time, making it even more difficult to assess the preform of the arrowhead (Stafford 1999, 102ff). Arrowheads, which appear to be made from a blade, can actually originate from a symmetrical but randomly knapped flake. The same applies to arrowheads that seem to be manufactured from flakes, these can also originate from a coarser and more irregular blade production. By constructing a definition for an arrowhead manufactured from a blade, for example parallel sides and longitudinal dorsal lines, it will result in many irregular blades being classified as flakes, while many flakes will be classified as blades.

Mikkel Sørensen abstains from a metric definition of a blade and instead chooses a dynamic technological definition. He states: 'A blade is a serially produced removal made with the intention of being a tool or a preform for a tool. Blades in the same industry are produced by the same technique, method and mental representations and are characterized by a similar morphology and the same set of diagnostic attributes' (M. Sørensen 2006, 289). In addition, a flake is defined as 'Waste removals (i.e. serially produced removals which are knapped off to shape cores and blanks)' or 'Removals which are not serially produced' (M. Sørensen 2006, p. 290). With these definitions, the debate becomes even more complicated. As soon as flakes are deliberately produced to be included in arrowhead production, they are no longer a waste product and should therefore be characterized as being more than just a flake. Therefore, I have settled with a subjective assessment of the preform's regularity, which is based on objective metrics, including longitudinal dorsal lines, approximate parallelism between the dorsal lines and edge, and the absence of transverse dorsal lines. However, even with such a categorisation,

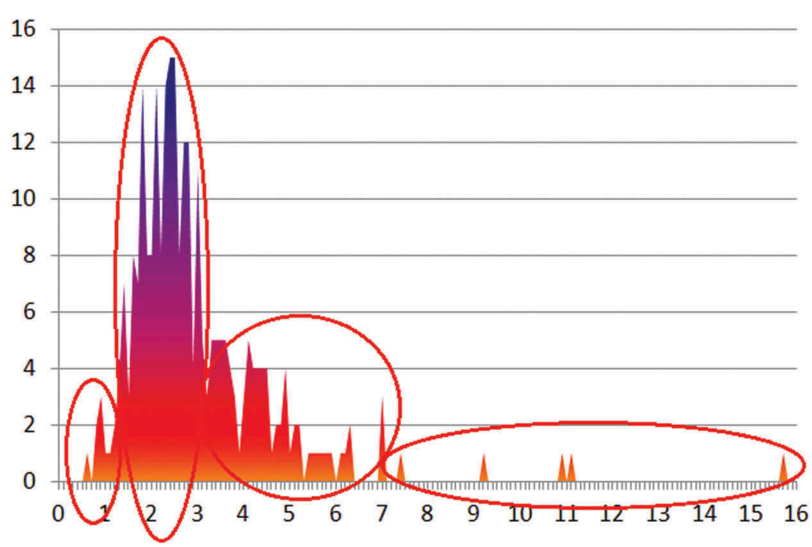

Figure 4. Interpretations of the different size groups. Small arrowheads range between 0.6 and 1.19, normal arrowheads range between 1.2 and 3.0, large arrowheads range between 3.01 and 7.09 and extremely large arrowheads range between 7.1 and 15.75.

there will still be actual blade-preforms that fall outside the category while flake-preforms fall within the category, but it is useful to provide a general overview of the material.

3. The data

To form a foundation of my typology before adding and comparing arrowheads from other parts of Southern Scandinavia, I first analysed the 296 arrowheads from Zealand, which range chronologically from the Ålekistebro phase to MNV. It was necessary to present the greatest possible nuance of the material to assess if there were chronological differences on minor details. Therefore, 15 types based on morphology with each up to three subtypes were defined (Figure 5).

Only by analyzing the arrowheads and their context's datings (Figure 6), could I assess the chronological diversification of the various types. It was clear that many of the types should be merged into fewer types, as their small different details were not of

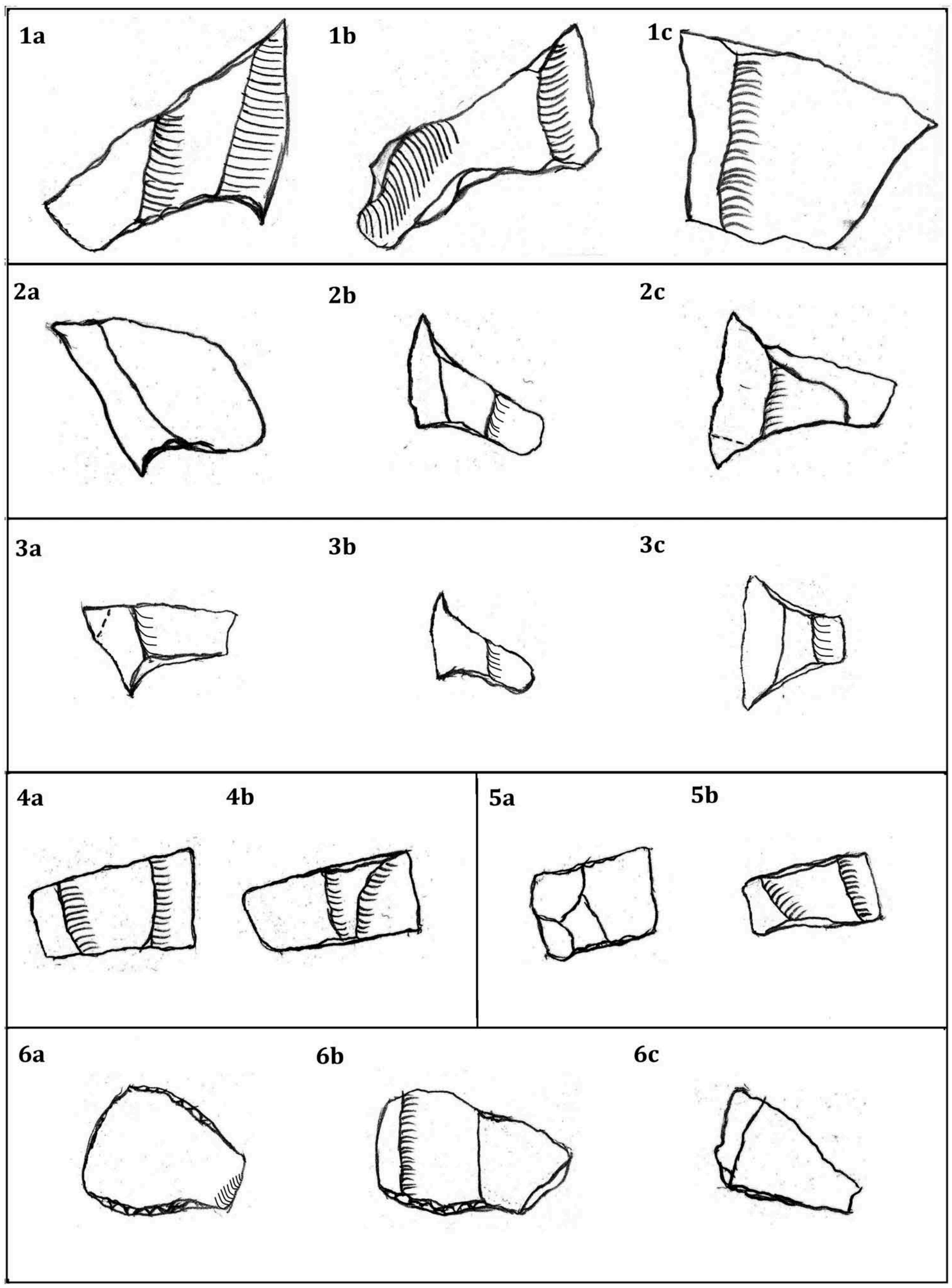

Figure 5. Morpho-typology of neolithic transverse arrowheads. Type 1a – 15a, 1:1. For descriptions see appendix A. (Illustrator: Michelle Zadstrov Pedersen).

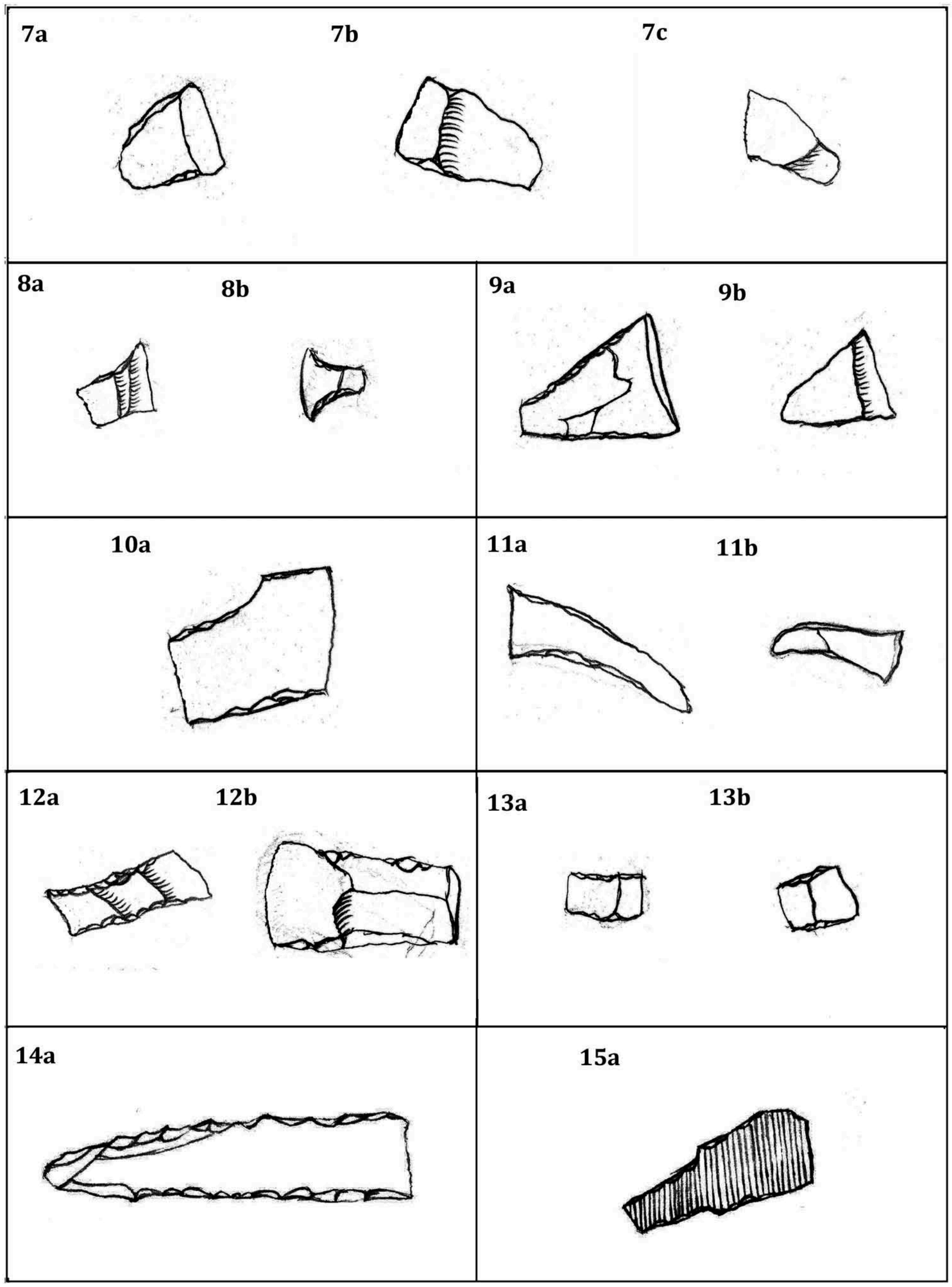

Figure 5. Continued.

chronological significance. The many types and subtypes also show a more inaccurate overview than what fewer types would, since one type might have been split into several types, which makes the type look less dominant than it actually is. In addition, an update of the types will provide a clearer overview of the typology.

Figure 7 clearly shows how certain subtypes blur the reality. For example, it appears that there is no clear dominance of a particular type in MNI, where Type 2b constitutes 25% and Type 2a constitutes less than 20%. These two types, however, differ very little morphologically, and as the figure shows, there is no chronological difference between them. As both are oblique arrowheads with wide and flared edges (Figure 8) they should be merged into one type.

4. Typo-chronology of neolithic transverse arrowheads

After a thorough review of the material, type-by-type, to figure out which subdivisions would prove

Site & Amount	Context & Dating	Blades Flakes Biconvex Polished	Broad	Straight	Flared Squared Convex	Triangular Curved Pentagonal Other	Small Normal Large Ekstreme	Dom. Type
Bryggergården IV – 11 pcs.	Floor layer from A73 **(MNI)** (Wadskjær typology)	- 100 % - -	90 %	0 %	91 % 9 % -	- - - -	- 9 % 64 % 27 %	2b -37 %
Salpetermosen Syd 11 -35 pcs.	Cultural layer A99 **ENI**(/ENII) (CeramiC)	65 % 35 % - -	88 %	70 %	86 % 5 % 3 %	- - - 5 %	3 % 82 % 15 % -	3c – 57 %
Salpetermosen Syd 1 –7 pcs.	Cultural layer A1 **ENII** (Ceramic)	14 % 71 % 14 % -	71 %	100 %	28 % 28 % 14 %	14 % 14 % - -	- 70 % 30 % -	3c – 29 %
Orebjerg Enge -41 pcs	Cultural layer A2 **ENII** (/MNI) (Ceramic)	20 % 70 % 10 %	73 %	92 %	12 % 51 % 30 %	- - 2,5 % -	- 30 % 65 % 5 %	4a – 37 %
Orebjerg Agre -5 pcs.	Cultural layer A20 **MNIb** (Ceramic)	- 80 % - 20 %	60 %	80 %	20 % - 40 %	- 20 % - -	- 40 % 60 % -	20 % hver
Ullerødgård -7 pcs.	Cultural layer A95, A901 & pit A689 **ENIb** (C14)	- 86 % 14 % -	72 %	85 %	57 % 14 % -	14 % 14 % - -	- 100 % - -	3c -43 %
Helgeshøj – 10 pcs.	Cultural layer A34 **MNV** (C14)	- 60 % 30 % 10 %	60 %	80 %	- 60 % -	10 % 10 % - 20 %	- 10 % 80 % 10 %	6a – 60 %
Maglemosegård -17 pcs.	Cultural layer **ENIa** (ENIb) (C14)	53 % 47 % - -	76 %	82 %	76 % 18 % -	- 6 % - -	6 % 82 % 12 % -	3c – 47 %
Dragsholm –9 pcs.	Grave **ENIb** (C14)	67 % 33 % - -	100 %	90 %	100 % - -	- - - -	- 67 % 33 % -	3c – 56 %
Præstelyngen – 40 pcs.	Cultural layer **Ålekistebro-phase** (C14)	90 % 7 % 3 % -	25 %	90 %	19 % 81 % -	- - - -	4 % 81 % 15 % -	5b – 81 %
Muldbjerg I – 43 pcs.	Cultural layer **ENIa** (C14)	60 % 33 % 7 % -	72 %	90 %	53 % 25 % 12 %	3 % 7 % - -	9 % 70 % 21 % -	3c – 34 %
Sigersted III – 5 pcs.	Pit A **ENIa** (C14)	20 % 40 % 40 % -	100 %	100 %	100 % - -	- - - -	- 20 % 80 % -	2c – 80 %
Havnelev – 66 pcs.	Cultural layer A31820 & A37008 **ENIb** (C14)	9 % 88 % 3 % -	77 %	80 %	71 % 10 % 6 %	- 12 % - -	- 55 % 45 % -	2c – 32 %

Figure 6. Table of the data (K. Andersen 1983, Andreasen 2002, Christensen 1964, Gron *et al*. 2016, Jepsen 2006, 2007, Juel and Kjær 2015, Jønsson 2015, Jørgensen 2015, Mathiassen 1941, Nielsen 1974, 1977, 1985, 1994, 1999, Nielsen and Nielsen 2018, Noe-Nygaard *et al*. 2005**, EB**. Petersen 1974, **2008a**, 2015**, EB**. Petersen and Egeberg 2009, Price *et al*. 2007, 2010, Rosenberg 2006, 2007, 2008, Troels-Smith 1954, 1957, 1960a, 1960b, Wadskjær 2018, Aarsleff 2013a, **2013b**, **2017**).

redundant, I can present the final typology (Figure 9).

The result of this reassessment is a much clearer overview of the types and not least on the most dominant types (Figure 10). Now, one type stands out as the most dominant type for each phase: ENI is dominated by type III; ENIa by type III-b; and in ENIb there is an almost equal representation of type III-a and type III-b. ENII is dominated by type IV-a, while V-a also is well represented. MNI is dominated by type II-a. MNV is dominated by type IV-a, as in ENII.

A single Neolithic transverse arrowhead cannot date a given context, however, there are several clear features that can be distinguished in the different phases from the Ålekistebro phase to MNI and MNV, as well as more

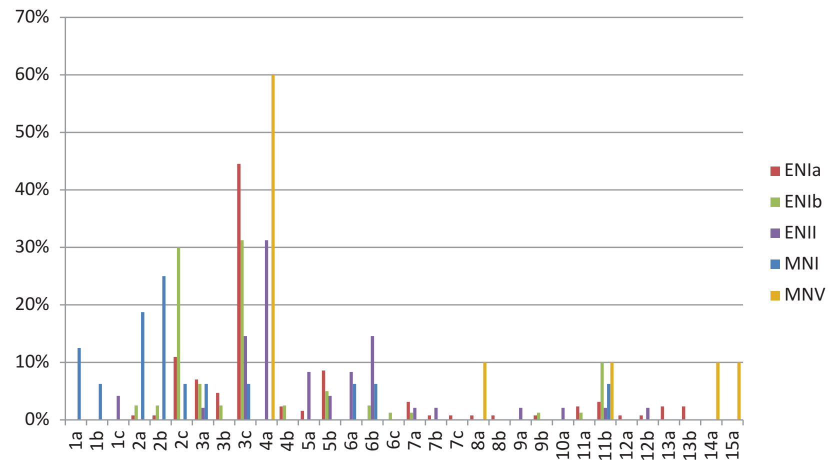

Figure 7. Diagram of the representation of each subtype through time.

Type 1	Type 2	Type 3	Chronological similarly	Morphological difference	Remarks	Result
1a	1b	1c	1a+1b	Broad/narrow	1a+1b can't be defined together without including 1c	1a→I-a 1b→I-b 1c→I-c
14a	1b	-	-	Oblique/straight	Chronological separated	14a→I-d
2a	2b	-	2a+2b	Top-retouche	2a+2b+3a+3b are chronologically and morphologically more similar than 2c+3c	2a+2b→II-a
3^a	3b	-	3a+3b			3a+3b→II-b
2c	3c	-	-	Size		2c→III-a 3c→III-b
4a	5a	-	4a+5a	Size	4a+5a differ from 4b+5b by broad edge and dating	4a+5a→IV-a
4b	5b	-	4b+5b			4b+5b→IV-b
6a	6b	6c	6a+6b+6c	Broad/narrow	Type 6 +7 are separated by size difference	6→ V-a
7a	7b	7c	7a+7b+7c	Straight/oblique		7→V-b
8a	8b	13b	8a+8b+13b	Concavity Straight/oblique	8a+8b differ from type 3+2 by size; because of chronological difference they are separated	8+13b→VI-a
13a	VI-a	-	13a+VI-a	Broad/narrow		13a→VI-b
11a	11b	-	-	Size	Too few for own type	11→VII
9a	9b	-	-	Size	Too few for own type	9→VIII
15a	-	-	-	-	Only type with shaft-retouche	15a→IX
10a	-	-	-	-	Other transverse arrowheads	10a→X-a
12a	-	-	-	-		12a→X-b
12b	IV-b	-	12b+IV-b	Thickness	Only difference is thickness	12b→IV-b

Figure 8. Table of the typology's update.

general features that gradually change over time (Wadskjær 2018).

4.1. A transverse arrowhead material can be dated to the ålekistbro phase if…

- It is certain that it is a context from around the Neolithisation and the vast majority of the transverse arrowheads are manufactured from regular blades (more than 80%).
- The narrow-edged transverse arrowhead dominates the material (more than 70%).
- The most dominant subtype is the narrow-edged squared straight transverse arrowhead (type IV-b), better known as the Ålekistebro-type (more than 70%).

There may be arrowheads manufactured from biconvex flakes, while arrowheads manufactured from polished flakes should not be found during this period. In addition, there should be a number of small transverse arrowheads represented in the material, but with a clear dominance of the arrowheads of normal size. Large transverse arrowheads can also be expected to be found in an Ålekistebro

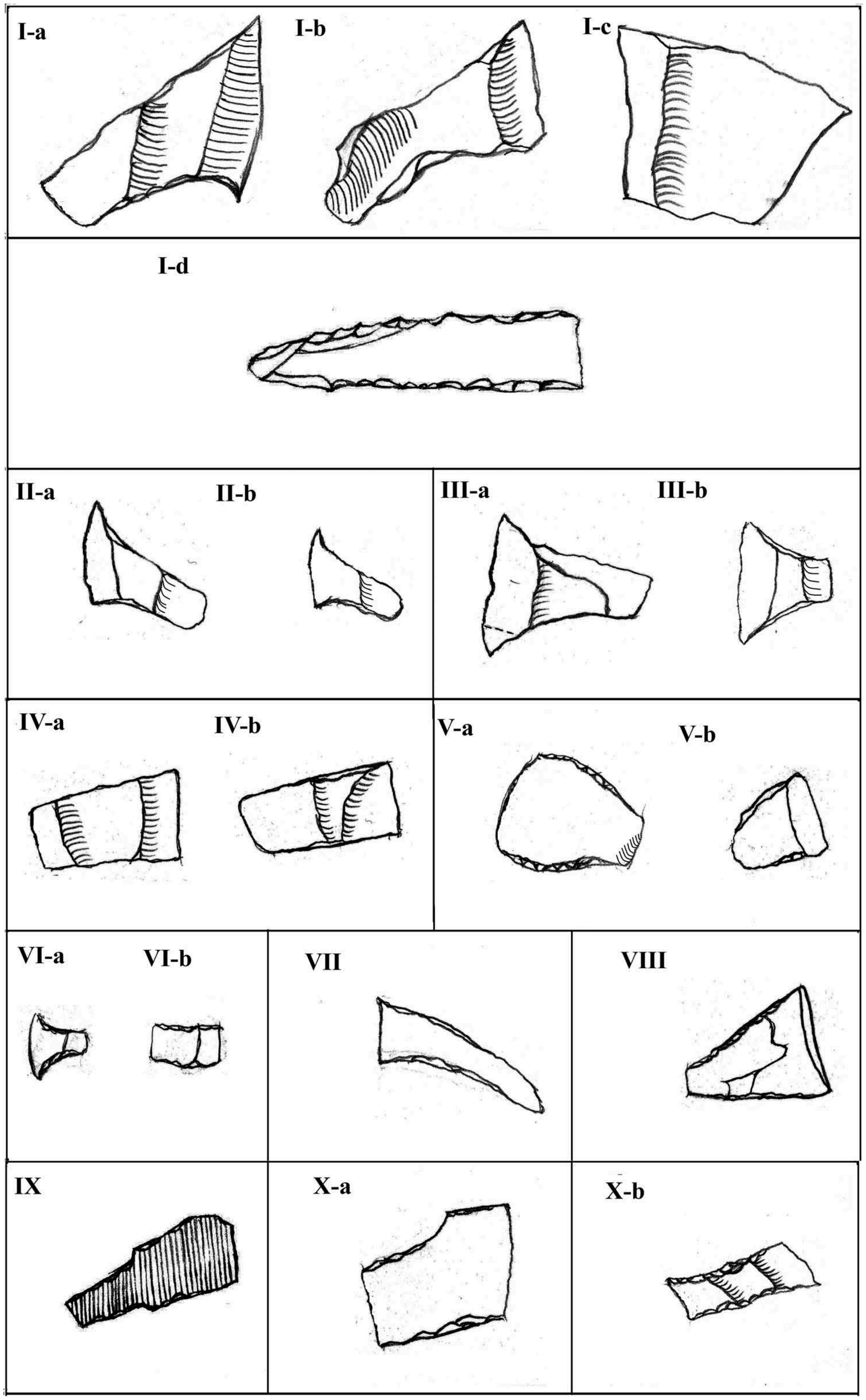

Figure 9. Updated morpho-typology of neolithic transverse arrowheads. Type I-a – X, 1:1. For descriptions see appendix B. (Illustrator: Michelle Zadstrov Pedersen).

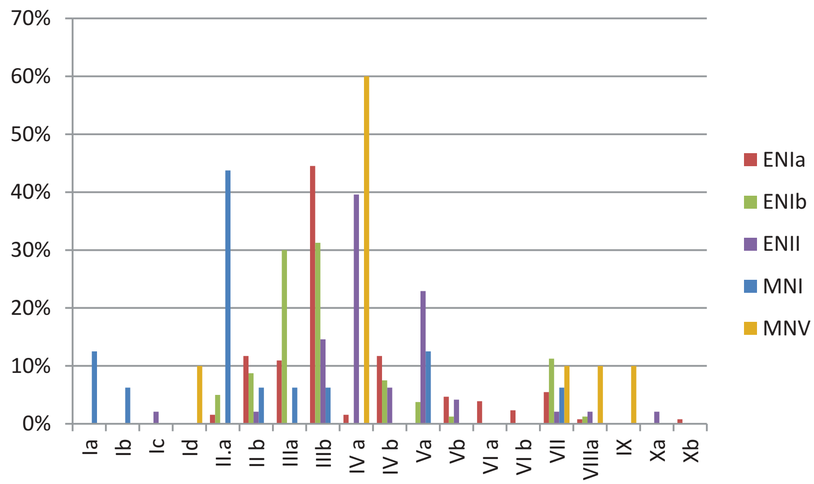

Figure 10. Revised diagram of the representation of each subtype through time.

material, while no extremely large arrowheads should be represented. The average edge-width should be below 1.1 cm, the average median should be below 1.89 cm, while the average size should be below 1.81. Finally, transverse arrowheads with wide and flared edges (type III), better known as the Stationsvej type, are also represented in this phase.

4.2. A transverse arrowhead material can be dated to enia if...

- Transverse arrowheads manufactured from regular blades make up about half of the material (about 40–65%).
- It is certain that it is a Neolithic context, and the material contains at least one small transverse arrowhead (type VI).
- It is certain that it is a Neolithic context, and transverse arrowheads with wide and flared edges are dominant (more than 50%), of which the straight one (Type III-B), better known as the Stationsvej type, alone must be the most dominant subtype (more than 30%).

Like the Ålekistebro phase, there may be arrowheads manufactured from biconvex flakes, while arrowheads manufactured from polished flakes should not be found in this period. In addition, there should be a number of small transverse arrowheads represented in the material, but with a clear dominance of the arrowheads of normal size. Large transverse arrowheads can also be expected to be found in an ENIa material, while no extremely large arrowheads should be represented. The average edge-width should be between 1.1 and 1.27 cm, the average median should be between 1.7 and 2 cm, while the average size should be between 2.1 and 2.5. Furthermore, the squared transverse arrowhead is still second best represented and accounts for about 16%. In addition, there are other types, which are not particularly well-represented.

4.3. A transverse arrowhead material can be dated to enib if...

- Transverse arrowheads of normal sizes are dominating the material (more than 50%) and at the same time no small or extremely large arrowheads are represented.
- It is certain that it is a Neolithic context and transverse arrowheads with wide and flared edges dominate (more than 50%), of which the straight ones of normal size (type III-b) and the large ones (type III-a) each constitute for more than 25%.

In ENIb, the arrowheads manufactured from blades are far less represented than earlier, except for in grave contexts. Like the earlier phases, there may be arrowheads manufactured from biconvex flakes, while arrowheads manufactured from polished flakes should not be found during this period. Large arrowheads can now constitute of 40% of the material. The average edge-width should be between 1.27 and 1.4 cm, the average median should be around 2.15 cm, while the average size should be around 3.

Furthermore, the curved transverse arrowhead is second best represented and accounts for about 11%. In addition, there are other types, which are not particularly well-represented.

4.4. A transverse arrowhead material can be dated to ENII if. . .

- Transverse arrowheads manufactured from regular blades are few (between 1 and 25%) and at the same time large arrowheads dominate or extremely large arrowheads are represented.
- It is certain that it is an Early Neolithic context and transverse arrowheads with wide and flared edges constitute of less than 30% of the material (types II & III).
- It is certain that it is an Early Neolithic context and the squared transverse arrowheads dominate (type IV).
- The broad-edged squared straight transverse arrowhead (type IV-a) is the most dominating type and arrowheads manufactured from blades are represented.
- The extremely large squared transverse arrowhead is represented (type I-c).
- The curved transverse arrowhead is not represented (type VII).

Like the earlier phases, there may be arrowheads manufactured from biconvex flakes, while arrowheads manufactured from polished flakes should not be found during this period. No small arrowheads should be represented. The average edge-width should be between 1.4 and 1.7 cm, the average median should be between 2.15 and 2.55 cm, while the average size should be between 3.1 and 4.5. Furthermore, the convex transverse arrowhead is second best represented and accounts for about 27%. In addition, there are other types, which are not particularly well-represented.

4.5. A transverse arrowhead material can be dated to MNI if. . .

- None are manufactured from biconvex flakes.
- No squared transverse arrowheads are represented (type IV).
- It is certain that it is a Neolithic context and oblique transverse arrowheads are dominating (more than 50%).
- The extremely large oblique transverse arrowhead with wide and flared edge (type I-a) or the extremely large and coarse narrow-edged oblique transverse arrowhead is represented (type I-b).

There should not be arrowheads manufactured from blades represented, but arrowheads manufactured from polished flakes may be represented. Like in ENII, no small arrowheads should be represented, however, the extremely large ones are now represented. The average edge-width should be between 1.5 and 2.1 cm, the average median should be between 2.45 and 2.75 cm, while the average size should be between 3.7 and 5.8. Furthermore, the convex transverse arrowhead is still second best represented and accounts for about 12.5%. In addition, there are other types, which are not particularly well-represented.

4.6. A transverse arrowhead material can be dated to MNV if. . .

- It is certain that it is a Neolithic context and no transverse arrowheads with wide and flared edges are represented (type II & III).
- The extremely large and long transverse arrowhead is represented (type I-d).
- The transverse arrowhead with shaft-retouche is represented (type IX).
- The broad-edged squared transverse arrowhead is dominating (type IV-a) and no arrowheads are manufactures from blades.
- The triangular arrowheads the most or second most dominating type (type VIII).

There should not be arrowheads manufactured from blades represented, however, now arrowheads manufactured from polished flakes may be represented and arrowheads manufactures from biconvex flakes are common. Like in ENII, no small arrowheads should be represented; on the contrary, the extremely large ones are now represented. The large arrowheads are most represented, which means that the average edge-width should be around 1.5 cm, the average median should be around 2.9 cm, while the average size should be around 4.3. There are types, which are not particularly well-represented.

4.7. How does the transverse arrowhead develop from the ålekistbro phase to MNV?

- The transverse arrowhead develops from almost being 100% manufactured from regular blades in the Ålekistebro phase, to about 50% in ENIa, to less than 25% in ENIb and ENII, and eventually missing completely in MN (Figure 11).
- The transverse arrowhead develops from a clear dominance of narrow-edged ones in the Ålekistebro phase to a clear dominance of broad-edged ones from ENIa.
- The transverse arrowhead develops from a clear dominance of straight ones from the Ålekistebro phase to ENII to be dominated by oblique ones in MNI and again by straight arrowheads in MNV (Figure 12).
- The transverse arrowhead gradually grow in size from the Ålekistebro phase and at least until MNI, where the small arrowheads no longer are represented from ENIb and are replaced by the extremely large ones in ENII. Likewise, the dominance is changed from normal sized ones to large arrows in ENII (Figure 13).
- In the Ålekistebro phase, the preferred type is the narrow-edged squared straight transverse arrowhead, which in ENI is replaced by the straight transverse arrowhead with wide and flared edge, which again is replaced in ENII by the broad-edged squared straight transverse arrowhead, which is replaced by the oblique transverse arrowhead with wide and flared edge in MNI, which eventually is replaced by the broad-edged squared straight transverse arrowhead again (Figure 12).

In general, the Neolithic transverse arrowheads are most often manufactured from more or less irregular flakes/blades, giving the arrows a rougher appearance, with the exception of the arrows from ENIa, where they mainly are manufactured from

	^50 % blades	Few blades	No blades	Biconvex flakes	Polished flakes
Ålekistebro phase	X			X	
ENIa	X			X	
ENIb		X		X	
ENII		X		X	
MNI			X		X
MNV			X	X	X

Figure 11. Representativity table of the transverse arrowheads' prefroms.

	^50 % straight wide and flared edge	3a far most dominating	Squared most dominating	No squared	No curved	^50 % oblique
Ålekistebro phase			X			
ENIa	X	X				
ENIb	X					
ENII			X		X	
MNI				X		X
MNV			**X**			

Figure 12. Representativity table of various types.

	Small	^50 % normal sized	^50 % Large	Extremely large
Ålekistebro phase	X	X		
ENIa	X	X		
ENIb		X		
ENII			X	X
MNI			X	X
MNV			X	X

Figure 13. Representativity table of the sizes.

regular blades. In addition, a few ones may be manufactured from biconvex flakes and from MN also from polished flakes. The arrowheads are generally larger than in the Mesolithic and they grow in size throughout their usage. Due to the varied flake preforms from which the arrowheads were manufactured, the retouche can be knapped both from the ventral and dorsal side and with 'propeller-retouche', depending on what was most convenient according to the given preform. The most important types in the Neolithic are shown in Figure 14.

5. Regional comparison – lolland

To test whether or not my typology is applicable to other parts of southern Scandinavia, I analysed 95 transverse arrowheads from cultural layers from four different sites at Rødbyhavn in Lolland.

Syltholm II has C14-dates from the Ålekistebro phase and from all of the Early Neolithic. ENIa is well-represented by the transverse arrowhead with wide and flared edge. In addition, there were a number of arrowheads manufactured from flakes, of which in particular the broad-edged squared transverse arrowhead suggests an activity in ENII. The Ålekistebro-type was missing, but according to Søren A. Sørensen (personal

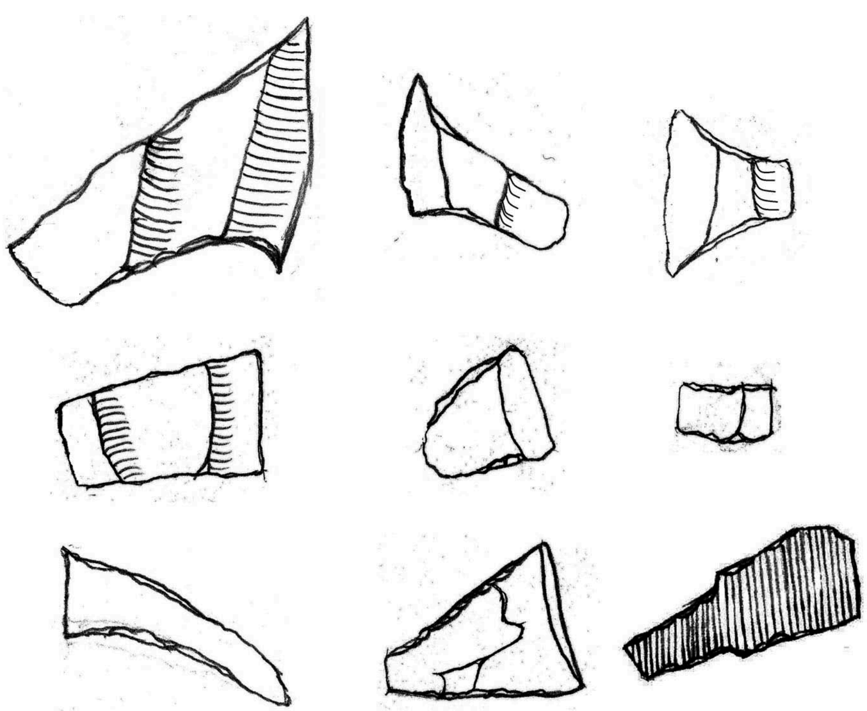

Figure 14. Most important neolithic transverse arrowhead types. Type I-IX, 1:1. For descriptions see appendix C. (Illustrator: Michelle Zadstrov Pedersen).

comment) it is rarely found outside Zealand, where instead the Stationsvej-type continues in this phase.

Syltholm IX has datings from ENIb to MNI that does not match the dating of the transverse arrowheads, and which points to a ENIa date. This is due to the fact that the arrowheads originate mainly from dry land, while the samples for the C14-dates have been taken from the slightly later phase, where the site is flooded. The other tool material from the site also points to an earlier date: the Ålekistebro phase or ENIa. Thus, there was a former cultural horizon, which has not been acknowledged on the basis of the dates from the samples.

Syltholm XIV is dated to the Ålekistebro phase and is highly dominated by straight transverse arrowheads with wide and flared edges manufactured from regular blades. This corresponds well to the dating, if one keeps in mind the statement from Sørensen mentioned earlier.

Syltholm XIII is primarily dated to the Ålekistebro phase and ENIa, but few C14-dates also spread from ENIb to MNI. The early dating is confirmed by the presence of transverse arrowheads with wide and flared edges manufactured from blades, as well as small arrowheads. It is also clear that there is a later activity (possibly MNI), which is represented by the extremely large arrowhead; type I-a. The lack of type IV and the presence of curved transverse arrowheads also correspond to a late activity in MNI instead of ENII.

My proposed typo-chronology thus seems to apply for a material from Lolland, with the exception of the Ålekistebro-material, which outside Zealand seems to be dominated by the transverse arrowheads with wide and flared edges, as in the previous and subsequent phase.

6. Can the transverse arrowhead contribute to the neolithisation debate?

In 1955, Becker wrote that 'The question is central to Danish prehistory and is still relevant' (Becker 1955, p. 167), and now almost 65 years later, I argue that the question is still relevant for Danish prehistory.

Lasse Sørensen suggests a rapid transition from Ertebølle to Funnel-beaker culture with a lack of transition types in both the ceramics and the lithic material around cal. 4000 BC, suggesting that the indigenous population has had a great deal of commitment to the practical learning processes to become confident in the new material culture and agricultural technologies (L. Sørensen 2014, p. 231ff).

However, if one solely takes in accord the transverse arrowheads, it is not quite the same conclusion (Wadskjær 2018). There is not an immediate lack of transition types; on the contrary, the transverse arrowheads seem to have a gradual development in both morphology and technology from the Ålekistebro phase in to ENII. In the first phase of the Neolithic, the arrows are still manufactured from blades like in the Ertebølle culture. Over time, more and more arrowheads are nevertheless manufactured from irregular flakes. By the second phase of the Neolithic, it is the irregular flakes that are dominant, but blades are still used in around 15–20% of the cases in the rest of the Early Neolithic. At the same time, we see that the transverse arrowhead with wide and flared edge, best known from the Stationsvej phase in the Mesolithic, is present in all the phases of the Early Neolithic, thus uniting the old and new traditions. Furthermore, this type is gradually replaced by other types that are known from earlier phases. The same applies for the size of the arrowheads. In ENIa they are still slender and elegant, as we know it from the Ertebølle culture, and slowly they grow in size and thickness. One exception is the arrowheads from Sigersted, which are mainly made from irregular and biconvex flakes, while at the same time being larger and coarser than contemporaneous arrowheads from other sites.

Great similarities in artefact types and their frequencies point to a migration from the Michelsberg culture (Troels-Smith 1954, p. 5ff; L. Sørensen 2014, p. 125ff). However, when comparing the percentage of transverse arrowheads at Michelsberg culture sites and Funnel-beaker culture sites, there is a significant difference (L. Sørensen 2014, p. 236). In the Mischelsberg culture, the transverse arrowheads make up less than 2.5% of the flint tools on all the sites listed in the graph, and most often the percentage is below 1%. While in the Funnel-beaker culture, the transverse arrowheads usually constitute more than 2.5% and even make up more than 20% at several of the sites. If one though includes the leaf-shaped arrowheads from the Michelsberg culture, then the percentage is fairly similar from the Michelsberg culture to the Funnel-beaker culture. The transverse arrowheads could thus be this missing transition type from the hunter-gatherer society, which the native hunter-gatherers did not want to give up at the expense of the immigrants' different arrow-type.

Sigersted should probably be interpreted as a site where the first immigrants from the Mischelsberg culture settled or as a scouting expedition (L. Sørensen 2014, p. 227ff). While the other sites represent places where immigrants and natives have interfered with each other, the latter group apparently did not intend to let go of all of their old traditions and thus maintained their own arrowhead style. The transverse arrowheads stand out from the other flint tools by being based on ideals from the Ertebølle culture rather than ideals from the Mischelsberg culture, as the other flint tools seem to be in the Funnel-beaker culture in southern Scandinavia (L. Sørensen 2014, p. 231ff). With regard to Sigersted, there is also another possibility. Poul Otto Nielsen wrote about Sigersted, 'that in the field of blade technology, the Early Funnel-beaker culture does not stand back for the Ertebølle culture' (Nielsen 1985, p. 113). This means that they did have the exquisite blade technique at Sigersted, and the reason why it is not detected in the arrows (with the exception of a single piece equivalent to 20%) may be due to that the transverse arrowheads are very poorly represented.

With the exception of Sigersted, the development and frequencies of the arrowheads are almost identical, regardless of whether it is a coastal settlement or an inland settlement.

7. Conclusion

Before this study, it was generally accepted that the transverse arrowheads from the Neolithic almost exclusively were manufactured from flakes and that there were no chronological differences between them. Based on my study of 391 transverse arrowheads from sites on Zealand and Lolland, I can conclude that there are different types that dominate different phases and that other characteristics also change over time.

The Ålekistebro phase is dominated by the narrow-edged squared transverse arrowhead (Type IV-b), which is almost always manufactured from a blade: This is consistent with previous research on this point. Hereafter we have a dominance of the straight transverse arrowhead with a wide and flared edge (type III) manufactured from both blades and flakes in ENI. ENIa and ENIb differ by the fact that arrowheads in ENIa on average are smaller and more often manufactured from blades than in ENIb. In ENII the broad-edged squared transverse arrowhead dominates (type IV-a). The arrowheads grow larger, and now the extremely large arrowheads are also represented (type I). In MNI, it is the oblique transverse arrowhead with a wide and flared edge (type II) that dominates, and the extremely large arrowhead is now found more often than in earlier phases. In addition, a production of transverse arrowheads manufactured from polished flakes begins in MNI. In MNV, it is again the broad-edged squared transverse arrowhead that dominates, but now without pieces manufactured from blades. On the other hand, they are now more often manufactured from biconvex flakes. Furthermore, they appear to be trapezoidal, where they previously were rectangular. A new type is seen in this phase: the transverse arrowhead with shaft-retouche (Type IX). It has thus been possible to construct a typo-chronology for at least EN, and this seems to be applicable both for Zealand and Lolland-Falster, while a future study hopefully will explore whether the typology applies to all of Southern Scandinavia.

Last but not least, I can conclude that the development of the transverse arrowhead can contribute to the Neolithisation debate. The transverse arrowhead is one of the transition types that have not yet been recognized in archaeology. It seems to develop gradually in both morphology and technology from the Ålekistebro phase until at least ENII. It is thus a link between the indigenous people and the immigrants, and is based more on the ideals of the Ertebølle culture than the Mischelsberg culture, which the other flint tools seem to be. The transverse arrowhead can thus be an expression of cultural creolisation.

8. Perspectives

One has to keep in mind that this work has been based on a relatively limited material, and that larger analyses can adjust the conclusions. It should also be remembered that a typo-chronology never is final; when more finds appear, changes may occur and the classification system may become more detailed. In addition, I have focused on a geographically defined area, so it would be an obvious next step to analyse material from other regions in southern Scandinavia to acknowledge possible regional differences.

Furthermore, it could be interesting to complete the typo-chronology of the Neolithic by incorporating the missing phases of the transverse arrowhead's usage. Whether there have been any functional differences on the arrowheads, must also be determined by future studies.

I have shown that the transverse arrowheads gradually are developing through the Neolithisation, which may mean that other tool types did the same, but due to the lack of narrow studies of find categories, these are not acknowledged yet. A study on another find category could be important for nuancing the Neolithisation further.

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Appendix A

(1) Extremely large oblique transverse arrowhead: 1a) Extremely large oblique transverse arrowhead with wide and hanging edge, 1b) Extremely large and coarse narrow-edged oblique transverse arrowhead, 1c) Extremely large squared oblique transverse arrowhead.

(2) Large transverse arrowhead with wide and flared edge: **2a)** Large oblique transverse arrowhead with wide and hanging edge, **2b)** Large oblique transverse arrowhead with wide and upward edge, **2c)** Large straight transverse arrowhead with wide and flared edge.

(3) Transverse arrowhead with wide and flared edge: **3a)** Oblique transverse arrowhead with wide and hanging edge, **3b)** Oblique transverse arrowhead with wide and upward edge, **3c)** Straight transverse arrowhead with wide and flared edge.

(4) Large squared straight transverse arrowhead: **4a)** Large squared broad-edged straight transverse arrowhead, **4b)** Large squared narrow-edged straight transverse arrowhead.

(5) Squared straight transverse arrowhead: **5a)** Squared broad-edged straight transverse arrowhead, **5b)** Squared narrow-edged straight transverse arrowhead.

(6) Large transverse arrowhead with convex sides: **6a)** Large broad-edged straight transverse arrowhead with convex sides, **6b)** Large narrow-edged straight transverse arrowhead with convex sides, **6c)** Large broad-edged oblique transverse arrowhead with convex sides.

(7) Transverse arrowhead with convex sides: **7a)** Broad-edged straight transverse arrowhead with convex sides, **7b)** Narrow-edged straight transverse arrowhead with convex sides, **7c)** Narrow-edged oblique transverse arrowhead with convex sides.

(8) Small transverse arrowhead with wide and flared edge: **8a)** Small oblique transverse arrowhead with wide and upward edge, **8b)** Small straight transverse arrowhead with wide and flared edge.

(9) Triangular transverse arrowhead: **9a)** Large broad-edged triangular transverse arrowhead, **9b)** Broad-edged triangular straight transverse arrowhead.

(10) Pentagonal transverse arrowhead: **10a)** Large pentagonal transverse arrowhead.

(11) Curved narrow-edged transverse arrowhead: **11a)** Large curved narrow-edged transverse arrowhead, **11b)** Curved narrow-edged transverse arrowhead.

(12) Other narrow-edged transverse arrowhead: **12a)** Narrow-edged oblique transverse arrowhead with concave base-retouche, **12b)** Large and coarse narrow-edged straight transverse arrowhead.

(13) Small squared straight transverse arrowhead: **13a)** Small squared narrow-edged straight transverse arrowhead, **13b)** Small squared broad-edged straight transverse arrowhead.

(14) Extremely large straight transverse arrowhead: **14a)** Extremely large and long narrow-edged straight transverse arrowhead.

(15) Transverse arrowhead with shaft-retouche: **15a)** Large transverse arrowhead with shaft-retouche.

Appendix B

(I) Extremely large transverse arrowhead: **I-a)** Extremely large oblique transverse arrowhead with wide and flared edge, **I-b)** Extremely large and coarse narrow-edged oblique transverse arrowhead, **I-c)** Extremely large squared broad-edged oblique transverse arrowhead, **I-d)** Extremely large and long narrow-edged transverse arrowhead.

(II) Oblique transverse arrowhead with wide and flared edge: **II-a)** Large oblique transverse arrowhead with wide and flared edge, **II-b)** Normal oblique transverse arrowhead with wide and flared edge.

(III) Straight transverse arrowhead with wide and flared edge: **III-a)** Large straight transverse arrowhead with wide and flared edge, **III-b)** Normal straight transverse arrowhead with wide and flared edge.

(IV) Squared straight transverse arrowhead: **IV-a)** Broad-edged squared straight transverse arrowhead, **IV-b)** Narrow-edged squared straight transverse arrowhead.

(V) Transverse arrowhead with convex sides: **V-a)** Large transverse arrowhead with convex sides, **V-b)** Normal transverse arrowhead with convex sides.

(VI) Small transverse arrowhead: **VI-a)** Small broad-edged transverse arrowhead, **VI-b)** Small narrow-edged transverse arrowhead.

(VII) Curved narrow-edged transverse arrowhead.

(VIII) Triangular transverse arrowhead.

(IX) Transverse arrowhead with shaft-retouche.

(X) Other transverse arrowhead: **X-a)** Pentagonal transverse arrowhead, **X-b)** Narrow-edged oblique transverse arrowhead with concave base-retouche.

Appendix C

Type I: Extremely large transverse arrowhead. Aside from the fact that they may already be found in the Late Kongemose culture, they first emerge from ENII. In ENII, they are squared and broad-edged, in MNI they are either narrow-edged or have wide and flared edges, while in MNV they are long and narrow-edged.

Type II: Oblique transverse arrowhead with wide and flared edge. A small version of the type is known from the Trylleskov phase, but it is also represented in EN and MNI. In MNI it becomes the most dominant type, especially the large version (type II-a), and it is only sparsely represented other phases of the Neolithic.

Type III: Straight transverse arrowhead with wide and flared edge (Stationsvej-type). This classic form is the most common in the Neolithic and is represented in all phases except for MNV, but it is particularly dominant in ENI. In ENIa, the majority is of normal size (type III-b) and about half are produced on regular blades, whereas in ENIb both the normal size (type III-b) and the large ones (type III-a) are almost equally dominant and with a dominance manufactured from irregular flakes/blades. This type is previously known from the Stationsvej phase, where it is almost exclusively manufactured from regular blades.

Type IV: Squared straight transverse arrowhead. This type exists in a broad- and narrow-edged version. The narrow-edged one (type IV-b/Ålekistebro-type) dominated the Ålekistebro phase, but is also represented in all phases of EN, while the broad-edged one (type IV-a) is the most dominant type in ENII and MNV. The type has not been recognised in MNI.

Type V: Tranverse arrowhead with convex sides. This type is represented both in EN and MN, but it becomes more influential from ENII to MNI. The type consists of a large and a normal version, of which the first is not known in ENIa and the latter is not known in MNI.

Type VI: Small transverse arrowhead. The small transverse arrowhead is already known from the Ertebølle culture but is also represented in ENIa, after which it disappears.

Type VII: The curved transverse arrowhead. With one concave side and the other convex, the curved transverse arrowhead is sparsely represented in both EN and MN.

Type VIII: Triangular transverse arrowhead. Besides a few pieces from EN, the type is more influential in ENII and MNV, which corresponds to a dominance of squared broad-edged transverse arrowhead (IV-a). It is thus possible that these two types are the same type, which, however, in the manufacturing process has ended up with two different visual expressions.

Type IX: Transverse arrowhead with shaft-retouche. This type is only known in MNV.

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RESEARCH ARTICLE

Domestic cats (*Felis catus*) in Denmark have increased significantly in size since the Viking Age

Julie Bitz-Thorsen [a] and Anne Birgitte Gotfredsen [b]

[a]Norwegian College of Fishery Science, UiT – The Arctic University of Norway, Tromsø, Norway; [b]Zoological Museum, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

ABSTRACT
The earliest finds of domestic cat in Denmark date back to the Roman Iron Age (c. 1–375 AD). Initially, cats occurred sparsely and only from the Viking Age (c. 850–1050 AD) did they become more frequent in numbers, though primarily in urban contexts and in connection with fur production. In medieval times, cats became beasts of pest control in rural settlements, manorial estates as well as in the expanding towns, where large and numerous refuse heaps attracted various rodents. To investigate size trends over time of the domestic cat (*Felis catus*) in Denmark, bone measurements and statistical analyses were performed on archaeological and modern material. Domestic cats were found to increase significantly in size over time since the Viking Age. Limb bones and mandibles exhibited the most significant change in increase (up to 16%), as compared to modern female cats, and tooth size the least (c. 5.5%). The most plausible explanations for such a size increase were improved living conditions caused by increased food availability and a possible shift in human usage of the cats, from a rat and mice captor to a well-fed and well-cared pet. Despite the observed increase in size, domestic cats have kept many osteological features indistinguishable from their wild progenitor.

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Introduction

Domestication of cats

All domestic cats (*Felis catus)* descent from the wildcat (*Felis silvestris*) populations widely distributed over Europe, Africa and Southwest Asia (Kitchener 1991, Clutton-Brock 1999). The domestic cat we know today stems from the Middle East subspecies *Felis silvestris lybica* (Clutton-Brock 1999, Driscoll *et al.* 2007). One of the earliest probable finds of a domestic cat has been documented from Cyprus dated to approx. 7,500 BC (Vigne *et al.* 2004). Since there are no fossil records of wildcats from Cyprus, the cat must have been brought to the island intentionally by people (Vigne *et al.* 2004, Clutton-Brock 2012). It was a young cat buried together with a human, indicating a special bond or relation between humans and cats during the early Neolithic (Vigne *et al.* 2004, Driscoll *et al.* 2007). Furthermore, in ancient Egypt, around 3700 BC, we find archaeological records of mummified cats suggesting a close cat-human relationship (Van Neer *et al.* 2014). Zooarchaeological evidence points to a commensal relationship between humans and cats lasting thousands of years before humans exerted substantial influence on their breeding (Clutton-Brock 1999, Vigne *et al.* 2004, Van Neer *et al.* 2014). This prolonged human animal relationship without leaving domestication traits on the cats was termed 'commensalisation' (e.g. Vigne 2015), explained as the mutual benefits for the cats having increased food availability as formed by the many mice attracted by stored cereals and on the other hand people benefitting from this new pest control, eventually leading to domestication (Clutton-Brock 1999, Vigne *et al.* 2004, Van Neer *et al.* 2014, Vigne 2015).

The spread of domestic cat to Europe followed ancient land and maritime trading routes and Ottoni *et al.* (2017) showed that cats started to spread across the Mediterranean as early as 1700 BC and the spread was suggested to be due to their increasing popularity and usefulness on ships infested with rodents (Faure and Kitchener 2009). Between 400 and 1200 AD, ancient Egyptian cats became

CONTACT Julie Bitz-Thorsen julie.bitz-thorsen@uit.no Norwegian College of Fishery Science, UiT – The Arctic University of Norway, Tromsø, Norway
Both authors contributed equally to the work on this article.

substantially more frequent in the rest of Europe (Ottoni *et al.* 2017) and depictions of cats in domestic contexts are found on Greek artefacts from as early as the end of the sixth century BC (Faure and Kitchener 2009). In medieval times it was compulsory for seafarers to have cats on-board their ships (Johansson and Hüster 1987), leading to their dispersal across trading and warfare routes. Spread of the black rat (*Rattus rattus*) and house mouse (*Mus musculus*) by sea routes (Engels 2001, O'Connor 2008, Jones *et al.* 2013) encouraged cat dispersal for the control of these new pests (Engels 2001, Jones *et al.* 2013). Besides using cats as pest controls, the expansion of the domestic cat may also have been for cultural usage, which in Medieval Europe included trade of domestic cat pelts to be used as clothing (Ewing 1981).

Domestic cats in Denmark

During the Roman Iron Age (c. 1–375 AD), new pets were introduced to Denmark. Among these, and although rare, was the domestic cat (Hatting 1990, 2004, Damm 2000, Faure and Kitchener 2009), which easily found its place near the farms and in the open country. The oldest genuine find of a domestic cat derives from a cremation grave in Kastrup, Southern Jutland (ZMK 153/1971) dated to the Late Roman Iron Age c. 200 AD (Aaris-Sørensen 1998). The find consists of a single astragalus with visible cut marks together with burned bones from an adult person. Together with the cat bone a sheep astragalus with a drilled perforation was found – both astragali have undoubtedly been used as amulets (Aaris-Sørensen 1998). At this point, the wildcat populations were barely present in Denmark anymore (Aaris-Sørensen 1998). The latest occurrence of a wildcat in Denmark was from the site Næsbyholm Storskov (ZMK 106/1965) near Sorø, Zealand dated to the Early Roman Iron Age (c. 1–100 AD) (Damm 2000, Hatting 2004, Møhl 2010).

Through the Roman Iron Age and early part of the Viking Age the domestic cat was a sparsely distributed animal, represented by very few bones among a vast amount of animal bones, usually also by bone fragments in too poor conditions to measure. However, there are some sites with cat remains (besides those used in the study). Lundeborg, Svendborg (ZMK 78/1986, Hatting 1994) and Seden Syd, Odense (ZMK 238/2005, Kveiborg 2007b) dated to the Late Roman Iron Age c. 200–375 AD, Dankirke, Ribe (ZMK 125/1968) dated to c. 500 AD (Hatting 1991), Ribe (ZMK 120/1974, Hatting 1991) dated to c. 700 AD, and finally Posthuset, Ribe (ZMK 6/1992, Enghoff 2006) dated to c. 725–760 AD (see Table 1). Dental measurements on the Dankirke and Ribe specimens documented that the cats were the domesticated form (Hatting 1991).

During the Viking Age, it was common to trade domestic cat pelts for use in clothing throughout Europe (Ewing 1981) and they were highly priced (Damm 2000, Faure and Kitchener 2009). In Denmark, we find examples of what could possibly be cat fur production sites. For instance, in a pit from Overgade, Odense, Denmark, a large number (n = 1783) of cat bones comprising 83.5% of the mammal bones of the pit, providing a MNI of nearly 70 based on calvaria, exhibited clear signs of having been killed for their pelts (Hatting 1990, 2004). Hatting's conclusions were due to i) clear cut marks around the snout (upper jaw, *maxillare* and nose, *nasale* and lower jaws, *mandibula*) on the majority of skull bones and ii) evidence on the cats' neck bones indicating that the cats were killed by a powerful jerk when the head was pulled from the body (Hatting 1990, p. 184). All skeletal elements of the cats were present in the Odense pit but in varying numbers with skulls being the predominant element; some bones were disarticulated and some formed complete skeletons. Furthermore, the age and size distribution, with most of the cats having been killed at an age just less than one year and the remainder (adults) presumed female cats, led Hatting to suggest that the adult females were part of a breeding stock (Hatting 1990, p. 192). Although the relative abundance of cat bones found at Viborg Søndersø was smaller than at Odense, these cats exhibited skinning traces like those of the Odense cats (Hatting 1998). Likewise, during the Middle Ages recently excavated finds further support to the possible existence of skin production farms and evidence of specialized pelt production. A pit from Læderstræde, Roskilde dated to c. 1200–1400 AD revealed a large number of cat bones (n = 434), comprising c. 19% of the domesticates of the find, showing that the cats had age patterns, skeletal element representation and

Table 1. An overview of samples used in the present study compared to a selection of contemporaneous Danish sites. The number (NISP = number of identified specimens) of domesticates (dog, cat, pig, cattle, sheep/goat, and horse), the number of cats and the relative frequency of cat remains are given. The sites and contexts are chronologically arranged.

Site	Dating	NISP (domesticates)	NISP (cats)	% cat bones	Collection no.	Reference
10. Almosen, Tyvelse[a]	1100-500 BC	380	1	<0.1	Z.M.K. 48/1992	*det.* G. Nyegaard 1992
"Jernkatten"[a]	500 BC – 375 AD	NI	6	-	Z.M.K. 81/0000	*det.* U. Møhl
2. Gyngstruplund Nordøst	c. 0-200 AD	244	1	<1	Z.M.K. 136/2005	Kveiborg 2007a
Lundeborg, Svendborg	c. 200-375 AD	7,210	4	<0.1	Z.M.K. 78/1986	Hatting 1994
Seden Syd, Odense	c. 200-375 AD	3,624	3	<0.1	Z.M.K. 238/2005	Kveiborg 2007b
Dankirke, Ribe[B]	c. 500 AD	NI	2	-	Z.M.K. 125/1968	Hatting 1991
Ribe, Ribe Excavations 1970-76	c. 700 AD	5,995	7	<1	Z.M.K. 120/1974	Hatting 1991
Posthuset, Ribe	c. 725-760 AD	1,078	5	<1	Z.M.K. 6/1992	Enghoff 2006
11. Strøby Toftegård	650-1075 AD	3,074	1	<1	Z.M.K. 53/1996	*det.* A.B. Gotfredsen
3. Overgade, Odense[C]	1070 ± 100 AD	2136	1783	83.5	Z.M.K. 142/1970	Hatting 1990
1. Viborg Søndersø	1000-1300 AD	10,992	166	1.5	Z.M.K. 14/1998	Hatting 1998
12. Vejleby, Lolland[D]	1000 – 1300 AD	928	6	0.65	Z.M.K. 109/1971	*det.* U. Møhl
8. Kongens Nytorv Early	1050-1550 AD	9,487	247	2.6	Z.M.K. 19/2011	Enghoff 2015, Steineke & Jensen 2017
6. Næsholm Slot[E]	1240 -1340 AD	2,494	23	0.9	Z.M.K. 140/1941	Møhl 1961
7. Læderstræde, Roskilde[C]	1200-1400 AD	2251	434	19.3	Z.M.K. 61/2015	Hansen 2017
4. Svendborg, Matr. nr. 607a	1200-1500 AD	16,264	251	1.5	Z.M.K. 154/1977	*det.* Tove Hatting
5. Ørkild Borg	1200 -1534 AD	5,288	109	2.1	Z.M.K. 127/1978	Jansen et al. 1988
9. Kongens Nytorv Late	1550-1660 AD	7,481	466	6.2	Z.M.K. 19/2011	Enghoff 2015, Steineke & Jensen 2017

[a]Designates that the find is a sacrificial bog deposit.
[b]The Dankirke bone material was not quantified, only the cat bones were counted and presented in (Hatting 1991).
[c]Designates that the assemblage derives from one single context a pit.
[d]The measured bones of Z.M.K. 113/1962 derived from a cemetery, therefore the NISP counts were taken from a contemporaneous settlement at Vejleby Z.M.K. 109/1971.
[e]The number of domesticates were estimated from Møhl (1961) who did not publish the exact NISP counts for the most abundant species.
NI = No Information

skinning traces very similar to those of cats from the Odense pit (Hansen 2017).

During the Middle Age, cat remains were more commonly found in refuse layers, and in greater numbers (Møhl 1971), together with bones of other medieval domestic livestock (Hatting 1990, 1998, 2004). The earliest known find of black rat in Denmark is from the Viking Age (Rantzau 2015). The fact that subfossil occurrences of black rats in Denmark were from locations near the coast suggests that seafaring vessels were the dispersal vectors of rats (Rantzau 2015) and domestic cats probably followed the same dispersal pattern. The expanding towns resulted in great amounts of consumption waste deposited, which may very likely have been an important food source for the cats, directly as well as indirectly by attracting rodents especially mice and rats.

Measurable implications of domestication

The domestic cat is one of the world's most numerous pets (Driscoll *et al.* 2009), yet it is probably the least domesticated. The cat still has its hunting instinct, is territorial and generally solitary and it also lacks so-called neotenous characteristics (i.e. retention of a juvenile characters seen in other domesticated animals) (Clutton-Brock 1999). There are some modern cat breeds that exhibit phenotypic variation, but overall it is nowhere near the variation seen in dogs. It has been argued, and is also well accepted, that mammals subject to domestication, although not uniformly present in all species, undergo a decrease in body size (Tchernov 1984, Grigson 1989, Meadow 1989, Tchernov and Horwitz 1991), reduction in cranial capacity, shortening of the facial region of the skull, including jaws and sometimes associated with reduction in size of cheek teeth, and reduced sexual dimorphism (Tchernov and Horwitz 1991, Clutton-Brock 1999). These morphological changes appear to hold true for most mammals, e.g. sheep and goat (Zohary *et al.* 1991), cattle (Grigson 1969, Tchernov and Horwitz 1991), pigs and dogs (Davis and Valla 1978, Tchernov and Horwitz 1991, Clutton-Brock 1999) and finally cats (Kratochvíl 1973, 1976, 1977, French *et al.* 1988, Clutton-Brock 1999). The domestic cat of northern Europe was from the very beginning reported to be small sized because its wild progenitor the subspecies *F. s. lybica* had a smaller body size than the *F. s. silvestris* (Johansson and Hüster 1987, p. 24). In present-day Denmark the zoogeography and size trends of the wildcat was studied by Damm (2000), whereas the domestic cat has never been subjected to systematic biometric studies. In this study we aim at exploring the phenotypic variation and possible size changes by conducting biometric analyses on remains of domestic cat from its first appearance in Denmark through the Middle Ages to present day.

Materials and methods

Archaeological material

The archaeological bone material available from the collections of the Zoological Museum, Natural History Museum of Denmark (NHMD) covers a wide range of time periods and localities in Denmark (Table 2, Figure 1). The material was sub-divided into six groups according to chronological period, although temporal overlaps could not be avoided. Group 1) Late Bronze Age, Group 2) Iron Age, Group 3) Viking Age, Group 4) Viking Age/Early Middle Age, Group 5) Middle Age and Group 6) Post Medieval Time.

The excavated material from Kongens Nytorv (ZMK 19/2011), Copenhagen, was temporally split into two: Kongens Nytorv Early (1050–1550 AD) and Kongens Nytorv Late (1550–1660 AD), and assigned to groups 5 and 6, respectively. Three assemblages, Odense (142/1970), Læderstræde (ZMK 61/2015) and Svendborg (ZMK 154/1977) originate from structures that may be characterized as fur production sites. In order to include medieval material from other contexts, we included two contemporaneous collections, Ørkild (ZMK 127/1988) and Næsholm (ZMK 104/1941), deriving from high-status settlements where cats served different purposes. The sample sizes of Ørkild and Næsholm were too small to allow for a pooling of high-status sites in a separate group. For groups 1 and 2, the museum collections consisted of very few specimens: Almosen (ZMK 48/1992) of one tibia only, Gyngstruplund Nordøst (ZMK 136/2005) also of one tibia, Strøby Toftegård (ZMK 53/1996) of one radius and the bog find 'Jernkatten' (ZMK 81/000) of a single individual comprising of both calvarium and postcranial bones.

There is not much information about sexual dimorphism in domestic cats. Previous studies have focused on the wildcat, finding few measurements of the calvarium to differ significantly between sexes, although with some overlap (Kratochvíl 1976, Knospe 1988, Petrov *et al.* 1992). Sex identification of the domestic cat, however, is limited to only a few morphometric characteristics on pelvis and mandible (Pitakarnnop *et al.* 2017). Pitakarnnop *et al.* (2017) generated an equation for parameters on pelves applicable with 97.3% accuracy. However, this analysis used measurements on complete pelves (left and right pelvic bones fused at the pelvic symphysis) which in archaeological material only on very rare occasions have been found. Pitakarnnop *et al.* (2017) also generated an equation from mandible measurements, but with only 64.9% accuracy. We therefore chose to omit assessing a sex ratio of the archaeological material and instead assumed both sexes to be represented in the material.

Table 2. An overview of archaeological collections and modern material of domestic cats from Denmark dating from 1100 BC to the present time. Groups designate the grouping for the statistical analyses.

Site no.	Site	Time Period	Dating	Collection no.	Reference	Group
10	Almosen*, Tyvelse	Late Bronze Age	1100-500 BC	Z.M.K. 48/1992	*det.* G. Nyegaard 1992	1
-	"Jernkatten"$^{\Delta}$, Bog find	Pre Roman – Roman Iron Age	500 BC - 375 AD	Z.M.K. 81/0000	*det.* U. Møhl	2
2	Gynstruplund Nordøst	Early Roman Iron Age	1-150 AD	Z.M.K. 136/2005	Kveiborg 2007a	2
11	Strøby Toftegård	Germanic Iron Age/Viking Age	650-1050 AD	Z.M.K. 53/1996	*det.* A.B. Gotfredsen	2
3	Overgade, Odense	Viking Age	1070 ± 100 AD	Z.M.K. 142/1970	Hatting 1990	3
1	Viborg Søndersø	Viking Age/Early Middle Age	1000-1300 AD	Z.M.K. 14/1988	Hatting 1998	4
12	Vejleby, Lolland	Viking Age/Early Middle Age	1000-1300 AD	Z.M.K. 113/1962	*det.* U. Møhl	4
7	Læderstræde 4, Roskilde	Middle Age	1200-1400 AD	Z.M.K. 61/2015	Hansen 2017	5
4	Svendborg	Middle Age	1200-1500 AD	Z.M.K. 154/1977	*det.* T. Hatting	5
5	Ørkild Borg	Middle Age	1200 - 1534 AD	Z.M.K. 127/1978	Jansen et al. 1988	5
6	Næsholmd Slot	Middle Age	1240 - 1340 AD	Z.M.K. 104/1941	Møhl 1961	5
8	Kongens Nytorv Early	Middle Age	1050 - 1550 AD	Z.M.K. 19/2011	Steineke and Jensen 2017	5
9	Kongens Nytorv Late	Post Medieval Time	1550-1660 AD	Z.M.K. 19/2011	Steineke and Jensen 2017	6
	Modern females	Present	1870 – present			7
	Modern unknown sex	Present	1870 – present			8
	Modern males	Present	1870 – present			9

*Nyegaard (1998) noted that the cat bone was of a slightly different coloration than the remaining bones of the find hence there is a risk that the bone may be an intrusion.

$^{\Delta}$ There is little information on the "Jernkatten" bog find regarding provenance and exact dating within the Iron Age.

Figure 1. Map showing the locations of sites providing cat remains for the biometric analysis. Numbers are referring to numbers in Table 2. Drawing: Julie Bitz-Thorsen modified from Knud Rosenlund.

Modern reference material

To investigate the size trends of domestic cat through time, the archaeological material was compared to modern material of domestic cats (1870–present). To account for sexual dimorphism in cats, the modern material had to be divided into three groups: Group 7) Females, Group 8) Unknown sex and Group 9) Males. None of the modern cats represent modern special breeds such as Angora or Siamese because selective breeding has caused these particular breeds to have different proportions of the calvarium and possibly also post cranial discrepancies compared to modern common breeds (e.g. Hatting 1990). Table 2 provides an overview of the nine groups of all the material.

Selection and measurements

To avoid duplicate measurements of the same individual, only the bones from the right side of the animal were used. For the Kongens Nytorv material bones from the left side were measured when no corresponding right-side bones had been found from the context in question. Further, only adult cats were used – or rather, immature or juvenile individuals with unfused epiphyses and/or a porous rough bone surface were omitted. For the limb bones, the individual is defined as adult when both epiphyses are fused to the diaphysis but still included if the fusion lines are visible (O'Connor 2008). For the mandible, it is difficult to distinguish the adult cats. An individual was included when the permanent dentition was present (see Hatting 1990, Damm 2000), and additionally for the modern individuals, only included when the limb bones belonging to the specimen in question were determined as adults. Measurements of the bones were performed according to the standards proposed by von den Driesch (1976). An electronic slide calliper with 0.01 mm accuracy was used. The bone measurements on cat remains of Odense and Svendborg (Matr. nr. 607a) were extracted from Hatting

(1990). The bone measurements selected for this study for the limb bones were: greatest length (GL) and smallest breadth of the diaphysis (SD), and for the mandible: total length of mandible from the condyle process – infradentale (TL), height of mandible between P_4 and M_1 (HM (P4)), length of the cheek tooth row (CTR) P3-M1 and length of M_1 (M1).

Statistical analyses

A Kolmogorov-Smirnov Test was used to test the data for normal distribution and further a Tukey's outlier test was performed. None of the datasets of the measurements contained outliers that needed to be removed. For the statistical analysis, one-way ANOVAs were performed on eight bone and tooth measurements. See Table 3 for further details. Finally, *post hoc* Tukey-Kramer Multiple Comparison Tests were performed for pairwise analyses of the groups.

A linear model of the data used to calculate percentage of increase between groups was created from a selection of the data: groups 3–9. Groups 1 and 2 were excluded due to small sample size ($n \leq 2$). Hatting (1990) suggested that the adult individuals of the Odense material might solely be females. As this possibility could not be ruled out and since we did not assess the sex ratio of the archaeological material, we took the conservative approach to use only females of the modern material for comparison (Table 3). This means, that observed increases constitute the smallest possible differences between archaeological groups and modern material.

Results

For the statistical analyses, groups 1 and 2 could not be included in all analyses due to paucity of material. The statistical results are displayed in Table 3. The one-way ANOVA values for all measurements are significantly different between groups, ($p < 0.001$). From the linear model of GL of femur measurements, we estimate the percentage increase in size over time. We find an average increase of the limb bones of 16% between the Odense cats (group 3) and the modern females (group 7), and an increase of 4% between Post Medieval Time (group 6) and the modern females (group 7). For the mandible measurements, the average increase between the Odense Cats (group 3) and modern females (group 7) was also 16% and between Post Medieval Time (group 6) and modern females (group 7) 4%. The measurements to show the least increase are those of the teeth, CTR and M1. For M1, the increase between the Odense cats (group 3) and the modern females (group 7) is c. 5.5% and between Post Medieval Time (group 6) and the modern females (7) only 1.5%. Percentage increase for the other measurements can be found in Table 3 (see also Figure 2).

The multiple comparisons of femur length between groups are displayed in Figure 3 show that the size of domestic cats increased with time. The Viking Age and Middle Age groups together (a) and the Post Medieval Time and Females group together (b), which also groups with Unknown Sex and Roman Iron Age (c). Males group with 'Unknown sex' and Roman Iron Age (d). Group 4 is also included in group (b) but this could very

Table 3. Statistical analyses and calculations on bone measurements of Danish domestic cats: Kolmogorov-Smirnov Test for normal distribution, One-Way ANOVA and linear regression for eight bone measurements, and calculations of size increase between groups 3, 6 and 7.

Measurement	N	Kolmogorov-smirnov	One-Way ANOVA	a	b	R^2	y(3)	y(6)	y(7)	%Increase (group 3 vs. 7)	%Increase (group 6 vs. 7)
Humerus (GL)	50	D = 0.0731, p = 0.9340	$F_{7,42}$ = 18.509, p = 0.001	3.8863	69.820	0.7065	81.479	93.138	97.024	16.02%	4.00%
Radius (GL)	53	D = 0.0739, p = 0.9138	$F_{7,45}$ = 20.356, p = 0.001	3.5932	69.087	0.7039	79.867	90.646	94.239	15.25%	3.81%
Femur (GL)	64	D = 0.0881, p = 0.7030	$F_{7,56}$ = 22.225, p = 0.001	4.3319	76.129	0.7024	89.125	102.12	106.45	16.27%	4.06%
Tibia (GL)	65	D = 0.0725, p = 0.8596	$F_{8,56}$ = 18.579, p = 0.001	4.7457	78.248	0.6647	92.485	106.72	111.47	17.03%	4.26%
Mandible (TL)	94	D = 0.0971, p = 0.3377	$F_{7,86}$ = 43.738, p = 0.001	2.2866	45.932	0.7681	52.792	59.652	61.938	14.77%	3.69%
Mandible (HM(P4))	148	D = 0.0913, p = 0.1697	$F_{7,140}$ = 35.828, p = 0.001	0.4666	7.5117	0.5264	8.9115	10.311	10.778	17.32%	4.33%
Cheek tooth row (CTR)	126	D = 0.0725, p = 0.5211	$F_{7,118}$ = 16.514, p = 0.001	0.3376	16.596	0.4379	17.609	18.622	18.960	7.13%	1.78%
M1	141	D = 0.0580, p = 0.7306	$F_{7,133}$ = 9.1503, p = 0.001	0.0740	6.6816	0.0860	6.9036	7.1256	7.1996	4.11%	1.03%
Average Increase Limbs										**16.14%**	**4.03%**
Average Increase Mandible										**16.05%**	**4.01%**
Average Increase Teeth										**5.62%**	**1.41%**

Abbreviations: GL = Greatest length. TL = Total length of mandible from the condyle process – infradentale. HM(P4) = Height of mandible between P_4 and M_1. CTR = Length of the cheek tooth row. M1 = Length of M_1.
Group 3 = Odense (Viking Age), Group 6 = Post Medieval Time (1550–1660 AD) and Group 7 = Modern material (1870 – present), females.

likely reflect the small sample size (n = 3). The same trend is seen for the mandible measurements and teeth measurements but not as evident (Figure 4).

Figure 5 shows a plot of the breadth and length of tibia with all groups included. This plot also shows the natural overlap in size between groups that overlap in chronological time periods. The one measurement of group 1 Bronze Age falls between the Middle Age and Post Medieval period, and the two measurements of Group 2 Iron Age, falls within the range of the modern material.

Discussion

We find clear evidence of an increase in body size of the domestic cat from the Viking Age till today. Some of the groups, especially those from the Viking Age and Middle Age (groups 3–6), have broad and overlapping time periods hence some of the groups overlap chronologically. The Viking Age and Middle Age cats also overlap in their measurements. However, if we look at the pairwise comparison graph of femur length (Figure 3) we still see a gradual increase from the Viking age through the Middle Age. As previously stated it was not possible to divide the archaeological material according to sex. It was, however, evident from the size variation of cats from the Viking Age and medieval materials that both sexes were present. This means that the observed size increase is an absolute minimum increase and that the size increase was in effect larger.

An early medieval assemblage of domestic cats (n = 1030) from Haithabu, present-day Northern Germany, dated between the ninth and eleventh century, was examined by Johansson and Hüster (1987). The Haithabu domestic cats were shown to comprise both sexes and further to be significantly smaller than modern domestic cats (Johansson and Hüster 1987), and comparable in size to the Viking Age and medieval cats of the present analysis. O'Connor (2007) too found Viking Age/medieval cats to be smaller than modern domestic cats.

Figure 2. A selection of cat calvaria from the examined groups of this study. From the left to the right upper row: modern wildcat, MK689, Hungary, male; 'Jernkatten' (Group 2); Overgade, Odense (Group 3); Læderstræde 4, Roskilde (Group 5). From the left to the right lower row: Svendborg (Group 5); Næsholm (Group 5); female modern cat, K330 (Group 7); male modern cat, K362 (Group 9). Scale bar unit is 1 cm.

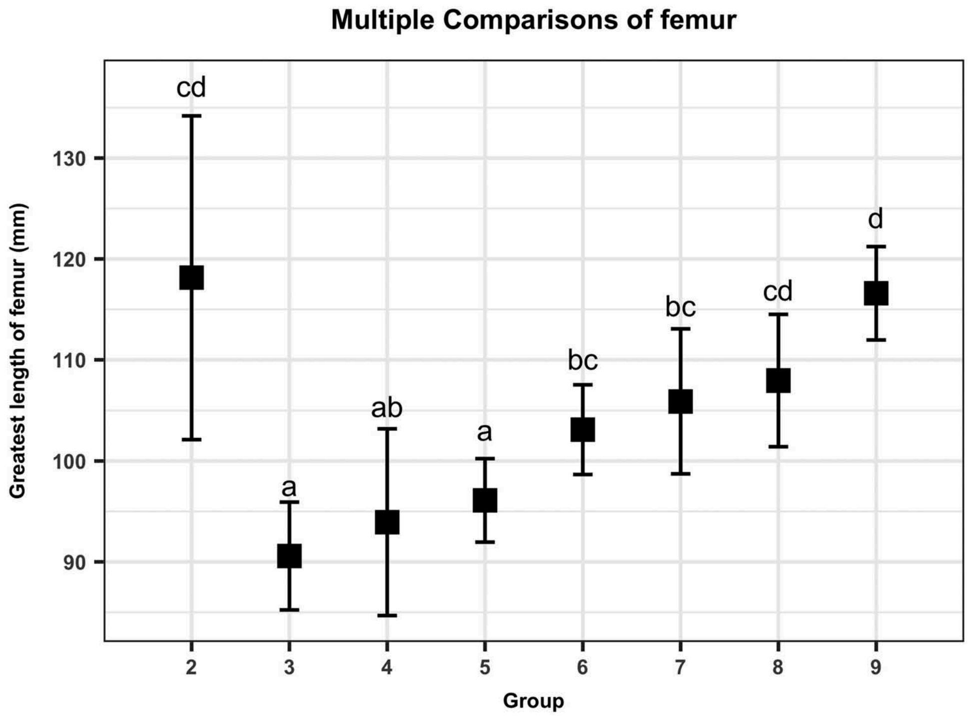

Figure 3. Plot showing the differences in femur length between chronological groups of domestic cats. This was done by multiple comparisons using Tukey's HSD. Boxes indicate the mean for each group and error bars indicate the 95% confidence interval. Means sharing a letter are not significantly different. Group 1: Late Bronze Age (*n* = 0), Group 2: Roman Iron Age (*n* = 1), Group 3: Viking Age (*n* = 9), Group 4: Viking Age/Early Middle Age (*n* = 3), Group 5: Middle Age (*n* = 15), Group 6: Post Medieval Time (*n* = 13), Group 7: Modern females (*n* = 5), Group 8: Modern unknown sex (*n* = 6) and Group 9: Modern males (*n* = 12).

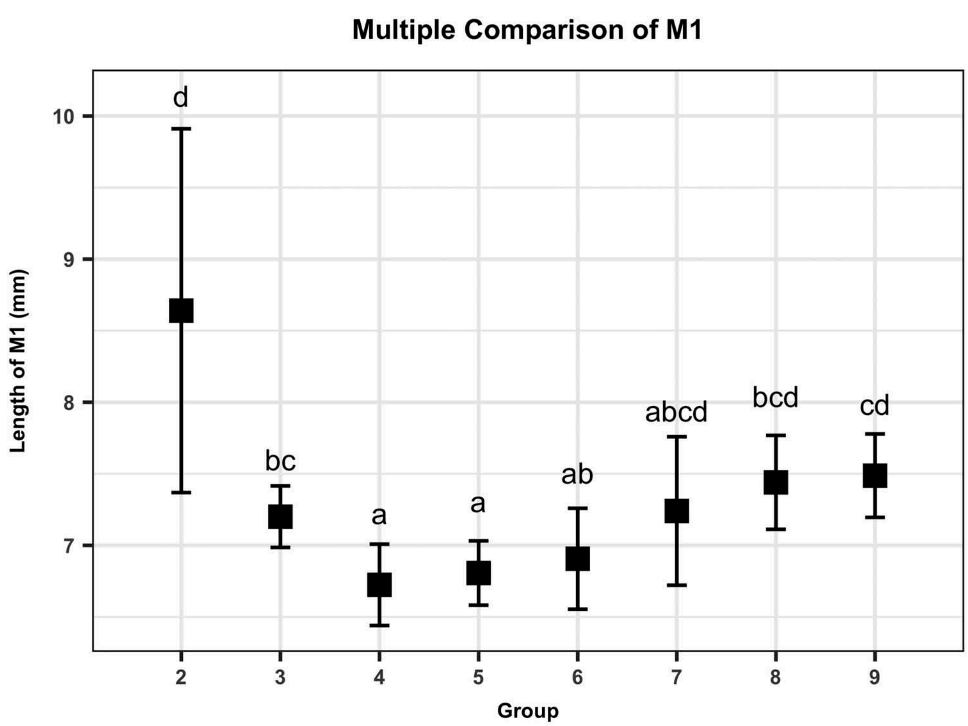

Figure 4. Plot showing the differences in M1 length between time groups of domestic cats. This was done by multiple comparisons using Tukey's HSD. Boxes indicate the mean for each group and error bars indicate the 95% confidence interval. Means sharing a letter are not significantly different. Group 1: Late Bronze Age (*n* = 0), Group 2: Roman Iron Age (*n* = 1), Group 3: Viking Age (*n* = 35), Group 4: Viking Age/Early Middle Age (*n* = 20), Group 5: Middle Age (*n* = 32), Group 6: Post Medieval Time (*n* = 13), Group 7: Modern females (*n* = 6), Group 8: Modern unknown sex (*n* = 15) and Group 9: Modern males (*n* = 19).

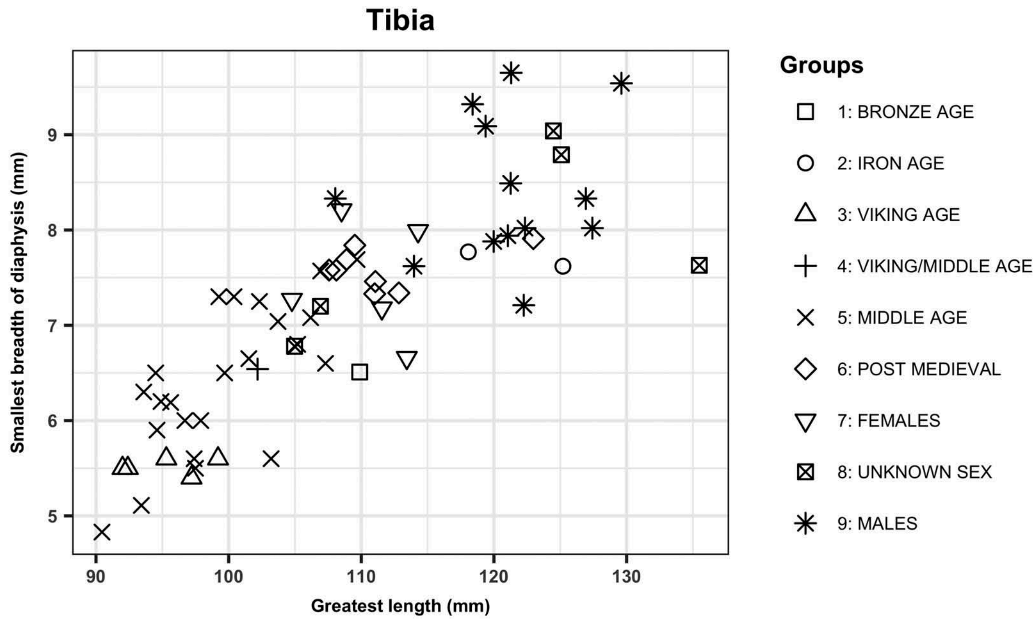

Figure 5. Plot showing the measurements of tibia, greatest length and smallest breadth of diaphysis, for the groups of domestic cats. Group 1: Late Bronze Age (n = 1), Group 2: Roman Iron Age (n = 2), Group 3: Viking Age (n = 5), Group 4: Viking Age/Early Middle Age (n = 1), Group 5: Middle Age (n = 23), Group 6: Post medieval time (n = 8), Group 7: Modern females (n = 5), Group 8: Modern unknown sex (n = 5) and Group 9: Modern males (n = 13).

As for the modern material, Group 8 Unknown sex will naturally also overlap with both Group 7 Females and Group 9 Males since we expect to have both sexes in this group. Despite some overlaps of the chronological groups, we do find a clear tendency for an increase in size of the species from the Viking Age through all groups compared with the modern material, for the mandibles as well as limb bones.

Furthermore, in Figure 3, Group 4 (Viking Age/Early Middle Age) overlaps with the Post Medieval Time and modern females. This could possibly reflect the small sample size of this group (n = 3). The earliest groups (1 and 2) comprise very few specimens but are remarkably large in comparison to the Viking Age/Early Middle Age individuals (Figure 5). A hypothesis to this observation could be that the earliest and indeed rare occurrences of the domestic cats in Denmark may represent high prestige gifts or goods imported for trade. At the early stage present-day Denmark did not have a domestic cat population. The Kastrup urn find of a domestic cat astragalus, which could unfortunately not be measured due to burning, was from a high-status burial site (see Jensen 2006). Further, the Almosen, Tyvelse, as well as the 'Jernkatten' finds were recovered from ritual bog deposits (U. Møhl in litt., Jørgensen 1992). The early domestic cats were special and valued creatures, which is very much in accordance with the status of early domestic chicken (*Gallus domesticus*) which were found as whole skeletons in ritual contexts or in graves (e.g. Gotfredsen 2017).

We do not find the same increase in size for the teeth as seen for limb bones and mandible measurements, especially regarding length of M1. Although we see significant statistical differences between groups, the length of CTR and M1 do not have as steep an increase over time as the limbs and mandibles (Table 3), which is also in accordance with the findings of both Hatting (1990) from Odense and Johansson and Hüster (1987) from Haithabu. Altogether, this means that the body of domestic cats has increased over time, but the teeth did not follow the same rate of size increase. Perhaps teeth evolve more conservatively or slowly than other skeletal elements. Teeth may have withstood reduction during the domestication process as proposed by Clutton-Brock (1999), Damm (2000) and Kratochvíl (1976) before body size started to increase again.

General changes in size are well documented for other carnivores (Davis and Valla 1978, Tchernov and Horwitz 1991, Clutton-Brock 1999). Most studies find an increase in body size.

These studies primarily concern changes taken place within the last century and seen in relation to global warming. A typical case is Bergmann's rule, which states that the same species is larger in cold areas (i.e. further to north) and smaller in warm areas (Bergmann 1847). This applies to the stone marten, *Martes foina*, in Denmark, which became smaller with rising temperatures (Tom-Tov *et al.* 2008) but also due to changes in dietary access. Size change in relation to food availability was found for the Eurasian lynx, *Lynx lynx*, in Sweden (Tom-Tov *et al.* 2009) with dwindling food availability resulting in smaller body sizes. In contrast, also an increase in body size may be due to changes in the environment, expanding agriculture and altered land use. This in turn could have led to an increase in food availability as in the case of the red fox, *Vulpes vulpes* and badger, *Meles meles*, in Denmark (Tom-Tov 2003, Tom-Tov *et al.* 2003). The amounts of waste and garbage produced by an increasing human population and urbanisation allow for certain species to fully rely on human waste as their primary food source (Tom-Tov 2003).

Plausible explanations for the observed increase in size of the domestic cat could be increased food availability, most likely from human waste, and/or perhaps intentional selection by humans as also suggested by Hatting (1990). Further, it has been shown that food availability during growth has a major effect on body size of animals (Tom-Tov *et al.* 2009). The cat underwent a change from a fur providing and rodent catching animal (Johansson and Hüster 1987, Hatting 1990, Engels 2001, O'Connor 2008) to the present-day pet invited indoor, fed and cared for. The implication is that cats would have had to use less energy to find food thereby enabling them to spend energy on body growth instead. Domestic cats in medieval Schleswig c. eleventh to fourteenth centuries exhibited a larger size and a larger size variability than the aforementioned early medieval Haithabu cats (Benecke 1994). Although no differentiation into cat breeds were observed, Benecke (1994, p. 353) still considered this to be a result of a more intensified cat household. A paleogenetic study by Ottoni *et al.* (2017) found no signs of selective breeding induced by humans prior to 1300 AD in Europe. Instead they document a new type of coat pattern to emerge which, however, did not become common until 1700 AD (Ottoni *et al.* 2017). The first appearance of more 'fancy breeds', such as Persian or Siamese, was around 1800 AD (Driscoll *et al.* 2009). Despite how far back in time we can trace the first occurrence of the domestic cat, this proves how remarkably little domestic cats have changed in appearance over time. The most familiar trait of pet domestication is the shorting of the snout, which gives the animals a more juvenile look the so-called neotenous traits and this is of course present for some cat races. However, most domestic cats still resemble their wild progenitor very much in the skeletal structure, in size and regarding specific muscle attachments on single skeletal elements. The domestic cat also displays a very independent nature like the wildcats – even though they are being fed they still go on successful hunts for birds and mice.

French *et al.* (1988) conducted a study of the Scottish wildcat, *Felis silvestris grampia*, domestic cat, and their hybrids. They found the wildcat material from the first half of the twentieth century (1901–1941) were genetically purer, whereas more recent individuals (1953–1978) had a significant hybrid proportion due to interbreeding between the two species. Hybridization may have been caused by the decreasing numbers of wildcats from around the 1940s and the destruction and division of suitable habitats (French *et al.* 1988, Damm 2000). Simultaneously, the encounter of domestic cats had steadily risen (French *et al.* 1988).

According to Hatting (2004) and Møhl (2010) there were no longer wildcats in Denmark by the Early Roman Iron Age (c. 1–100 AD). In addition to the aforementioned Kastrup cat dated to the Late Roman Iron Age (Aaris-Sørensen 1998) there are a few other occurrences of cat from the Late Roman Iron Age, for instance, Lundeborg, Svendborg (Hatting 1994) and Seden Syd, Odense (Kveiborg 2007b). Further, a recently excavated Iron Age site Postgården VI, Aalborg dated to c. 250 BC–100 AD, provided a cat bone (Østergaard 2016) which was directly radio carbon dated (S. Østergaard, pers. comm. 2016). However, it could not be ascertained that these cat remains were in fact from domestic cats. In addition, there are a few sites with possibly older specimens of the domestic cat but with very broad dates: Almosen (ZMK 48/1992) dating to the

Late Bronze Age (1100–500 BC) and the bog find 'Jernkatten' ('the Iron Cat') (ZMK 81/0000) that dates to the Iron Age (500 BC–375 AD).

One cat in our dataset, the 'Jernkatten' (Group 2), stands out. Its' measurements of postcranial bones fall within the range of the modern males of domestic cat – however, the measurements of the calvarium fall within the wildcat category according to measurements of Kratochvíl (1973, 1976) on Czechoslovakian wildcats. We find the mean value for wildcat length of M1 to be 8.5 mm (min = 7.4 mm, max = 9.8 mm) and for the domestic cat 7.00 mm (min = 5.7 mm, max = 8.0 mm) (Kratochvíl 1973, 1976). The length of the 'Jernkatten' M1 is 8.64 mm, falling within the wildcat range. According to Damm (2000, appendix F) the length of M1 of wildcats (n = 18) from the Ertebølle period to the late Neolithic/Early Bronze Age in Zealand had a mean value of 8.60 mm (min = 7.6 mm, max = 9.1 mm). Also, for the CTR, where the wildcat range is in average 21.70 mm (min = 19.4 mm, max = 24.0 mm) and for the domestic cat 18.41 mm (min = 16.6 mm, max = 20.5 mm) (Kratochvíl 1973, 1976). For the Danish wildcats on Zealand this measurement varied between 19.8 and 22.8 mm with a mean of 21.8 mm (n = 11) (Damm 2000, appendix F). Again, 'Jernkatten' falls within the wildcat range with its 21.35 mm of the CTR. Consequently, we suspect the 'Jernkatten' specimen might be a hybrid of the wildcat and the domestic cat. Petrov *et al.* (1992) also performed measurements on calvaria of Bulgarian wildcats. If we compare the measurements (both mandibles and teeth) then 'Jernkatten' falls within the range of a male wildcat. Thus, 'Jernkatten' has limb bone measurements falling within the range of our modern domestic male cats but skull and teeth having the size as those of wildcats.

If we assume that the Almosen cat is from the very late phase of the Late Bronze Age (500 BC) and that last appearance of the wildcat was in fact from around 100 AD, then there should have been at least 5–600 years of overlap between wildcat and domestic cat in Denmark and hence an opportunity for hybridization. However, it should be noted that the wildcat at this point was decreasing in number (Degerbøl 1933, Damm 2000) and that the domestic cat was still very rare (Hatting 1990, 2004). The late find of wildcat at Næsbyholm Storskov dated to the Early Roman Iron Age led Møhl (2010) to suggest a possible refugium for wildcats to have existed on central Zealand, Denmark, since another late wildcat from the Late Bronze Age locality Kornerup near Roskilde (Degerbøl 1933) have been found in the vicinity. Such a refugium in central Zealand would have made such an overlap in time plausible, at least in eastern Denmark. According to Damm (2000) there are no hybrids documented from Danish excavations so far. Considering the striking resemblance between the domestic and the wild form is it may never have been considered to investigate this aspect.

Conclusion

Present-day domestic cats of Denmark have increased significantly in size since the Late Viking Age. Archeological material found in the NHMD, Zoological Museum collections indicate that the earliest finds of domestic cats were from the Bronze Age/Iron Age. They were large in size, comparable to present day cats, and possibly represented rare and perhaps precious gifts or goods imported for trade. In contrast, the domestic cats of the Viking Age and Middle Age were much smaller, although gradually increasing in size than the early Iron Age cats and today's domestic cats. This may be due to the influx of small type domestic cats to the urban centres developing during that period.

For future studies, we would like to further investigate the early domestic cats including 'Jernkatten' and the possibility of hybridization. We would need more direct radio carbon dates on the last wildcats and the earliest domestic cats in order to fully shed light on the first occurrence of this late coming domesticate in Denmark and in combination with paleo genomic studies to investigate whether hybridization really happened.

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ORCID

Julie Bitz-Thorsen http://orcid.org/0000-0002-0815-5432

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RESEARCH ARTICLE

Asnæs Havnemark: a late Mesolithic Ertebølle coastal site in western Sjælland, Denmark

T Douglas Price[a], Kenneth Ritchie[b], Kurt J. Gron[c], Anne Birgitte Gebauer[d] and Jens Nielsen[e]

[a]Laboratory for Archaeological Chemistry, University of Wisconsin-Madison, Madison, WI, USA; [b]Moesgaard Museum, Højbjerg, Denmark; [c]Department of Archaeology, Durham University, Durham, UK; [d]National Museum, Prinsens Palæ, København K, Denmark; [e]Kalundborg Museum, Kalundborg, Denmark

ABSTRACT
Archaeological material was initially discovered in 1993, eroding from a small cliff on the north side of the peninsula of Asnæs near the town of Kalundborg in western Sjælland, Denmark. Ertebølle Excavations in 2007 exposed the Ertebøllwe cultural layer and obtained materials to describe the site and its contents before it was destroyed by the sea. The 22 m^2 of careful excavations exposed a terrestrial midden deposit and the late Mesolithic cultural layer which had been partially preserved under a raised beach ridge. The flint tools consist primarily of projectile points, flake axes, some distally concave truncated blade knives, and a very few scrapers. There were large numbers of well-preserved faunal remains including bone fishhooks and preforms, seal bones, large bird bones, and an extraordinary amount of fish bone. A quantity of pottery was recovered in the excavations as well, including both pointed-bottom vessels and oval lamps in different sizes from the late Mesolithic and several examples of what are probably Early Neolithic ceramics. The rich occupation layer with its diverse artifactual content, including a fragment of a human jaw, documents a sizable residential settlement on the north coast of the Asnæs peninsula.

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Introduction

The west Sjælland town of Kalundborg sits at the head of a lovely fjord that extends for more than 10 km between the two peninsulas of Røsnæs to the north and Asnæs to the south (Figure 1). The fjord is one of the deepest in eastern Denmark and has been attractive for human settlement for millennia. There are many prehistoric sites reported in the National Register (Sognebeskrivelse), more than 100 barrows from the Bronze Age, along with substantial remains from the Mesolithic and Neolithic on the peninsula of Asnæs. Asnæs is also well known as a source of very good flint raw material along the beaches, particularly at its west end.

The site of Asnæs Havnemark was discovered in 1993 eroding from a small cliff on the north side of the peninsula of Asnæs by amateur archaeologist Egon Iversen. A visit in 2005 confirmed the location of the site and the threat of continued erosion. The cultural layer contained flint, bone, and pottery diagnostic of the Ertebølle period. A radiocarbon date was obtained on a sample of bone and provided a date of 4330–4040 cal BC (details of ^{14}C dating are to be found in the Supplementary Material for this article). A heavy winter storm in 2006 further eroded the cliff face, exposed more material, and reiterated the danger that the site faced.

The site is named Asnæs Havnemark and its full designation in the Danish national catalog system (*Sognebeskrivelse*) is Årby sogn, Ars herred, Holbæk amt. Stednr. 030110-365 (KUAS j.nr) or Årby 365 for short. The site is located on a small high point along the north coast that remains as a slight bulge along the coastline (Figure 2). Excavations took place over five weeks in June and July 2007, intended to determine the extent of the site, expose the cultural layer where it was present, and obtain materials to describe the site and its contents before it was completely destroyed by the sea. The excavations exposed a terrestrial midden deposit and cultural layer that were protected and preserved under a raised

CONTACT T Douglas Price tdprice@wisc.edu Laboratory for Archaeological Chemistry, University of Wisconsin-Madison, Madison, WI, USA
Supplementary data for this article can be accessed here.

Figure 1. The location of the site of Asnæs Havnemark toward the tip of the peninsula of Asnæs near the town of Kalundborg, Denmark, looking east. The red arrow marks the site.

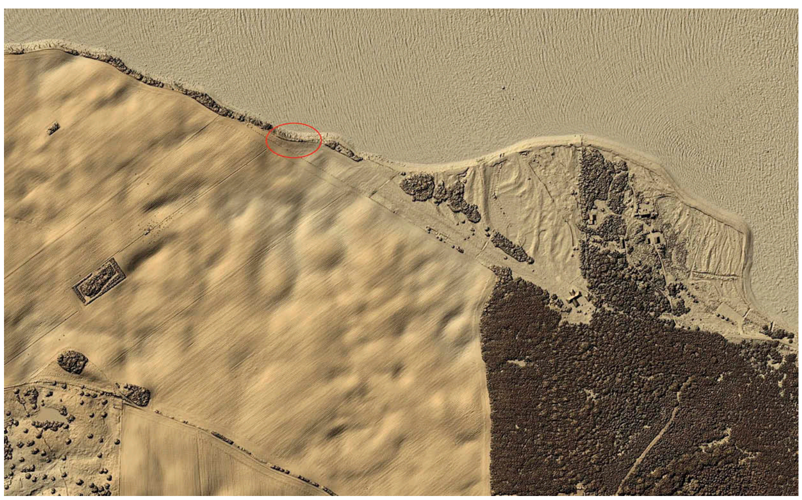

Figure 2. LIDAR image of the location of Asnæs Havnemark along the north coast of the Asnæs peninsula.

beach ridge along the coast, but largely destroyed elsewhere by older erosion and continuing beach ridge formation in this area. The site itself sits on top of beach ridge deposits and moraine clay and was subsequently covered by later beach ridge materials. Significant finds at the site included substantial quantities of fish bone and other faunal remains, fishhooks, and a number of medium size pot sherds from typically thick and heavily tempered Ertebølle ceramics. There were also some unexpected finds discussed below.

This study is intended to provide an introduction to the site and our findings and some interpretation of the activities that characterized this place during the Late Mesolithic. The major lesson that we learned from these excavations concerned the variation that defined the settlements and activities of Late Mesolithic groups.

The organization of this article follows standard practice. The location and setting of the site are provided, followed by some information on the excavations. Site stratigraphy and dating are discussed in the online Supplementary Information. Various categories of finds are then documented including features, flaked flint, pottery, fish and faunal remains, and worked bone. This study ends with some conclusions regarding the site and the implications of these findings for understanding the Mesolithic and the beginning of the Neolithic.

Location and setting

The landscape of the peninsula is dominated by the end moraine that is Asnæs and the sea which is gradually changing the shape of the peninsula. The sea erodes and builds along the coast – this process has been going on for millennia. The archaeological site of Asnæs Havnemark (Årby 365) is in fact in an active area of modern beach ridge construction. It appears that the Mesolithic settlement was directly on an ancient beach ridge in this area and that there were at least two episodes of occupation. The major focus of our project was the cultural layer that was exposed by wave erosion on the north coast of Asnæs, but we also uncovered a deeper settlement layer at the same place just on top of the moraine surface (described in more detail in the Supplementary Material).

In the early Holocene, the area of the Kalundborg fjord would likely have been dry land, a long valley out the fjord into the river that would become the Storebælt (the Great Belt, the waters connecting the Baltic and Kattegat between the islands of Funen and Sjælland). As sea levels rose during this period, the area was gradually inundated by a series of transgressions during the Atlantic and early Subboreal periods (e.g. Iversen 1937, Jessen 1937, Berglund 1971, Jacobsen 1981., 1983, Christensen 1994, 1995, Christensen *et al.* 1997). As the seas reached higher and the area flooded, a fjord was created in this narrows between Asnæs and Røsnæs. Maximum sea level in this area was probably +2.0–2.5 moh (asl) according to Mertz (1924) and our own observations at the site. The end of the Asnæs peninsula may have been inundated, leaving only a few higher, small islands for human occupation. The deep waters of the fjord and the sea of the Storebælt created a rich environment for Mesolithic hunter-gatherers. In all probability, large runs of eels, herring, and other species of fish passed along the coast of Asnæs, as is known to have been the case in historical and modern times (Pedersen 1997).

Excavations

We began field work at Asnæs Havnemark in early June of 2007 by relocating the cultural materials eroding from the sea cliff and orienting our site grid to that cliff. The site grid is 14° W of North. We laid out a 10 m^2 grid across the site and adjacent field to provide complete coverage for our excavations and finds. The site grid was given an arbitrary 100 N/100 E start. We used the southwest corner of excavation units for designation of meter squares. We placed a fixed point on the top of a deeply buried red wooden stake on the west side of a fence post at UTM coordinates 622680/6171480. The top of the stake was 3.188 m moh (asl). The elevation for the site was obtained by collating the results of two methods: an estimate from the mean tidal height and a surveyed transect from a geodetic fixed point at a residence on the peninsula. From the transect, we calculated an elevation of 3.187 which corresponded almost exactly with the sea level measurement and which we used as the site fixed point. The UTM coordinates for the site are 622601/6171516 Zone 3.

An elevation map was made of the part of the agricultural field in which we were located (Figure 3). We began a program of hammer coring to map subsurface layers, but this was largely unsuccessful because of all the stones in the beach ridge deposits and the difficulty of recognizing the cultural layer away from the coastline. We then turned to 1 m^2 test pits and excavated six tests south of the coastline in order to determine if the cultural layer continued to the south and what the depth and contents of this layer might be. The two southern most tests reached moraine subsoil within 30–40 cm indicating that there was no cultural layer and few artifacts on this surface. A test pit to the east also contained little cultural material, but a distinct series of beach ridge deposits. It is clear that to the east there are more beach deposits. Apparently beach ridges have been accumulating in this area for millennia. The analysis of the test pit contents suggested that the cultural layer was largely preserved to the north under the raised beach ridge. This was the material eroding along the sea cliff at Asnæs Havnemark.

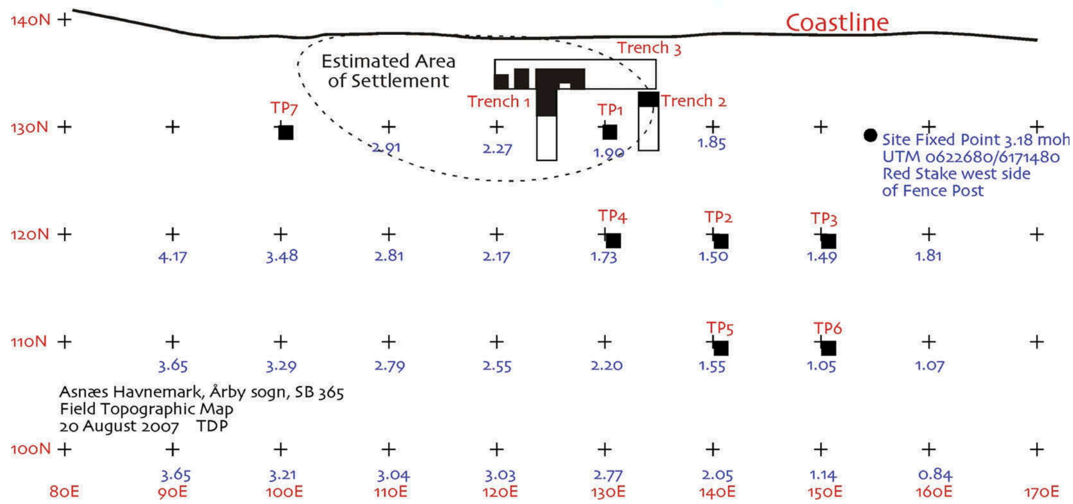

Figure 3. Schematic plan of excavations as Asnæs Havnemark including grid and elevations for the general area of the project.

After some consideration of the test pit data, we used a backhoe to open a north-south trench (Trench 1) near TP1 (Figure 4). This trench was 2 m wide as excavated by the machine. We then moved approximately 10 m east and excavated a second north-south trench (Trench 2) through the deposits with a similar width. Both trenches were begun to the north, as close as possible to the raised beach ridge that marks the border of the landscape here. Artifacts were collected and sections were drawn to record the finds and context, but we were still searching for the cultural layer which appeared in the north ends of Trenches 1 and 2. A subsequent excavation unit, Trench 3, was dug, running east-west across the Trench 1 and 2 units to uncover these deposits. This excavation by machine removed the raised beach ridge deposits along the coast that had protected the cultural layer from earlier erosion and destruction.

Careful and intensive excavation was undertaken in the cultural layer in Trench 3 and a total of 22 m^2 were excavated with water sieving of all deposits (Figure 5). Details of recovery methodology are given in the Supplementary Material.

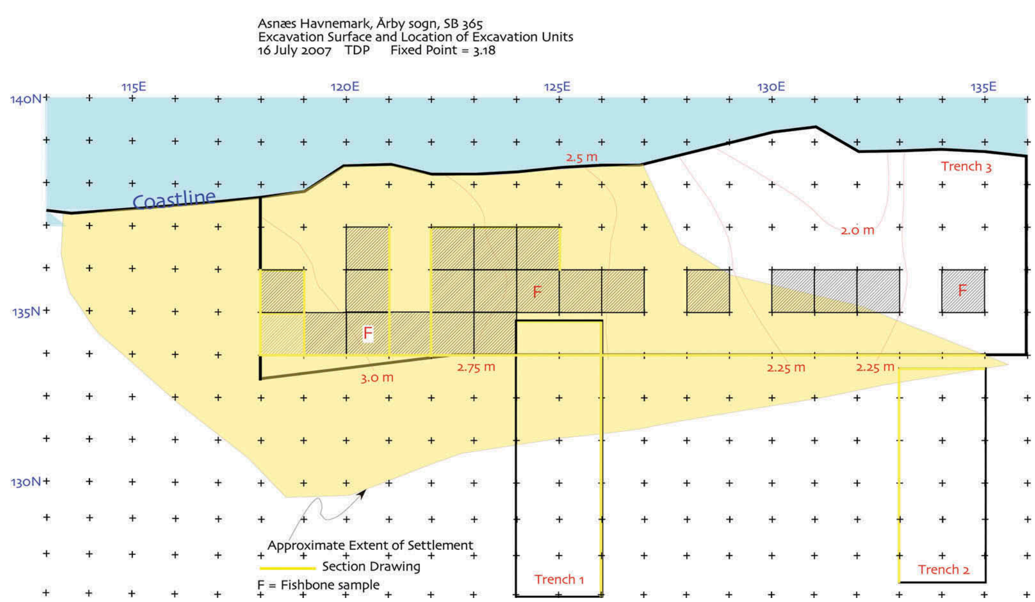

Figure 4. Plan of the excavation trenches at Asnæs Havnemark 2007 with shaded meter squares marking the area of intensive excavation.

Figure 5. Overview of excavations in Trench 3 looking east.

The excavated squares are shown in Figure 4. This strategy allowed us to obtain a longitudinal sample of the occupation horizon defined by the cultural layer. Sections were drawn in a number of the squares in order to record the stratigraphy and a longitudinal section of Trench 3 was drawn along the south wall of the trench. The estimated extent of the settlement, at least the area of remaining cultural layer, is indicated in Figure 4 by the yellow zone. Meticulous recovery of fish remains was focused on three squares as indicated in Figure 4, with some fish bones recovered from other squares as well.

The stratigraphy of the site documented a mix of terrestrial and marine deposits that comprise a base of ground moraine beneath a series of episodes of marine beach ridge formation along this coast. The radiocarbon dates in general confirm a Late Mesolithic date and fit with the archaeological material we recovered. There appear to be two groups of dates, an older pair around 4500 cal BC and a series of nine between 4300 and 4000 cal BC that date the primary cultural layer. Several of the dates appear to overlap the transition to the Neolithic around 4000 cal BC. Details of both site stratigraphy and radiocarbon dating can be found in the Supplementary Material for this article.

Features

A total of 10 features were designated in the excavations at Asnæs Havnemark. These features were photographed, drawn, cross-sectioned, and sampled. These features consisted either of a pit or a group of stones distinctive in either number or arrangement. Most of these small pits were generally nondescript. No large structures or graves were encountered in our excavations. There was a probable Bronze Age cooking pit uncovered at the west end of the excavations, perhaps part of a linear arrangement of such pits that are a characteristic feature of the Bronze Age. Evidence of at least three such pits were observed in our excavations.

Flint

There were more than 320 kg of flint artifacts excavated at the site, a total of 45,202 pieces. There were 4992 burned pieces, 31,747 flakes,

Figure 6. A distal concave truncated blade knife from Asnæs Havnemark (Årby 365).

2996 blades, of which approximately 1350 were produced using a hard hammer. There were 264 flake cores, 18 blade cores, 49 retouched flakes, 12 blade knives (Figure 6), 284 projectile points (Figure 7) and 33 point preforms, 110 flake axes (Figure 8), only 2 core axes neither of which were specialized, and 10 blade scrapers. Core axes, if that is what they are, were poorly made, typical of late Ertebølle. The flint tools consist primarily of projectile points, flake axes, some distal concave truncated blade knives, a very few scrapers, and a very few possible burins.

Flint from the site is all shapes and sizes and many shades – mostly gray, but there is also some brown material from the deeper cultural layer in Trench 2 that appears lighter than the

Figure 7. Selected projectile points from various contexts at Asnæs Havnemark (Årby 365).

Figure 8. Selected flake axes from Asnæs Havnemark (Årby 365).

rest, perhaps due to carbonate accumulation on the flint. Marine patination is minimal in most layers/squares. Very few hammer stones were noted during the excavation. There were many small flakes that indicate flint working at the site. Perhaps, the rough preparation of artifacts took place near the sources of flint elsewhere on the peninsula and only finer, finish flaking was done on site at Asnæs Havnemark. The Asnæs peninsula has lots of high-quality flint, particularly at the west end of the peninsula, so that availability is in part responsible for the massive amounts of flint present at the site. My (TDP) impression is that there were more blades at other sites we have excavated, but perhaps the quantity of flint débitage is so much greater here that it masks the importance of blades.

The flint generally is very fresh and sharp. At the same time, some flint materials from the Upper Beach Ridge deposit are wind polished, rolled with worn and fractured edges and slightly marine patinated. This material gives the appearance of having been in the water briefly and having rolled with other stone objects. This material is probably either from the primary occupation at Asnæs Havnemark that was eroded from former coastline to the north or from the earlier occupation horizon that is buried deeply in Trench 2. Some of the layers in some of the squares show a good bit of burning in the flint (and bone) which appears as lots of broken, burned, gray pieces along with much more color including a reddish tint to many pieces which must have been heated.

The projectile points (Figure 7) seem largely to fit Petersen's (1984) Stationsvej phase, but there are a number of exceptions suggesting that this chronological ordering of late Mesolithic projectile points does not work quite so well in western Zealand. Further study of the preforms for projectile points (blade segments vs. flakes and cortical pieces) and the flake axes (or 'Havnelevøkser' or small pointed base axes that are more common in the Early Neolithic) may help document connections with the Early Neolithic.

Ceramics

Ceramic vessels are seen in the later Ertebølle in southern Scandinavia after around 4800 cal BC. Early ceramics in northwestern Russia and Finland predate the ceramics in the Ertebølle and closely resemble them technologically (Hartz *et al.* 2012). It now seems clear that ceramic technology spread from east to west along several routes, one of which appears to have been across northern Eurasia (Hallgren 2008). Early Neolithic ceramics known as Funnel Beaker pottery appear to have their beginnings in the pottery of Central Europe, probably in the Michelsberg culture (Sørensen 2015) and replace Ertebølle ceramics after 4000 cal BC.

Traditional distinctions between the coarse Ertebølle and finer Early Neolithic pottery have focused on shape, construction and decoration. There are changes from a pointed bottom to a flat or slightly rounded bottom, from large grains of temper and thick walled pottery to a finer temper in thin walled vessels, and from limited decoration such as finger impressions around the rim to elaborate patterns made by cord marking and stick impressions around the neck and shoulder. Decoration is rare in the earliest phases of TRB, limited largely to the area below the rim. Decoration of the vessel body became more common and elaborate between 3500 and 3000 cal BC, often with numerous vertical incisions.

There are two forms in the Ertebølle, pots and lamps; the early TRB inventory contained seven forms of ceramic artifacts, including beakers, slender and broad bowls, flasks, lugged amphorae, spoons, and flat discs (Grohmann 2010). A wide range of sizes are known from both periods. Differences are seen in the use of pottery from the two periods; only TRB vessels were used in ritual depositions. While the general characteristics of these two traditions are quite different, it is another matter to consistently distinguish small body sherds, unless they have very diagnostic features.

The overwhelming part of the pottery from the site appears to belong to the Ertebølle pottery tradition. It was our sense that there was a good deal of pottery at Asnæs Havnemark compared to other Mesolithic sites we had excavated. There were ca. 300 sherds both collected and excavated from the site. However, the ceramic material was complex and often difficult to classify. Due to fragmentation, little diagnostic information was available on the shape and size of many of the vessels, and distinction between Ertebølle and TRB was often not possible. The description and analysis of the ceramic materials from Asnæs Havnemark was undertaken by Anne Birgitte Gebauer in consultation with Eva Koch, Anders Fischer, and Aikaterini Glykou (Pers. Comm. 2008). The pottery came from two sources. A small group of sherds was collected by Iversen who originally found the site and donated his collection to the museum. The Iversen collection, less than 20 sherds, includes only Ertebølle pottery. In addition to the pottery, two very small pieces of fired daub, one with stick impressions and one with some reddish color, were found in the cultural layer.

Figure 9. Round base of Ertebølle vessel. The label provides a scale, the site name, the meter square provenience, and the layer name.

A much larger group of sherds came from the 2007 excavations, approximately 275 pieces. The overwhelming part of the pottery from the site appears to belong to the Ertebølle tradition. Most of the pottery consists of body sherds with a thickness between 1.0 and 1.5 cm. Fragments of pointed bottoms were found in three excavation meter squares (Figure 9). An Ertebølle rim sherd with a diameter ca. 20 cm was found nearby. This rim sherd and one of the base fragments clearly came from larger vessels. Another sherd appears to be part of a small vessel with a diameter of only ca. 8 cm. Heat spalling typical of Ertebølle pottery was seen on the surface of several body sherds.

Fragments of Ertebølle clay lamps were found in three squares. One fragment had a grayish brown color on the outside, while the inside was covered with a black crust. Another lamp was represented by three rim sherds that fit together (this group measured 5.2 cm in width, 2.1 cm in height and was 1.0–1.1 cm thick) along with three body sherds. The rim was turned slightly inwards; finger impressions had been made in the smoothed edge of the rim. The third lamp fragment had a rather uneven surface and a clear bend in the side wall. The rim of this lamp fragment was turned inwards, the edge was smoothed and decorated with oblique strokes. The second and the third lamp fragments might be from the same piece?

Sherds clearly belonging to the Funnel Beaker tradition were found in a number of squares. This TRB classification was confirmed by Eva Koch and Anders Fischer. The sherds seem to represent a total of six or more different vessels of small to medium or unknown size. These fragments included a rim sherd with possible traces of decoration, a single vessel represented by three concave neck sherds with a total diameter ca. 24 cm, a sherd showing a clear, sharp angle between neck and belly (Figure 10), a number of body sherds and a flat bottom sherd, two rim sherds from a small vessel, possibly a funnel-neck beaker with rim diameter ca. 12 cm, and another rim sherd from a thin-walled vessel with impressions probably made with finger nails in the upper edge of the rim. In addition, there were two sherds with oblique coil construction that are TRB in origin, several sherds with worn edges that are generally less than 1 cm in thickness and appear to be Funnel Beaker tradition. There is a large convex belly sherd 3.4 × 2.7 cm in size as well as a concave neck sherd with oblique construction and traces of oblique imprints from rim decoration belonging to the TRB. The general absence of decoration fits well with an early TRB date for this pottery.

Some ceramics from the excavations were examined chemically in two different studies.

Figure 10. TRB pottery sherd, neck-belly transition. The label provides a scale, the site name, the meter square provenience, and the layer name.

One of these involved strontium isotope ratios and the other employed Instrumental Neutron Activation (INAA or NAA) to characterize some of the pottery. This aspect of our study is reported in the online Supplementary Material. In sum, the chemical composition of the Funnel Beaker pottery is indistinguishable from the Ertebølle ceramics.

Nutshell

Burned hazelnut shell was observed in the excavations and in the water-screened material from the site, but was not abundant and could not be systematically collected or counted. Its presence is simply noted here. Such burned nutshell has been reported as very common at some Mesolithic sites such as Smakkerup Huse in Denmark (e.g. Price and Gebauer 2005) and Duvensee in northern Germany (Bokelmann 2012) and must have been an important food source for Mesolithic groups (Holst 2010).

Molluscs

There was a substantial deposit of sea shells (molluscs) in the upper part of the upper cultural layer, composed largely of northern horse mussels (*Modiolus modiolus*), along with sea snails (*Littorina littorea)*, some cockles (*Cardium glaucum*), a few oysters (family Ostreidae), and a small predator snail (*Nassarium pygmaeus*). In places this appeared to have been part of a midden deposit, ca. 20 cm in thickness, with a distribution covering several tens of square meters. On the other hand, this may well be a natural deposit of shells accumulated on a beach, especially since horse mussels are usually found at a depth of 5 m or more below water surface, beyond ready human access (Comely 1978).

Bone

Preservation at the site of Asnæs Havnemark was very good and the presence of smaller bones as well as larger pieces is a testament to that fact. In addition to a few human remains, there was an exceptional amount of faunal material, including enormous quantities of fish bone. It is important to remember that only a small part of the larger settlement that was originally at this location has been preserved and only a small part of that has been excavated, so that the materials found represent only a tiny part of what would have been present. This material is described in some detail in the following paragraphs and in another publication by Ritchie *et al.* (2013a). The non-fish fauna study is part of a larger consideration of Mesolithic fauna at a series of sites in Denmark that originally was the PhD thesis of Kurt Gron (2013) at the University of Wisconsin-Madison and has also appeared in a recent publication (Gron 2015).

Human remains

A fragment of a human mandible with four teeth attached was excavated in unit 122 E135 N at the site and at least five other human teeth were recovered in the excavations. A few small pieces of human bone and tooth were also identified during the sorting and identification of the faunal remains. These materials were forwarded to the Anthropology collections associated with the Department of Forensic Medicine at the Panum Institute in Copenhagen. The presence of these human remains in the deposits at Asnæs Havnemark strongly suggests that there were Mesolithic burials at the site.

Faunal remains

The bone material from Asnæs Havnemark was separated by meter square and level during the excavation, bagged, and weighed. In addition, any special finds were noted. There were 131 bags of bone material from 104 different levels and units at the site, for a total of approximately 18 kg. In sum, the faunal material from Asnæs Havnemark consists of 50,005 identified bones. Of these, 47,760 (95.5%) are fish (Pisces), 2214 (4.4%) are mammals (Mammalia), 29 (0.1%) are birds (Aves), and 2 (<0.1) common toads (*Bufo bufo*). A total of 799 bones exhibited evidence of burning, including 728 fish bones.

The horizontal and vertical distribution of the faunal remains from the site shows remarkable uniformity. Three layers (culture, shell, and brown) constitute the majority of the vertical provenience information for the samples. The relative abundances of fish from those layers are quite similar, with codfish holding a dominant position of between ca. 75% and 87% of all identified specimens. Overall, all classes of faunal remains from the site show uniformity in their relative abundances across contexts and therefore it is reasonable to treat the assemblage as a unit, as there is remarkably little variability.

Mammals

The identified mammals are listed in Table 1. Identifications were made using the comparative collections at the Zoological Museum Copenhagen and the former Department of Geology and Geography at Copenhagen University. A wide range of species are represented. Numerous long bone fragments are present along with a variety of other bones. For the most part long bone is marrow fragmented. Several species were identified from only a few bones: red squirrel, otter, mouse, wildcat, and two voles. Fur-bearing animals are present in modest numbers. Otter and wildcat are rare, while fox, beaver and pine marten are not uncommon. Marine mammals – seal and porpoise – appear frequently among the faunal remains. Due to the fact that much of the seal material was not confidently identifiable to species owing in many cases to a lack of diagnostic skeletal elements (e.g. Storå and Ericsson 2004), seal specimens were assigned to a general class of 'seal'. This class includes the grey seal (*Halichoerus grypus*) and at least one member of the genus *Phoca*.

Table 1. Identified mammal remains.

Taxa	Common name	NISP	MNI
Capreolus capreolus	Roe deer	1493	19
Martes martes	Pine marten	65	5
Sus scrofa	Wild boar	141	4
Canis familiaris	Domestic dog	119	4
Erinaceus europaeus	Hedgehog	12	4
Cervus elaphus	Red deer	122	3
Vulpes vulpes	Fox	43	2
Castor fiber	Beaver	21	2
Sciurus vulgaris	Red squirrel	5	2
Lutra lutra	Otter	5	2
Apodemus flavicollis	Yellow-necked mouse	4	2
Phocoena phocoena	Harbor porpoise	14	1
Felis silvestris	Wildcat	2	1
Clethrionomys glareolus	Bank vole	1	1
Arvicola terrestris	Water vole	1	1
Phocidae	Seal	166	5
Totals		2214	58

The identification of mammalian species by skeletal element was tabulated by Gron (2013), along with Number of Identified Specimens (NISP) (after Payne 1975) and Minimum Number of Individual (MNI) statistics. The most common species is roe deer, comprising two-thirds (66.5%) of the identified material, deriving from at least 19 individuals (MNI = 19). The next most common individual taxon by NISP is wild boar, making up 6.3% of the assemblage and deriving from at a minimum four individuals (MNI = 4). However, taken together, seals (Phocidae), regardless of specific identification, comprise 7.4% of the identified material (MNI = 5). They are therefore the second most common mammalian prey. The only domesticated species is the dog, represented by at least four individuals and 5.3% of the assemblage.

A few specimens could be assigned ontogenetic age. One very porous roe deer calcaneus, too young to have even developed epiphyses, probably represents a newborn. Additionally, one wild boar specimen died at around 5 months of age on the basis of a recently erupted first mandibular molar, and

Table 2. Identified bird remains.

Taxa	Common Name	NISP	MNI
Penguinis impennis	Great auk	3	2
Cygnus olor	Mute swan	6	1
Pandion haliaetus	Osprey	4	1
Haliaeetus albicilla	White-tailed eagle	3	1
Aquila chrysaetos	Golden eagle	3	1
Gavia stellata	Red-throated loon	2	1
Podiceps grisegena	Red-necked grebe	2	1
Cygnus cygnus	Whooper swan	1	1
Larus argentatus	Herring gull	1	1
Mergus serrator	Red-breasted merganser	1	1
Podiceps cristatus	Great crested grebe	1	1
Turdus merula	Common blackbird	1	1
Turdus philomelos	Song thrush	1	1
Totals		29	14

another specimen died under a year of age on the basis of an unerupted second mandibular molar (Matschke 1967). Additionally, the cervical vertebral fusion of a harbor porpoise specimen indicates an animal of at least six years of age (Galatius and Kinze 2003).

In all, the sample cannot provide a mortality profile for any single species at the site although qualitatively, roe deer are represented by animals of multiple ages and therefore there probably was no clear focus on a particular age class indicative of a more specialized procurement strategy (e.g. Richter and Noe-Nygaard 2003).

The preponderance of roe deer in the material is notable, comprising almost two-thirds of the mammalian faunal remains. Body-part representational data indicate that the deer were not butchered elsewhere or selectively transported (Gron 2015) to the site, an assessment supported by the rather tight distribution of isotopic values (Ritchie *et al.* 2013) which indicate that these roe deer lived in extremely similar, if not the same, habitats. Despite their high representation in the assemblage however, roe deer were not necessarily the most important species in terms of subsistence. They rarely exceed 25 kg in body weight (Fruziński *et al.* 1982), so multiple roe deer are needed even to approximate the equivalent of one red deer.

There are a large number of seal remains and extensive cutmarks on several elements which indicate their utility to the hunters. The location of the site on this peninsula likely explains this as seals generally prefer secluded locations when they haul out (Riedman 1990). The seals may therefore have been clubbed while on land at a haul out location near the site, although hunting with harpoons from boats may have occurred as well.

The location on the Asnæs peninsula may also explain the rather lower numbers of red deer at the site relative to other Ertebølle sites (Møhl 1971; Skaarup 1973; Noe-Nygaard 1995; Gotfredsen 1998; Price and Gebauer 2005; Enghoff 2011), as limited land area may have restricted the numbers of such a large animal (Geist 1998; Kamler *et al.* 2008). The location would have less affected the abundance of the much smaller roe deer, a species that often lives at higher population densities (Gill *et al.* 1996, Kamler *et al.* 2008).

Birds

Bones from a variety of birds are present as well, especially long bones from large birds that appear to have been used in the production of fish hooks. Thirteen species of birds were identified among the avian remains, listed in Table 2. The presence of each species of bird is determined by the find of single or only a few skeletal elements. The birds can be characterized as divers, waterfowl, or birds of prey. A number of these are large birds including the great auk, swan, and eagle. The presence of the great auk (*Pinguinus impennis*) was of interest because this flightless bird, standing approximately 90 cm tall and weighing ca. 5 kg, became extinct in the mid-nineteenth century. Several examples of third phalanges (talons) from birds of prey were also recorded in the faunal remains. Birds probably would have been hunted with nets or bow-and-arrow, likely taken either as a source of meat (waterfowl) or in the case of birds of prey, to obtain feathers for fletching or for ornamentation, or to use the bone for other specialized purposes (Clark 1948).

Isotopic analyses

Bone collagen carbon and nitrogen isotope analyses of the faunal remains were undertaken (Ritchie *et al.* 2013). The focus of the isotopic studies was on the bones of wild animals and domestic dogs from the site in order to determine the environments from which the wild animals were hunted, using dogs as a proxy for human diet (Clutton-Brock and Noe-Nygaard 1990; Fischer *et al.* 2007; Noe-Nygaard 1988; but see Eriksson and Zagorska 2003). Results are indicated in Table 3.

All wild animals show values that are within normal ranges for southern Scandinavia (Fischer

Table 3. Stable isotopes of carbon and nitrogen from Asnæs Havnemark (from Gron 2015).

Number	Species	Lab #	%C	%N	C:N	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
AH24-49	*Capreolus capreolus*	258926	21.78	7.2	3.53	−23.0	4.8
AH40-19	*Capreolus capreolus*	268260	16.41	5.24	3.66	−22.9	5.5
AH74-15	*Capreolus capreolus*	268261	18.45	5.82	3.70	−23.1	5.9
AH70-14	*Capreolus capreolus*	268262	20.07	6.58	3.56	−22.8	5.8
AH73-16	*Sus scrofa*	268266	17.24	5.74	3.50	−20.9	5.2
AH-84–1	*Sus scrofa*	284462	35.46	12.70	3.26	−20.9	5.1
AH70-20	*Phoca/ Halichoerus*	268269	18.88	6.37	3.46	−9.56	14.2
AH85-4	*Canis familiaris*	268272	15.06	4.88	3.60	−11.9	10.1
AH83-10	*Canis familiaris*	268273	14.30	4.60	3.63	−13.2	11.89

et al. 2007). The roe deer show highly consistent values, indicative of an herbivorous diet in a very similar, and probably forested environment (Gron and Rowley-Conwy 2017). Given the limited width of the Asnæs peninsula, this may indicate a largely forested environment in the Mesolithic if the deer were hunted nearby. The wild boar have higher $\delta^{13}C$ values than the deer, but not higher $\delta^{15}N$. While omnivory cannot be ruled out, this is more likely due to their browsing in more open environments such as open grasslands, feeding in which will elevate $\delta^{13}C$ values (Gron and Rowley-Conwy 2017). A seal specimen, identified as a grey seal, has much higher $\delta^{13}C$ and $\delta^{15}N$ values, as is expected for a marine carnivore. The dogs' values indicate they were eating an almost entirely marine diet, similar to other Mesolithic dogs from Denmark (Fischer *et al.* 2007). It is in this context that the aggregate faunal remains need be understood, and in particular the fish.

Fish

A substantial part of the effort of our excavations and analysis involved the fish remains at Asnæs Havnemark, as it was clear that this was a large and important component of the site deposits. Eventually, these materials became a focus of a PhD thesis at the University of Wisconsin-Madison (Ritchie 2010) as well as several important publications in Mesolithic studies (e.g. Ritchie *et al.* 2013a, 2013b). More detail on the sampling and identification of fish bone appears in the online Supplementary Material.

The identified family and/or species of fish in the bone material from Asnæs Havnemark is listed in Table 4. A total of 47,760 specimens were identified from the three trenches at Asnæs Havnemark, from 18 fish families. The number of unidentified vertebrae in the 4 mm fractions is 4.7%, unidentified fishbone 4.2% by weight. The fish assemblage from Asnæs Havnemark is remarkable because of its size and diversity. Codfish dominate the assemblage, with eel following at a distant second and other fishes contributing relatively minor amounts. Freshwater fish are rare (only eight cyprinid vertebrae), but diadromous fish include eel, shad, and trout/salmon. These results are very much in accord with the

Table 4. Identified fish remains.

Family	Species	Common name	NISP
Anguillidae	*Anguilla anguilla*	Eel	3949/598*
Belonidae	*Belone belone*	Garfish	45/-*
Callionymidae	*Callionymus lyra*	Dragonet	1/-*
Clupeidae	*Clupea harengus*	Herring	158/106*
	Alosa sp.	Shad	13/-*
Cottidae	*Myoxocephalus scorpius*	Bullrout	601/96*
Cyprinidae	Various	Carp family	8/2*
Gadidae	Various	Codfish	38,103/2244*
Gasterosteidae	*Gasterosteus aculeatus*	3-Pined stickleback	-/44*
Gobiidae	*Gobius* sp.	Goby	-/3*
Pleuronectidae	*Platichthys flesus/Pleuronectes platessa/Limanda limanda*	Flounder/plaice/dab	897/59*
Salmonidae	*Salmo* sp.	Trout/salmon	13/2*
Scombridae	*Scomber scombrus*	Atlantic mackerel	444/117*
Scophthalmidae	*Scophthalmus* sp.	Flatfish	1/-*
Squalidae	*Squalus acanthias*	Spurdog	40/1*
Syngnathidae	Various	Pipefish	-/1*
Trachinidae	*Trachinus draco*	Greater weever	34/9*
Triglidae	*Trigla lucerna/Eutrigla gurnardu* stub/grey gurnard		136/5*
Zoarcidae	*Zoarces viviparus*	Viviparous eelpout	18/12*
Totals			44461/3299*

*Numbers are from the screen-test samples; a version of this table appears in Ritchie *et al.* 2013a.

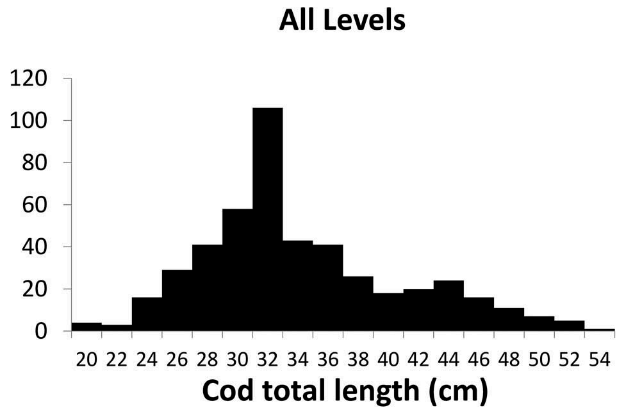

Figure 11. Total lengths of cod for all levels combined.

site's location on the Asnæs peninsula with no major bodies of freshwater in the vicinity.

Another important category of evidence regarding the fish remains at Asnæs Havnemark comes from 898 recovered otoliths. Otoliths are small calcium carbonate structures in the inner ear of many vertebrate species. The otoliths were used for estimating fish size and also isotopically analyzed for information on season of death.

Summary data are graphically displayed in Figure 11. Estimates range from cod as small as 20 cm (with a weight of ca. 100 g) up to a maximum of 53 cm (weight ca. 1.5 kg), with an average of around 33–34 cm (weight ca. 300 g). Weights are estimated from similarly sized fish in the comparative collection of AZA in Schleswig, Germany. Estimates of eel sizes ranged from 42 to 86 cm, with an average of approximately 61 cm (obtained from formula in Enghoff 1994). There was not a great deal of variation in the sizes of the flatfish, with an average length of about 25 cm.

The size estimates for the fish are similar to those from other Ertebølle sites in Denmark. Cod usually average around 30–40 cm, slightly larger at Lystrup Enge and Grisby. In general, the maximum size of the Asnæs Havnemark gadids is less than seen at other sites, but sizes here were estimated solely with otoliths. There areelements in the assemblage that indicate larger fish were caught. Eels from the site are similar in size to those seen elsewhere, although the absence of any specimens less than 42 cm is notable. The flatfish from Asnæs Havnemark are also similar in size to those found in other Ertebølle assemblages (Enghoff 1994). The fish bones represent a minimum of hundreds of individuals, demonstrating that fish were a significant part of the diet, even if their precise importance is difficult to ascertain.

Stable isotope analyses of seven cod otoliths from two late Mesolithic Ertebølle sites (Asnæs Havnemark and Fårevejle) were conducted to determine the season of catch for the fish (Ritchie *et al.* 2013b). Results indicate fishing during the late winter, spring, and summer. This is a considerably broader fishing season than that estimated solely from the presence of migratory fishes in the assemblages and suggests that fishing played a larger role in the annual subsistence cycle than previously acknowledged.

In regard to the fish, the fact that at least 22 types of fish from 18 different families are present in the assemblage shows that there were many fishes available that the inhabitants could choose to take. While fishes were locally available in higher or lower numbers depending on the species, the many bones of codfish (and to a lesser extent eel) demonstrate that they were the preferred catch. The rocky, exposed shoreline near the site, the predominance of codfish (including large individuals of cod and haddock), and the recovery of numerous fishhooks and preforms suggest that angling (possibly offshore in boats) played a major role in the fishery. This interpretation is supported by the very low incidence (0.1%), of weever, a species often used as a marker of fishing with stationary structures (Enghoff 1994). A further indication of the importance of the cod fishery is the otolith evidence showing that they were caught at many different times of the year. That most of the eel are larger than 50 cm and thus presumably females points to eel fishing in the fall when they were migrating from freshwaters into the sea (Muus *et al.* 2006). Some of the smaller fishhooks could have been used in this fishery, but it is also possible that nets, traps, or spears were employed during this event. Access to good cod fishing grounds and migrating eels in the fall may have been the reasons behind why the site is located far out on the Asnæs peninsula, a setting that was the location of an important historical fishery for several different species (Drechsel and Petersen 1988).

Bone modification

Burning, butchery, and tool production were all ways that bone at Asnæs Havnemark was modified by human activities. Less than 1% of the mammal material is affected by burning, indicating that most cooking occurred after removal of meat from the bones. Other options involve meat being either cooked (stewing, earth ovens) or preserved (drying, smoking) by methods that would not result in burnt bones. Burning is the principal manner in which the fish remains have been modified, although this was a fairly rare occurrence. Despite the fact that a total of 728 fish bones from the 4 mm sieving assemblage exhibit signs of burning (ranging from partial blackening to complete calcination), this is a small percentage (ca. 1.6%) when considered in the context of over 44,000 identified specimens.

Evidence of butchery (including sawing, cutmarks, scrape marks, etc.) was present on some mammal bones, although any systematic patterns are obscured by the condition of the bone material and their relative rarity. Cutmarks, for example, were observed on only 2.9% of the roe deer specimens, 2.8% of the wild boar specimens, and 1.6% of the red deer specimens. However, nearly all of the appropriate mammal bones were marrow-fractured, and no systematic choice of one species over another is evident. Other than the previously described burning, osteological evidence for how fish were prepared is scant. There were almost no cutmarks observed during the analysis and skeletal element representation provides little additional information about butchery methods.

Bone tools were generally limited to the 43 fishhooks and preforms, along with six roe deer antler *retouchoirs*, five bone points, four bone awls, two bone needles, and one tooth pendant. The tooth pendant was made from the reticular canine or grandeln tooth of a red deer (*Cervus elaphus*) shown in Figure 12 (Sørensen 2016). The root had been perforated for attachment. Such pendants are often found in graves and there were probably some burials at the site.

The bone fishhooks and preforms were a special category of artifact from this site (Figure 13). There were a total of 43 fishhooks, (25) and preforms (18). These specimens were in various states of preservation, both complete and fragmentary. Several of the preforms exhibited preliminary engraved lines to mark the outline to be cut from the bone.

In general, relatively few bone specimens were worked or prepared for the manufacture of tools. However, one aspect particularly worthy of note is the degree and specificity of working traces found on bones of domestic dog. In total, 119 fragments of bone are attributable to dog. Of this number, nearly every long bone is worked in a very similar fashion, with minor differences probably owing to variations in bone morphology. Regardless of the specific long bone to be worked, the flattest surface was first selected and then incised on either side, to prepare a relatively flat section of cortical bone with parallel edges. Subsequently, the prepared section was incised perpendicular to the edges in order to weaken, and eventually remove, a flat and broadly rectangular piece of bone.

This preparation resulted in a preform for making fish hooks. While the majority appear to be made from the long bones of dogs, one of these preforms came from a swan ulna (*Cygnus* sp.). Several of these preforms show the general method of making fishhooks from these flat pieces of bone. Several hooks could apparently be made from one flat piece of bone by hollowing out the curvature of the hook and snapping the nearly complete hook off from the flat piece.

Seasonality

Figure 12. Grandeln tooth from red deer made into tooth pendant.

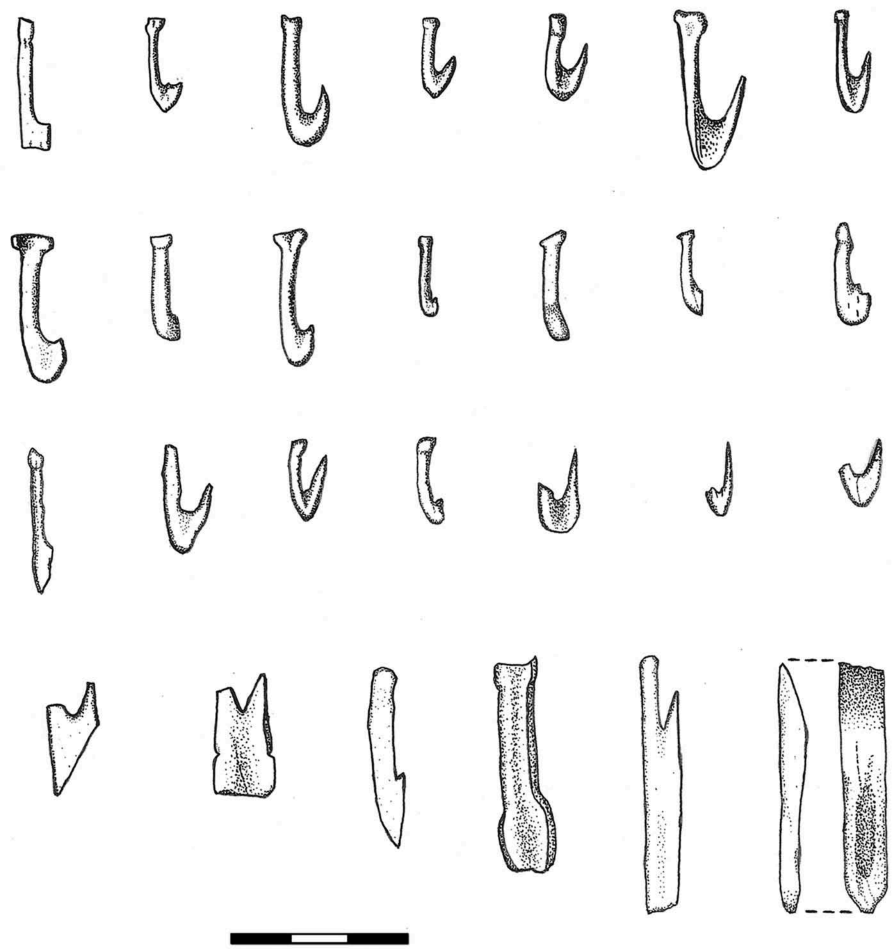

Figure 13. Some of the fishhooks and preforms from Asnæs Havnemark. The scale is 3 cm.

The faunal remains provide a means for examining the seasons of site use at Asnæs Havnemark. Multiple lines of evidence including animal behavioral ecology, oxygen isotope analysis of cod otoliths, and ontogenetic aging of select species indicate use of the site in all seasons of the year. As Sørensen (2017, p. 31) noted, at large coastal settlements from both the Kongemose and the Ertebølle periods, all seasons of the year are usually represented in the faunal remains.

The presence or absence of animals at specific times of the year can be a useful tool for establishing the season of occupation at archaeological sites. Seasonal information is restricted to species with migratory patterns. The seasonal information from the birds at Asnæs Havnemark is limited. The golden eagle, mute swan, white-tailed eagle, herring gull, red-breasted merganser, great crested grebe, red-necked grebe, song thrush, and common blackbird (Table 3) are all possibly year-round residents in Denmark (Génsbøl 2006). The osprey only leaves in winter and the whooper swan is only absent in summertime. Red-throated loons seasonally migrate through Denmark in the spring and autumn (Génsbøl 2006). As there is a single specimen for most of these species at the site, it is probably best not to draw strong conclusions regarding seasonality from this category of evidence.

Migratory behavior is also present in the fish evidence, especially with regard to garfish and mackerel that are present in Danish waters from the late spring to early fall. The presence of bones from both of these species in the assemblage, albeit in limited numbers, strongly suggests summer occupation at Asnæs Havnemark. Three diadromous fishes (eel, shad, and salmon/trout) provide some evidence for site use during spring and fall based on the fact that they are most easily caught during migration, although individuals could also

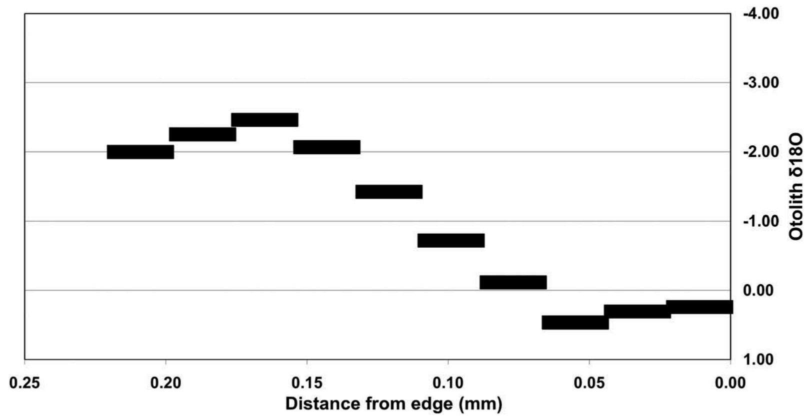

Figure 14. Results from 48 cm long cod. Readings higher (more negative) on the y-axis indicate warmer temperatures and readings further to the right on the x-axis are closer to the time of capture.

have been taken at other times of the year (Muus *et al.* 2006).

In contrast with the evidence from migratory fish, the predominance of codfish in the assemblage (including large examples of cod and haddock) may be evidence for winter occupation, based on comparison with the Danish fishery in the nineteenth century (Moustgaard 1987, Drechsel and Petersen 1988). To test this idea, a pilot study using a newly developed methodology was conducted on four cod otoliths to determine in which season these fish were caught. The method relies on three factors: that fish otoliths grow incrementally throughout the life of the fish, that they incorporate isotopes of oxygen in ratios that reflect their surroundings, and that the ratio of ^{16}O and ^{18}O in their aquatic environment varies in response to water temperatures (see Hufthammer *et al.* 2010, Ritchie *et al.* 2013b). By comparing the result from the sample taken from the outer edge of the otolith (the area being formed when the fish died) with the annual cycle of water temperature changes revealed by the complete series of samples, it is possible to determine at what time of year the fish was caught. The 48 cm fish, for example, was caught when water temperatures were just beginning to warm from their annual low, corresponding to a seasonality indication of late winter or early spring (Figure 14). Although the sample size is small, these results show that while some cod were caught during the summer, winter and spring were also seasons of the fishery at Asnæs Havnemark.

Two lines of evidence are available for the estimation of season of occupation using the mammalian remains; the seasonal casting of antlers by deer, and the ontogenetic development of, in this case, roe deer and wild boar. Modern roe deer cast their antlers in November and December (Sempéré *et al.* 1992) after which, they grow back in an annual cycle. Several roe deer frontal bones and their attachment points for antlers, the pedicles, are present at Asnæs Havnemark which provide evidence of different stages in this cycle. Uncast antlers still attached to the pedicle, antlers in the process of being cast from the pedicle, and pedicles that have recently cast their antlers are all present in the assemblage. This indicates that the deer in question died at that stage of their life cycle. The recently cast antlers that have not yet started to regrow and the antlers in the process of being cast are therefore very strong indicators of a late autumn, or early winter time of death.

Figure 15 summarizes the cumulative seasonality information from the animal remains. In aggregate, there is evidence for a human presence at Asnæs Havnemark for much of the year with the caveat that visits need not have been continuous. It is, nonetheless, apparent that hunting and fishing took place in similar seasons. It would seem that there is good evidence for year-round use of the site at Asnæs Havnemark and very strong evidence for human presence in the summer.

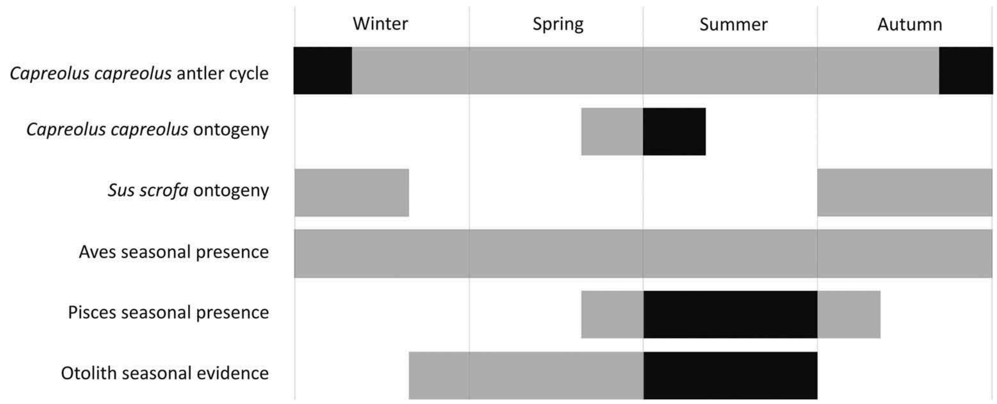

Figure 15. Seasonality at Asnæs Havnemark (dark gray indicates confidence, lighter gray less confidence).

Interpretation

The site location, faunal assemblage, and tool technology all point to the conclusion that the people who lived at Asnæs Havnemark oriented their lives toward the sea. Isotopic evidence indicates that seafood was the most important part of the diet, although the relative contribution of marine versus terrestrial foods is not completely clear. The overall impression of animal use at the site is one of both focus and breadth. In this sense, the diet of the inhabitants appears to be similar to the pattern known from many other Ertebølle sites. While the assemblage is strongly dominated by fish of the cod family

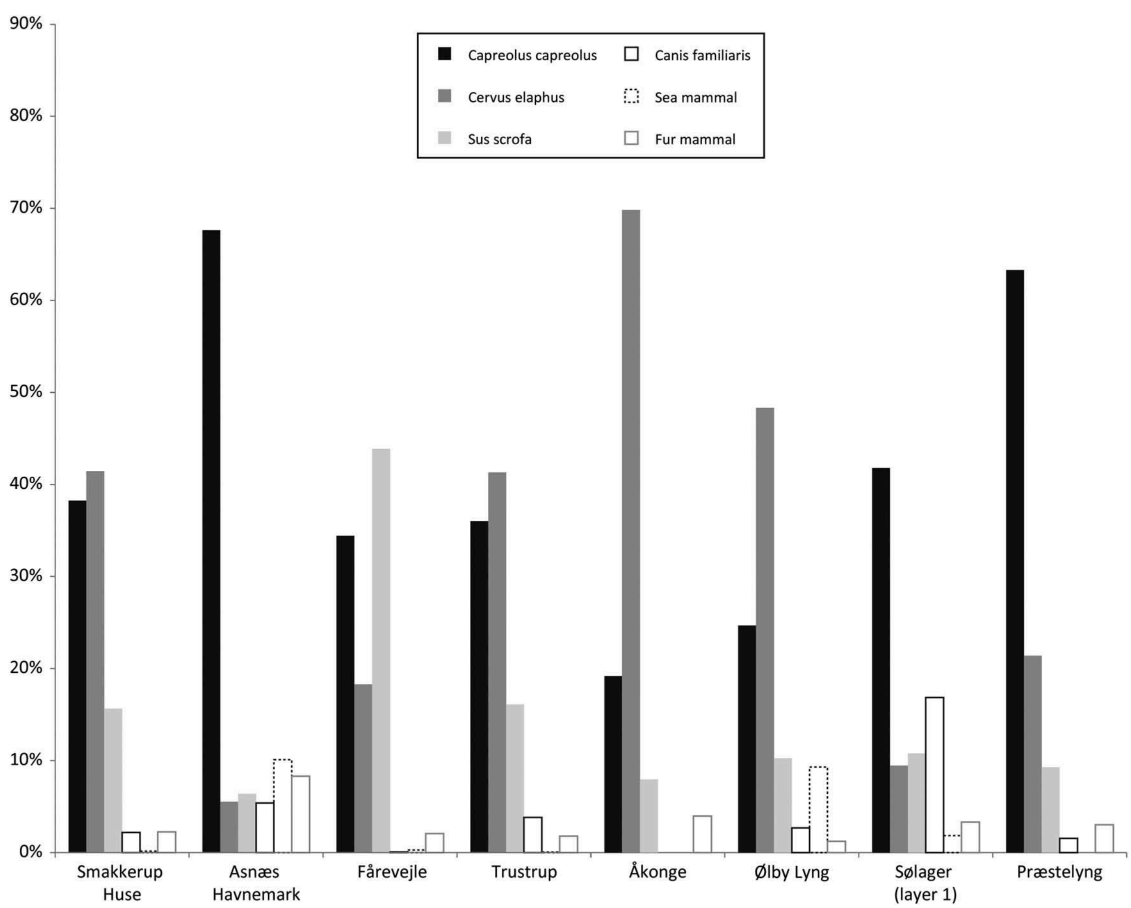

Figure 16. Variation in relative abundance (NISP) of mammal bones from Ertebølle sites on Zealand (Hede 2005; Ritchie *et al.* 2013, Møhl 1971, Skaarup 1973; Noe-Nygaard 1995; Gotfredsen 1998; Gron 2013).

and roe deer, there is a wide range of other species present. With availability of these primary food sources ensured, other animals could be incorporated into the subsistence regime as opportunity arose.

There is variability in Ertebølle faunal use that has not generally been recognized. While the same species are generally present in most assemblages, their relative abundance does vary widely among sites. Five other sites from Denmark (Bjørnsholm on the Limfjord in northern Jutland, Vængesø III in east-central Jutland, Tybrind Vig on Funen, Nivågård in northeastern Sjælland, and Smakkerup Huse in northwestern Sjælland) have reasonably large faunal assemblages excavated with methods appropriate for recovering a good sample of fish remains (Bratlund 1993, Price and Gebauer 2005, Andersen 2009, Enghoff 2011). The assemblages from these sites help to demonstrate that broad differences in fishing practices existed within the larger framework of available resources.

Examining the different families of fish at these sites makes it apparent that generally the same types of fish were caught. Despite this exploitation of common species, the fisheries were actually quite variable when relative abundances are considered. At most sites, a majority of the specimens are from one type of fish, but that type varies between codfish, flatfish, and eel (most often codfish). The fact that mostly the same types of fish are found at Ertebølle sites throughout Denmark, but in widely varying abundances points to fully competent fishing capabilities tailored to local conditions.

The same pattern is seen with the mammal bone, even if restricted to only Ertebølle sites on Zealand (Figure 16). The same mammals are generally present at these sites. Where dissimilarity does occur, it often can be attributed to the local availability of species. The relative abundance of species is quite different at individual sites. Variability is observed particularly among the three main terrestrial game animals (red deer, roe deer, and wild boar), as well as sea mammals and fur-bearing species. The faunal material from Asnæs Havnemark highlights this variability and underscores the reality of differences among certain classes of resources.

These comparisons show that within almost all classes of animals exploited by Ertebølle hunters and fishers, there is a great deal of inter-site variability. While the same animals generally occur in all assemblages, the focus of the subsistence at each site represents an adaptation to local conditions. In the case of Asnæs Havnemark, the location of the site may explain to some degree the preponderance of just a few species in the archaeological material. However, a major caveat is that while this is the case, the breadth of species and range of classes of animals utilized remains quite impressive, indicating an ability to employ multiple hunting and fishing strategies to fully exploit local resources. We take this to strongly indicate that in the face of either seasonal or atypical environmental stresses, Ertebølle hunters at Asnæs Havnemark had the knowledge and skills to readily switch between vastly different classes of resources as needed.

Conclusions

The Asnæs peninsula has been associated with fishing for generations. There is an historical fishing village on the south coast of the peninsula with well-known fixed weirs (Pedersen 1997). There are former fisherman's houses and processing buildings 2 km east of the site of Asnæs Havnemark. A herd of seals is still often seen off the west end of the peninsula. The area is also a well-known hunting area and both roe deer and pheasant are taken in large numbers. The peninsula has probably been a resource rich area for millennia.

The site of Asnæs Havnemark is unusual for a number of reasons and has substantial potential to provide information on the transition to agriculture in this region. The radiocarbon dates now available place the second phase of the site occupation at the time of the transition to agriculture in southern Scandinavia, ca. 4000 cal BC. The deposits are terrestrial, rather than waterlain, and a portion of the settlement area is intact. The cultural layer appears to represent a short-term occupation, lying between two episodes of beach ridge formation. Beach ridge deposition at this elevation must have taken place during a time of higher sea level, likely during the Littorina transgression at the end of the Atlantic climatic episode. This event fits extremely well with the radiocarbon dates for the site and also provides important information on potentially significant environmental changes at the end of the Mesolithic period.

The site is of interest for a number of reasons including the coastal location, the unusual ceramics, the nature of the fishery, and the focus on specific game species. Beyond the normal assemblage of materials that characterize a late Mesolithic site in this region, there are high numbers of stylistically homogeneous projectile points, distinctive flake axes, bone fishhooks and preforms, seal bones, large bird bones, and an extraordinary amount of fish bone at Asnæs Havnemark. The rich occupation layer, including a fragment of a human jaw, suggests a substantial residential settlement on this coast. While a variety of species are represented, eel and cod are very common.

In addition, a large quantity of ceramic material was recovered in the test excavations. This abundance of pottery includes both pointed-bottom vessels and oval lamps from late Mesolithic, as well as several examples of Early Neolithic ceramics. Assuming contemporaneity, the unusual pottery, TRB in tradition, suggests some contact with early farmers either in Denmark, southern Sweden, or across the Baltic in northern Germany. The unusual types of pottery, however, appear to be locally made.

The cod family dominates the fish assemblage, while roe deer account for the vast majority of the mammal remains. Despite the preponderance of these two species of animals, the assemblage presents an impressive variety of other fish, mammals and birds. Different skills and procurement strategies are required to obtain terrestrial game, fur animals, seals, raptors, waterfowl, and the various species of fish. The wide variety of animals represented in the Asnæs Havnemark assemblage indicates that the people who lived there were proficient in a number of different hunting and fishing techniques. The predominance of roe deer in the mammal material and cod in the fish material does indicate a distinct degree of economic specialization. However, it is important to remember that the inhabitants of Asnæs Havnemark were not so much constrained by the availability of animals in the vicinity of the site, as drawn there because of the prey that was present.

Despite the preponderance of roe deer and codfish remains, the Asnæs Havnemark assemblage is the result of a highly flexible hunter-gatherer subsistence strategy able to adapt to local, seasonal, and longer-term shifts in resource availability. In turn, this means that environmental stresses would have less effect in creating major changes in general subsistence patterns. As noted earlier, the major lesson that we learned from these excavations concerned the variation that defined the settlements and activities of Late Mesolithic groups.

Because of this flexibility, we contend that substantive environmental changes could not have been the major causal force for the introduction of agriculture at the end of the Ertebølle period. The evidence we have presented greatly weakens such arguments. The abundance of food in the form of marine resources and roe deer found at the site suggests that food stress was not an issue for the local population. Such evidence argues that more food was not an incentive when the Neolithic was introduced in southern Scandinavia.

Acknowledgments

We would particularly like to thank the landowner Eirik Vinsand who was most gracious and hospitable in facilitating our investigations at Asnæs Havnemark. It is also important to recognize Egon ('Columbus') Iversen recently decreased, who originally found the site eroding from the sea cliff on Asnæs and reported it to the Kalundborg Museum. This article is dedicated to his memory. As always the Kalundborg Museum was a wonderful host.

Research excavations were sponsored by the Carlsberg Foundation and the University of Wisconsin-Madison Graduate School. The project was a collaboration between the Kalundborg Museum and the Department of Anthropology, University of Wisconsin-Madison. Discussions with Lisbeth Pedersen prior to the start of the project resulted in further information and permission for the study. Permission for the excavations was obtained from the landowner Eirik Vinsand, the Teknisk Forvaltning in Kalundborg Kommune, and the Regional Miljø office in Roskilde. The Kalundborg Museum was responsible for the project documentation and finds. These materials were stored at Kalundborg Museum and some were later moved to the regional museum stores at Museum Vestsjælland in Holbæk.

The participants in the excavations for the long haul were Jens Nielsen, Ken Ritchie, Terry Slocum, Lone Ritchie Andersen, Vanessa Smolenski, Kurt Gron, and

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RESEARCH ARTICLE

Wiggle-match dating the fortification of Køge

Aoife Daly [a,b] and Karen Bork-Pedersen[c]

[a]Dendro.dk, Copenhagen, Denmark; [b]Saxo Institute, University of Copenhagen, Copenhagen, Denmark; [c]Cultural heritage, Museum Southeast Denmark, Vordingborg, Denmark

ABSTRACT

During archaeological fieldwork in the eastern part of the coastal city of Køge, situated on the east coast of the island of *Zealand* (Sjælland) in *Denmark*, remains of a rampart were found and, due to the lack of suitable material for dating via the more traditional dendrochronology, wiggle-match dating was conducted. This article aims at presenting the method used and discussing the result it provides for medieval and renaissance archaeology, in situations where there is an absence of dateable dendro-samples or for dating of non-oak samples.

Having unearthed the rampart remains, a major objective of the excavation became answering the question: Are the ramparts found those that were built during the short Swedish occupation of the town in 1658? And, could the C14 dating method provide us with a sufficient level of precision to answer this question? The results show that the ramparts found belonged to the medieval fortification of the town and have a long history of renewal and repair, allowing us to map the long life of the town despite the limitations of the small 'key-hole' style excavations. Applying this method more extensively on small-wood remains will perhaps help us to finally identify that elusive Swedish fortification.

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Introduction

At the time of writing, a large-scale development project is taking place in the eastern part of the coastal city of Køge. The project is referred to as *Køge Kyst*, and it is a partnership between *The Municipality of Køge* and *Realdania By og Byg*, aiming to develop the central harbour area into a cluster of residential, cultural and commercial premises (http://koegekyst.dk/).

Prior to and during the many and vast building projects, the Museum Southeast Denmark (Museum Sydøstdanmark) has conducted a series of excavations in the area as required by Danish legislation (The Museum act no. 1505). Amongst the central finds were rampart remains that probably had several functions including legal and military boundary for the town in the medieval and renaissance period as well as serving as a dyke to prevent the low-lying town from being flooded. The locations of the excavations are dictated by the (projected) building works, and take the form, for the most part, of small trenches in classic urban rescue 'keyhole' archaeology. In other words, it is not possible to fully excavate the structures that are exposed; but rather, we must try to interpret the structures from these patchy discoveries.

Køge and its fortifications

Køge is situated on the northern bank of the stream Køge Å only a short distance from its mouth in the bay Køge Bugt (Figure 1). In the medieval period, the coastal town of Køge held an important strategic position amongst the cities in the eastern part of Zealand. The town was founded by the king by relocating the old village of Køge further up-stream probably sometime in 13th century and given the same privileges as Roskilde by King Erik Menved in AD 1288. Besides serving as a port for the export of grain, it probably also served as a counterweight to the towns of *Roskilde* and *Copenhagen* owned by the powerful bishop of Roskilde (Johansen 1986, p. 28).

The fortification of Køge is not mentioned in any preserved written sources until AD 1440

CONTACT Aoife Daly aoife.daly@hum.ku.dk Saxo Institute, University of Copenhagen, Karen Blixens vej 4, 2300 Copenhagen S, Denmark
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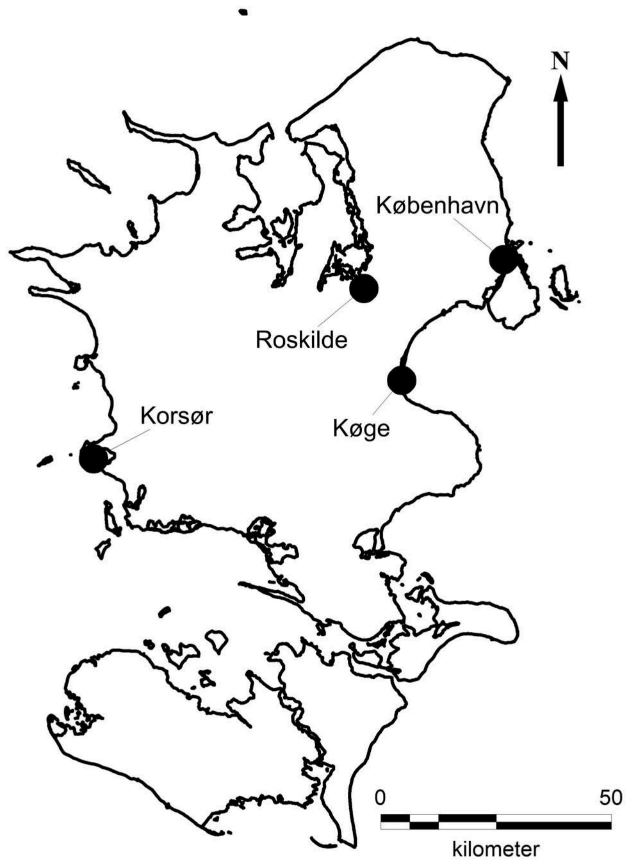

Figure 1. Map of the Island of Zealand showing the locations mentioned in the text (map: Karen Bork-Pedersen).

but must have been in place sometime prior to this mentioning (Johansen 1986, p. 35). The oldest fortification appears to have consisted of a small rampart with a palisade on top and a moat on the outside. The rampart and moat surrounded the eastern, western and northern parts of the town. To the south, the stream of Køge formed a natural boundary albeit without the fortification properties, giving the impression that the medieval fortification served more of a legal purpose rather than a military. From AD 1440 and onwards, the fortification is mentioned a number of times in different documents, often emphasising that the citizens are required to maintain the moat and fence/palisade, leaving the impression that these duties were perhaps sometimes neglected (Johansen 1986, pp. 33–35). However, such a requirement was not unusual for the citizens of a fortified town.

Upon the death of *King Frederic I* in AD 1533, a disagreement about his successor led to a civil war, known as *The Count's Feud*. Shortly after the King's death, the local nobility decided to demolish the ramparts, preventing the city to be used as a platform for attacking Copenhagen, some 45 km away. An attempt to rebuild and restore the rampart had been initiated by *Christopher, Count of Oldenburg,* during his short stay and occupation of the city in AD 1534 on behalf of *King Christian II*. In AD 1536, *King Christian III* faced no problems taking the city (Johansen 1986, p. 77).

By the end of the 16th century, written sources tell us that the fortification decayed; the ramparts were leased to the citizens for gardening and the moat turned into fishponds (Johansen 1986, p. 35, Frandsen and Nielsen 1976, p. 61–62).

The Swedish fortification?

In AD 1657, the Danish King Frederic III declared war upon Sweden. The signing of a peace treaty (in Roskilde) in February AD 1658, known today as '*The Treaty of Roskilde*' only brought a brief peace as, no sooner than August that same year, the treaty was broken by the Swedish *King Charles X* who went ashore in Korsør situated on the west coast on Zealand, advancing towards Copenhagen. During this advancement, the Swedes conquered and occupied Køge and subsequently set out to fortify the town (Johansen 1986, p. 78).

Their plans are well-known as we have the map of *Erik Jönsson Dahlberg* (1625–1703), a Swedish commoner made nobleman and holding many titles such as count, field marshal, soldier and engineer, depicting not only the town with the planned fortification AD 1659–1660 but also, importantly, showing the remains of the medieval moat (Figure 2).

The swedes only held the town until Charles X died 4 January 1660 after which peasants were deployed to destroy the rampart. Today, there are no visible remains of the Swedish occupation in Køge (Johansen 1986, p. 80).

How much of the fortification was actually built? According to an eyewitness, Axel Juul, the work was almost completed despite the short

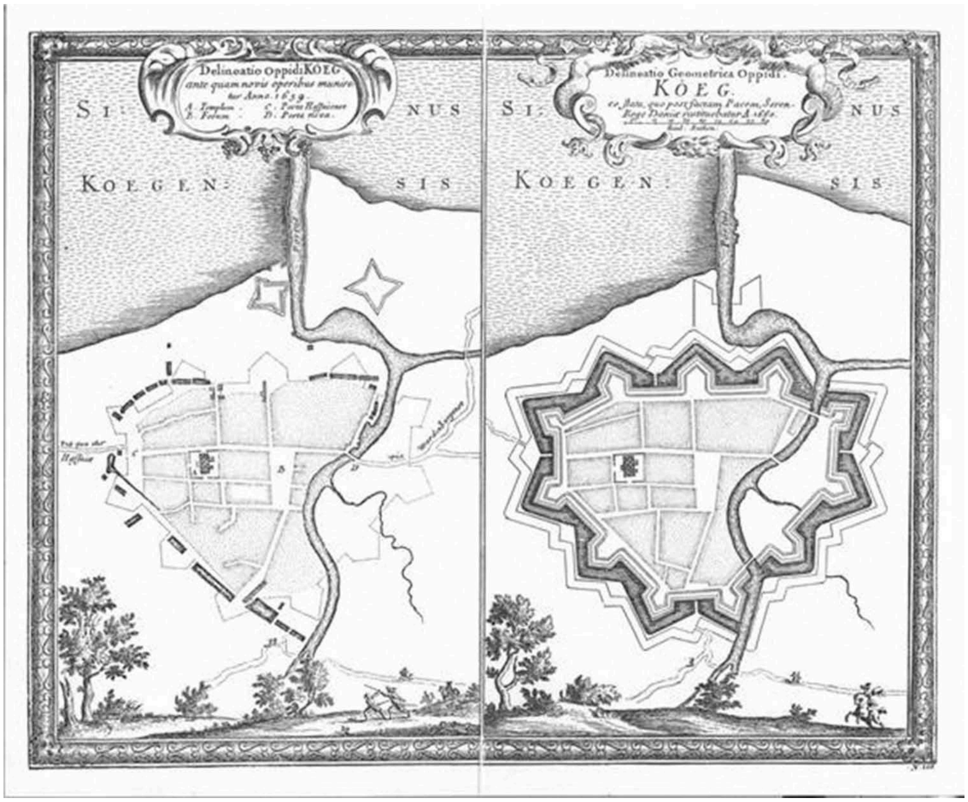

Figure 2. Map of Køge 1659–1660 by the Swedish field marshal Erik Dahlberg. To the left, the map shows Køge as it appeared when the swedes took the town; and to the right, the Swedish plans for fortifying the town (by permission, Køge Arkiverne).

duration of the Swedish occupation and he describes a fortification that fits very well with the design on Dahlbergs map as he writes that Køge is now '*regulær befæstet med sine courtiner og Volde og 11 Bolværker hvoraf Havnen og Indsejlingen synes smukt at kunne defenders; dog behøver Volden vel nogle steder at fortykkes og Brystværnene at forhøjes, og I Synderlighed Gravene omkring Fæstningen, hvilke ikke nær færdige er, at ville endelige fordybes fluks mere og jævnes, saa og Contrescarpen smukt at forfærdiges, saa synes det kunne vorde en fornem Fæstning*' (Frandsen and Nielsen 1973–1975, Nordentoft 1941). (Køge is now properly defended with its curtain wall and ramparts and 11 bulwarks of which the harbour and the seaward approach can be beautifully defended; though the fortification needs in some places to be strengthened and the ramparts raised, and in truth the moats around the fortification, which are nowhere near finished, should be promptly deepened and levelled, so that the escarpment is complete, then it could become a great fortress (authors' translation)) Apparently, the citizens of Roskilde, *Næstved, Ringsted* and *Store Heddinge* were commanded to take part in the construction of the fortification, and the buildings in the north-eastern part of the city were allegedly demolished and the materials used to build the fortification (Johansen 1985, p. 69) (Figure 1). In AD 1660, a map drawn by or under the command of the Swedish Commander Stahl (Jakob Staël von Holstein 1628–1679) shows the plan of the city and the fortification (Figure 3). In all likelihood, the Swedish fortification had a short life. On a later map by the Danish Oceanographer Jens Sørensen (1646–1723), only the bastions to the south are still visible, having apparently avoided demolition (Figure 4). Nothing is left visible today.

The archaeological surveys from the 1970s and up until today

In the 1970s, a series of archaeological excavations sought to confirm, or disprove, the fortification shown on the maps of Dahlberg by placing

Figure 3. Map of Køge from 1660, drawn or commissioned by the Swedish Jakob Stahl (by permission, Køge Arkiverne).

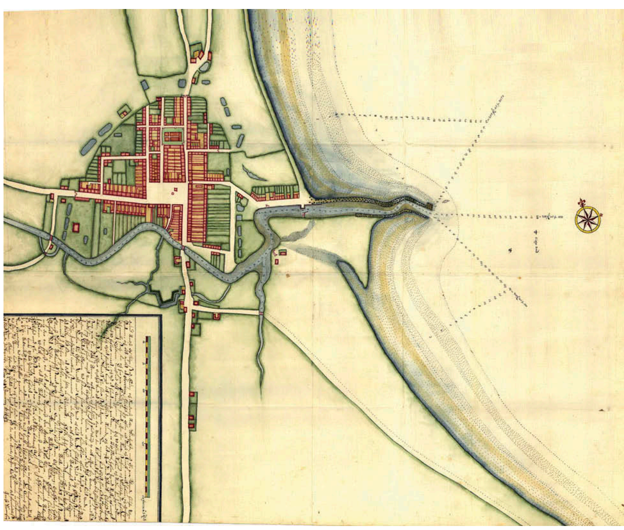

Figure 4. Map of Køge from 1693, drawn by Danish Oceanographer Jens Sørensen (by permission, Køge Arkiverne).

trenches according to the maps. The excavations took place in the western part of Køge in *Lovparken* and in the eastern part at the parking lot, *Bag Haverne*. Both excavations confirmed the existence of a rampart and a moat. Several construction phases were hypothesised, based on the different strata in the rampart, though lack of finds made it difficult to validate this interpretation. At Bag Haverne, C14 dating was conducted on a piece of wood (K-3162 380BP +- 50) found beneath peat tiles covering the rampart, dating the rampart to, to quote: '1475 e.Kr. Kal.' (Tauber 1979). These were in the early years of calibrating the radiocarbon timescale, and ranges were not quoted. However, using modern calibrating methods, this date re-calibrates to AD 1431–1645 (OxCal v4.2.4, accessed 18 April 2018 (Bronk Ramsey and Lee 2013) using IntCal13 (Reimer *et al.* 2013)). This is, unfortunately, a very wide calibrated age range when dealing with the historic period, leaving many questions unanswered.

Between 2012 and 2015, the Køge Kyst project has led to several archaeological surveys of which four have encountered remains of a fortification (Figure 5). *KNV80 Iver Huitfeldts Vej* was the first excavation, conducted in 2012–2013. The excavation took place in the north-eastern part of Køge, along the railway track and was conducted mainly as a watching brief in the trench alongside the construction of a large water pipe. West of this excavation, another, *KNV96 Jernbanegade*, took place in 2015, and in 2014 the parking lot *Bag Haverne* to the southeast of the town, was once again the centre of an archaeological excavation: *KNV123 Bag Haverne*, as the waterpipe from Iver Huitfeldts Vej continued here. In 2015, another excavation in connection with the construction of a new sewer pipe, *KNV306 Strædet* also provided evidence of a rampart and a moat (Figure 5). This article draws on the results of the excavation and dating analyses otherwise produced as unpublished reports (Bork-Pedersen 2015, Daly 2015a, Daly 2015b, Færch-Jensen 2017 & Rasmussen 1979).

The surveys in the 1970s were conducted as research excavations enabling the archaeologist to decide the size and location of the trench. The recent excavations, as mentioned earlier, took place alongside and prior to construction work, often resulting in a longitudinal trench within and/or along the rampart rather than across the rampart – the construction work dictated where to dig next.

The recent excavations, like the 1970s excavations, have uncovered the lower part of a sand-built rampart in several places and possibly a moat in at least one place. Nowhere do the remains of the rampart exceed 1.2 m in height but it might of course have been higher. The top sandy layers consisted of debris, probably from the destruction of the rampart and from erosion whilst exposed to wind and possible flooding. The rampart was built of multiple layers of sand with peat applied to keep the sand in place and subsequently held in

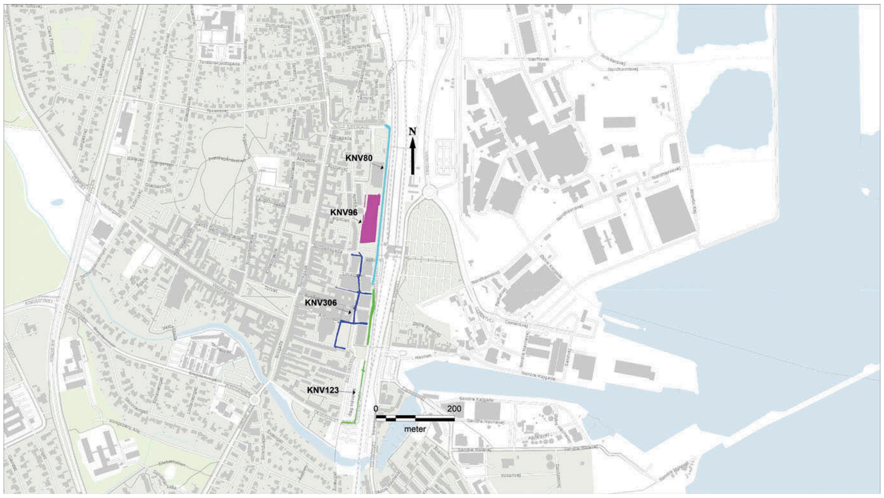

Figure 5. Map of the four surveys © TStyrelsen for Dataforsyning og Effektivisering (Map: Karen Bork-Pedersen).

Figure 6. Facing north, cross-section of the rampart found at KNV00080, with the wattle fence in front (photo: Karen Bork-Pedersen).

place by a wattle fence on the front side (Figure 6). In a few places, willow logs were laid out horizontally beneath the rampart; probably to stabilise the ground beneath the structure. The peat has been determined as heather-peat by Annine Moltsen from NOK, Natur og Kultur (Moltsen 2015). The provenance of the peat has not been determined but it is likely to derive from a bog nearby.

The most coherent structures of the fortification were found in the north-eastern part of Køge, whilst the finds in the south-eastern part are more dubious regarding whether they can be linked to the fortification. It should, however, be noted that the post-processing of the southern excavation is currently in the early stages. The processing of that excavation in combination with forthcoming archaeological work may shed further light on the construction of the fortification. At KNV80 Iver Huitfeldts Vej, the rampart was identified in two places, approximately 87 m apart; to the north over a course of 34 m and to the south over a course of 6 m. To the north, a wattle fence supporting the outer foot of the rampart (facing east), was found. Approximately, 20 m west of the wattle fence, a fence of more substantial posts facing the town (west) and supporting the inside foot of a rampart was found during the KNV96 Jernbanegade excavation. The trajectories of the two fences (Figure 7) are almost exactly parallel, which initially led to the assumption that these were contemporary but the datings suggests otherwise and we shall return to this later.

Lack of material for conventional dating

Very few artefacts were retrieved from the rampart; most of them came from the upper layers, themselves questionable as to whether they were indeed functional parts of the rampart or disturbed/demolition layers/debris. Within the certain construction layers, the finds were scarce, and the few artefacts only provided a wide date range. Taking into consideration the massive relocation of deposits, the artefacts retrieved are considered discarded and redeposited material, contributing only a *terminus post quem* for the deposit(s). However, two ceramic sherds are attributed to a primary deposit: a handle from

Figure 7. Map of KNV80 and KNV96 © Styrelsen for Dataforsyning og Effektivisering (map: Jeppe Færch-Jensen).

a redware tripod, and a sherd from a green-glazed plate, X6 (Figure 8). The latter was retrieved from between the peat tiles beneath the small yew posts in the wattle fence and was most likely deposited during the construction of the peat coating. This was the only artefact directly linked to the construction of the rampart. The sherd was from an earthenware plate or dish made of very bright clay with a grass-green glaze on both sides covering a slip-coating on the inside and with a suspension hole. Presented with the sherd, Dr. Jette Linaa has suggested that it may have been manufactured in Poland or Niedersachsen no earlier than AD 1650 (Linaa pers comm).

One oak post, (L233/P17), within or at the outer foot of the rampart, was dendrochronologically dated to after AD 1523. Since written sources suggest that the timber from the buildings demolished in the eastern part of the city were used for the construction of the fortification, the date of this post possesses an inherent conflict as it could just as well originate from earlier buildings in the area (Nordentoft 1941).

The horizontally placed willow log used as a stabiliser beneath the rampart was not suitable for dendrochronological dating and as this log contained only 14 rings, it was not ideal for attempting wiggle-match dating either. A few

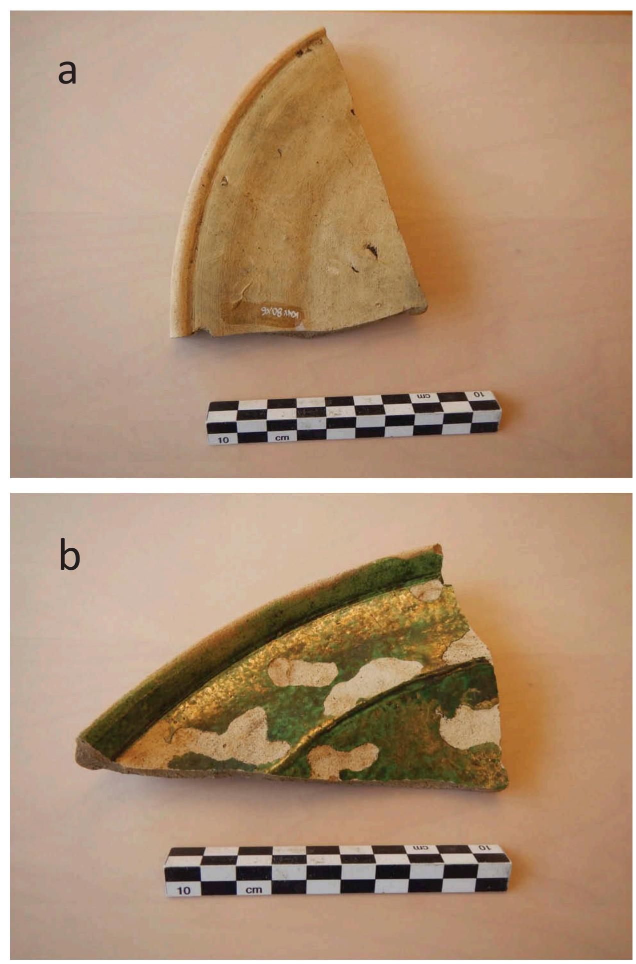

Figure 8. The green-glazed sherd, X6, found between the peat tiles (photos: Karen Bork-Pedersen).

other successful dendrochronological dates were produced for timbers that could not be linked to the fortification, even though some may derive from it. The objective was primarily to establish which activities in the area belonged to modern disturbances, and which were of archaeological interest. The dendrochronological results showed activities in the proximity of the fortification from the second half of the 15th century and well into the second half of the 16th century. These finds from KNV80 Iver Huitfeldts Vej includes a - 20 × 20 cm square oak post (L220/P18) from a row of five (AD 1461–1476), a post (L161) (winter AD 1537–38), and a barrel (A1/P4), made of beech, (after AD 1564) (Daly 2014b)).

The wiggle-match dating

Owing to the lack of sources for dendrochronological dating, an alternative to the more common dating practices in Danish archaeology was attempted. Several of the small posts contained, despite their size, as many as 70 tree-rings, and whilst having too few for a reliable dendrochronological dating and being of a genus that is not widely subject of dendrochronological analysis, their potential for dating the structure would be essential to the interpretation of the find. One post from each of the three excavations, KNV80, KNV96 and KNV123, were, therefore, selected for wiggle-match dating. The selected posts did not fall into the category of recycled timber and all had the bark edge preserved. (The full list of C14 samples is given in Table 1.)

The technique of wiggle-match C14-dating of tree-ring series is described and carried out widely (e.g. Bronk Ramsey *et al.* 2001; Galimberti *et al.* 2004, Lorentzen *et al.* 2014, Daly 2014a). The method involves extracting sub-samples from single tree-rings in a timber at known intervals along the tree's growth. When the exact time span between the resulting series of C14 dates is known, calibration of the group of C14 results is carried out together, taking the known exact distance (i.e. the number of tree-rings) between the separate sub-samples into account. For two posts, six sub-samples were extracted at various intervals (Figure 9). As the tree-rings were very narrow in both cases, wide rather than narrow rings along the tree-growth were selected in order to attain enough material for Accelerator mass spectrometry (AMS) dating, whilst at the same time avoiding contaminating the sample with material from adjacent rings. From the third sample, only two sub-samples were taken for analysis: from the innermost and outermost rings. The rings were very clear on the samples, and all sub-sampling was done under a stereo microscope, so there was no doubt as to how many rings were present between sub-samples.

As with the calibration of single sample C14 dating, the width of the calibrated dating range depends on where on the calibration curve the dating falls. Some parts of the curve are steep, allowing a narrow calibrated dating range. But if the dating falls at places where the calibration curve is flatter, a wide calibrated dating range is the result. Taking samples at known intervals along the tree-rings of a wooden post, for wiggle match dating, (using the D Sequence function of OxCal (Bronk Ramsey et al. 2001)), attempts to reduce the effect of the fluctuations in the calibration curve, producing a narrower dating range for the post and, thus, for when it was felled to be used in the structure.

To the south, at the parking lot Bag Haverne, a small post (L1258/P28) was wiggle-match dated. The post was initially linked to a feature interpreted as belonging to the front of the rampart, but further analysis and post-processing needs to be done in order to confirm or reject this. Nevertheless, we have chosen to include the result for this post in this article because with the appearance of yew post fences in different locations it was important to see if these were from the same construction activity. This yew post contained 78 tree-rings and six sub-samples were taken at intervals along the tree's growth, from outer to inner tree-rings. The outermost sub-sample was taken from a ring two rings under the bark edge. Calibration of this sample alone gave a dating range AD 1436–1478 (95.4% probability). The modelled (wiggle-matched) dating for this tree-ring is a little narrower, at AD 1450–1461 (again 95.4% probability) and if we add the two rings to bark the formation of the last ring before this post was felled, can be placed at c. AD 1452–1463 ((95.4% probability) (Figure 10).

Table 1. The table lists all C14 dated samples including the laboratory numbers and the original, uncalibrated results.

Site name	Submitter Number	Genus & no. of rings	Sample size (mg)	Comments	Beta Analytic no.	Pretreatment	δ13C (‰)	Conventional radiocarbon age	2 sigma calibration
Bag Haverne	KNV00123 P28.6	*Taxus baccata*, yew, 78 rings, bark	20	Rings 5&6	409251	Acid/alkali/acid/ cellulose extraction	−21.4	641 ± 19 BP	Cal AD 1288 to 1319 and CAL AD 1351 to 1390
	KNV00123 P28.5		c. 50	Ring 20	409252	Acid/alkali/acid/ cellulose extraction	−22.0	569 ± 19 BP	Cal AD 1317 to 1353 and Cal AD 1390 to 1413
	KNV00123 P28.4		c. 50	Ring 33	409253	Acid/alkali/acid/ cellulose extraction	−21.4	497 ± 18 BP	Cal AD 1413 to 1439
	KNV00123 P28.3		26.8	Ring 47	409254	Acid/alkali/acid/ cellulose extraction	−20.1	490 ± 18 BP	Cal AD 1415 to 1441
	KNV00123 P28.2		13.1	Ring 64	409255	Acid/alkali/acid/ cellulose extraction	−20.4	457 ± 18 BP	Cal AD 1429 to 1449
	KNV00123 P28.1		14.6	Ring 76. Two rings to bark	409256	Acid/alkali/acid/ cellulose extraction	−19.5	424 ± 18 BP	Cal AD 1440 to 1466
Ivar Huitfeldtsvej	KNV00080 P11.6	*Taxus baccata*, yew, 49 rings, bark	17.6	Rings 1&2	409257	Acid/alkali/acid/ cellulose extraction	−21.8	313 ± 18 BP	Cal AD 1500 to 1503 and Cal AD 1513 to 1601 and Cal AD 1616 to 1644
	KNV00080 P11.5		23.2	Ring 14	409258	Acid/alkali/acid/ cellulose extraction	−19.6	330 ± 18 BP	Cal AD 1486 to 1641
	KNV00080 P11.4		c. 50	Ring 23	409259	Acid/alkali/acid/ cellulose extraction	−20.1	306 ± 18 BP	Cal AD 1517 to 1594 and Cal AD 1618 to 1646
	KNV00080 P11.3		c. 50	Ring 33	409260	Acid/alkali/acid/ cellulose extraction	−21.7	356 ± 18 BP	Cal AD 1462 to 1525 and Cal AD 1556 to 1632
	KNV00080 P11.2		c. 50	Ring 43	409261	Acid/alkali/acid/ cellulose extraction	−20.3	336 ± 18 BP	Cal AD 1480 to 1640
	KNV00080 P11.1		c. 50	Ring 49 just under the bark	409262	Acid/alkali/acid/ cellulose extraction	−19.8	304 ± 18 BP	Cal AD 1518 to 1593 and Cal AD 1618 to 1646
Jernbanegade	KNV00096 P7	*Fagus sp.*, beech, c. 40 rings, bark	225.5	Ring under bark	423358	Acid/alkali/acid/ cellulose extraction	−22.6	506 ± 24 BP	Cal AD 1407 to 1440
	KNV00096 P1	*Alnus sp.*, alder, 18 rings, bark	288.6	Ring under bark	423359	Acid/alkali/acid/ cellulose extraction	−25.7	529 ± 24 BP	Cal AD 1331 to 1337 and Cal AD 1398 to 1433
	KNV00096 P3B	*Fagus sp.*, beech, 55 rings, bark	263.2	Outermost ring	423360	Acid/alkali/acid/ cellulose extraction	−25.5	596 ± 24 BP	Cal AD 1299 to 1369 and Cal AD 1380 to 1409
	KNV00096 P3A		225.6	Innermost rings	423361	Acid/alkali/acid/ cellulose extraction	−28.6	666 ± 24 BP	Cal AD 1280 to 1312 and Cal AD 1359 to 1387

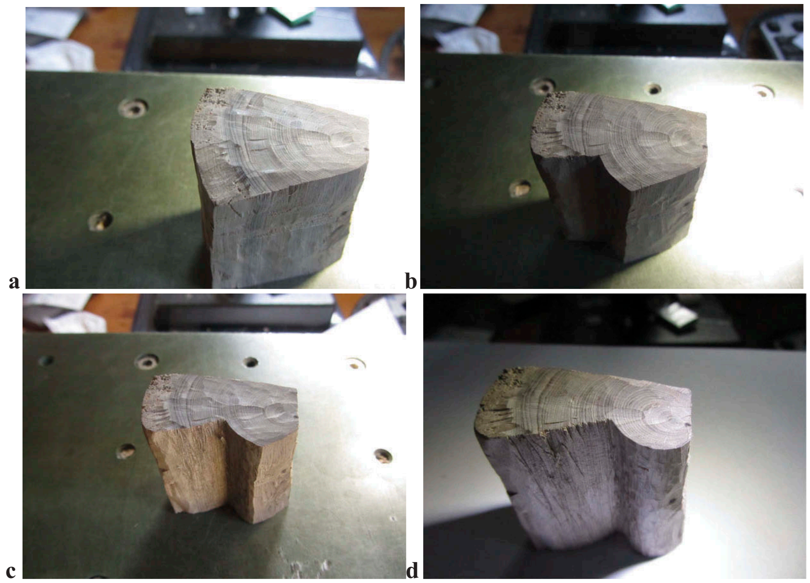

Figure 9. Sampling for the wiggle-match analysis. Sub-samples from single tree-rings along the tree's growth are sampled. The exact distance (number of tree-rings) between each sub-sample is recorded. (Photos: Aoife Daly).

The fence, holding the outer face of the rampart in place in the north-eastern part of the city (KNV80) was made of small yew posts. The post containing the most tree-rings (L120/P11) was selected for wiggle-match dating and six sub-samples were extracted, again taking wider rings along the tree's growth from outer to inner ring. The first sub-sample was taken from the last formed ring on the post, just under the bark. Calibration of this sample alone results in a calibrated dating range of AD 1515–1647 (95.4% probability). The dating of the formation of this tree-ring using the modelled (wiggle-matched) calibration falls at c. AD 1561–1636 (95.4% probability) (Figure 11). In spite of the fact that the series of C14 dates for this post fall at a flat part of the calibration curve, the dating range is still narrower than if the outer ring had been dated alone. This dates the fence 14–89 years earlier than the aforementioned sherd found between the two peat tiles held in place by the posts and, thus, the result poses more questions. Either the date of the sherd has to be pulled back a couple of decades or the turf represents a repair or renewal of the rampart, perhaps during the Swedish occupation, reusing the yew posts.

Northwest of KNV80, the shallow remains of a suspected rampart covered with peat, were found at KNV96. A fence, to which a least 107 posts belonged, kept the inner side of the rampart in place. The posts were larger than those in the front of the rampart at KNV80, and of different wood species such as oak, beech, and alder. Two sub-samples from a beech sample (L230/P3) from this structure were taken; one from the innermost four rings and the other from the outermost ring just under the bark. There are precisely 50 rings between each sub-sample. If only the sub-sample from the outermost ring had been C14 dated the resulting calibration of this would give a range Cal AD 1299 to 1369 and Cal AD 1380 to 1409 (2 sigma). However, when the C14 results of the two sub-samples are calibrated together taking the distance of 50 years between them into account, the resulting calibration of the dates is AD 1326–1407 (95.4% probability).

Regular C14 AMS was performed on two other posts, from the same fence (L225/P1 and L173/P7) with fewer growth rings. The C14 samples from these were each taken from the outermost ring just under the bark. The results of the two regular AMS datings were AD 1331–1337 and AD 1398–1433 for L225/P1 and AD 1407–1440 for L173/P7 (see Table 1).

Unfortunately, the dating of this structure falls at a place in the calibration curve (IntCal13, Reimer *et al.* 2013), which exhibits a marked bend, producing a very wide calibrated dating

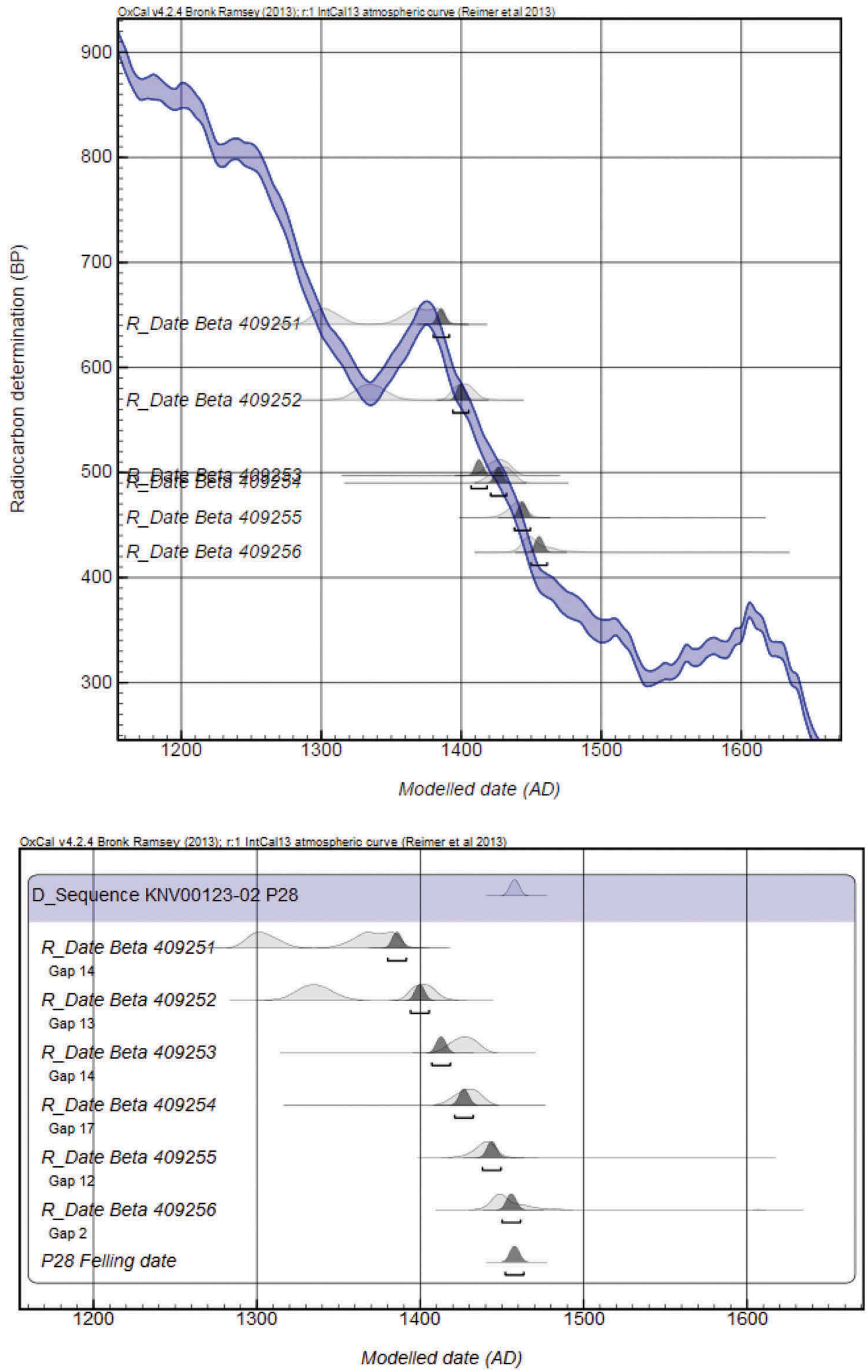

Figure 10. Bag Haverne, Køge. The diagram shows the calibration (Bronk Ramsey 2009; Reimer *et al*. 2013) of the C14-results for the six sub-samples from L1258/P28 (light grey), and the narrower calibration when the actual temporal distance between the sub-samples is accounted for (dark grey). The estimated felling date for the tree that the post was made from is placed at c. 1452–1463 (95% probability).

range. Perhaps, the combined evidence of the wiggle-match dating and the calibrated date for L173/P7 at AD 1407–1440 might allow us to suggest that if the structure is built from wood felled at the same time, then this felling took place in the early decades of the 15th century.

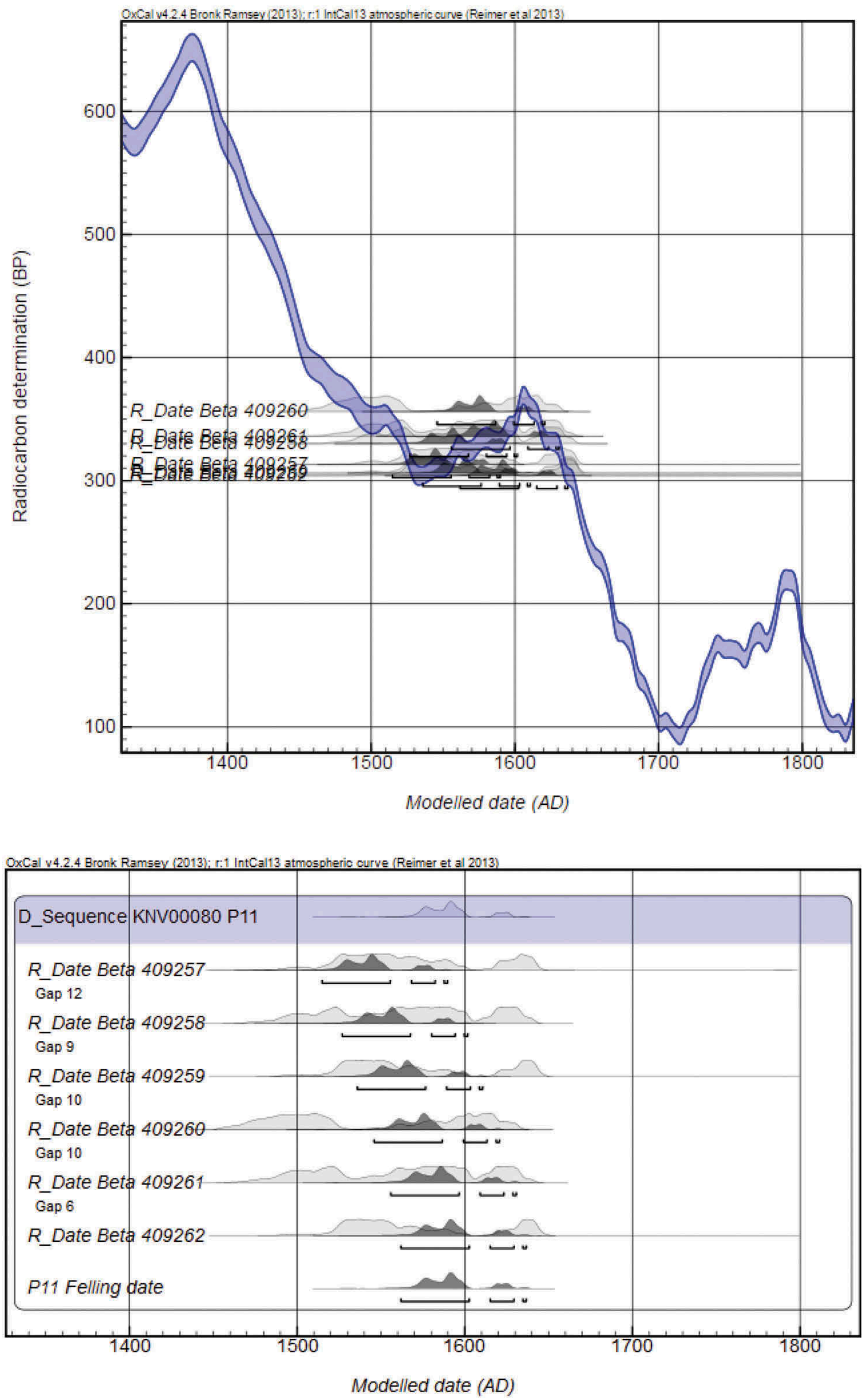

Figure 11. Ivar Huitfeldtsvej, Køge. The diagram shows the calibration (Bronk Ramsey 2009; Reimer *et al*. 2013) of the C14-results for the six sub-samples from L120/P11 (light grey), and the narrower calibration when the actual temporal distance between the sub-samples is accounted for (dark grey). The estimated felling date for the tree that the post was made from is placed at c. 1561–1636 (95% probability).

Discussion/conclusion

As can be seen in Figure 12, where the dating evidence from the material is summarised, a long series of building events in Køge are identified from these recent excavations. While the dendrochronological analysis produced a range of precise dates for the felling of trees for various uses, most of the timbers found suitable for dendrochronological analysis were found in disturbed contexts, or in contexts not associated with the establishment of defensive town ramparts. Additionally, the probability (backed by written sources) that large timbers were derived from reuse was high.

A number of fencing structures made from smaller timber posts in firm contexts associated with rampart building are most likely made from wood felled for that purpose, and these could probably be harvested locally. Even though they were not suitable for dendrochronological analysis, they presented us with the possibility of scientific dating of these construction phases. As previously mentioned, the trajectories of the two fences found to the east and west of today's Ivar Huitfeldts Vej, respectively, were thought to represent the inside and the outside of the same rampart (Figure 4). The C14 wiggle-match results suggest that these two parallel lines of posts are more than a century, perhaps as much as two-and -a-half centuries apart. While we still do not know what structural remains lay between these two fence lines, we can surmise that the evidence indicates that the layout of the ramparts continued to follow the same alignment from the c. 15th to 17th centuries.

The use of the wiggle-match dating method in this case has primarily provided dating where none of the usual methods could be applied successfully. The dating of the structures spans as much as 300 years, even when looking only at the material from the two northern excavations, and suggest a very organic process of numerous repairs or/and variations of the fortification rather than discrete, successive fortifications surrounding the town.

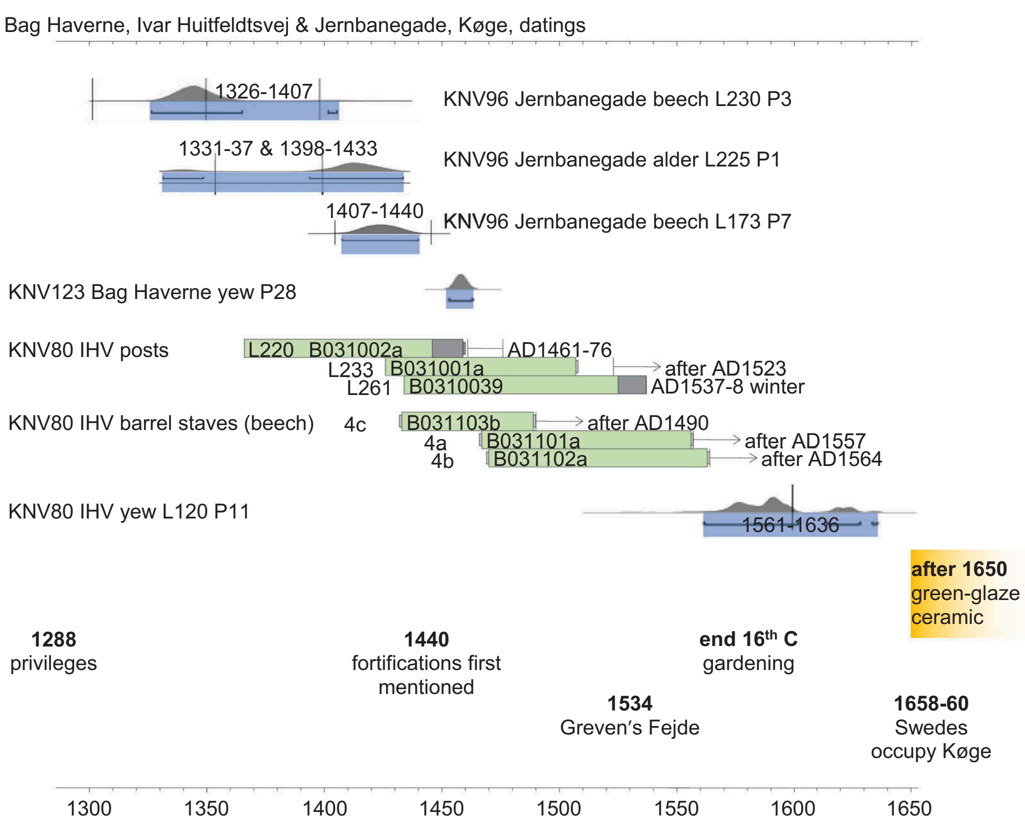

Figure 12. Timeline for Køge. The diagram summarises the chronology of the scientific dating of the wood remains from the three sites, placed with the dating of the ceramic sherd and the main historic events mentioned in the text. The dating ranges for the C14 calibration are marked in blue, the dendrochronological dating of other timber from IHV are highlighted in green and the dating of the ceramic is in yellow (diagram: Aoife Daly).

Perhaps unexpectedly, none of the current finds can be attributed to the fortification built in AD 1658. Even though the design by the Swedish occupiers in AD 1658 with its bastions differed in layout from the medieval fortification, the materials used for the construction and the location may not have changed significantly, being built within a short timeframe by an occupying power using local workers. This underlines the importance of exact dating rather than relying solely on typological or stylistic grounds or indeed written or iconographic/cartographic sources.

Furthermore, it is dubious to use 'dating by association' where only random scattered parts of the supposed construction have been excavated. The dating results show us that this would have been an erroneous approach. In addition, the lack of solid timber constructions of non-recycled wood and the lack of suitable artefacts for typological dating necessitated the use of alternative dating methods. All in all, the present project has demonstrated that the wiggle-match dating method is effective. It has provided us with the first elements of a chronology of construction, repair and, maybe even, demolition phases of the fortification of Køge, which will be of great value in future projects.

The initial assumption that the remains of fortifications that were found might be those built during the Swedish occupation of Køge in 1658 meant that conventional C14 dating method for the structures might not deliver the desired precision. Though still lacking the precision to date – and thus identify – exact, singular events such as the 1658 fortification, wiggle-match dating allows us to see the complexity of the phases of building and maintenance of the town defences through maybe as much as at least three centuries. The written evidence, as mentioned earlier, for ramparts at Køge before 1440 is confirmed and parts of it located, and furthermore it is now also shown that in the late 16th or early 17th century these defences were reinforced. This could imply that the requirement for the citizens to maintain the fortification, mentioned in the written sources, at least to some degree was executed. As additional structures are discovered in future excavations, they may provide additional snapshots from the construction, usage and decay and, thus, the method can help us understand the organic process and life of a long-lived structure.

Even though excavation cuttings have in many places crossed the purported position of the ramparts (Figure 13), the physical evidence for the fabled Swedish fortification has, however, still not been produced.

The use of the wiggle-match method for dating wood is a costly exercise. Applying the method here has allowed us to gain extensive insight into its advantages and limitations. As we wished to

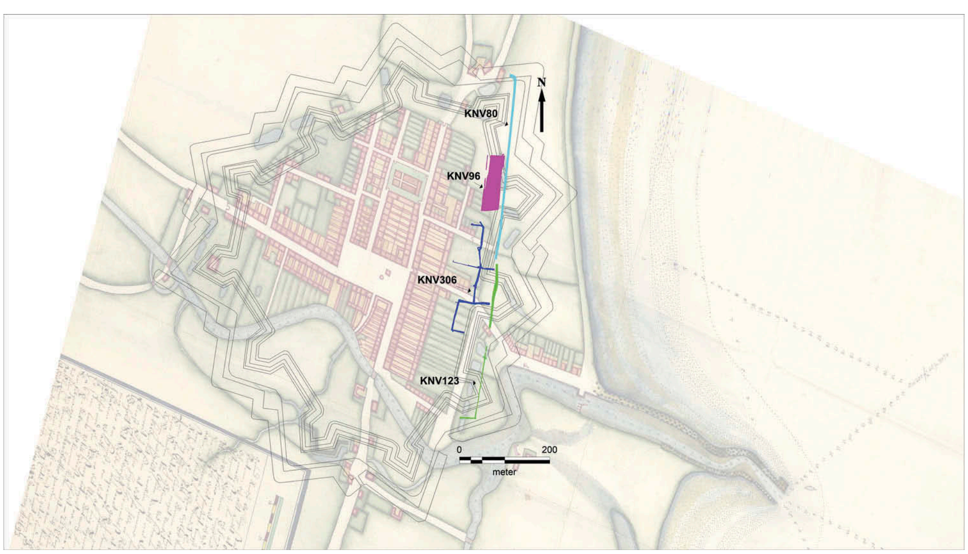

Figure 13. The planned Swedish fortification by Dahlberg is superimposed (to its best fit) on the 1693 map of Køge by Jens Sørensen, with the locations of the four excavations. Jens Sørensens Map by permission Køge Arkiverne. Digitzation of Dahlbergs map by Jeppe Færch-Jensen.

use the method to identify a very specific historical building event, the expense was justified. However, as the results of the analysis show, the wood constructions analysed are several centuries apart. This could have been discovered using fewer than six sub-samples for two of the posts. Strategies for adapting the choice of samples, the number of sub-samples per wooden component and the interval between sub-samples, to optimise the dating precision while minimising costs can now be developed for future excavations.

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Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Aoife Daly http://orcid.org/0000-0002-4389-3238

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RESEARCH ARTICLE

Reconstructing Maglemose bone fishhooks – a craftsmanship from Zealand

Solveig Chaudesaigues-Clausen

MA, University of Copenhagen, København, Denmark

ABSTRACT
The first fishhooks that have been found on the Danish territory date back to the Maglemose period (c. 9600/9500–6700 B.C.), and they are made of bone and antler. Most of them were excavated at the start of the twentieth century in settlements next to inland bogs and lakes and have since then only been studied in a very few cases. The aim of this paper is to analyse the assemblage of at least 30 fishhooks and 23 manufacturing products from that period and produce new knowledge about the Maglemose culture through fishhook typology, technology and comparison with the North European bone production.

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KEYWORDS
Danish Mesolithic; Maglemose culture; fishhooks; bone technology; prehistoric fishing practices; experiments

Introduction

Line fishing is a commonly practiced activity today across the world, both for pleasure and economic purposes. It is highly specialised and requires a great variation of fishhook sizes and shapes (Chacón *et al.* 2015), as well as implements such as lures or spoons (Brinkhuizen 1983, Table 1 p. 14, Bergsvik and David 2015). Although they are today mainly made of metal, they can also be crafted in traditional materials such as wood, animal body parts, bone and many others (Gruvel 1928). This fishing implement, with the shape we know today – a shank, a curved bend and a point – has its European roots in Final Palaeolithic (Gramsch *et al.* 2013) and has been used ever since.

The Danish Mesolithic comprises numerous fishhooks, especially the Early Mesolithic culture of Maglemose (c. 9600/9500–6700 B.C.) and the Late Mesolithic culture of Ertebølle (5400–3950 B. C.). The study of fishing in these periods is of particular interest as this region, in Mesolithic times, was a changing 'waterworld' (Mansrud 2017, Mansrud and Persson 2017), comprising fresh, brackish and salt water, and was, therefore, rich in resources. This paper will focus on the fishhooks from the Maglemose period, where groups of people were living primarily in landscapes dominated by lakes, rivers and bogs, and were using inland fishing (Clark 1936, p. 89). The aim will be to analyse the typology and technology of bone fishhooks from the Danish Maglemose culture on Zealand. The study will comprise:

- The Åmose sites: Øgårde, Vinde-Helsinge, Mullerup I, Ulkestrup Lyng Øst I
- The Sværdborg sites: Sværdborg I, Lundby I

Problems and goals

Through this paper, we will try to analyse how an artefact or a combination of techniques can be representative of an archaeological culture. Defining archaeological cultures started at the end of the nineteenth century, when the English ethnologist E. B. Tylor defined culture as a set of behaviours and traditions comprising morals, art, law, beliefs, knowledge and habits (Tylor 1871, p. 1, Friman 1996, p. 143). This definition was given by ethnologists, who were looking at living societies and, therefore, were focussing on non-material aspects. When the archaeologists tried to define archaeological cultures at the start of the twentieth century, the focus was at first on material evidence only. For instance, Gordon Childe's definition in 1929 was that certain types of finished artefacts or *fossiles directeurs* that were constantly recurring together were corresponding to an archaeological culture (Friman 1996, p. 145,

CONTACT Solveig Chaudesaigues-Clausen solveig.chaudesaigues@gmail.com

Roberts and Vander Linden 2011, p. 2). This definition, which only considered the most prominent material evidence, has evolved since. Not only the final objects are representative, all the remnants of a culture – both material and non-material – play an active part in the tradition of a group and define an archaeological culture (Friman 1996, p. 150, Apel *et al.* 2018, p. 5ff). Then, studying the material evidence of an archaeological culture can lead to the identification of techno-complexes, social traditions and differences or similarities in practices, which is what this paper will intend to do.

In search of adding to the definition of the Maglemose culture, one of the goals is to establish a typology of the fishhooks, by answering these questions:

- Is it possible, when presented with a stray find, to be able to place the fishhook in its original chronological context, based on morphological criteria?
- Can a fishhook type be characteristic of a culture?
- How do we discern cultural traits? Is there a morphological evolution of the shapes?

The other goal will be to study the fishhook manufacture, with the purpose of characterising one – or several – production(s) and understand how it is integrated in the technology of the other bone and antler objects. The following problems will be tackled:

- How many manufacturing methods can be defined and what do they tell about the social group and its contacts?
- Can chronological differences be observed?
- Is technology shared on a wide area or on the contrary restrained?
- What level of freedom can a person making a hook have?

It will be possible to answer these questions with the study of the fishhooks, the products from manufacture, as well as with experimentation. Experiments have been carried out in order to reconstruct the operational scheme of Maglemose fishhooks and to understand what type of waste derived from it. It was done by following the observations and stigmas found on the archaeological material. The material chosen was a red deer metacarpus and the whole process followed the Maglemose method, from the *débitage* of the bone to the final fishhook.

Environmental and cultural context

During the Ancylus Lake stage (c. 9500–8000 BP), the South Scandinavian area was composed of inland lakes, bogs and coastal landscapes around Kattegat, creating favourable conditions that attracted people who settled on lake borders or on the coast (Clark 1936, p. 89, Rößler 2006, p. 15). It is in this context that the Maglemose culture developed as the first Mesolithic culture of the Danish territory (Figure 1). Its centre is considered to be the island of Zealand, where big inland sites have been found and contained a huge amount of archaeological material. Jutland and South Sweden are also traditionally integrated in this central Maglemose culture (David 1999a, p. 25). A greater Maglemose territory with differences and similarities in industries has also been recognised in northern Germany, East England and northern Poland (Figure 1).

Considering the bone industry, the island of Zealand is most representative of the Maglemose culture as bone artefacts are to be found contrary to Jutland, where the limestone sediments have not preserved the organic material (David 1999a, p. 23). As the archaic coastlines from the Maglemose period are today flooded due to eustatic sea-level changes (Rößler 2006), only the inland sites are left to study (Figure 1); therefore, the visible fishing economy is only based on freshwater fish (Ritchie 2010, p. 35). The equipment is represented by barbed bone points, which have been used as spears for fish, as on the Boreal site Kunda in Estonia where two spears were found in pike remains (Clark 1975, p. 144). On the pre-Boreal German site of Friesack, a probable fishnet was discovered (Johansson 2000, p. 110). A paddle from Ulkestrup suggests the use of log boats (Jensen 2001, p. 100). The fish that probably played the most important role in the economy was pike (Clark 1975, p. 142) and the fishhooks used were massive and made for carnivorous fish.

Maglemose fishhooks: characteristics

The Maglemose fishhooks are very varied in shapes and lengths. The shank is usually long and straight, and the bend is curved or has a rectangular outline

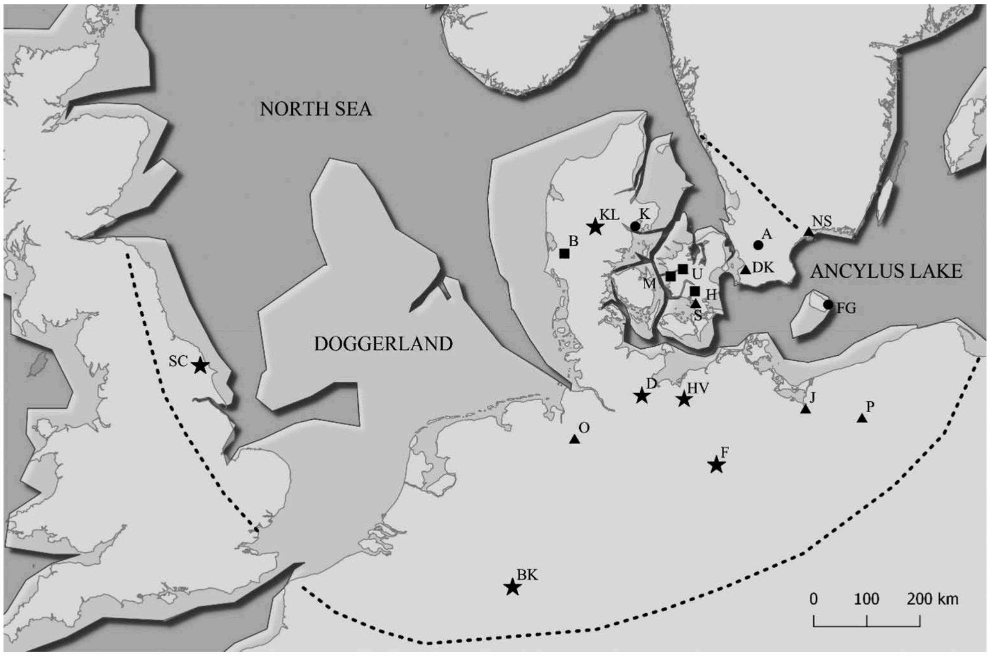


Figure 1. Map over the Maglemose culture and Maglemose-affiliated sites, with some of the sites mentioned in the text and the contemporary coastline. The stippled line represents the rough limits of the greater Maglemose area. Preboreal sites marked with a star: SC: Star Carr. BK: Bedburg-Königshoven. D: Duvensee. HV: Hohen Viecheln. F: Friesack. KL: Klosterlund. Phase 2 sites marked with a square: B: Bøllund. M: Mullerup I. U: Ulkestrup Lyng Øst I. H: Holmegård V. Phase 3 marked with a triangle: O: Oldendorf 69. J: Szczecin-Jezierzyce. P: Pomorski 3. S: Sværdborg I. DK: Draken MK 356. NS: Norje Sunnansund. Late Maglemose sites marked with a circle: K. Kalø Vig. A: Ageröd I:D. FG: Frennegård. After: Brinch Petersen (1973), p. 103, Fischer (1994), David (1999b), David (2006b), p. 96, Casati and Sørensen (2006), p. 36, Novak (2007), p. 90, Sørensen *et al.* (2013), p. 21, Sørensen *et al.* (2018a), p. 174, Sørensen *et al.* (2018b), p. 306. Map of the Doggerland area around 7000 B.C.: Solveig CC, after Gaffney and Thomson (2007), p. 3.

(Friis Johansen 1919, p. 207). The part for attaching the line can be individualised by a knob or a thickening of the shaft and, in some cases, there is no attachment modification. The internal bend is U-shaped and the point is barbless.

Based on data from four sites (Figure 2), 84% of the fishhooks are made from long bone (Mullerup I, Sværdborg I, Øgårde, Vinde-Helsinge) and 12.5% from flat bone (Mullerup I, Sværdborg I). The remaining 3.5 % represent roe deer antler (Mullerup I, Figure 2). On all sites, long bones are the predominant choice for making fishhooks. There can, however, be variation in the selection of the animal species, as some of the bones are very massive (10.8 mm thickness for X.7369 from Sværdborg I), and others are thinner, around 3.5–4 mm thickness. Long bones were probably preferred for their tubular properties, their sturdiness, and the fact that they do not need the scraping of the spongy tissue. The use of roe deer antler for one single fishhook from Mullerup I (Figure 2) may, on the other hand, constitute a special or opportunistic choice (David 1999a, p. 179).

Maglemose fishhooks are rather big, as seen by the size of the fishhooks from Øgårde and Sværdborg I (Figure 3). The longest in the assemblage is the one from Sværdborg I-1923 (Figure 3, drawing), which is 124.1 mm long. These massive fishhooks seem perfect to catch big carnivorous lake fish such as pike (*Esox lucius*) or wels catfish (*Silurus glanis*). On the other hand, smaller ones can also be found. They have especially been seen on Vinde-Helsinge, where all the small fishhooks are fragmented, so only their minimum size could be measured. Their mean full size would be estimated around 40 mm. They could be used for smaller lake fish such as perch (*Perca fluviatilis*) or tench (*Tinca tinca*).

From these observations, can a more precise typology of the Maglemose fishhooks be established?

Typology: a useful tool?

Typological classification is based on technological and morphological attributes and has a long

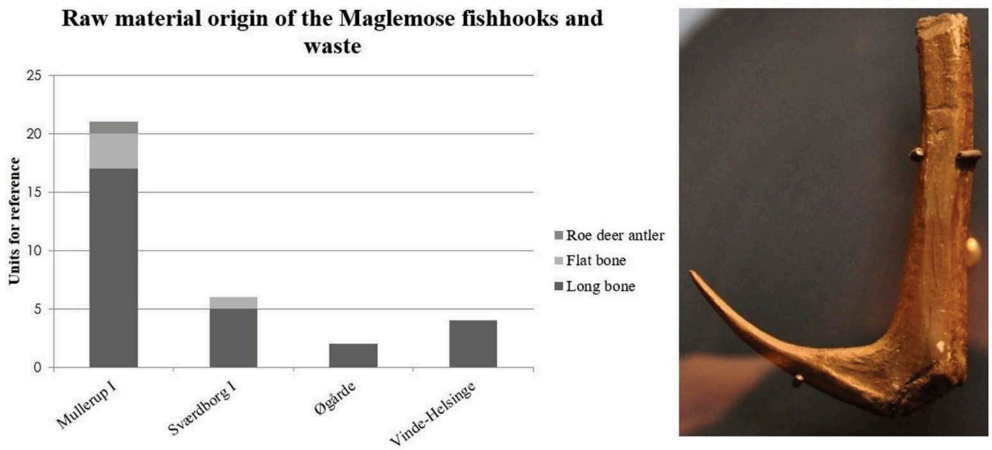


Figure 2. Identified raw material origin of the Maglemose fishhooks and waste. Material from Mullerup I: data from David (1999a). Picture taken by Solveig Chaudesaigues-Clausen: roe deer antler fishhook from Mullerup I (M497).

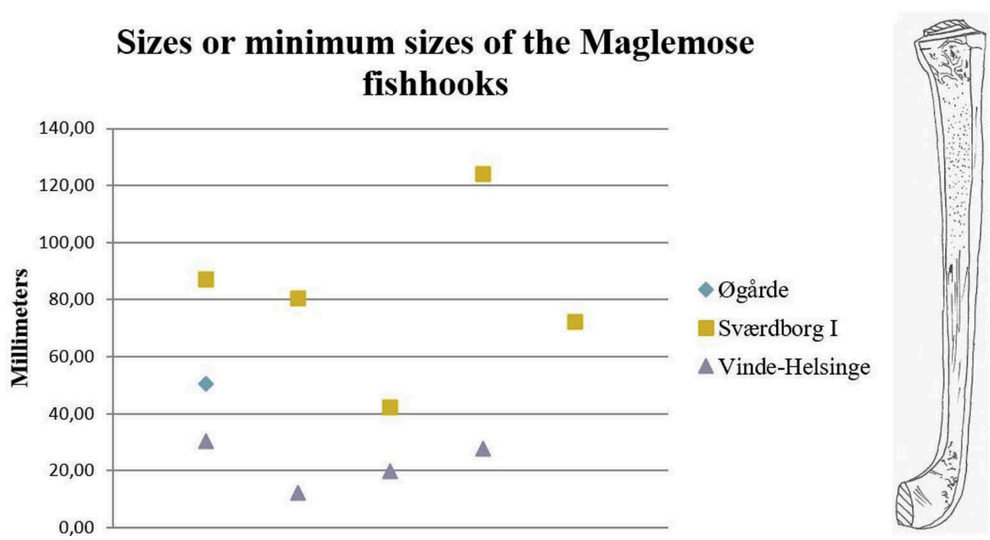


Figure 3. Sizes or minimum sizes of the Maglemose fishhooks. Fishhook: the longest one in the assemblage, Sværdborg I-1923 (X.5326). Drawing: Solveig CC.

tradition in archaeology (Bordes 1961, p. 11). It serves two purposes (Karsten and Knarrström 2003, p. 14, Clarkson *et al.* 2014, p. 168):

- Faced with a large number of archaeological objects, it objectively structures our observations into limited categories, where artefacts can be said to be alike in a defined way. Then, the objects can be studied, compared, contrasted and explained.
- It provides universal terminological conventions: thus, artefacts acquire a scientific status.

Typological classifications were extensively developed in the second half of the twentieth century in order to cope with the huge amount of archaeological material that was excavated. It can be used under various categories: morphological typology, functional typology, classificatory typology, *etc.* (Bordes 1967, p. 26ff, Clarkson and O'Connor 2014, p. 172). However, it has to be handled carefully, as it creates a level of abstraction (Clarkson and O'Connor 2014, p. 172, Karsten and Knarrström 2003, p. 14ff). An overreliance on typology only can for example be seen with the Early and Middle Palaeolithic biface classification developed by François Bordes in the 1960s (Bordes 1961, Depaepe 2018, p. 127, Soressi and Geneste 2011, p. 335). According to him, typology was superior to technology: the techniques were only the means, while the artefacts were the final intention (Bordes 1961, p. 27). He classified each biface on a morphological basis and for him, the morphological differences were only cultural and not resulting from use or technology. But the emergence of the technological approach in the 1980s created a rejection of the Bordian typology (Soressi and Geneste 2011, p. 339). Even if some of the morphologies were culturally connoted, the shape of numerous bifaces was rather linked to their long use, resharpening and reshaping, than to their immutable type (Depaepe 2018, p. 217). Today, prehistorians still use Bordes' typology, as it is practical and is a part of the archaeological discourse (Pettitt 2009, p. 210), but it has to be remembered that it is a classificatory typology. Therefore, the purpose of each typology has to be expressed clearly.

As for the Maglemose fishhooks, their shape is mainly dependent on the prey to catch and the raw material used (Friman 1996, p. 161, Bergsvik and David 2015, p. 193, Chacón *et al.* 2015). From the observations noticed, there does not seem to be a definite Maglemose type, except from two fishhooks from Sværdborg I with a rectangular outline (Figure 4 n.5, Friis-Johansen 1919, p. 207). Their diversity is also seen *intra* sites, where the assemblages are not homogenous either, and represent probably different purposes. However, Eva David made a typology of fishhooks from Mullerup I, making a distinction between the fishhooks with a shaped bend and the fishhooks with an uneven base (David 1999a, p. 110). These uneven-based 'fishhooks' – the so-called *bentvejer* – are already present in the early literature (Sarauw 1904, Friis Johansen 1919). They are composed of an uneven or rough base, a defined point and another supposed point or shaft, which is broken at the base. Sarauw interpreted them as needles for binding fishnets (Sarauw 1904, p. 263). He thought that the objects were discarded when one of the points broke off during use (Sarauw 1904, p. 264). For Friis Johansen, they may have been small leister prongs (Friis Johansen 1919, p. 211). These *bentvejer* are for the moment only found on Zealand. Eva David integrated the manufacture of these uneven-based fishhooks in the production of the fishhooks with a shaped bend (David 1999a, p. 199). If they are considered fishhooks, the base should then have a function. On the Neolithic site of Vinča-Belo Brdo in Serbia, 41 hook-like objects made of flat bone have been found. They are quite unique because they have a big long rectangular base, a shank and a point, and could be lure hooks (Cristiani *et al.* 2016, p. 135). Lure hooks are sophisticated composite objects that are traditionally adorned

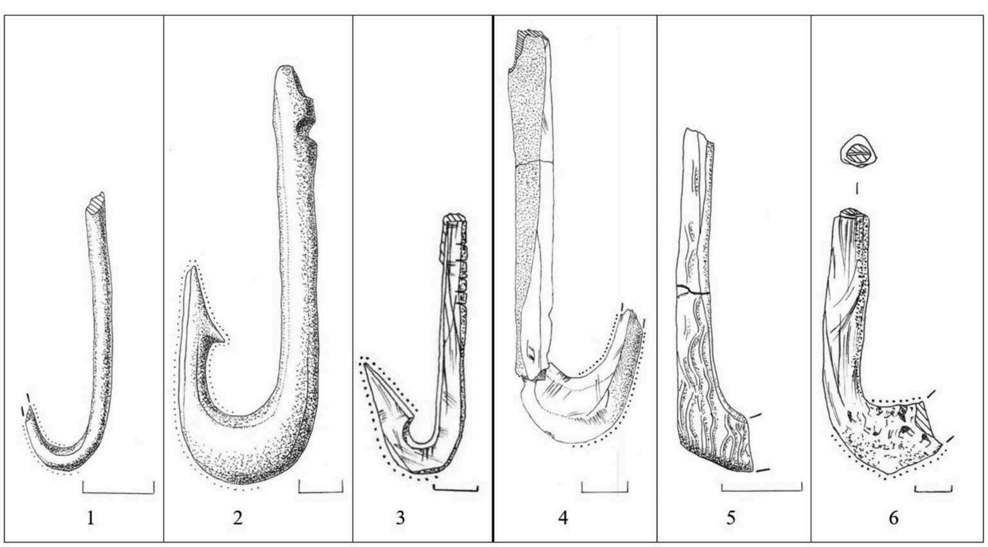


Figure 4. Left: stray finds interpreted as Maglemose: N.1: Grundmosegård (A42903). N.2: Unknown locality (22251). N.3: Søborg lake (A28539). Right: fishhooks from Maglemose contexts: N.4: Sværborg I (X.1448). N.5: Sværdborg I (X.5283). N.6: Sværdborg I (X.7369). Drawings: Solveig CC.

with feathers, leather, ropes, plant fibres or shells, and simulate a small fish to attract carnivorous fish when they vibrate in the water. They combine the properties of both fishhook and bait (Cristiani *et al.* 2016, p. 136). Coloured concretions were found on the base and top shank of nine of these Vinča-Belo Brdo artefacts, supporting the lure hook theory (Cristiani *et al.* 2016, p. 139). Could the Maglemose *bentvejer* then be lure hooks? If so, remains of organic material or modifications would also be found on the base of the uneven hooks, but it was not the case. Another interpretation of these artefacts will be presented later in this paper.

There is also a certain number of old stray finds of fishhooks that have been attributed to the Maglemose culture, based on morphological criteria. However, these criteria are rather vague. Very different morphologies are present in these stray finds, from a barb (Figure 4 n.2), to a visible bend perforation (n.3) or a very slim fishhook (n.1). The visible perforation has not yet been proved in a Danish Maglemose context, and barbs are considered a feature that mainly appears in the Neolithic (Clark 1936, p. 137). Metal hooks were first common in the late Bronze Age and early Iron Age (Clark 1952, p. 56), so bone hooks could belong to another period than the Mesolithic. These observations show that fishhook morphological typology must be taken carefully.

Technological study of the Åmosen and Sværdborg bog fishhooks

Table 1 sums up the techniques involved in the manufacturing of Maglemose fishhooks.

A list of the Zealand fishhooks studied is provided in Table 2.

The débitage to produce blanks

Based on David (1999a, 1999b) and the observation on rough-outs, fishhooks and *bentvejer*, two *débitage* methods can potentially be related to the creation of blanks for fishhook production (further descriptions in David 1999a, 1999b):

- The *débitage* of big game ribs or F-method (Figure 5, left): breaking off the proximal end of the rib, scraping and/or grooving the sides of the rib, using the shaft-wedge technique both laterally with a bone piece and longitudinally with a flint flake in order to separate the rib in two pieces (David 1999a, 1999b).
- The *débitage* of metapodials or D-method (Figure 5, right): vertical percussion on the edges of the proximal epiphysis of the bone metapodial to regularise the bone shaft, grooving longitudinally, sawing and breaking off the distal end and splintering the grooves with the shaft-wedge technique to detach long pieces of bone (David 1999a, 1999b).

The obtention of the blanks for fishhooks can also result from an opportunistic piece of bone that was fractured for marrow extraction, or from the recycling of a former bone tool.

The rough-outs

There are in the assemblage three rough-outs that can be assigned to fishhook production and one possible one. They are all broken longitudinally on the bend region so they could not be further shaped and have been discarded. The one from Vinde-Helsinge, the possible one (Figure 6), was probably discarded near a fireplace, as the surface is burnt.

These rough-outs are coming from both Åmosen and Sværdborg bog and are very similar. The raw material is in two cases (Mullerup I and Lundby I) long bone from big land game, and in one case (Ulkestrup I) rib from big land game. Different shapes of outer bend are chosen, curved and square. They can come from a *débitage*, a marrow-fractured bone or from recycling (the Ulkestrup I rough-out (Andersen *et al.* 1982, p. 74) seems to be recycled from the proximal end of a barbed point).

Regarding the techniques involved in the shaping of the rough-out, they are strictly similar. They consist of (Figure 7 left):

- Bifacial boring on the lower part of the rough-out. Boring easily permits the shaping of the bend. Experimentation has shown that the hole permits the elimination of the powder produced during grooving. The perforation could have a double purpose, both of shaping the

Table 1. The principal techniques visible on the Maglemose *débitage* and fishhook production (Averbouh *et al*. 1999, p. 304ff, David 1999a, 1999b, p. 648–701, 2007). Experiments: Solveig CC.

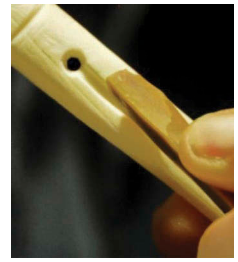
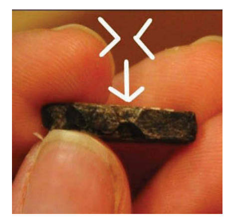
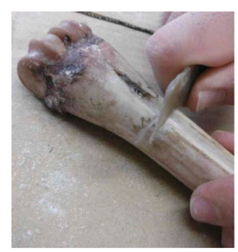
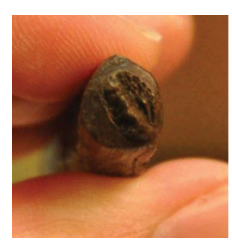
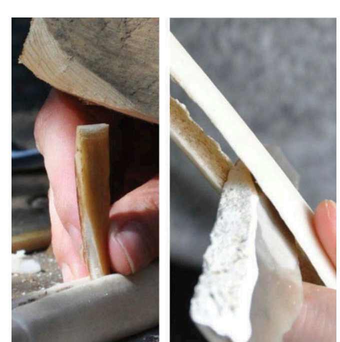
Working processes	Characteristics	Illustration
Grooving	Consists in incising an osseous material, then deepening the incision by abrasion. Repetitive linear movement towards oneself or the exterior to create a groove. Tool: burin or a thin flake. Thin sideslips from grooving can be noticed.	
Scraping	Technique used to scrape smooth a surface. Movement towards oneself or the exterior. The macroscopic traces are linear-undulated parallel striations, with perpendicular successive depressions that correspond to a different pressure created when the tool was applied.	
Boring	Continuous abrasion with a pointed flint tool with an alternate circular movement with the hand. It leaves parallel circular striations. The movement is applied on one face and then on the other face, creating a double cone profile.	
Sawing	Consists in digging a furrow with a sharp flint tool in a back and forth unidirectional movement. Sawing is usually better adapted to elements of little thickness. Sideslips with parallel more or less deep defined striations can be noticed. Sawing can locally be associated with other techniques, like deepening a groove or fracturing.	
Fracturing/ Prepared fracturing	Fracturing can be used alone on thin elements, but without any control of the fracture line. It is the reason why this technique is often combined with others. On the break, the sawing zone is completely flat, while the flexion zone is irregular and presents small indentations.	
Shaft-wedge	Used to divide a bone in its length. For ribs, an osseous wedge is placed transversally in the groove and permits the creation of a split along the bone. Then a flint wedge is placed in the split and is hit perpendicularly to the grooves. The blanks can then be separated. For long bones, only the flint wedge can be used.	

Table 2. The Zealand Maglemose fishhooks studied (Sarauw 1904, Friis Johansen 1919, Broholm 1924, Mathiassen 1943, Brinch Petersen 1973, Henriksen 1976, 1980, Andersen *et al.* 1982, David 1999a).

Site	Region	Maglemose culture phase	Date BP/Date cal. BP	Date B.C./Date cal. B.C.	Dated material	Fishhooks	Material of fishhooks	Museum	Museum number
Lundby I	South Zealand	Phase 1–2				1 *bentveje* during official excavation, 1 rough-out during private excavations	Bone		
Vinde-Helsinge	Northwest Zealand	Phase 2	8550–8350 BP			Min. 7 fishhooks + small fragments + min. 2 *bentvejer* + 1 rough-out	Bone	Nationalmuseet, Denmark	A36512: VI 57 VI 81 VI 132 VI 214 VI? VI 169 VI 133 VI 91 VI 30 VI 185
Mullerup I (*locus classicus*)	Northwest Zealand	Phase 2	8660 ± 120 and 8330 ± 110 BP	6700–6400 B.C.		7 fishhooks 14 *bentvejer* 1 rough-out	Flat and long bones and roe deer antler	Nationalmuseet, Denmark	A18269: M497 M866 M1081 M551 M566 M160 M524 M255 M256 M460 M1160 M1152 M1133 M788 M767 M1157 M245 M? M436 M257 M433 M892 M897
Ulkestrup Lyng Øst I, hut II	Northwest Zealand	Phase 2	8370 ± 130 and 8140 ± 100 BP	Hut II: 6230 B.C. (K-2176)[1], 6100 B.C (K-1509)[2]	[1] Birch from the floor [2] Tinder fungus from waste area	1 rough-out	Flat bone	Nationalmuseet, Denmark	UL17447 and 21,344

(*Continued*)

Table 2. (Continued).

Site	Region	Maglemose culture phase	Date BP/Date cal. BP	Date B.C./Date cal. B.C.	Dated material	Fishhooks	Material of fishhooks	Museum	Museum number
Sværdborg I-1917 & 1923	South Zealand	Phase 3	8350–7850 BP			3 + 8 fishhooks	Bone	Nationalmuseet, Denmark	A29293: X.1448 (Sværdborg-1917) X.? (Sværdborg-1917) X.5 (Sværdborg-1917) X.5283 X.5326 (Sværdborg-1923) X.7369
Øgårde	Northwest Zealand	Phase 2, 3 or 4				4 fishhooks + 1 *bentveje*	Bone	Nationalmuseet, Denmark	A38444: Øl 1453 Øl 1554

interior of the bend and the technical purpose of improving manufacture.

- Central longitudinal grooving, from the perforation towards the upper part of the rough-out, until the opening of a groove. It permits the placing of the shank. The next stage after this initial groove can be seen in Figure 7 left 13b, where the groove is widened by inner scraping.

Waste

Going back to the *bentvejer*, they could simply be waste from fishhook production rather than objects with a function. They are of various sizes, a small one is from Vinde-Helsinge (39.9 mm long, Figure 8 n.4) and among the biggest is another one from Vinde-Helsinge (84 mm, Figure 8 n.3). The fact that they are of various sizes matches well the size range of the fishhooks.

The *bentvejer* have some characteristics in common (Figure 8):

- A completely preserved or nearly complete defined point.
- A missing broken off opposite ‘shank’. The breakage pattern is always the same: the object is broken at the ‘shank’, which seems to be the weakest point.
- A V-shaped internal bend. Bifacial traces of grooving to shape the bend and sideslips can be seen.
- There is no regularity in the shape of the base between the different *bentvejer*, the base can be either broken or worked. In terms of function, this part could probably have a less significant purpose if it was used as an active object.
- Like fishhooks, most of them are made out of long bone, and the others of rib. Like the rough-outs, recycling is also used (Figure 8 n.2).

The fact that the base does not have a defined shape could suggest that either it does not constitute the important part of the object or that these objects are in fact not tools but simply waste from fishhook production. When looking back at the operational scheme of Eva David (Figure 7, left), the only way the central grooving can be widened to make a fishhook is by scraping the inner sides of the rough-

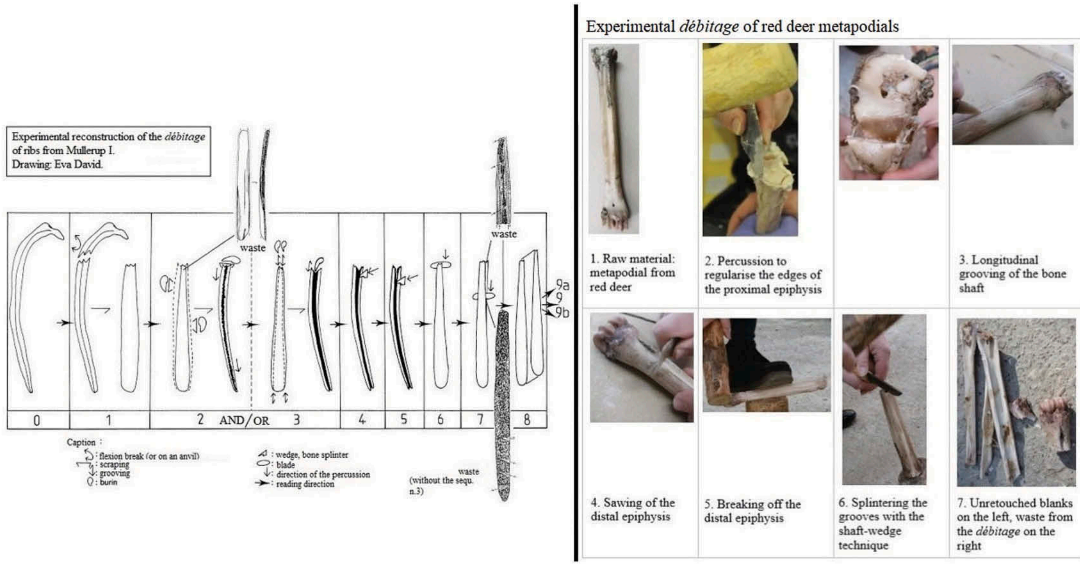


Figure 5. Left: *débitage* of ribs from big land game from Mullerup I (David 1999a: 212). With permission by E. David to use the drawing. Translation: SCC. Right: experimental *débitage* of metapodial. Experiments: SCC, under the direction of E. David.

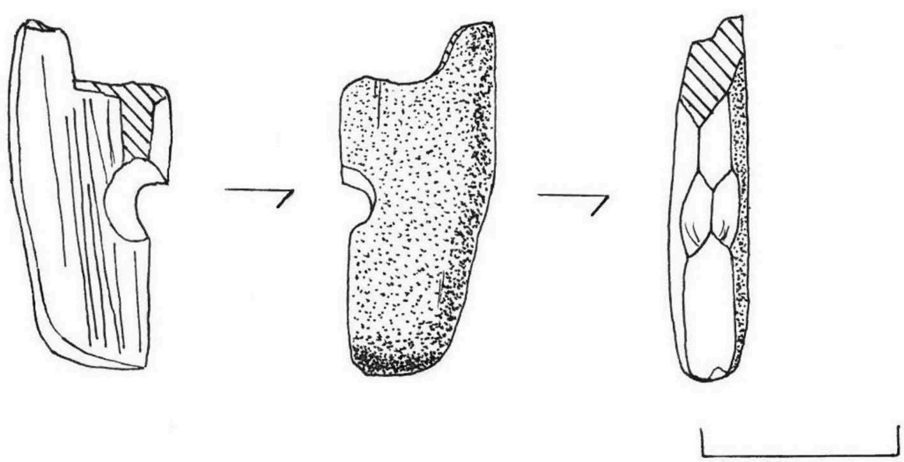


Figure 6. Probable rough-out from Vinde-Helsinge (VI 185). Drawing: Solveig CC.

out. It should automatically result in the shaping of the *bentveje*. Experimentation confirmed this result and showed that scraping the point of the hook naturally creates an hourglass shape, and with further circumferential scraping on the point area, it produces two individualised opposing points. Thus, the point of the supposed *bentveje* could be a result from the shaping of the point of the fishhook and ends up being as individualised as the fishhook point (Figure 9).

Then, if the *bentveje* is a waste product from fishhook manufacture, it has to be found out how it is separated from the top shank of the hook. The literature states that it is simply broken. Eva David notices that the shank bases have a burnt aspect (David 1999a, p. 110). Direct study of the *bentvejer* did not provide an answer. The fractures did not seem to have been through any preparation. Hand fracturing (flexion break) on rather thin pieces and on fresh bone could be undertaken. When examining the upper part of the shank of three fishhooks from Sværdborg I, a prepared sawing and then fracturing can be seen, permitting

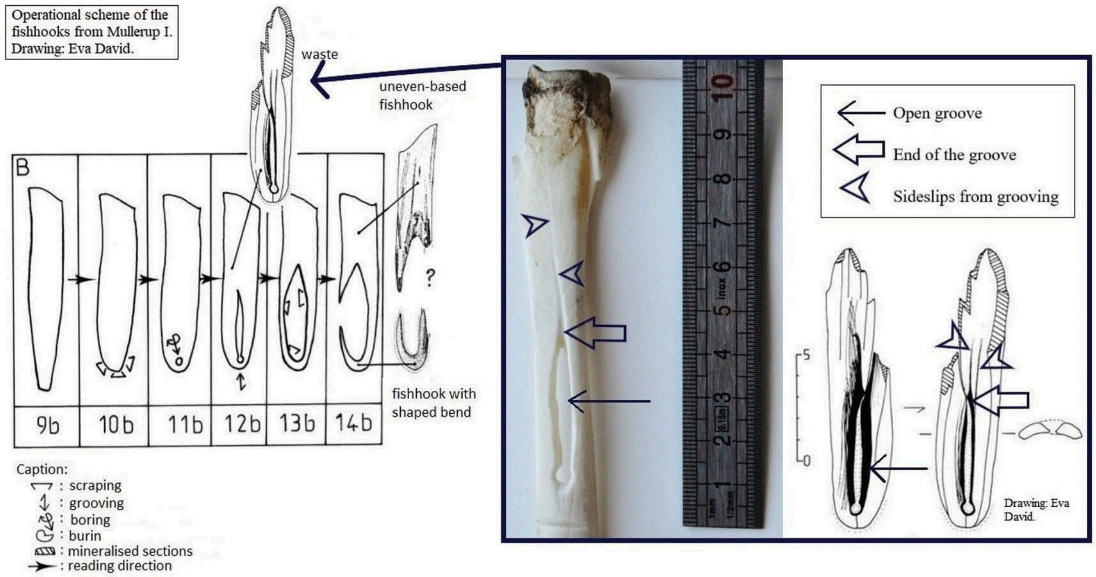


Figure 7. Left: the operational scheme of a fishhook with shaped and uneven base (*bentveje*) from Mullerup I (David 1999a: 199). Translation: SCC. Right: experimental rough-out showing the exact same stigmata as the Maglemose rough-outs (drawing: David 1999b: pl. 36). Photo and experiment: Solveig CC. Drawings: Eva David, with permission to use the drawings (1999a, 1999b).

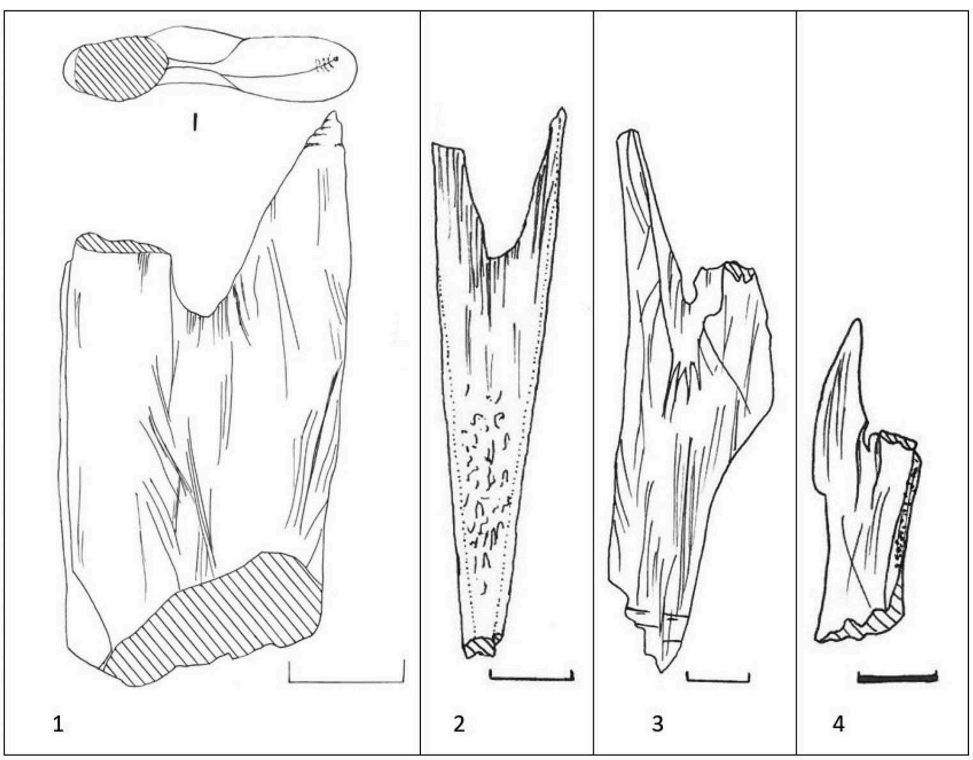


Figure 8. *Bentvejer*: N.1: Øgårde (ØI 1453). N.2: Sværdborg I-1919 (X.5). N.3: Vinde-Helsinge (VI 81). N.4: Vinde-Helsinge (VI 132). Drawings: Solveig CC.

a controlled fracture (Figure 10). It is possible that on massive fishhooks, a prepared sawing was undertaken to detach the fishhook more easily from its rough-out. This was also the solution that was chosen during the detachment of the experimental Maglemose fishhook.

Once the shank is taken off, it should be the last stage of manufacture, as the rest has already been

Figure 9. Experimental Maglemose fishhook under production.

shaped by scraping. Regarding other possible waste products, none have been noticed.

Discussions and perspectives

The technological analysis of the Maglemose fishhooks showed that if the choice of raw material does not seem to be normalised, the fishhook shaping techniques (boring-grooving-scraping) are in contrast identical on the six studied Zealand sites. Maglemose bone artefacts have not been preserved from Jutland; it is, therefore, impossible to tell whether this production method characterises the whole Danish territory. As for a chronological variation, it has not been noticed. From the observations on the rough-outs, there is continuity of this shaping method at least from phases 1–2 (Lundby I) to at least phase 3 (Sværdborg I). The fact that it is a time-consuming inner longitudinal grooving and scraping that was undertaken for the shaping shows that strict rules were followed, even for massive hooks. Therefore, Maglemose fishhook production is strongly culturally connoted and highly standardised. When looking at other objects such as the barbed bone points, a strict standardisation of the operational schemes is also followed and it is characteristic of the Zealand Maglemose bone industry (David 1999a, 1999b).

Comparing the Danish fishhooks and their manufacturing method with bone technology from northern Europe, some assumptions can be made. Eva David has identified several methods for making barbed bone points from England to the Russian plain (David 2006a, p. 138ff). The barbed points made from ungulate metapodials

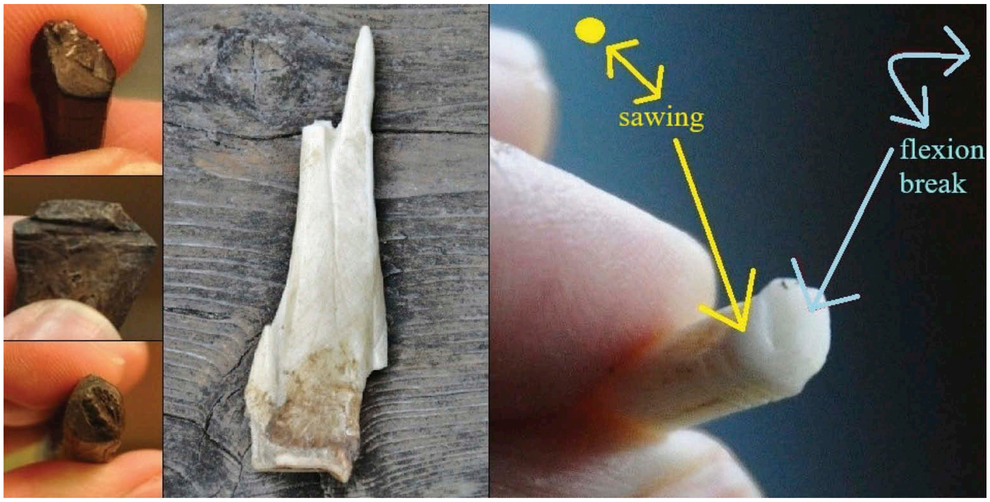


Figure 10. Left: the upper part of shanks of Maglemose fishhooks that present a prepared fracture (sawing + fracture): X.?, X.5326, X.7369 from Sværdborg I. Middle: experimental *bentveje* with sawn off and flexion-broken shank base. Right: upper part of the corresponding experimental fishhook, with sawn and broken off upper shank.

and flat bones are a common artefact in the whole area (Clark 1936, p. 87), but different *débitage* methods show that these weapons look alike but are not made the same way, and she demonstrated different technological traditions (David 2006a, p. 138ff). These traditions can for example be seen in the *débitage* of metapodials. David recognised a north-eastern techno-complex, represented by the Z-method, consisting of splitting the bone with a shaft-wedge-splinter technique (Bergsvik and David 2015, p. 214). It was first identified on the Russian site of Zamostje II but is also present on the western Norwegian coastal sites Viste and Sævarhelleren (David 1999a, p. 359ff, Bergsvik and David 2015, p. 213). There is another techno-complex: the northern techno-complex. It includes Star Carr, Hohen Viecheln, Duvensee, Friesack, and Zealand sites (David 2006a, p. 138–140). In this northern techno-complex, the D-method of *débitage* of bone shafts – the groove and splinter technique – is found in the Zealand Maglemose settlements and constitutes a special group in this northern techno-complex (David 2006a, p. 138ff).

There is one fishhook from Southern Sweden that could be affiliated to the Zealand production method, it is the Late Maglemose fishhook from Ageröd I:D (Figure 11). But no waste from the shaping process was recognised (Larsson 1978, p. 132). Even if Larsson suggests the possibility that it was shaped following the Maglemose method, it cannot be ascertained without waste material. Therefore, bone material from this layer should be studied in order to determine how the fishhook was manufactured. Looking at the older site of Ageröd I:A-H-C in the VL horizon, which is dated to the late Boreal chronozone (David 1999a, p. 31), it comprises both influences: the western Danish D-method and the eastern Z-method for the *débitage* of bone shafts (David 1999a, p. 353ff, 1999b pl. 104 & 105, Bergsvik and David 2015, p. 214). Ageröd I:A-H-C, along with the neighbouring site of Norje Sunnansund (pit area E2), mark the limits of the south Scandinavian eastern Z-method (David and Kjällquist 2018, p. 254). According to this, even if the Øresund did not exist in Maglemose times, there seems to be a *stricto sensu* Zealand Maglemose tradition (David 2006b, p. 96), different from the southern Swedish one that is subject to different influences. It seems again that the operational scheme of the Maglemose fishhooks is a part of the definition of the Zealand Maglemose group and adds to its characterisation as a singular techno-complex (Figure 11).

The Maglemose Zealand bone technology appears to be a long conservative tradition that does not allow innovation. Concerning the lithic industry, it also tends to be quite conservative.

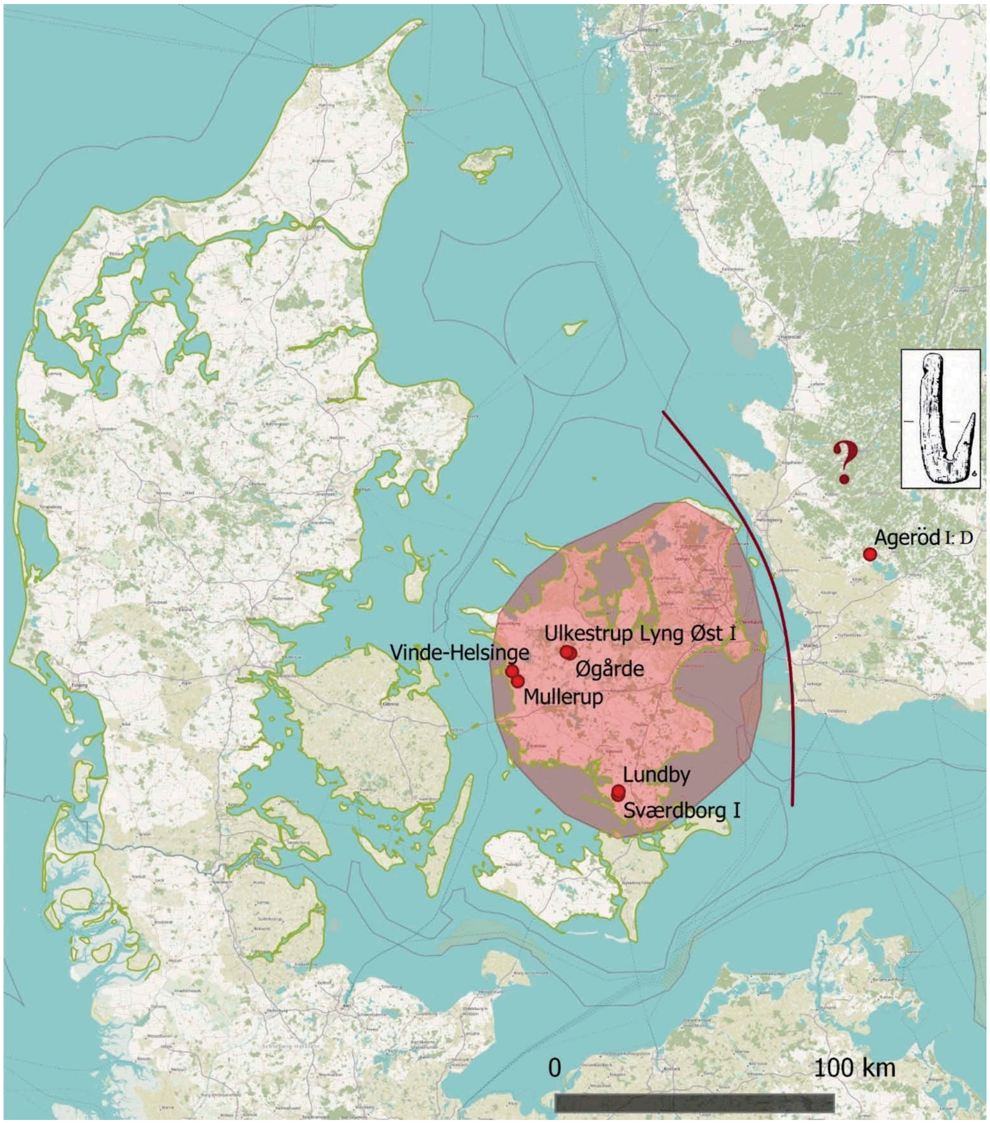


Figure 11. Map over the sites with Maglemose fishhooks, showing that the same technology is shared on all Zealand sites. The integration of Ageröd I:D in this techno-complex is not known. Fishhook: drawing by B. Centervall (Larsson 1978, p.132) with permission by L. Larsson to use the drawing. Map: Solveig CC.

However, during phase 3 of the Maglemose period, it is subject to change: a new flint knapping technology is introduced, called the conical core blade concept (Sørensen 2012, p. 241, Sørensen *et al.* 2013). It is a blade production method that consists of using the pressure technique to detach blades from regular conical cores. This technique permits the creation of very regular blades, and it requires a highly specialised knowledge (Sørensen 2012, p. 237ff, Sørensen *et al.* 2013, p. 23). This technology seems to originate from western Russia – the oldest date being from Stanovoye 4: 9375 ± 50 BP – and it spreads throughout Scandinavia. It arrives in Denmark through the Baltic countries and is present on Zealand around 8170 ± 120 BP on Ulkestrup II, during the phase 3 of the Maglemose culture (Sørensen *et al.* 2013, p. 25ff). The theory of an eastern contact is also confirmed by DNA analysis of individuals from Hummervikholmen in southern Norway (dated to 9452-9275 BP for Hum1 and Hum2) and Motala in southern Sweden (dated to 6977 ± 69 BP for Motala3) (Eriksson *et al.* 2018, p. 908, Günther *et al.* 2018, p. 3ff). DNA from two sites shows that the individuals' genetic affinities were from both western and eastern hunter-gatherers (Günther *et al.* 2018, p. 3ff). It seems then that the exchange of knowledge also accompanied the exchange of DNA. However, even if the conical core blade concept is a new technology, it is only seen by the Maglemose people as an optimisation of the blade production and does not generate new artefact types or eastern-inspired artefacts. As for the bone industry, they did not consider the Z-method to be efficient or interesting enough to replace their own traditional method.

These observations show that some practices, whether they are symbolic or material – often combining both in hunter-gatherer societies (Mansrud 2017, p. 2) – create a sense of belonging to a certain group, to a community of practice that shares the same knowledge and skills (Wenger and Snyder 2000, p. 139ff). The restricted Maglemose Zealand fishhook production or the regional differences in blade technology in South Scandinavia during phase 3 are witnesses of the communities of practice that seemed to exist in the Maglemose culture (Sørensen *et al.* 2018a, p. 195).

Even if the fish species caught on the different Danish Maglemose settlements were approximately the same (Rosenlund 1976, p. 22), it did not seem to generate identical-looking fishhooks, except from the two ones from Sværdborg I. There does not seem to be a standardisation in their shape. But looking further north, on the Middle Mesolithic sites of the southern coast of Norway as well as the southwestern coast of Sweden (8300–6300 BC), it appears that there is a recurring style all along the settlements of these regions. From Viste in southwestern Norway, to Prestemoen in southeastern Norway and Dammen in southwestern Sweden, most of the fishhooks have the same shape, are made from metapodials, have an average size of c. 30 mm and notches on the shank (Persson 2014, Bergsvik and David 2015, Mansrud 2017, p. 5). All these coastal sites have fished the same fish species, especially codfish and deep-sea fish (Århberg 2007, p. 47, Persson 2014, p. 220), and the fishhooks have the same style, contrary to the Maglemose ones.

Conclusion

This paper has attempted to give a structured overview of a single group of artefacts from the Maglemose period. It tried to demonstrate that, considering the fact that fishhooks are weapons used to catch fish, the Maglemose fishhook typology is rather linked to their use, the raw material chosen and the person who made the hook. Considering how specialised the choice of a fishhook still is today, where fishermen have their own preferences depending on the intended fish and the period of the year (Chacón *et al.* 2015), it is highly likely that fishhooks from Mesolithic times were produced by the fishermen themselves.

It has been established that it was difficult to place a stray find with complete certainty back in its original chronological context, when no manufacturing products were present. The manufacturing products – rough-outs, *bentvejer* – and the technical actions are on the contrary the true cultural markers. It is by their study and identification that it was possible to recognise a community of practice on the Zealand area, which shares the same knowledge and techniques about fishhook production.

To go further, a study of fishhooks in the Mesolithic of Europe contemporary to Maglemose times – choosing both coastal and lacustrine/riverine communities, as well as the ones that do not use fishhooks – should be undertaken. It would then be possible to draw a map of the use of fishhooks, their context and manufacture, in order to understand how specialised line fishing was in other European regions. We know from Russian sites that are contemporary to the Maglemose culture, such as Zamostje II, Stanovoye and Ivanovskoye 7 layer IV (Zhilin and Matiskainen 2000, p. 699, Maigrot *et al.* 2014, p. 246ff, Zhilin 2014, p. 101ff), that the fishhooks are made by hole-drilling on the rough-out and by convergent grooving to detach a triangular offcut. This method is very similar to the one used on the Middle Mesolithic coastal sites of south Norway and southwestern Sweden (Mansrud and Persson 2017). Since the Zamostje II Z-method of *débitage* of bone metapodials is also present on the southwestern Norwegian Viste and Sævarhelleren sites (Bergsvik and David 2015, p. 209), there could be an eastern-related production method of fishhooks on those sites. However, the Russian fishhooks are not similar in style to the Swedish and Norwegian ones (Zhilin and

Matiskainen 2000, p. 699, Zhilin 2014, p. 101). It would be interesting to study how widely this manufacturing method is practiced in time and space, and see what the connections between the western Russian plain and the Scandinavian area are.

As for coastal fishing, an analysis of stable isotopes on a human humerus from Køge Sønakke dated to 8250+-25 BP showed that this coastal Late Maglemose human consumed sea fish (Fischer *et al*. 2007). Underwater investigations in the coming years will probably bring more information about the submerged coastal Maglemose settlements in Denmark and what fishing gear they used there (Fischer 2001, p. 5, Moe Astrup 2018).

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