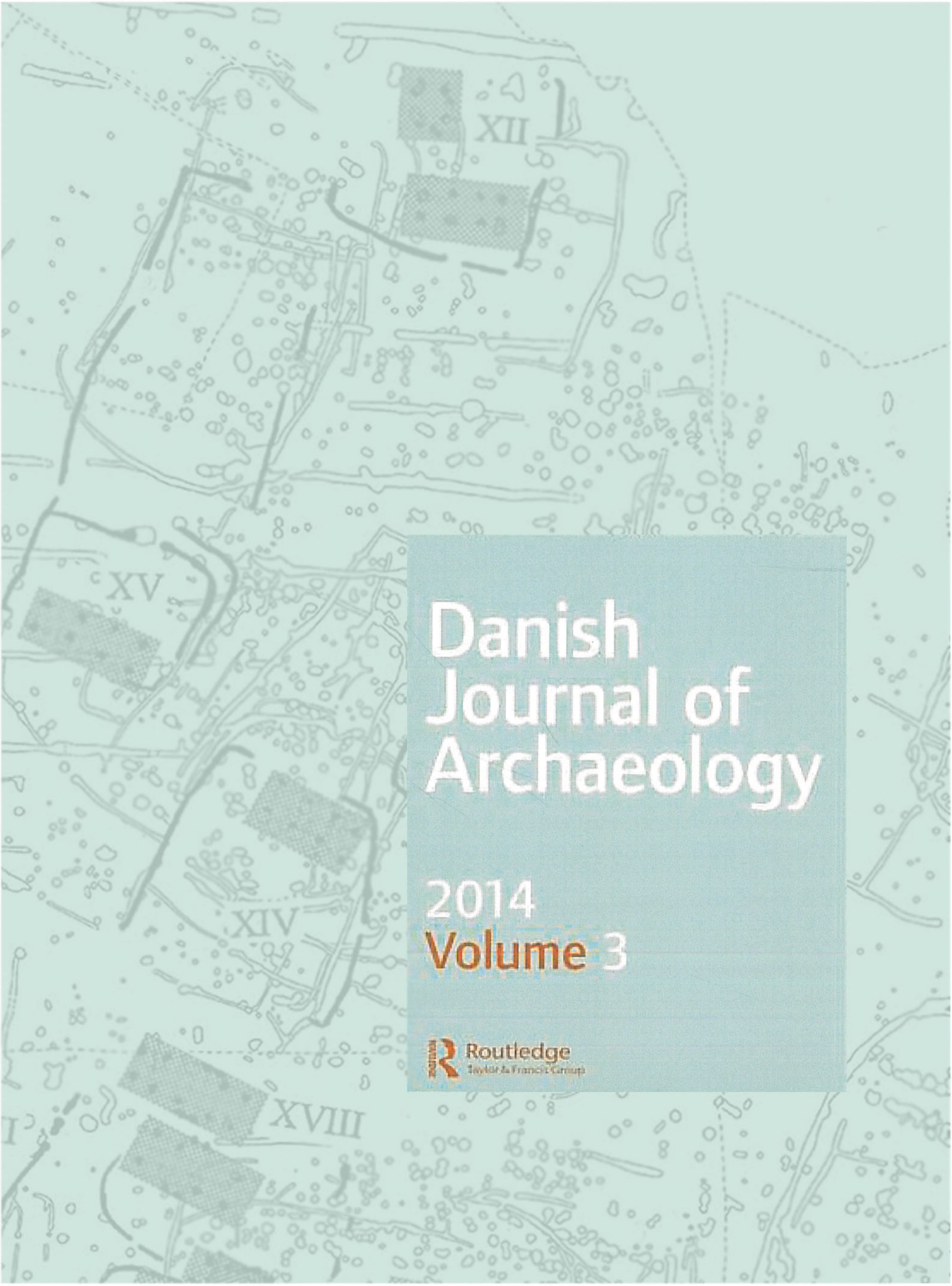

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Editorial

The readership of *DJA* continues to grow apace with over 3000 full-text downloads from Denmark, the UK, USA and elsewhere at the end of June 2014, up from 880 in September 2013. It is a growth rate that our publishers consider unique given the *DJA*'s comparative 'youth', i.e. its new form. It thus fulfils our most important aim: making current Danish and Scandinavian archaeological research and debates, exciting new finds and theoretical discourses available to both a national and an international public. *DJA* is now the forum for Danish and other Scandinavian archaeologists wishing to communicate their research to a widespread international readership. In the meantime, we are continuing to promote *DJA* extensively via *press releases*, an *introductory online access offer* and at *conferences* (e.g. EAA, Nordic TAG). At EAA in Krakow 2013 and Istanbul 2014, *DJA* attracted a great deal of attention and many people expressed their enthusiasm about the revitalized *DJA* since there was a lack of a forum to publish especially empirical contributions in English and for a wider audience. To further promote *DJA*, we have targeted digital campaigns, measured by, e.g. Webpage 'views' and Social Media 'Shares' in order to promote the journal and gain more readers and contributions. At least for our Danish readers, it is interesting to note that DJA will now be indexed as a level 1 journal and we are on course to attain level 2 ranking in the near future.

A crucial new tool is *Editorial Manager* 'www.editorialmanager.com/rdja/' where authors can easily submit their contribution to the *Danish Journal of Archaeology*. This website allows authors to upload manuscript files for review and also to follow the editorial processing of the article. *Editorial Manager* is used for the review process and all reviewers would have to upload their comments via the website. This will speed up the process, for as soon as manuscripts are accepted in their final form, the contribution will appear online, offering unique opportunities for dynamic and rapid publication, and the ability to participate in current debates. However, we as editors will not be anonymous to the authors. All contributions will have an editor in charge who may be contacted, if necessary.

At the same time, the discussion on open access continues. All authors are given the option to publish their article with *gold open access*, but, even more important is the possibility to use *green open access*, which enables authors to post the accepted version of their paper immediately on a personal and/or departmental (internal) website. However, a quarantine period of 18 months is applied to university repositories, open databases, etc.

The new issue 3.1 is as broad as volumes 1 and 2 and covers a wide range of topics and time periods. It also contains research articles and reports, brief communications and discussion articles. Mortensen *et al.'s* article, 'Vegetation development in southeast Denmark', clearly demonstrates how the combination of pollen and plant macrofossils can give a detailed and accurate reconstruction of the local environment. A different environmental theme and its impact on society is addressed in Bondeson and Bondesson's *brief communication* article 'On the mystery cloud of AD 536' in which they offer a specific mechanism or middle-range link for how the sixth-century agrarian societies of the Iron Age may have been affected by the suggested environmental downturn at that time.

Karg *et al.'s* research report, 'Vegetal grave goods in a female burial on Bornholm from the Late Roman Iron Age period', shows the potential of combing methods in natural science with archaeology. Here, the authors discuss the possible interpretation of healing processes based on finds of amulet boxes and vegetal objects that were analysed with gas chromatography/mass spectrometry. New aspects on 'The Typology and function of Late Bronze Age and Early Iron Age cremation graves' are presented in Harvig et al.'s article. In Wood's article, 'The pictures on the greater Jelling stone', the imagery of the stone is discussed and interpreted in unorthodox ways. Wienberg's article, 'Four churches and a lighthouse – preservation, creative dismantling or destruction', published online earlier this year, has already attracted much attention, and this issue contains no less than three discussion articles that all debate Wienberg's approach to the dismantling of heritage objects and his use of the notion 'creative dismantling'.

Issue 3.2 will also offer a wide range of articles, such as 'First evidence of lime burning in Southern Scandinavia' and 'Repertoires of landscape regulations: southern Scandinavia in the Late Bronze Age and Pre-Roman Iron Age'. Furthermore, as a part of 3.2, we have invited three scholars to reflect on Jørgen Jensen's *The Prehistory of Denmark: From the Stone Age to the Vikings*. This book is an abridged and slightly updated version of Jørgen Jensen's seminal four-volume, *Danmarks Oldtid*, which was published in 2001–2004; the English version was translated by James

Manley and published in 2013. It is considered to be a continuation of a Danish archaeological tradition going back to 1836 and the publication of the seminal book *Ledetråd til Nordisk Oldkyndighed* (*Guide to Northern Antiquity*) by C.J. Thomsen. Common to these archaeological descriptions of our past is that while they discuss Danish origin and identity, they also reflect the most important archaeological issues at the time of their publication. How these issues are approached in Jensen's book and how they are presented to the wide world will be discussed by the reviewers.

The endeavour to place *DJA* on a firm footing continues, and its success so far is thanks to our readers, reviewers and authors, as well as our good collaboration with the team at Taylor & Francis, support from *Jysk Arkæologisk Selskab* (Jutland Archaeological Society), *Det Kongelige Nordiske Oldskriftselskab* (Royal Society of Northern Antiquaries) and the National Museum of Denmark, and the financial support from *Kulturarvsstyrelsen* (the Heritage Agency of Denmark). Our aim is to continue and follow up on the positive trend and to secure *DJA* as an active forum for our colleagues in all Danish museums and universities as well as make Danish and Scandinavian archaeological research and debate visible to a larger international public.

Eva Andersson Strand
Copenhagen University & The Danish National Research Foundation's Centre for Textile Research, Denmark

Felix Riede
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Typology and function of Late Bronze Age and Early Iron Age cremation graves – a micro-regional case study

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In Denmark, there has been little focus on characteristic differences between grave types from the transition period between the Late Bronze Age and the Early Iron Age with limited elaboration on the nature of the differences and on chronological variation. In nearby Scania, Sweden, a grave type classic for Southern Scandinavia, the 'cremation pit', has been interpreted as *in situ* remains of the actual cremation pyre, that is, a form of *bustum*. Here, we further explore this interpretation through both osteological and archaeological analyses of recently excavated graves from the Fraugde region on northern Funen, Denmark. In the Fraugde region, pyre debris in cremation graves clearly gain significance during the transition period from the Bronze Age towards the Pre-Roman Iron Age. The exclusive presence of cremation pits on the Pre-Roman Iron Age grave sites in contrast to the varied grave types present on the Bronze Age sites implies a change in cremation practice and technology during the transition period. Although clearly commemorated and left undisturbed for centuries, the cremation pits on the pre-Roman Iron Age sites must be interpreted as intentional, secondary deposits of the debris from the cremation pyre, but not as *in situ* pyre sites.

Keywords: cremation graves; grave typology; cremated bone; Late Bronze Age; Pre-Roman Iron Age; cremation pit

Introduction

Archaeologists face many challenges of interpretation linked to the classification of archaeological contexts. If we wish to understand the complexity of cremation practices and improve the methods we employ in the study of the many stages involved in past cremation ceremonies, we need to tackle and discern between intentional ritual technology and taphonomic processes. We further need to theorize and explore the varied and contrasting uses of 'fire' in the production of mortuary contexts. Although cremation graves vary in appearance, and also often in degree of preservation or 'intactness', they usually have the presence of cremated human bone in common. Nevertheless, we need to distinguish between what is a grave, that is, a place for a burial, and what is a burial, that is, the evidence of placing one or more dead bodies in a grave (the act of burial) (see, for example, Ericsson and Runcis 1995)[1]. This case study seeks to eliminate differences in osteoarchaeological results gained from various types of cremation graves and related archaeological features using data from the transition period between the Late Bronze Age and the Early Iron Age in the Fraugde region on northeastern Funen, Denmark.

In Scania, southern Sweden, grave sites hitherto interpreted as typical examples of transitional graves from the Late Bronze Age urn grave tradition towards the simple Early Iron Age cremation pit, have been interpreted as sites representing simultaneous phenomena with separate functions. Based on both similar ^{14}C-dates and osteoarchaeological interpretations, the graves of the urn grave tradition are interpreted as actual graves, whereas the cremation pits are seen as *in situ* remains of the associated cremation pyre, or, in particular, as a draught-creating pits similar to the roman *bustum* graves (see under Terminology). The combination of the two, the urn cremation pit, is suggested to represent an individual grave, cut into the associated pyre site (Lindahl Jensen 2004, Arcini 2005, 67ff., Arcini and Svanberg 2005, 323ff.).

These suggestions are a valid and much appreciated contribution to the debate on the interpretation of these archaeological features, which are found with similar characteristics in large areas of southern Scandinavia during the transition period and in the Early Iron Age (e.g., Vedel 1870, Albrectsen 1954, 1973, Klindt-Jensen 1957, Becker 1961, 128ff., 1990, Hansen 1975, Thrane 1984, 2004, Lind 1991, Jensen 1997, Hornstrup 1999, Ejstrud and Jensen 2000, Edring 2004, Arcini 2005, Arcini and Svanberg 2005, Feldt 2005, Fendin 2005, Frisberg 2005, Hornstrup *et al.* 2005, Widholm 2006, Therkelsen 2011, Clemmensen 2013, Kristensen 2013, Runge 2013, Mikkelsen 2013a). However, experimental studies reveal that further elaboration on this matter is needed. We can definitely rule out *in situ* cremation, which first and foremost would result in clearly visible burnt sides of the cut

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(e.g., Dodwell 2010, Marshall 2011, 36), which is not documented for cremation pits in the Bronze Age or earliest Iron Age in southern Scandinavia (Klindt-Jensen 1957, 46, Thrane 1984, 78, Henriksen 1993, 105). Second, *in situ* cremation would result in an identifiable stratigraphy reflecting the pyre settling gradually in the pit during the course of the fire. Lastly, only a very shallow pit is needed for creating draught, and expanding the cut does not increase the draught effect (Henriksen 1993, 2009, 83 and 102). Simple stratigraphic observations of Danish urn cremation pits and cremation pits further reveal that there is little or no difference in sequence between the cut and the placing of the urn or other artefacts. Hence, they were constructed in one single action, indicating that the pyre was originally located elsewhere and 'poured' as relatively cooled debris into the pits (Hornstrup *et al.* 2005, Runge 2010). Furthermore, although well preserved, there is rarely pyre debris corresponding to the remains of an entire cremation pyre, particularly for the Late Bronze Age cremation pits (e.g., Runge 2010, 24–25). In addition, the many Bronze Age pyre constructions excavated hitherto in southern Scandinavia are extremely varied and have very different dimensions and appearances than typical cremation pits. For example, the exceptionally preserved three-pole constructions excavated in southern Funen (Thrane 2004, 227, 237, 242, 275) and other examples of pyre constructions from the periods in question, which have markedly different characteristics (see Klindt-Jensen 1957, 46ff., 209ff., Henriksen 1991, 52ff., Olsen and Bech 1996, 171ff., Andersson 1997, Arcini 2005, 67–68). Hence, although the pyres may well have been located right next to the pit in the Bronze Age, which is known from both Pre-Roman and Roman Iron Age sites in Scandinavia and northern Germany (Lind 1991, Henriksen 2009, 84–85), they were not located exactly in or on top of the pits. In addition, there are several indications in Danish archaeology of a chronological difference between urn graves and the majority of the cremation pits. Although they clearly overlap chronologically, cremation pits are the typical archaeological remains of cremations found in several early Pre-Roman Iron Age sites in Denmark (e.g., Broholm 1949, 97ff., 100, Albrectsen 1954, 1971, 1973, Klindt-Jensen 1957, 44–45, Becker 1961, 181, 191, 1990, 68ff., Thrane 1984, 131, Lind 1991, 26, Ejstrud and Jensen 2000, 18, Hornstrup *et al.* 2005, Henriksen 2009, 72–73, 89, Runge 2010). Unfortunately ^{14}C-dates from this period fall into the so-called Hallstatt plateau, resulting in calibrated dates notoriously lying between 800 BC and 400 BC despite accuracy in sampling and measurement precision (see, for instance, van der Plicht 2004).

To osteologically confirm parts of the Swedish theory, it would therefore require an individual bone match (a positive refitting of bone fragments) between a given urn grave and a cremation pit within a site, which in anyway would be an extremely lucky coincidence. In contrast, the absence of such a match would not prove the opposite (see also Arcini and Svanberg 2005, 327). Also, if the classic cremation pit truly represents the cremation pyre alone, where are then the associated burials[1] on all the sites that exclusively contain cremation pits?

To follow up on these discussions, the above-mentioned hypothesis about the various functions and chronological aspects of the cremation grave types is evaluated. Several osteological parameters are interpreted in combination with grave typology.

Terminology

To discuss functional aspects of prehistoric cremation graves and related archaeological features, terminology of excavated structures containing cremated bones are crucial. In 1980, Tillmann Bechert discussed the phenomena *Bustum* and *Ustrinum*, known from roman literary sources and which archaeological traces they left behind (Bechert 1980, 254ff.). *Bustum* (comb-ustum) is a grave where the deceased is both cremated and buried, whereas *Ustrinum* (ustum) is a cremation spot without grave function. Despite the functional difference, *ustrina* can, in praxis, both contain cremated human remains, ceramics and other artefacts and thus, in principle, be easily confused with various other types of cremation pits and urn graves. In the following, the typical archaeological features from the periods in question, often determined 'graves' and 'pyre remains', are described. The below listed typology follow definitions of M. B. Henriksen (2009), originally based on N. F. B. Sehested (1878) and E. Albrectsen (1971). To embrace possible variations of these within the Late Bronze Age and Pre-Roman Iron Age, the types are correlated with definitions in recent publications (Lindahl Jensen 2004, Arcini 2005, Arcini and Svanberg 2005, 323ff., Hornstrup *et al.* 2005, Henriksen 2009, Wangen 2009, Runge 2010, Therkelsen 2011, 175ff.).

Stone-set cremation graves and similar differentiating features

Many cremation graves, particularly in Periods III and IV[2], are symbolically similar to the inhumation burials of the previous periods (e.g., Broholm 1949, 13ff., Brøndsted 1966, 156–257, Aner and Kersten 1973, no. 1548A, Thrane 1984, 45–46, 57, 2004, 163, Ille 1991, 111–127, Feveile and Bennike 2002, 120, 127, Arcini and Svanberg 2005, 339). The graves may be of human length, stone set, in stone cists or similar outer grave constructions, containing sorted remains from the cremation pyre such as cremated human remains, animal bone, artefacts or other personal belongings, either spread randomly in the grave fill or neatly placed. There is, however, a marked variation within these early cremation graves, which reflect local traditions rather than being chronologically significant (see, for instance, Olsen and Bech 1996, Feveile and Bennike 2002, Goldhahn 2012).

Urn grave

The typical urn grave consists of a container of inorganic material (often a ceramic vessel) cut into the ground, containing sorted remains from the cremation pyre such as cremated human remains, animal bone, artefacts or other personal belongings, which may or may not have been with the deceased on the cremation pyre (Henriksen 2009, 68–69). During the Late Bronze Age, particularly in Periods IV and V, artefacts were primarily added to the burial after the cremation process, that is, as grave goods[3]. The urn grave is known as early as Period II of the Danish Bronze Age (Olsen 1992). Outer grave markings such as stone packing, stone cists, wooden cists and similar additional constructions are often associated with Bronze Age urn graves (Figure 1).

Bone layer grave

As in urn graves, cremated remains in bone layer graves are deliberately sorted out from the pyre, to be placed in a pit, occasionally associated with artefacts[2]. Bone layer graves seemingly represent grave content wrapped up or placed in organic material (e.g., an organic urn), and are therefore closely linked to the urn graves (Henriksen 2009, 69). Bone layer graves exist with or without a layer from the cremation pyre (pyre debris). Each version is closely linked to either the regular urn grave or the urn cremation pit (see below). Bone layer graves are known from Period III of the Bronze Age, yet becomes more common towards the end of the Bronze Age (Feveile and Bennike 2002, Hornstrup *et al.* 2005, 87ff., Runge 2010) (Figure 2).

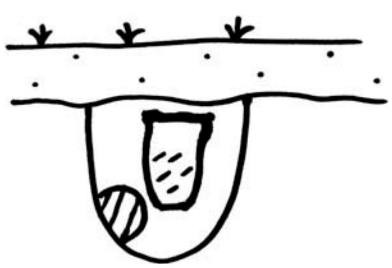

Figure 1. A simple sketch of the urn grave and its elements.

Legend: / cremated bone **Θ** stone · · plough soil.

Urn cremation pit

The urn cremation pit is clearly a category in between a regular urn grave and a cremation pit/patch, containing remains of the cremation pyre, and possibly cremated remains both inside and outside the container (Henriksen 2009, 70–71). The type appears sporadically from Period V of the Bronze Age in Denmark, but becomes common towards the Pre-Roman Iron Age in several Danish regions (see, for instance, Hornstrup *et al.* 2005, 887, Mortensen 2010) (Figure 3).

Cremation pit/patch

The cremation pit is defined as a cut in the ground containing remains of the cremation pyre, amongst other cremated remains. The difference between the cremation pit and the cremation patch is defined differently in practically all publications, but is generally the size and shape of the cut (e.g., Ejstrud and Jensen 2000, 18, Wangen 2009). The features are otherwise fairly similar in their content and are therefore described together here. The filling is often pitch-black with pieces of charcoal or heat-altered (often clearly burnt and destroyed) artefacts[3] from the cremation pyre. The cremation pit usually contains less cremated bone than other grave types. The function has

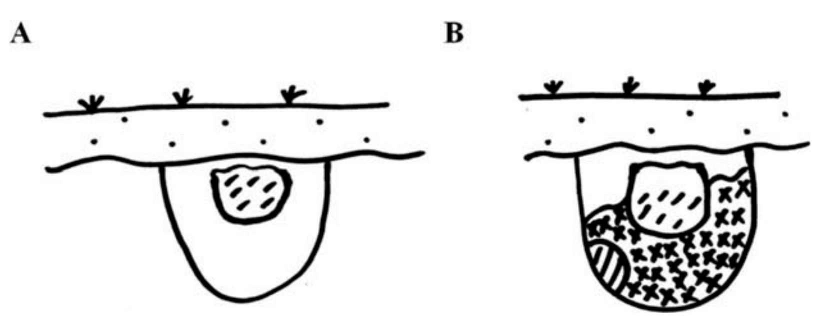

Figure 2. A sketch of the two types of bone layer graves and their elements. (A) the regular bone layer grave and (B) bone layer grave with cremation layer (pyre debris).

Legend: / cremated bone **Θ** stone · · plough soil **x** charcoal.

Figure 3. A sketch of the urn cremation pit and its elements. Legend: / cremated bone ϴ stone · · plough soil x charcoal.

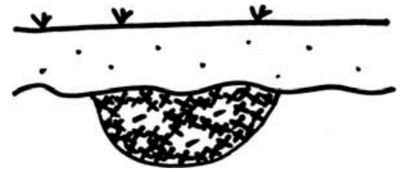

Figure 4. A sketch of cremation pit and its elements. Legend: / cremated bone · · plough soil x charcoal.

often been interpreted as part of the construction of the actual cremation pyre (*bustum*) (e.g., Madsen 1990, 36–37, Lindahl Jensen 2004, Arcini 2005, Dodwell 2010). The cremation pit is distinct from other archaeological evidences of cremation pyres by the actual cut in the ground, and not merely traces on the original surface (see, for instance, Madsen and Thrane 1992, Thrane 2004, 220ff., Henriksen 2009, 69–70). Besides examples of similar features in Stone Age contexts, cremation pits are known in a few examples from Period III of the Bronze Age in Denmark (e.g., Feveile and Bennike 2002, 122), and appears more frequently in Periods IV and V in the rest of southern Scandinavia (Stjernquist 1961, Thrane 1984, Edring 2004, 91, Runge 2013). Cremated remains from cremation pits or patches are often difficult to determine as of definite human origin (e.g., Arcini and Svanberg 2005, 326–327) (Figure 4).

Grave typology in the Late Bronze Age and Early Iron Age

In summary, many types of cremation graves[1] and cremation-related features exist in Late Bronze Age and Early Iron Age Denmark. In Table 1, the different types are described with common interpretations of their functions and representation.

Material

Late Bronze Age and Pre-Roman Iron Age cremation grave sites from the island of Funen, Denmark, are chosen as primary material for this case study because of their unique status as a totally excavated cultural landscape revealing the development of the mortuary landscape from the Bronze Age towards the Early Iron Age. Furthermore, each of the sites is recently excavated (2001–2008), and uniformly registered and sampled. The material comprises 137 graves from 7 sites; 1. ØSTRE BOULEVARD III (OBM 8441), 2. KILDEHUSE II (OBM 8414) and KRISTIANSMINDE NORD (OBM 8429), 3. KROGSGÅRD (OBM 8698), 4. SKOVLUND

Table 1. Types of cremation graves and cremation-related features known from Late Bronze Age and Pre-Roman Iron Age grave sites in Scandinavia. Definitions and descriptions are in consideration of other recent publications on the subject (Lindahl Jensen 2004, Arcini 2005, Arcini and Svanberg 2005, 323 ff., Hornstrup *et al.* 2005, Henriksen 2009, Wangen 2009, Runge 2010, Therkelsen 2011, 175 ff.). * Urn cremation pits occur much earlier in southern Jutland and northern Germany; however, these are chronologically and typologically different from the typical Bronze Age and Early Iron Age cremation pit discussed here. * Bone layer graves with pyre remains may be more common, but have only been published as such in a few cases (e.g., Hornstrup *et al.* 2005:87–88).

Type	Description	Main contents	Burial?	Periods	Representation
Early stone-set cremation grave	Highly varied cremation graves, e.g., cists or stone-set.	* Cremated human bone * Artefacts (grave goods)[2]	Yes	II–IV	Individual grave
Urn grave	Urn grave	* Cremated human bone * Artefacts (grave goods)	Yes	From Period II onwards	Individual grave
Bone layer grave	Similar to the urn grave, yet with organic container or no protection of the bones	* Cremated human bone * Artefacts (grave goods)	Yes	All	Individual grave
Urn cremation pit	Urn grave + pyre debris	* Cremated human bone * Artefacts (grave goods) * Pyre debris	Yes	From Period V* onwards	Individual grave + pyre debris
Bone layer grave with pyre debris	Urn grave (organic container) + pyre debris	* Cremated human bone * Artefacts (grave goods) * Pyre debris	Yes	Few from Period V*	Individual grave + pyre debris
Cremation pit/patch	Pyre debris in pit with few skeletal remains	* (Cremated bone) * Artefacts (pyre goods) [2]* Pyre debris	?	(BA III/IV) – PRIA III	Pyre debris?

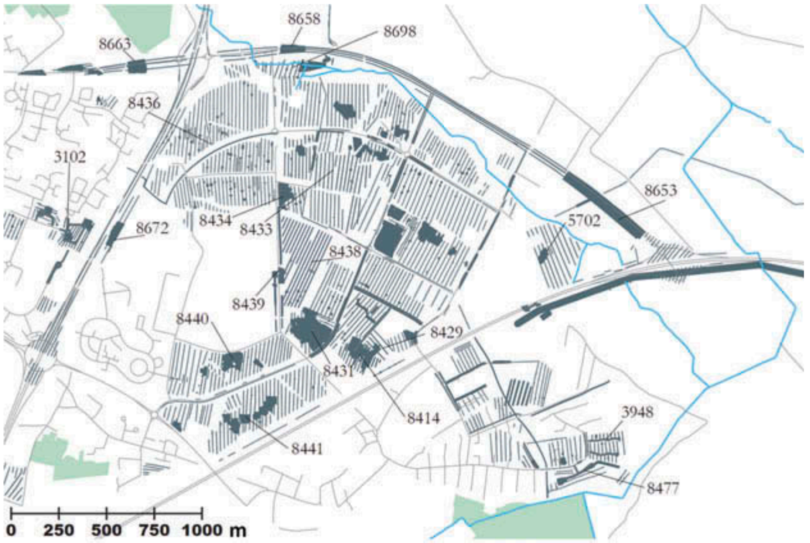

Figure 5. Map showing the location of the sites mentioned in the text.

(OBM 8658), 5. TIETGENBYEN NORDVEST (OBM 8433), 6. ENGBLOMMEN/FRAUGDE ØST (OBM 8477) and 7. KOHAVE SYD (OBM 8663) (see also Runge 2010, 102ff., 2013; and Figure 5).

Cremated remains were preserved in only 96 (71%) of these graves with a clear difference between the Bronze and Iron Ages; From the two Late Bronze Age sites, 56 out of 59 graves (95%) contained cremated bone, whereas only 39 out of 78 graves (51%) from the Pre-Roman Iron Age sites did – all cremation pits or undefined grave types (see Table 2).

Graves without cremated bone were only defined as graves because of striking similarity with other graves on the respective sites, horizontal stratigraphy and/or the presence of urn fragments or grave/pyre goods in the content (see also Runge 2010). For the Bronze Age cremation graves, there was a natural relation between the intactness of the individual grave contexts and the amount of cremated bone recovered (see also Runge 2010, 180–265, Harvig and Lynnerup 2013, 2717–2718, and Figure 6).

However, on the Pre-Roman Iron Age sites, there was no correlation between the intactness of the individual grave contexts and the amount of cremated bone recovered, with the highest amount of cremated bone weighing only 590 g, despite the presence of several intact grave structures within the individual grave sites (Figure 7).

Chronologically, the sites cover the transition period from the Early Bronze Age towards the Late Bronze Age, where cremations begin to outnumber inhumations, particularly the transition period between the Late Bronze Age and the Pre-Roman Iron Age. The grave sites all represent the common way of burying the dead in the Late Bronze Age and the Early Iron Age on Funen (e.g., Albrectsen 1954, 1973, Thrane 2004, Therkelsen 2011, Runge 2013), but the grave types represented on the analysed sites are

Table 2. Characteristics of the seven sites in the Fraugde area. Abbreviations used are LBA for Late Bronze Age and PRIA for Pre-Roman Iron Age. In all, 4 cremation pits at Skovlund (OBM 8658) cremated bone fragments were observed during excavation. These were, however, not preserved after excavation.

Site *(abbreviated)*	ØB III	K II	KRG	SKL	TGB NV	ENGB	KHV S	Total
OBM number	**8441**	**8414**	**8698**	**8658**	**8433**	**8477**	**8663**	
Primary dates	*LBA III/IV*	*LBA VI*	*PRIA (early)*	*PRIA per. II*	*PRIA per. II*	*PRIA per. IIIa*	*PRIA (late)*	
Number of graves	**19**	**40**	**41**	**4**	**13**	**7**	**13**	**137**
Graves with cremated bone	**19**	**37**	**16**	**1**	**6**	**6**	**11**	**96**
Inhumation-like graves	1	–	–	–	–	–	–	1
Urn graves	14	4	–	–	–	–	–	18
Bone layer graves	–	4	–	–	–	–	–	4
Urn cremations pits	–	21	2	–	–	–	–	23
Cremation pits	4	8	14	4	6	6	11	54
Uncertain cremation graves	–	3	25	–	7	1	2	38

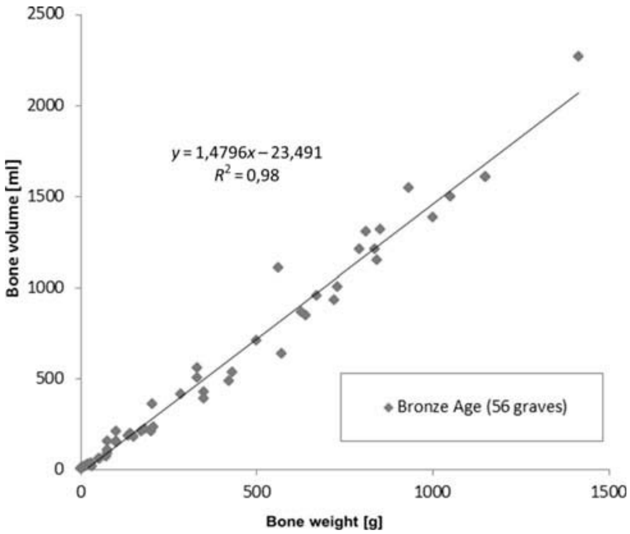

Figure 6. Plot of the regression line for weight and volume of the cremated remains from the 56 Bronze Age burials. The weight–volume ratio is approximately 1:1.5, reflecting a low degree of fragmentation.

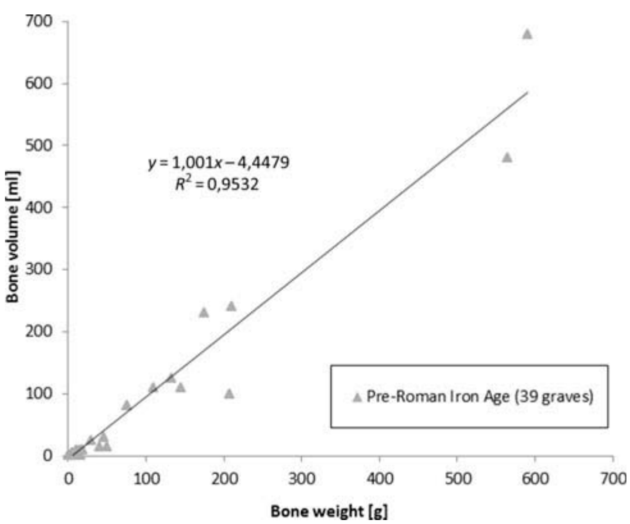

Figure 7. Plot of the regression line for weight and volume of the cremated remains from the 39 Iron Age graves. The weight–volume ratio is approximately 1:1, reflecting a high degree of fragmentation.

similar in construction and content to the types represented on many other southern Scandinavian grave sites from the transition period (e.g., Vedel 1870, Klindt-Jensen 1957, Thrane 1984, Becker 1990, Lind 1991, Ejstrud and Jensen 2000, Edring 2004, Arcini 2005, Feldt 2005, Fendin 2005, Frisberg 2005, Arcini and Svanberg 2005, Hornstrup *et al.* 2005, Clemmensen 2013, Kristensen 2013, Mikkelsen 2013a). They exhibit no exceptional wealth or status, and therefore reflect the 'norm' for the low status lineages in contrast to the exceptional elite evident in the rich sites on southern Funen in the same period (e.g., Thrane 1999, 227ff.). Archaeologically, the graves represent the general preservation state of graves found on modern excavations in contract archaeology on heavily cultivated lands.

The Fraugde area in its context

Although prehistoric cremation practices varied markedly both regionally and chronologically in southern Scandinavia, cremation practices dominated on Funen from the onset of the Late Bronze Age, around 1100 BC, until and including the Roman Iron Age, around 400 AD. Hence, the development was chronologically continuous. Furthermore, the landscape is thoroughly studied, in that a rich source material of cremation and inhumation graves is already published (Albrectsen 1954, 1973, Aner and Kersten 1977, Henriksen 1995, 2009, Thrane 2004, Runge 2010, 2013). The grave types on the sites analysed here are not unique. Cemeteries under level ground from the Late Bronze Age and the Pre-Roman Iron Age are found in several sites in southern Scandinavia with similar chronological developments of the grave types. As contract archaeology has emerged and larger connected areas have been excavated, focus has naturally changed from single finds of graves right below plough soil or in connection to mounds, towards the study of surrounding landscapes and fully excavated grave sites (Vedel 1870, Broholm 1949, 18ff., 64, 98ff., Thrane 2004,1, 33ff., Lindahl Jensen 2004, Arcini and Svanberg 2005, 333ff., Hornstrup *et al.* 2005, Runge 2010, 2013, Mikkelsen 2011, 42, 2013a).

The seven analysed sites were excavated by Odense City Museums in the period 2001–2008. The sites are situated north and east of the medieval village 'Fraugde', where a still standing twelth-century roman church indicates the long history of the area (Runge 2012). The landscape is characterized by wider landscape contours with regular smooth hillsides (Klitgaard 2002, 11–12, 22, Runge 2010, 15ff.). The Bronze- and Iron-Age settlements in the Fraugde region are, as the graves, primarily found within the 350-hectares large development area, Tietgen Byen, where Odense City Museums has conducted extensive excavations and uncovered a regular cultural landscape from the period (Runge 2010, 2012, 2013). The area represents the central third of a supposed village (bygd), which is bounded by the natural landscape (Runge 2012, 115).

The settlements of Tietgen Byen, the central part of Fraugde parish; OBM 5702, 8414, 8431, 8433, 8440, 8441, 8658 and 8698, all represent continuity from the earliest Bronze Age until and including the early Pre-Roman Iron Age (see Runge 2012, 113,132ff.). The settlements are all but one small and consist of one or a couple of contemporary farms. The exception is the locality OBM 8436, with around 100 houses, which must have been a regular village through generations (Runge 2012, 122ff.).

During the periods in question, the settlements have moved gradually within the resource area. Single graves are in a few cases located between almost contemporary settlement features. However, in other cases, defined separations of grave sites or graves are clearly visible, for instance marked in the landscape by rows of cooking pits (Runge 2010, 83ff., 2013). The resource area consists of settlements, graveyards, gathering areas, and in one case a larger production area (OBM 8416). Between the resource areas, gathering areas are located. These were presumably used by more of the settlement units. Within Tietgen Byen, six to seven resource areas can be defined, separated by natural boundaries. The resource areas generally have an approximate diameter of 500–900 metres, whereas the large settlement, OBM 8436, may have had a somewhat larger resource area (for further discussions of the area in relation to the mortuary landscape, see Runge 2013, 18–19).

The grave sites

Østre Boulevard III, Tietgenbyen (OBM 8441)

Østre Boulevard III was excavated in 2007 and 2008. Besides a Stone Age grave and a cremation grave from the Germanic Iron Age (Migration period), the excavation revealed traces of settlement from the Late Bronze Age and Early Iron Age and two ploughed-over Early Bronze Age grave barrows (Figure 8). The site further contained two Early Bronze Age house constructions, which may have been related to the grave sites, and which are therefore not regarded as settlements, 16 Bronze Age cooking pit trenches oriented towards a moist hollow in the landscape (AMS-dated to the Early Bronze Age, Period III (1300–1100 BC)), 84 regular Bronze Age cooking pits, and lastly the fully excavated cremation grave site from the Late Bronze Age (see also Jakobsen 2009).

The Bronze Age grave site with 20 cremation burials date to the transition period and first half of the Late Bronze Age, Periods III–IV (1300–900 BC), evident through 14C-dates, ceramics, artefacts and stratigraphy. The graves are primarily located northeast of the northernmost Bronze Age barrow (Figure 8). One of the early cremation graves at the site, grave QA from Period IV (1057–921 cal. BC), represents a variation of an early stone-set cremation grave. With its oval shaped stone setting, it symbolically resembles other early cremation graves from the transition period (Broholm 1949, 13ff., Brøndsted 1966, 156–157, Aner and Kersten 1973, no. 1548A, Thrane 1984, 45–46, 57, 2004, 163, Arcini and Svanberg 2005, 339). The grave contained cremated bone and personal artefacts (a razorblade with a highly stylized animal head, and the poorly preserved remains of a set of tweezers) spread randomly in the grave. The grave site further consisted of seven simple urn graves, seven stone set urn graves and four cremation pits.

Kildehuse II, Tietgenbyen (OBM 8414)

Kildehuse II follow the site Østre Boulevard III (OBM 8441) both spatially and chronologically. The site was

Figure 8. Location of the flat grave cemetery at Østre Boulevard III (OBM 8441) in connection to the two Early Bronze Age barrows.

excavated in 2004 and 2006. Besides a fully excavated grave site from the Viking Age, the excavations revealed two ploughed-over mounds, traces of settlement from the Late Bronze Age and Early Iron Age and a fully excavated Bronze Age grave site. Based on 14C-dates, ceramics, artefacts and stratigraphy, the 41 cremation burials date to the second half of the Late Bronze Age, Period VI (700–500 BC). The graves were primarily located in a belt between the two (undated) mounds, whereof one may have been a grave barrow (Figure 9). Several cooking pits in rows, besides various other features of unknown function were found in connection to the grave site. Several artefacts of distinctive character, for example, face urns, besides many and varying natural scientific results make the site unique (see Runge 2010, 11, 29–30, Harvig and Lynnerup 2010, 58ff.).

Krogsgård (OBM 8698)

The Krogsgård site was excavated in 2004, 2005 and 2006. Based on 14C-dates, ceramics, artefacts and stratigraphy, the graves on the site are dated to the beginning of the Pre-Roman Iron Age. Of a total 14 cremation pits and 25 uncertain cremation graves, primarily from the Pre-Roman Iron Age, only 16 graves contained cremated bone. Of these, only one grave contained bone fragments that could be determined as definitely of human origin, a fragment of a premolar. The graves seemingly cluster in two main groups, an eastern and a western, similar to the cooking pits in the area. Some of the graves further cluster in pairs of two and two, but it is unclear whether this is related to preservation or reflects social hierarchy on the site. Ceramics in the graves were in several cases affected by secondary burning.

Figure 9. Plan of cremation graves, cooking pits and the two mounds at Kildehuse II (OBM 8414). The two parallel rows of cooking pits form a boundary between the grave site and the profane settlement area to the west, although the AMS-dates are both early and Late Bronze Age (Runge 2010, 85–86). South of the southernmost mound, a possible cultic house with large stones in a floor-like construction was excavated. Both construction types may have facilitated various mortuary ceremonies.

Tietgen Byen Nordvest (OBM 8433)

Tietgen Byen Nordvest was excavated in 2008. Besides a large cooking pit field (with AMS-dates spanning from Early Bronze Age to the beginning of Early Iron Age), a minor cremation grave site was excavated. Of the 300 cooking pits, only few have been excavated and dated. The grave site consisted of six cremation pits, four uncertain cremation graves and three charcoal pits, all seemingly dating to Pre-Roman Iron Age (*AMS-dates from Pre-Roman Iron Age, around per. II,* 300–150 BC). The graves were oval shaped pits of 60–80 centimetres in diameter with a filling clearly containing remains of the cremation pyre (charcoal, ashes, cremated bone and ceramics). Intact ceramic vessels were found in several graves, but the content was similar to the grave fill. Ceramics from the graves revealed secondary burning, indicating that they were with the deceased on the pyre.

Skovlund (OBM 8658)

The Skovlund site was excavated in 2004. The excavations revealed a small concentration of cremation pits dated to Pre-Roman Iron Age. In the same area, five ploughed-over cremation pits had earlier been recognized during surveys, containing ceramic shards from Pre-Roman Iron Age, Period IIIa (150–50 BC). The extremely poor preservation of the graves indicates that the site could continue northwards beyond the limits of the excavated area (see also Runge 2010, 92, 97–98).

Engblommen/Fraugde Øst (OBM 8477)

Engblommen (or Fraugde Øst) was excavated in 2004. Besides a few pits, postholes and a fence, a grave site consisting of seven poorly preserved cremation pits was excavated. Based on ceramics, four of the graves have been dated to the late Pre-Roman Iron Age (Period IIIa)[2]. All seven graves were oval shaped cremation pits, less than a metre in diameter containing several remains of the cremation pyre (wood, charcoal, ashes and secondarily burned ceramics). One grave was located exactly in the middle of a Late Bronze Age or Early Iron Age house. It cannot be ruled out that there is some connection between the two, and that the house has served cultic purposes in connection to the grave sites and the cooking pits, possibly after decay or demolition of the construction. Probably some or all of the graves have been marked with stones on the surface. At least one (grave AFD) had stones placed around it resembling a ship setting. In the periphery of the grave site were 14 cooking pits.

Kohave Syd (OBM 8663)

Kohave Syd was excavated in 2001. Besides postholes and other features, 13 cremation pits with ceramic dates to late Pre-Roman Iron Age (250–0 BC) and 4 cooking pits, seemingly older than the graves, were found. The small cluster of 13 cremation pits was, except for one, located within a small area of 20 × 20 metres. The site may represent a single family group, if used over two to three generations. All graves were between 0.5 and 1 metre in diameter and contained charcoal, cremated bone fragments and few other remains of the cremation pyre, which as earlier described is a common phenomenon for these sites. A piece of iron had likewise been with the deceased on the pyre.

Methods

In supplement to discussions on handling of artefacts and pyre remains in relation to grave typology (e.g., Henriksen 2009, 87ff.), specifically the handling of the cremated human remains is in question here. By studying traits of the preserved skeletal material, such as wear patterns and post-cremation fragmentation patterns, in combination with methods commonly used in cremation osteology such as dehydration and crack patterns, colouration and skeletal representation, it is possible to compare the two mentioned periods and pinpoint similarities and differences in the cremation ritual despite the state of preservation. Collecting these descriptive data therefore gives an opportunity to compare material from the transition period without the bias of being totally dependent on post-depositional taphonomy (e.g., intactness of the individual graves) and stages of combustion of the cremated remains.

Results

Osteoarchaeological data

In the following, specific osteoarchaeological data for each of the graves in the Fraugde region containing cremated bone is discussed. The collected data sets reflect the huge variation in obtainable data from each grave depending on, for example, grave type, preservation and intactness. The raw data are available (in Danish) as an electronic supplementary file.

Chronological aspects

Because ^{14}C-dates are difficult to interpret during this period, primarily due to the Hallstatt plateau in the calibrated curves (see introduction), typological data are essential for differentiating funerary data during the transition period. Therefore, artefact typology (primarily ceramics and metal), ^{14}C-dates and stratigraphy are withheld in the interpretation of the overall chronology of the individual graves discussed in this study (see Table 2; materials section; and Runge 2010, 180ff.). Based on ^{14}C-dates, artefacts and/or stratigraphy, 92 graves from

Table 3. Grave typology and chronology based on data from 92 graves from the seven analysed sites in the Fraugde region. Whereas urn graves are linked to the first half of the Late Bronze Age in Period IV and V, and Urn cremation pits and Bone layer graves are associated with the second half of the Late Bronze Age in Period VI, cremation pits are primarily a Pre-Roman Iron Age phenomenon.

	LBA IV/V	LBA VI	PRIA I/II	PRIA II/III
Early stone.set cremation grave	1	–	–	–
Urn grave	18	5	–	–
Bone layer grave	–	4	–	–
Urn cremation pit	–	23	–	–
Cremation pit	1	7	16	17

the seven analysed grave sites have been categorized according to grave typology (Table 3).

Although the groupings naturally reflect the traditions at the individual grave sites within their given chronological time span (see Table 2), they also reflect the changing use of particular grave types over time, in that urn graves are predominantly found in the first half of the Late Bronze Age in Period IV, whereas urn cremation pits and bone layer graves are predominantly found in the second half of the Late Bronze Age in Period VI. Conversely, cremation pits are predominantly a Pre-Roman Iron Age phenomenon. Hence, pyre debris in the grave structures are a relatively late phenomenon in the Fraugde region, and the combination grave types, that is, urn cremation pits and bone layer graves with pyre debris, may therefore be the key to understanding the symbolism behind the gradual change in this region.

On Funen, the increase of pyre debris in the graves corresponds very well to a small peak in cooking pit complexes as a phenomenon in southern Scandinavia in the Periods IV and V (Thörn 1996, Edring 2004, 91, Mailund Christensen 2005, 29, 54–55), which in several ways seem to be linked to the mortuary ritual practices (Kaliff 1997, 70, Ejstrud and Jensen 2000, 19, Thrane 2004, 46–47, Mailund Christensen 2005, 41, 49–50, Henriksen 2005, 2009, 95–96, Runge 2013, 17ff.). Interregionally, however, the variety of the different grave types in this period and marked differences between (even closely located) sites (e.g., Olausson 1987) reflect that the gradual shift towards the Iron Age cremation rituals, as seen in the Fraugde region, is not a unilinear evolution, but a slow and complex process.

Throughout Scandinavia, fire symbolism and hearths seem to be related to the ritual sphere between burial practices and cosmology. In eastern Scandinavia, hearths, burials, layers of fire-cracked stones covering rock art figures and motifs damaged by fire are common (Lundström 1970, Bertilsson 1987, Wahlgren 2002, Bengtsson 2004, Kaliff 2007, 105). We, however, still face many challenges in deciphering the relative chronology of many of these pyrotechnical features, which are often broadly dated to the Bronze Age or dated through horizontal stratigraphy (see also Lütken 2013). Nevertheless, around 900–800 BC (Period IV/V) seem to be a time of radical changes in several aspects of material culture (Skoglund 2012, 34–35). Around this period, an increasing and different use of fire beyond the already diverse use of fire in mortuary technologies is also evident (Klindt-Jensen 1957, 209ff., Gansum 2004, Skoglund 2012, 27). These changes seemingly follow the beginning of the Early Iron Age in the rest of Europe around 800 BC, where a variety of cremation and inhumation practices were common (Collis 1984, 42,52,59). Particular changes in the Scandinavian burial traditions around 500 BC were similarly inspired by the European cremation practices, particularly those of the northern German and Polish cultures (von Keiling 1962, Nortmann 1983, Müller 1985, 45, Dąbrowska 1997, Schlüter 2007, 299, Budesheim and von Keiling 2009).

Fragmentation index

Bone fragmentation appears to be a good indication of how cremated remains were handled and deposited in the past, both intersite and intrasite (Harvig and Lynnerup 2013, 2720). In the Fraugde region, there appears to be markedly different traditions for handling the cremated remains for the two periods in question (see also Figures 6 and 7). If we calculate the Fragmentation Index[4] for the graves containing cremated bone and compare this with grave typology, the graves in the Fraugde region fall in separated categories (Table 4). Again, the cremation pits stand out, representing the highest degree of fragmentation.

Cremation intensity

It becomes increasingly evident, that oxygen supply and duration of the fire are equally, if not more, important parameters than temperature alone, when describing

Table 4. Grave typology and Fragmentation Index (N_{graves} = 64 graves) from the sites in the Fraugde region. Urn graves generally exhibit little fragmentation, whereas Urn cremation pits and Bone layer graves are associated with medium fragmentation of the cremated remains and cremation pits are closely linked to high fragmentation of the cremated remains.

	0–0.5	0.6–1	1.1–1.5
Inhumation-like grave	–	1	–
Urn grave	3	15	2
Bone Layer grave	–	3	1
Urn cremation pit	1	19	4
Cremation pit	–	9	6

Table 5. Grave typology and cremation intensity (N_{graves} = 72). The cremated remains from the Fraugde region were registered as representing high, medium or low cremation intensity. Low and medium cremation intensity is more closely related to cremation pits and urn cremation pits, whereas urn graves show highest cremation intensity. This contrasts the common assumption that cremation intensity increases during the period along with the increase of pyre remains in the graves. In fact, the opposite seems to be the case.

	High	Medium	Low
Urn grave	18	3	–
Bone layer grave	3	1	–
Urn cremation pit	7	11	4
Cremation pit	8	14	–
Uncertain type	3	–	–

cremation intensity based on the macroscopic appearance of cremated bone (Walker *et al.* 2008, Gonçalves 2011, 218). Therefore, the term cremation intensity is used here. Osteological evidence of varying cremation intensities should be clearly chronological or typologically differentiated to indicate differences in cremation technology for the periods in question. Nevertheless, a presumed increase in cremation intensity during the transition period from the Bronze Age towards the Iron Age, along with the increase of pyre remains in the graves, is a commonly discussed issue (Schutkowski and Hummel 1991, Kaul 2004, 186ff., Frisberg 2005, 148). However, this pattern is not seen in the Fraugde region. Conversely, the early Late Bronze Age grave types (e.g., bone layer graves and urn graves) are more often associated with high cremation intensity, whereas cremation pits and urn cremation pits (dated to the transition period and the Pre-Roman Iron Age) are associated with lower cremation intensity (Table 5).

Skeletal representation

One of Caroline Arcini's primary reasons for interpreting the Scanian cremation pits as pyre sites and not primary burials was the skeletal representation in the graves. She could demonstrate that cremation pits contained systematically fewer recognizable skeletal elements, particularly the petrous portion of the human skull, than did urn burials (Arcini 2005). For the Fraugde graves, similar tendency is seen (Table 6). Urn graves and urn cremation pits contain more recognizable elements and often elements from the entire skeleton (whole body representation), whereas cremation pits often contain few recognizable elements, independently of intactness of the grave and preservation. However, here it is evident that the main reason for this is the general amount of bones present in the cremation pits in combination with the high degree of fragmentation of these, which makes them less recognizable.

Table 6. Grave typology and skeletal representation (N_{graves} = 65). Urn graves and urn cremation pits contain more recognizable elements and often elements from the entire skeleton (whole body representation) whereas cremation pits often contain few recognizable elements.

Skeletal representation	Unclear/poor preservation	Only few recognized elements	Whole body representation
Urn grave	7	6	6
Bone layer grave	1	2	1
Urn cremation pit	2	9	11
Cremation pit	6	10	2
Uncertain type	1	1	–

Wear and handling

Post-cremation activities such as sorting, moving and otherwise handling the cremated remains, is reflected in wear on the (cremation-induced and post-cremation) fracture surfaces. Fresh fractures with sharp edges reflect little post-cremation handling, whereas smooth and heavily worn fractures reflect much handling. However, these patterns clearly also reflect post-burial taphonomic processes in the soil, in that the type of container used in the burial clearly seem to be the primary structuring factor for the Fraugde graves. This is reflected in markedly less wear for the two grave types with inorganic containers (urn graves and urn cremation pits; see Table 7).

Table 7. Grave typology and sample characteristics (N_{graves} = 63). Besides handling, the wear patterns clearly also reflect the type of container in which the bones were deposited, that is, deposits in bone layer graves (organic container) and cremation pits are less protected and therefore contain more heavily worn remains and fewer fragile elements.

	Few worn breaks, many fragile elements	Few worn breaks, some fragile elements	Some worn breaks, many solid fragments	Many worn breaks, only solid fragments	Unclear
Urn grave	3	8	2	1	3
Bone layer grave	–	–	2	1	1
Urn cremation pit	10	5	2	1	2
Cremation pit	1	2	5	8	3
Uncertain type	1	1			1

Discussion

Cremation technology and pyre construction

Based on osteoarchaeological analyses and skeletal representation in Swedish cremation graves, Caroline Arcini suggested three separate types of cremation pyre constructions for the Late Bronze Age and Early Iron Age; first, the well preserved human-length pyre site preserved under a mound at Gualöv; second, a log construction on large stones and then lastly, the typical cremation pits of the period were interpreted as draught-creating pits under the cremation pyre, that is, a form of *Bustum* (*in situ* cremation) (Arcini 2005, 67–68, Arcini and Svanberg 2005, 323ff., 331–332). However, as mentioned in the introduction, the several southern Scandinavian Bronze Age pyre constructions excavated hitherto have extremely varying dimensions and appearances (Klindt-Jensen 1957, 46ff., 55, 209ff., Thrane 1984, 171ff., 2004, 34, 43, 48, 221ff., 227, 237, 242, 275, 287, 305ff., Henriksen 1991, 52ff., Olsen and Bech 1996, Andersson 1997, Arcini 2005, 67–68, Arcini and Svanberg 2005, 323). Therefore, this is probably too simple a categorization of a vast and relatively unexplored material.

Besides the excavated features and osteological evidence of cremation technology in the Late Bronze Age and Pre-Roman Iron Age, we also have knowledge from other sources. The gradual decrease in cremation intensity from the Bronze Age towards the Iron Age, as suggested by the osteological material in the Fraugde region, is also reflected in the pyre remains from the sites. For the Fraugde region in general, oak logs larger than 20 cm in diameter were used in the Late Bronze Age cremation pyres, whereas samples of oak from the Pre-Roman graves were from wood of less than 5 cm in diameter (see also Mikkelsen 2010, 55, 2013b, 121–122). Particularly at the Late Bronze Age site Kildehuse II (OBM 8414), clinkers of organic material (slag) indicated that temperatures in some pyres had reached 1000ºC (Jensen 2010, 51), which is in line with temperatures gained in other Late Bronze Age cremation pyres on Funen, in some cases reaching 1100ºC (e.g., Thrane 1984, 78).

A similar gradual change in pyre technology may be relevant in other areas of Scandinavia, and could be related to a changing use of wood. Although ash, hazel and other fast burning wood for small firing branches are known from southern Scandinavian pyre remains throughout the transition period (Arcini and Svanberg 2005, 315, Fendin 2005, 401ff., Mikkelsen 2010, 55ff.), oak was frequent in Bronze Age cremation pyres (Mikkelsen 2013b, 123), whereas beech, hazel and alder of a more modest size became common towards the Roman period (Henriksen 2009, 273, Mikkelsen 2013b, 123–124).

Collecting the cremated remains from the pyre

A growing experimental work has revealed that cremated remains in a cooled pyre or in cooled pyre debris that is left untouched, contain large and diagnostic fragments with exclusively heat-induced fragmentation patterns and little, if any, post-cremation wear. Moreover, several studies indicate that it is surprisingly easy to collect cremated remains from the cooled pyre with high efficiency (Henriksen 1991, 1993, Marshall 2011, 34, Gonçalves 2011). Hence, it is argued that deposits that are obviously partial already at the stage of burial are so for deliberate reasons (e.g., Arcini 2005, 67ff., Marshall 2011, 37–38). However, from studies in modern crematoria we know that it is highly varying what is preserved from cremation to cremation. The lack of anatomical regions alone should therefore, ideally, never be used as indicator of ritual selection of bone (Gonçalves 2011, 221ff.). Nonetheless, the significant differences in skeletal representation diachronically, do imply a marked difference between the Late Bronze Age burials and the Iron Age cremation pits in the Fraugde region.

Sorting the pyre remains

In a recent methodological study using the majority of the Late Bronze Age graves from the Fraugde region, we were able to demonstrate that the typical Late Bronze Age urn burials often represented entire cremated individuals (Harvig and Lynnerup 2013). Conversely, the opposite is the case for the Early Iron Age cremation pits in the region, which is reflected in lack of anatomical regions, extreme fragmentation, heavy wear and overall characteristics of the cremated remains. This further suggests that we are not dealing with pyre debris falling directly from the pyre and into a pit in the ground, but instead sorted pyre debris. The high degree of fragmentation clearly suggests that the bones have been handled before deposition. Whether the fragmentation occurred during staking of the pyre while burning, clearing the pyre or similar post-cremation handling of the cremated remains is uncertain, but we are not dealing with post-depositional taphonomic processes alone. Conversely, the pyre debris in the cremation pits have clearly been sorted, and during this sorting process, the majority of the cremated remains have been sorted out, as also partly suggested by Caroline Arcini (2005). This leaves us with interpretations of the cremation pits as either solely pyre remains or symbolic representations of 'graves', but not actual pyre sites and by definition not burials[1].

Intentionality

Instead of discussing how much bone is needed to define a burial, we instead have to focus on the degree of intentionality. If we accept that there is a difference between the terms 'burial' and 'grave'[1] as often discussed in current Scandinavian archaeology (e.g., Ericsson and Runcis 1995); we clearly see a change of focus from one towards the other during the transition period in the Fraugde region. Although the remaining secondary deposition of cremated human remains in the cremation pits gives the impression of being 'unintentional', deliberate reburial, replacing and reusing of cremated remains is also worth considering (e.g., Gansum 2004, 51, Wickholm 2008). Moreover, evidence of markings of the cremation pits on the surface, as well as the fact that these graves extremely rarely cut one another, suggests that these grave types are in fact purposeful constructions, symbolically similar to many other grave types from the periods in question. Seemingly, they were commemorated during centuries on the accumulated grave sites, and therefore they were not merely unintentionally discarded pyre debris.

Although the many Pre-Roman Iron Age cremation pits excavated in the Fraugde region appear to be fairly similar, there is some variation intersite. Variation in shape (from oval to circular and from rounded to sharp-edged cuts) reflects local traditions and variation over time of the otherwise extremely conservative grave type.

Summary and conclusions

In the Fraugde region, grave typology and overall chronology are correlated in groups, reflecting the traditions at the individual grave sites and the chronological time span of the sites. However, it is evident that pyre debris in the cremation graves gradually gained significance during the Late Bronze Age. As such, urn graves were common in Periods IV and V, urn cremation pits and bone layer graves became common in Period VI, whereas the Pre-Roman Iron Age sites in the region almost exclusively contained cremation pits.

As for the cremation pyres themselves, we have no archaeological record of the actual cremation pyres in the Fraugde region. However, analyses of the cremated remains and pyre debris from the sites leaves us with evidences of highly varied cremation pyres, with temperatures up to 1100ºC in the Bronze Age and a decrease in cremation intensity from the Bronze Age towards the Pre-Roman Iron Age, which could be related to a changing use of wood species.

Whereas the many individual grave types on the Late Bronze Age sites in the Fraugde region contained deliberately collected cremated remains of deceased individuals, the occurrence of randomly deposited human remains in the Pre-Roman Iron Age cremation pits almost appear 'unintentional'. However, the pyre debris in the cremation pits were clearly sorted, and during this sorting process, the majority of the cremated remains were sorted out. Same goes for much of the archaeological material in these graves, which may have been left in the pyres or elsewhere. Although commemorated and left undisturbed for centuries, the evidence presented in this micro-regional case study leaves us with interpretations of the cremation pits as either solely pyre remains or symbolic representations of 'graves', but not *in situ* pyre sites and by definition[1] not burials. Seemingly, the meaning of the practice of burying changed gradually during the transition period in the Fraugde region, from being a burial of an individual to becoming a place in the ground for selected remains of the actual cremation process.

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Notes

1. Definitions used: Grave = a place for a burial (e.g., symbolic), Burial = the evidence of placing one or more dead bodies in a grave (the act of burial) (see also Ericsson and Runcis 1995).
2. Chronological periods mentioned are for the Bronze Age Oscar Montelius' typology-based chronology, Periods I–VI, 1700–500 BC (Montelius 1900), and for Pre-Roman Iron Age, Periods I–III, 500 BC–1 AD (after Albrectsen 1954 and 1973 (specifically for Funen), but see also Becker (1961). The datings of the graves after excavation was made according to this chronology by Odense City Museums.
3. Artefacts found in cremation graves can be separated into primary adding of artefacts on the cremation pyre (pyre goods) and secondary adding of artefacts during the funeral process (grave goods) (see, for instance, Williams 2008, 243–244, Henriksen 2009, 89).
4. The numbers for the fragmentation index are derived by dividing cremation weight in grams with cremation volume in millilitres (g/ml) for each of the graves. The Fragmentation Index is therefore not affected by the degree of preservation or the representation or the intactness of the grave. The numbers describe the general fragmentation of the sample, the Fragmention Index (FI). High volumes in relation to weight result in a low Fragmentation Index (0–0.5) and less volume in relation to weight result in a high Fragmentation Index (1.1–1.5) (see also Harvig and Lynnerup 2013).

Supplemental data

Supplemental data is available via the supplemental tab on the article's online page at http://dx.doi.org/10.1080/21662282.2014.942980

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The pictures on the greater Jelling stone

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The greater Jelling stone, with an informative runic inscription mentioning King Harald Blåtand and the conversion of the Danes, is at the core of a large and important archaeological site of the late tenth century situated in the centre of the Danish peninsula. The stone is thought to have been positioned immediately to the south of some sort of church, and between the two mounds ever since that period. The great boulder has three main surfaces, all closely covered by carving. The first face has most of the inscription, which, unusually for runes, is arranged in parallel lines as for a Latin text. The second face shows an animal entwined with a snake, and the third face has the earliest image in Scandinavia of Christ – these two 'pictures' can be compared to a diptych since they share a similar border and are connected by a 'hinge'. Identifying a diptych implies that the two faces must have compatible not antagonistic subjects. It is suggested that the design and carving was controlled by a missionary party from Ottonian Germany, and that in choosing the motifs they used various sources, mostly in the writings of Pope Gregory the Great. Following these early sources, the animal and snake can be interpreted as God the Father and God the Holy Spirit. It is likely that Christ is shown ascending to heaven in triumph, so that the two pictures show the Trinity united in celebration of the redemption of mankind.

Keywords: Jelling; conversion; Gregory the Great; Trinity; Ascension; interlace; lion; snake

Historical context

The greater Jelling stone, thought to have been erected by King Harald Blåtand *c.* 965, is a national icon for Denmark, and has a correspondingly impressive literature (http://www.velkommenihistorien.dk/Sider/litteratur1.html). In its prime, the stone probably stood alone in front of some kind of church, close to where it is now, a massive boulder which is taller than any man (Figure 1). The lesser rune-stone of Harald's father King Gorm was reset near it *c*. 1630, but came from an unknown position, perhaps as remote as the prow of the stone ship (Holst *et al.* 2013: Figure 3).

A recent publication on King Harald's runestone giving an overview of current opinion is that by Else Roesdahl; it is an update of an earlier paper (Roesdahl *et al.* 1999, Roesdahl 2013). Excavations of the surrounding landscape from 2006 onwards have greatly enlarged our knowledge of the contemporary physical context (Holst *et al.* 2013). The Jelling stone has never been better photographed than by Erik Moltke in 1973 after he had painstakingly examined all three sides and given the background a wash of lamp-black in water; he had the advantage of free access to the stone and also mellow sunlight (Moltke 1974, Figures 3, 6, 7 and 8; Roesdahl 2013, Figures 3, 4). In the following 40 years, the stone deteriorated as individual crystals separated themselves from the block under the influence of acid rain and frost, and the carvings were also daubed with paint, so that it was decided to erect the present shelter. Moltke's photographs have, in a way, become the Jelling Stone for modern times, a venerable relic we can hold in our hands, contemplate and attempt to understand.

Signe Horn Fuglesang insists that 'the Jelling crucifixion must be seen against [a] European background … which has its beginning in Late Antiquity and continues throughout the Middle Ages' (Fuglesang 1981, pp. 87–89, 1986, p. 207). Else Roesdahl describes the well-known images on Faces A, B and C as being three pictures, laid out in the manner of three pages of an illuminated manuscript (Roesdahl 2013, pp. 867–870). Egon Wamers has examined the style of the carvings, linking it to Ottonian manuscripts (Wamers 2001). In making these comparisons, these authors are turning our attention away from the immediate Nordic surroundings and local precursors, and towards the wider European context, to the circumstances of the conversion of the Danes by the Christian church as established in Ottonian Germany (Wamers 2001, pp. 132–4, 156–8; Gelting 2007, pp. 80–81). The present paper follows that lead, believing that the three pictures can only be understood if they are considered as sourced in the new religion.

The inscription on the stone tells us that it was set up to commemorate the parents of King Harald and that this Harald 'made the Danes Christian'. It seems to be accepted that the whole inscription was planned and carved at the same time, not in two stages (Moltke 1974, pp. 187–93; Roesdahl 2013, pp. 866–7). The stone thus

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Figure 1. The three sides of the greater Jelling Stone. Face A (left) contains the main part of the rune text which begins: ‘Harald king commanded to be made monuments/memorials these after Gorm father his and after Thyre mother his that Harald who for himself won Denmark’. Face B (centre) contains a large animal entwined with a snake, and the text continues ‘all and Norway’. Face C (right) shows a haloed Christ with his arms spread, and the text ends with ‘and the Danes made Christian’. Literal translation from Roesdahl 2013, p. 866. (Photo: National Museum of Denmark, R. Fortuna).

also commemorates the conversion of the Danes, that is, it records a radical change of Danish society from one condition to another. How long the conversion took and when it might have been considered complete are not questions of concern here: the inscription tells us that there was an identifiable moment of change when ‘the Danes’ turned from heathens into believers. The inscription implies that the king and his closest followers, and their followers in turn, would accept a new god, and that a Christian hierarchy would replace the officiants of the various pagan cults (Sanmark 2002, pp. 81–2).

In modern discussions of the stone and its pictures, the missionary partner has often been overlooked for the sake of tracing Nordic parallels, yet the new culture is literally at the very core of the majestic site at Jelling; the proto-church found by excavation (Holst *et al.* 2013, 480ff. and Figure 6) and the inscription on the runestone itself represent something radically new. The surrounding mounds, ship setting, long houses and palisade are works of the established local culture, some coeval with the great runestone. Together, these remains form the climax of a short-lived royal ritual site that, by chance or intention, never grew into a town. Available archaeological data reveal ‘no certain structural traces earlier than the 10th century AD… [this was] an area dominated by heather’ (Holst *et al.* 2013, p. 486); when King Harald died *c.* 987, Adam of Bremen says he was buried in Roskilde.

The carvings themselves combine two cultures, as has been remarked before. The inscription shows this most clearly, since it comprises Nordic runes written in parallel horizontal lines as for Latin script. The imagery likewise has not been traced to one universally agreed source, but is given a variety of stylistic derivations according to the expertise of each commentator. Our difficulty in giving labels is a mark of the success of the makers of the carvings. The melding of styles is characteristic of the carvings, and the fusion is deliberate and skilful: perhaps it is a mark of a peaceful conversion that the carvings have both freedom and unity.

Working on an unshaped boulder was a traditional skill, but this particular design was mapped out with intense forethought to pack the stone to its limit, as if there was some purpose for every detail or perhaps the artist had dense manuscript ornament in mind: later engraved stones allowed randomly placed motifs or blank spaces, as on Ramsundsberget, Sö 101 (Sweden) or subsequent Christian memorials in Denmark (Fuglesang 2005, Bertelsen *et al.* 2006). Egon Wamers has illustrated the influence of Ottonian manuscript styles in the interlacing stems and leaves which appear on all three sides of the stone; he believes that a native, Nordic, artist combined those foreign styles with his own local style (Wamers 2001, pp. 135–8). Similarly, the animal and snake on the Jelling stone could be seen as imported Christian symbols given Nordic dress; the Christ figure is treated in a manner without close parallel in Christian art.

The man whose specialism was to carve stone in the Nordic manner was an artist in whom a fusion of the two cultures seems already in being. Given both the general and detailed mixture of styles on all three faces, and his success in fusing them, it is possible that the workman was a convert and had been a believer for some time. Christianity was already known in Denmark, for example, over a century before, King Harald Klak had been baptised while an exile in Mainz; the diocese of Hamburg had had an interest in the conversion of the Nordic countries since the ninth century; Christian burials of the ninth century have been found at Ribe (Søvsø 2010); seaborne trade and the land boundary with the Empire could have contributed to an easy interchange in times of peace and would have allowed men to become familiar with the new religion; the contemporary chronicler Widukind of Corvey (died after 973) suggested that some Danes already worshipped Christ at the time of king Harald Bluetooth's baptism.

The motifs will be interpreted below as entirely Christian and from a clerical source; indeed this is suggested immediately by the stone having the first appearance of a Christ figure in Scandinavian art, as well as the three 'pages' that resemble a manuscript. King Harald no doubt supplied the wording of the inscription; the organisers took care to choose motifs accessible to the local, Danish, converts, not only through their artistic style, but also in their choice of basic forms (Moltke 1974, p. 187); animals and snakes appear in the art of both cultures. This care to engage the sympathetic interest of the Danes also appears in the decision to spread the imagery over an unshaped granite boulder and in the use of runes for the inscription: elsewhere in Christian Europe, squared stone and Latin text would have been obligatory – perhaps the superfluous lines below the runes might suggest a plinth. As for the two main pictures, they contrast with the court or monastic art of the Empire, which is predominantly elaborate, Christ-centred and figural (Mayr-Harting 1999, I, pp. 57–118): on the stone there are very few components, and these include symbolic animals. These examples show that it was clearly appreciated that sculpture for the pagan Danes needed 'user-friendly' imagery, so we may assume that the pictures themselves likely have a simple focussed message similarly attuned to the needs of converts.

These sensitive organisational decisions were almost certainly made by clerics of the Ottonian church. It cannot be known for certain if the organiser or designer was also the sculptor, but considering the range of skills required, it seems very likely that they would have been different individuals. The designer, the man who chose the message and the motifs to represent it, is key, but his work is of the kind which leaves little obvious trace. Lise Bertelsen found rare proof that more than a patron and a sculptor were needed to produce similar medieval works when she noted that a Christian runestone at Vaksala church, Sweden, was 'jointly signed by Igulfast, who gave advice, and Öpir, who carved' (Bertelsen *et al.* 2006, caption to Figure 1; see also Källström 2007, pp. 184ff).

A focussed message

The selected boulder had three sides, and the triquetra is 'the stone's favourite motif' according to Moltke (1974, p. 193). Teresa Paroli appreciated Moltke's 'acute flashes of intuition', for example, his noticing the importance of the triquetras; she remarked on the frequency of threes and expanded on the cosmic and numerological references to the Trinity that might be found in the ornamentation throughout the stone – though it is not certain that all the corner ornaments form triquetras as she asserted (Paroli 1987, pp. 402, 403). Yet despite such insights, the fact remains that, in this and other explorations of the meaning of the pictures, the most obvious three-some, the three-ness of the three characters in the two pictures, is not mentioned. Instead, the animal and snake are seen as opposed to Christ, a supposition which frequently gives rise to a narrative of final struggle and paganism vanquished. At first sight, this idea seems relevant to the contemporary situation, but it can be taken too far. Paroli (1987, p. 403), for example, went on to suggest that the animal 'is suffocated by the evil which it itself exudes': if this were true, it would surely raise questions as to what sort of Christianity the Danes were supposed to be adopting!

A suggestion has been made by Fuglesang that the animal and snake represent the earthly power of Harald Gormsson as expressed in that part of the runic text which is on Face B, just as Christ represents the spiritual victory described in the text on Face C (Fuglesang 1986, p. 189). She hypothesises that the animal and snake are a reference to Widukind's account of the victory of the Saxons over the Thuringians in 531 and that they thus make Harald a victor in the line of such great heroes (Fuglesang 1986, pp. 190, 207). Widukind says that the (then still pagan) Saxons went into battle carrying standards of *leonis atque draconis et desuper aquilae volantis insignatum effigie*. There is a long tradition of the Christian church being pictured as an army led by Christ, for example, a sixth century hymn for Passiontide begins *vexilla regis prodeunt*…, that is, it mentions the banners of the king, or Christ, advancing. After this, there are scattered references to banners and other items being used by the Church in liturgical processions, among which is one reference linked to a significant centre of reform in the tenth century, Gorze Abbey (Mayr-Harting 1999, I, pp. 83, 86). It is known that Gorze-related customs included the monks processing with a candlestick in the shape of a serpent or dragon (Klukas 1983, p. 169), and this practice may reasonably have been familiar to the contemporary Widukind. The widely used but later Sarum customs mention Rogation and Ascension processions carrying, for example, *prius leo, deinde minora uexilla per ordinem; ultimo loco draco* – the order of the three items varies according to the occasion (Frere 1969, pp. I, 173–5). It is now suggested that, when Widukind wrote his account more than 400 years after the battle, he gave these items to the Saxon army so that, by prolepsis, the Saxons might represent the power of the Christian god, and perhaps a Roman army, overcoming pagans. On the Jelling stone, the animal and snake could be powerful Christian symbols such as were carried in contemporary liturgical processions, these uses stemming from a common iconography.

It is Face B of the Jelling stone that gives rise to the greatest amount of interpretative speculation, but on what basis? Have the natures of the animal and the snake yet been correctly identified? The inscription ends on Face C, saying Harald 'made the Danes Christian', which must mean that he and they were baptised. The dramatic figure of Christ above those words is impressive, but more than 'christening' was involved: baptism was always given 'in the name of the Father, and of the Son and of the Holy Spirit', as commanded in the gospel (Matthew 28:19). Further, however much the instruction of baptism candidates had been reduced since the days of Augustine of Hippo, the converts must, in some way, have publicly assented to a summary of their new belief before receiving baptism. This summary was most likely in the form of the Apostles' Creed; in that creed there are statements about all three persons of the Trinity. It is known that, within some 20 years, King Harald built or founded a church in Roskilde in honour of the Holy Trinity (Paroli 1987, p. 411). The Danes were to believe not in three separate gods, but in a threefold Unity; it is suggested that this concept was physically put before them in the triquetras and in the three-sided stone itself. Knowledge of the Trinity was an essential doctrine that was unavoidable in the process of conversion; consequently, to show only Christ when commemorating this conversion or baptism would have been far from ideal, and it is hard to imagine the Ottonian church making such an error, however, Christ-centred its elite manuscripts were. In this instance, it would have been correct to picture the Three and One.

We have next to consider what sources might have supplied the missionaries with the imagery used for the stone, and there is one name of outstanding importance. Gregory the Great (monk, administrator, pope and saint; died 604) was influential throughout the Middle Ages, but it seems that he surpassed even Augustine of Hippo in his importance to the Ottonians. The best known medieval representation of Gregory the Great was painted *c*. 984 at Trier, Figure 2 (Mayr-Harting 1999, I, Figure 13; Beckwith 1969, ill. 83). The painting shows Gregory receiving words of inspiration from a dove (to be understood as the Holy Spirit); this is observed by his secretary who is waiting to take dictation. The elaborate semi-realist portrait was painted within some 20 years of the carving of the Jelling stone and demonstrates the depth of interest in the saint at that time. Henry Mayr-Harting describes Gregory's *Moralia in Job* as 'one of the most treasured texts in Ottonian culture' and says that it 'was treated in a manner approximating to the Bible itself' (Mayr-Harting 1999, I, 18; II, 209); moreover, within the empire, the diocese of Cologne seems to have had a particularly marked interest in Gregory's works (Mayr-Harting 1999, II, 118–9), which may be significant since King Harald is thought to have been baptised by Poppo, or Folkmar, who was probably in Denmark as an envoy on behalf of Bruno, archbishop of Cologne. It would not be surprising, therefore, if the designers and organisers of the Jelling stone project referred to the works of Gregory the Great when composing the pictures to accompany the king's inscription.

Gregory had discussed the Trinity in his most famous text, *Moralia in Job*. There he describes how David, Isaiah and Paul had all written in terms of the three-ness of God, but he pointed out that each writer had immediately added some words to show that God was One (*Moralia* xxix.70). Somewhat out of context, Gregory went on to reveal the literal fact that the Church 'preaches knowledge of the Trinity to infidels', whereas church members need to be taught about the four virtues (prudence, fortitude, temperance and justice; *Moralia* xxix.72). This passage has not been seized on by historians of the conversion period, perhaps because it is embedded in an abstruse allegorical interpretation of astronomical configurations, yet it has been mentioned a few times. Kahl (1978, p. 48, note 78) was interested in the relevance of the passage to those already in the Church and had no space to discuss the missionary aspect (he did, however, correctly identify the circumpolar constellation with seven stars, Ursa Major, the Great Bear, whereas Gregory's text has come down to us mentioning the single star Arcturus). Henrik von Achen picked out Gregory's emphasis on the ability of the Church to tune her teaching to her audience, that is, to use accessible imagery to get the message over (von Achen 1995); this attribute of the Jelling sculpture has already been mentioned. Markus (2001, pp. 33–4) was interested in Gregory's notion of *infideles* in a society nominally Christian. It is now suggested that the Ottonians, reading this passage in *Moralia*, would have taken it at face value: pagans must be taught about the Trinity.

The remainder of this article sets out evidence for an interpretation of the three characters on the two 'illuminated' pages as representing the three persons of the Trinity, and it will refer again to the *Moralia in Job*.

Christ

The famous wooden Gerokreuz in Cologne cathedral is thought to date from *c*. 975 and shows Christ dying on the Cross (Mayr-Harting 1999, I, 133–5, 137–8; Figure 82). At Jelling, there is no cross nor is the body distressed, so the carving must illustrate some other aspect of Christ than his earthly crucifixion. Christ wears a knee-length skirt and his arms are scored with the transverse folds characteristic of medieval sleeves; he is wearing a short tunic. There are numerous crucifixion illustrations, both earlier and Ottonian, in which Christ wears a long robe, but a better comparison for this short tunic is with the symbolic crucifixion in an Ottonian manuscript of *c*. 1020, Figure 3 (Beckwith 1969, p. 116; Mayr-Harting 1999, I, pl. XVIII;

Figure 2. Pope Gregory and his secretary. Frontispiece to a collection of the pope's letters. Source: Stadtbibliothek/Stadtarchiv Trier; Hs 171a Thronender Gregor; Photo, Anja Runkel.

Figure 3. The symbolic crucifixion. Christ wears items symbolic of his role and is flanked by personifications of Church and Synagogue. The *Uta Codex;* (Munich, Bayerische Staatsbibliothek, Clm. 13601), fol. 3v. Reproduced by permission.

Cohen 2000, pl. 4). Both that figure and the one on the stone are wearing clothing suitable for an active man such as a workman, traveller or soldier. In the illumination, Christ's robe is wine-red, he is at work treading grapes to make wine (Isaiah 63:1; John 17:4, 19:30), while the implication of the crown is that Christ is in command; the stole indicates his function as priest, that is, he intercedes with his Father for mankind. The Christ on the Jelling stone is not shown crucified in the literal sense. The figure's widely spread arms allude to the crucifixion, but a cross only occurs in the halo, where it is radiant. The figure is symbolic of some other state, after the Crucifixion.

The feet are not like those of a crucifix figure on near-contemporary metal pendants, in which the feet are of large size and turned sideways (Sanmark 2002, Figures 3 and 4); on the contrary, on the stone the feet are small in comparison with the hands. Further, the artist has used a natural ledge in the stone to show the feet projecting forwards in a normal standing position. One analytical drawing even marks transverse lines across the ankles, that is, Christ may have been shown wearing boots (Wamers 2001, Figure 1, after Moltke and Gabriel); a photograph (in Willemsen 2004, p. 53) additionally suggests gaiters, or bindings, worn on the legs. Unfortunately, because of the present state of the surface and restrictions on access, it cannot be known if such transverse incised lines ever existed or might remain to be studied. The relevance of these features of the clothing is discussed in the next paragraph.

Paroli defined the figure as Christ '*triumphans'* (1987, p. 406), and it is further suggested by Wamers that the carving shows Christ as if crucified on the Tree of Life but at the same time triumphant, anticipating the Resurrection and Ascension (Wamers 2001, p. 147). These are satisfactory interpretations in that they accord with the atmosphere of victory which the liveliness of the surroundings engender, but Christ is surrounded by at least four separate motifs, not one united tree-like structure. The lively surroundings, and the details of the clothing and posture, would all be appropriate if Face C depicted Christ ascending after his Resurrection. When, at the last supper, Christ had spoken to his disciples about leaving them, he described his departure, that is, his death and return to Heaven, as a journey (John 14:2–4); this metaphor would account for his wearing boots and gaiters, if such had existed, and the short tunic is suitable for a workman or a traveller. The posture with arms extended is certainly that of crucifixion, but Christ holds himself upright. There is nothing under his feet, while his fingertips on both sides overlap the cable border, adding to the perception of the figure floating freely, or rising, in space.

His hands show no certain sign of nail-holes now, but those might have been painted if not actually bored; tenth century Ascensions, on an Irish cross and in the Sacramentary of Warmundus, show Christ's hands raised to display the wounds as trophies of victory (Harbison 1992, Figures 915, 916); similarly, the posture of crucifixion held by an obviously living Christ would also indicate victory. The various separate motifs around him are composed of foliage, interlacing strands and triquetras; these are positive symbols and therefore cannot be confining or restraining him: it would be more appropriate to say that they garland him. He is ascending victorious, one metaphor certainly in the mind of Christian artists being that of a Roman triumph (2 Corinthians 2:14). The irregularities of spacing and shape of the various foliate shoots on the Jelling stone enliven the experience of looking at the sculpture and enhance the symbolism of irrepressible life which surrounds the figure: Christ is ascending as Lord and eternal life-giver (Ephesians 4:8).

The patterns accompanying Christ

The active patterns of the interlacing on Face C do not readily bring to mind any particular physical object, though they might suggest Christ has already risen into a spiritual or heavenly environment, above the clouds and well beyond the sight of the disciples on the Mount of Olives. Foliage in Christian art is a symbol of new life and had been so from the earliest times; for Gregory the Great, for example, 'green-ness' is a metaphor for everlasting life (*Moralia* xii. 5–8). All over the stone, interlace strands sprout with shoots or leaves at their free ends, and randomly elsewhere. This interlace does not just provide the stems necessary for foliage, it seems to be the dominant form, with leaves as spasmodic additions. In Ottonian manuscript art, the addition of ornament to interlacing is often regular, balanced and even symmetrical (Wamers 2001, Figures 4, 13, 14), but Nordic and Insular artists exercised even more freedom and had been far more creative in their uses of interlace.

The triquetra is a favourable sign, an interlace pattern which is an aniconic reference to the Trinity (Reuterswärd 1986, II, 58–60; Paroli 1987, pp. 402–6). Patrik Reuterswärd notes that triquetras, although primarily to be associated with the Trinity, can sometimes, like other cosmic symbols, represent stars 'when the purpose is to render intelligible a celestial realm imbued with God' (Reuterswärd 1986, III, 115), so perhaps they might also have something of the nature of stars here. Both the sculptor and the designer seem to have been familiar with Insular interlace, perhaps through Ottonian sources, perhaps directly. We barely understand the significance interlace patterns had for the artists who used them, but we can appreciate that the patterns were a powerful tool in their hands, most of all in the famous 'carpet pages' of the Book of Kells or the Lindisfarne Gospels. The eye is drawn into the page and tempted to follow the course of the strands; perhaps we try to trace the shape of one animal between its head and even one of its feet – but eventually the chase has to be given up, the pattern has superior power, moves faster and more surely than the human eye. Perhaps it was this very chase, the weaving up and down, spinning round and round, that was the important quality of interlace – it enacted 'life' – in particular, it could have represented the energy of eternal life.

In Insular manuscripts, the triquetra was by no means always the perfectly regular, finite or closed, geometric unit that it became later. For example, there is a triquetra in the eighth century Book of Kells on the page with the Virgin and Child (fol. 7v), by her right shoulder (Figure 4). It is a loop attached to her chair; the strand from which it is made is continuous with other interlace behind the chair, and only this section of it is coloured bright yellow. In the sensitive pattern-making of this period, three loops close together were enough to suggest a triquetra. There are four, perhaps six, such units around Christ on the Jelling stone, and only one is a closed loop without additions, the others are contrived out of the trailing stems, and some are not immediately recognisable: look for groups of three spaces. In fol. 7v of the Book of Kells, the irregular triquetra might have suggested the hidden-ness of the three-fold god, or his presence in humble places, or the constant attendance of angelic spirits on the Christ-child; all these three, or more. Perhaps on the Jelling stone, the knots in the interlace are to suggest the excitement of creation at the implications of Christ's resurrection (Romans 8:19–21), or perhaps they represent the angels gathering, amazed to see Christ as a man, in his ascent (Isaiah 63:1).

The visual tricks with the triquetras and the random shoots of foliage make lively surroundings for the Christ-figure, in accord with the message of the upright figure itself. The pair of triquetras beside Christ's feet are closed loops; those at his head are closed but connected by the long strand that loops round his arms and across his body. In a standard Ascension, two or more angels lift a mandorla containing Christ; it is possible to imagine that the strand looping round the arms is supporting and lifting him – but it would, of course, be going too far to say that the two upper interlacements are the equivalent of those two conventional angels. Interlace is more subtle than that.

The least distinct (or most active?) of the triquetras are at either end of a transverse strand woven straight across the circle and behind his body. The circle at the centre could have had multiple functions – it may have suggested the eternity to which Christ returns, or perhaps it represented the sphere of the cosmos of which he is Lord, or indicated the One-ness of God to balance the triquetras with their insistence on the Trinity. In Ottonian art, Christ generally ascends not standing but enthroned: the Sacramentary of Warmundus, a manuscript of *c.*

Figure 4. Detail from The Book of Kells, (Dublin, Trinity College Library, 58), fol. 7v. Reproduced by permission of Durham University Library Special Collections, SC+10638.

969–1002, shows him seated on the rainbow (Harbison 1992, Figure 916); in an ivory panel from Magdeburg, of *c*. 962–963, Christ is seated on a circle which is a victor's laurel wreath, with his feet on the rainbow (Fillitz 2001, p. 31). Perhaps the circle and the strand passing through it hint at some such cosmic throne. Wamers (2001, p. 146) also relates the circle to examples in Carolingian and Ottonian manuscripts.

Christ was a victor, he had won a battle over Death and had raided the city of Hell to release mankind. The Church taught that he did not ascend for himself alone, but gave mankind the chance to follow him to an after-life in heaven. One cannot help recalling counsel given to the pagan king Edwin of Northumbria in 627: 'if this new teaching has brought any more-certain knowledge [of what went before this life or of what comes after it], it seems only right that we should follow it' (Bede II.13 trans. 1955). The Ottonians would have been familiar with that quotation, as the Venerable Bede was another of their favourite authors. The Ascension was thus a most suitable subject to put before converts, and consequently Egon Wamers can say, 'the promise of salvation and Paradise was the central message of the Christian church for the pagan peoples' (Wamers 1993, p. 38). Christ's victorious Ascension gave the believer access to Paradise, it was the most attractive reward to present to converts; parallels might well have been made with the actions of a victorious Viking war-lord giving gold to his followers. Illustrating the Ascension on the Jelling stone accords with the statement of Gregory the Great on 'preaching the Trinity to infidels', because Christ is returning to heaven to be 'reunited' with the Father and the Holy Spirit.

The animal and snake opposite Christ

This is 'the first occurrence in Scandinavia of this combination of animal and snake' (Fuglesang 1986, p. 188; Roesdahl 2013, p. 868), which might be a hint that they, like the Christ figure, are Christian symbols. It has often been assumed that the two animals are in conflict, either with each other or with Christ, but there is no need to see any battle at all. The boldness of the animal and the gyrations of the snake could express the vitality of the two creatures, while their intimate combination could demonstrate their fundamental association. Note that the foliage on this 'page' is not in isolated pieces as before, but it comes from the animals themselves; one piece only from the snake, but the animal has foliage emerging from head, mouth and tail. To continue with the earlier reasoning about these sprigs of foliage, the animal and the snake are shown as sources of life.

Faces B and C, Figure 5, have been likened to the opening of a book and have several times been illustrated as a pair (Moltke 1974, Figures 1 and 11; Roesdahl 2013, Figure 5 and 6); Fuglesang sees them equally as carriers of meaning (Fuglesang 1986, p. 189); the two faces have also been described as a 'kind of triptych' (Pedersen *et al.* 2006, p. 306). Indeed, a helpful comparison would perhaps be with a diptych, a small personal icon of rectangular shape; these have two leaves or 'pages' joined by one or two hinges. They were probably most often made of wood, though ivory ones have survived better. When closed, a diptych was easily carried in pocket or bag; when open to show its painted interior, it could stand without other support on prayer desk, niche or altar. It is the sort of item a travelling cleric would be likely to have

Figure 5. A view of Faces B and C together. (Photo: R. Wood).

with him, and the novelty of its painted images would attract attention when opened in the company of unbelievers. In 597, for example, the Roman missionary sent by Pope Gregory to convert England, Augustine, went to meet the pagan king of Kent with a procession of monks following a silver cross and carrying 'the likeness of our Lord and Saviour painted on a board' (Bede, I.25, trans. 1955). Small painted pictures on a diptych might have been useful in similar circumstances in Denmark in the late tenth century; they would have been more safely carried and passed round than an illuminated manuscript. It is not suggested that the subjects of the carvings are copied from an actual diptych, but that the form would have been very familiar to the designer, and perhaps to his audience.

A diptych model for Faces B and C is suggested by the treatment of the borders. Face A is the face most resembling a page of a manuscript; here the interlace borders the text, not the edge of the stone, and there was something vaguely like an initial clustered at the top. However, on Faces B and C, there are borders around the edges of the stone, and these borders are identical. The two faces are isolated from each other by a reflex angle, which is approximately 250° (Wimmer 1895, p. 18): with their matching frames they become unified and we are impelled to consider them together (Figure 6). On the ridge between the two faces are not two distinct lines of loose cable pattern as at their outer edges, but a tighter and generally symmetrical double cable pattern; additionally, a pair of transverse bindings at top and bottom of this pattern tie the two borders together (Figure 7). The feature is not intermittent as if imitating the stitching of a manuscript opening; it is compact like a hinge, as for a diptych. The distinction is suggestive, because, compared with the great majority of manuscript openings, the facing images of a diptych are certain to be positively related, largely because they are subjects selected for private prayer and contemplation; they are intended to generate worship or inner peace (Beckwith 1969, pp. 114–5, Figure 97; Nees 2002, ill. 83). It would be impossible to conceive of a diptych which, when shut, enclosed anything antagonistic with the victorious Lord, as would be the case if Face B of the Jelling stone depicted any kind of battle. The subjects on Faces B and C cannot be opposed (good against evil;

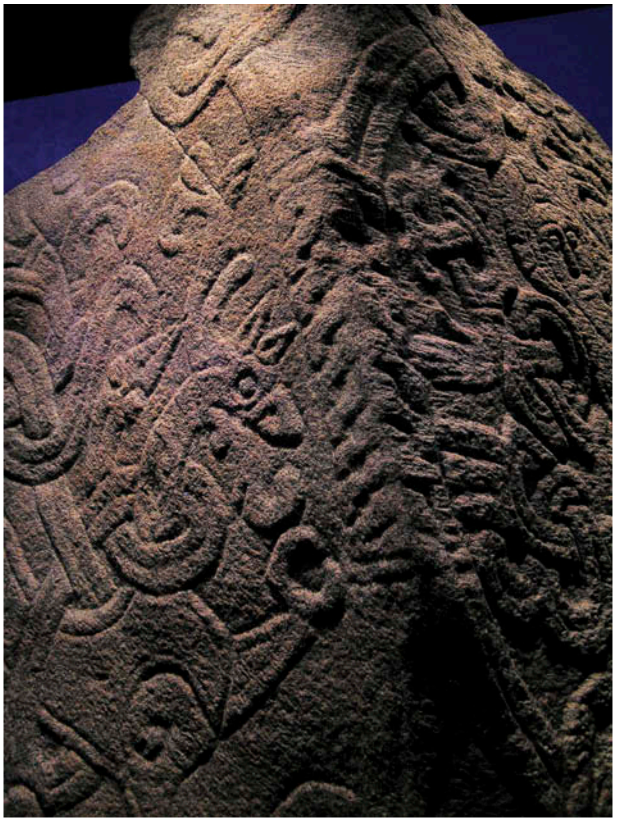

Figure 7. The ridge between Faces B and C showing the present state of the postulated hinge. (Photo: R. Wood).

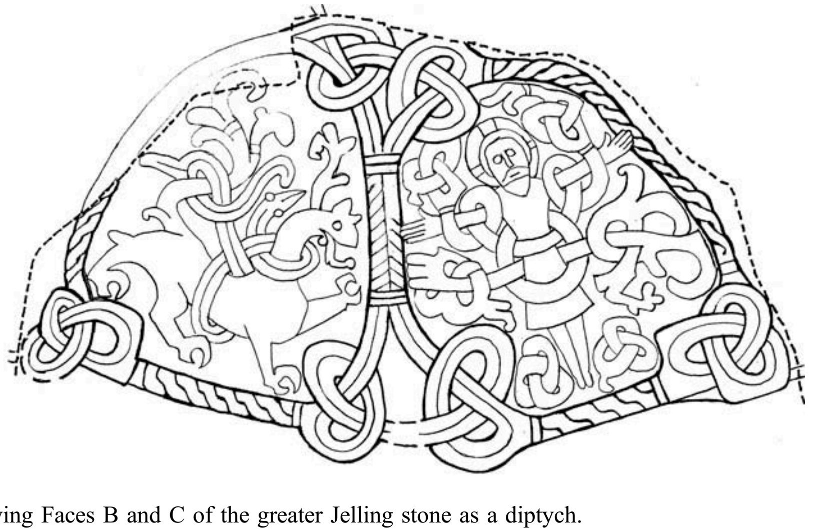

Figure 6. Diagram showing Faces B and C of the greater Jelling stone as a diptych.

Figure 8. The emperor Charles the Bald sees a vision of the worship of the Lamb of God in heaven. Codex Aureus of St Emmeram (Munich, Bayerische Staatsbibliothek, Clm 14000), fols. 5v and 6r. Reproduced by permission.

new religion against old) and, in an Ottonian scheme, they are unlikely to represent the earthly power of Harald on a par with the spiritual power of Christ. If Faces B and C form a diptych, their subjects must be compatible, of an equal intensity and status.

A few specialised manuscript openings survive, which work in a somewhat similar way to a diptych. One example is in a Carolingian manuscript made in 870 for the emperor Charles the Bald, Figure 8 (Mütherich and Gaehde 1997, pls. 37, 38, pp. 84, 85; Nees 2002, Figure 101). Folio 5v shows the emperor seated in state under a canopy. Opposite, on folio 6r, is a vision of the Lamb acclaimed by 'the four and twenty elders' as described in Revelation 4:10–11. As compositions, there is no visual correspondence in these two illuminations, but as pictures of royal courts, the comparison makes a point: the emperor must turn himself to look to the right, he must acknowledge the higher power and, metaphorically, remove his crown too. 'The last two lines of the verses under the Adoration miniature affirm that Charles views the revelation of the Lamb, praying to live with it in eternity' (Mütherich and Gaehde 1997, p. 108). As if to enact this prayer, shutting the book brings the head of the emperor against the single large star below the Lamb.

Another significant pairing of pages is in the *Uta Codex*. The mystic crucifixion already mentioned (Figure 3) faces a depiction of St Erhard at an altar (Beckwith 1969, pl. 97, 116–117; Mayr-Harting 1999, I, pl. XVIII and ill. 76; Cohen 2000, pls. 4, 5). Cohen says that 'the Erhard page (fol. 4r) shows the celebration of the Mass and the facing folio (fol. 3v) represents the historical grounding of that activity'. Being an Ottonian manuscript of the highest quality, there are further elaborate textual links within and between the two pages (Cohen 2000, pp. 78, 80, 81). The subjects on Faces B and C of the Jelling stone are relatively simple compared to those on the illuminations described, which involve complex interrelationships of a learned nature, for the sculpture on this monument was designed for converts, but once again we are driven to think Face B holds a positive Christian message. The animal and the snake must, in some way, be positively related to the crucified, risen and glorified Christ.

The animal as God the Father

The animal has been described cautiously by Moltke (1974) and others as 'the great beast' and by Wamers (2001) as a quadruped; Fuglesang (1986, pp. 188–9) says it has also been called a wolf and a griffin, but she concludes it is a lion. The animal can certainly safely be called a lion because it has powerful claws and there are the regular curls of a mane down its neck; it also has the proud stance and strong chest which is appropriate for the king of beasts.

Gregory the Great says that a lion can represent – among other things – Christ (*Moralia* xxx.66), but as Christ is already pictured on Face C, the preferred reading is that the lion represents God the Father, the All-Mighty [*omnipotens*]. Isidore of Seville (died 636) records several prevalent notions about the lion: that for the Greeks and Romans, the lion was thought of as a king and that its strength shows in its chest, forehead and tail [*virtus eorem in pectore; firmitas in frons et cauda indicat*]. Isidore also records the story that the father-lion breathes on its cub to give it life three days after it is born (Lindsay 1957, vol. 2, XII.II.3; 4; 6); this fable was seen as a reference to Christ's Resurrection. The animal on Face B might be described as a strong lion with a tongue or breath made of foliage – life – and it can reasonably be interpreted following Isidore, as representing God the Father. The image could have been used to connect the resurrection of Christ to the promised raising of believers (1 Corinthians 6:14).

The snake as God the Holy Spirit

The snake, looping round the neck, body and tail of the lion, forms an open triquetra, the largest and boldest one on the stone; it is alert and active, even muscular, and its eyes could be understood to show its intelligence and wisdom; these qualities would be more obvious than any threat. Once the triquetra has been identified, this snake can easily be read as a 'good' character. Bertelsen sees the head and the tip of the snake as completing a cross (Bertelsen *et al.* 2006, pp. 38–9), but considering the frequency of triquetras on the stone, this was probably not intentional: first, because, if it represents the Holy Spirit it does not represent Christ, and second, it is suggested that the snake must have its head in this position, away from the three loops and near the right side of the 'page', because both it and the lion are looking towards Christ.

A snake with its head seen from above and showing both eyes was a form which had been very common in Britain and Ireland in earlier centuries in illuminated manuscripts and on Christian monuments; the patterns of multiple snakes found in such places are discussed in a note at the end of this article. The large snake on Face B of the Jelling stone has that ancient form with two eyes, but it is being suggested now that this one is distinctive and represents God the Holy Spirit.

At the last supper, Jesus had introduced the Holy Spirit to his disciples as one who would come to them when he had left them and gone on his 'journey'; the Spirit would remind them of what he had taught them (John 16:13–15). In *Moralia* v.50, Gregory the Great describes his personal experience of the coming of inspiration, those 'hidden' or silent words from God that elevate the mind and make it desire eternal things. Such inspiration, he says, is the utterance of the Holy Spirit, and this hidden voice is the Paraclete (the advocate or comforter) promised by Jesus (John 14:16,17). Short though it is, this passage would have been important to medieval readers, because it gave such intimate knowledge of the saint's own experience.

Gregory does not explicitly compare the Spirit to a snake but, when he tries to describe his experience of heavenly inspiration, his language includes terms that suggest he had a snake in mind. For example, the words of inspiration are heard as an almost inaudible whisper [*susurrus*] (*Moralia* v.51), so perhaps as faint as the hissing of a snake, or its rustling movement. Inspiration arrives through mere chinks [*rimas*] in the mind (*Moralia* v.51), so is perhaps like a snake slipping through fissures or cracks among rocks. 'In a moment and in secret' [*raptim et occulte*], the ear of the heart receives the divine whisper, that is, the words come and vanish as swiftly, as mysteriously and with as little sound, as a snake (*Moralia* v.51). The Spirit 'insinuates itself into the ears of the heart [*in aurem cordis insinuat*]… the mind cannot understand by what openings this invisible power flows into it, in what ways it comes to, or recedes from, it' (*Moralia* xxvii.41); this could describe his marvelling at the winding, rapid but limbless movements of a snake. Gregory found the words of the Spirit hard to catch and hard to pin down. But why did he not name the snake openly, when he names so many other creatures used in his metaphors and similes?

In the Roman empire, snakes had had a range of functions, from being kept as pets or put on exhibition as curiosities, to being believed to attend the spirits of the dead, and figuring in shrines in private houses and in the mystery cults (Toynbee 1973, pp. 223–236). In the late sixth century, there were still pagan practices and beliefs current in many regions under Gregory's oversight, and these were a constant problem for him (Markus 1997, pp. 80–82). In *c.* 601, Gregory wrote a letter to bishop Desiderius of Vienne in Gaul who 'had opened a school for his clergy in which the course of instruction was the usual one, which included the classics' (Conte and Solodow 1994, p. 718). Gregory was disturbed by this and wrote to Desiderius, saying that 'in one mouth praises of Christ do not harmonize with praises of Jupiter… how wicked it is for a bishop to recite poetry that is not even suitable for a religious layman… do not allow your heart to be defiled by the blasphemies of wicked writers…' (Martyn 2004, III, p. 777, letter 11.34). The preceding letter is to Gregory's notary in Sicily, who was having trouble with 'wizards and soothsayers'. In such an atmosphere, Gregory himself could not name the snake as his model.

The cited passages on inspiration are not the only places in Gregory's *Moralia* where he made lengthy circumlocutions to avoid naming a creature connected to pagan Roman beliefs. There are at least two more instances where Gregory had in mind a creature from pagan myth because it provided a useful image for his exposition. The centaur, a licentious beast, can be detected under the name of 'the rider of the horseman' in *Moralia* xxx.42, where it symbolises Christ incarnate [*deus-homo*]. Again, Gregory seems to be thinking of the mermaid, the seducer of sailors, when he writes of a creature with 'two garments' (*Moralia* Preface ch.20; Bk.xxxv.25), she symbolises the Church [*Ecclesia*], or an individual female believer, in the afterlife (Wood 2010, pp. 31–37). The snake, understandably, was never popular as a symbol of the Holy Spirit; the dove is mentioned in the gospel (Matthew 3:16) and is much more often used. In portraits of Gregory the Great himself, it is a dove that whispers to him, approaching his ears or mouth (Figure 2; Zarnecki 1972, ill. 9); the dove is pictured even though a bird does not fit Gregory's own descriptions of the experience of receiving inspiration which have been quoted above.

On the Jelling stone, the Father and the Holy Spirit face the ascending Christ; they move towards him as if they are expecting his imminent arrival or are welcoming his return to heaven. Faces B and C together embodied the necessary doctrinal statements about the Trinity and also, in showing a moment of high triumph, they provided a suitably festive and attractive introductory image for converts. After that, it remained for the newly established Danish church to make provision for the new Christians to learn the four virtues and, hopefully, to progress through the three stages of a believer's life (Gregory the Great, *Moralia* xxiv. 25–31).

A final note: crowds of snakes

The pages of insular manuscripts were surely not laboured over for the sake of vain empty patterns. They are a context which is only suitable for 'good' creatures; the two-eyed snakes, and the animals and birds, which embroider such pages cannot all be evil or meaningless. Two-eyed snakes swarm in orderly patterns on Pictish Christian crosses, and on similar Anglo-Saxon monuments, many of which stood in graveyards and had a memorial function. Discussing the snakes on a late ninth to tenth century English monument, Jim Lang says 'it would hardly be complimentary iconography for the deceased' to think that the snakes' movement or proximity to the cross or the dead had any hellish or antagonist significance (Lang *et al.* 2002, p. 186; illus. 692). In a similar vein, Bertelsen, commenting on Late Viking Age picture-runestones describes the serpents on them as being 'humble and on friendly terms with the cross' (Bertelsen *et al.* 2006, p. 45). These observations suggest the existence of a positive interpretation for multiple snakes in medieval Christian art. However, it is a difficult problem, and Fuglesang (1986, p. 185, n.5) considered that snakes are so common in the Viking period as a purely ornamental motif [*rein ornamentales Motiv*] that it is questionable whether any iconological conclusions could be justified.

As has been said above, snakes were generally experienced as harmful and the snake was therefore not often used as a positive symbol. However, among all the many negative associations and meanings for snakes, the medieval bestiaries carried forward one further useful idea from pagan belief: the snake that shed its skin and emerged 'new' was an indication of an after-life (Toynbee 1973, pp. 234–5; Wheatcroft 1999, pp. 143–5). The many snakes on the graveyard monuments just mentioned, also those on picture-runestones which are also memorials to the dead (Fuglesang 1986, Figures. 15–19) could therefore represent those many who rejoice in eternal life because of the Cross. The same is possible with the snakes – and other animals – on the carpet-pages too. The activity of all these creatures certainly expresses an amazing vitality beyond what is known on earth. With regard to the Jelling stone, it is possible that what has been identified as the head of a snake in the broken interlace at the top of Face A (Moltke 1974, Figure 3) belonged to a snake representing one who had 'shed his skin' and was now in the foliage of Paradise: if so, the convert was being encouraged to think of his own future life.

That the snakes on later picture-runestones contain runes or letters is likely to be due to the opportunistic presence of the two parallel lines of the snake's body; with those lines available there was no need to write anywhere else. There was an artistic tradition of emphasising the integrity of a snake's body by some simple pattern – on the Jelling stone it is done by a medial line – and this would have encouraged the placing of the runes. The messages written in the snakes seem mostly to be between man and man (Bertelsen *et al.* 2006, Zilmer *et al.* 2006), like the inscription on the Jelling stone: serpent-like waving scrolls carry words in illuminated manuscripts but these are usually scriptural texts, that is, words from God. Two symbolic uses of the snake have been encountered in this article: as representing the Holy Spirit and as representing those living the new life in heaven. Later, the snake came to represent a carrier of messages from God to man, whispering at his ears in much the same way that the Holy Spirit spoke to St Gregory.

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Vegetation development in south-east Denmark during the Weichselian Late Glacial: palaeoenvironmental studies close to the Palaeolithic site of Hasselø

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Eastern Denmark was an important region for the early immigration of humans into southern Scandinavia throughout the Late Glacial period. One possible explanation for this is that the landscape provided an especially favourable environment for Palaeolithic hunters. To examine this, the local and regional environment is reconstructed through the analysis of pollen and plant macrofossils from a small kettle hole and is discussed in relation to human presence in the region. The kettle hole is situated close to a Palaeolithic occupation site with artefacts belonging to the Federmesser and Bromme Cultures. The lake sediments encompass the Bølling, Allerød, Younger Dryas and the early Preboreal biostratigraphic periods. An increase in charcoal dust between *c.* 14,000 and 13,900 cal. BP may be related to the occupation site. This study shows that an ecotone was positioned between present-day Denmark and northern Germany during a large part of the Late Glacial period. This was especially the case during the Older Dryas and early Allerød periods, when woodland was expanding in northern Germany while the Danish area remained open. Later in the Allerød period, northern Germany seems to have been the northern limit for pine woodland. The low-lying region separating Denmark and Germany was periodically covered by the Baltic Ice Lake and this may have delayed the dispersal of plants from south to north. Areas lying between different habitats are known to have a high biodiversity and this may be why a high frequency of Palaeolithic finds is seen here. It has long been thought that tree birch grew in the Danish region from the beginning of the Late Glacial, but this study of both local and regional proxies clearly shows that the immigration of tree birch was delayed by more than 1000 years. A delay of *c.* 250 years between the climatic transition from GI-1a to GS-1 and the biostratigraphic transition from the Allerød to the Younger Dryas periods is also shown. The three ^{14}C ages available from the Danish Bromme Culture are from this transition phase when the birch woodland was becoming more open. Pollen analysis also shows the classical Younger Dryas cold separated into an early dry phase (until *c.* 12,100 cal. BP) and a later wetter phase. This was most likely due to a change in atmospheric circulation and variation in the extent of sea ice in the North Atlantic. The combined analysis of both pollen and plant macrofossils has led to a detailed and accurate reconstruction of the local environment and, in turn, the preconditions for human presence.

Keywords: pollen analysis; macrofossil analysis; vegetation development; palaeoenvironment; Late Glacial; Late Palaeolithic; Denmark; Bølling; Allerød; Younger Dryas

Introduction

The region around Lolland, Falster and southern Zealand in south-eastern Denmark has a relatively high concentration of late Palaeolithic finds from the Hamburg, Federmesser, Ahrensburg and especially Bromme cultures (Pedersen 2009). The region must have been important for humans during the Late Glacial period. There is a long history of archaeological research in Denmark, so this Palaeolithic ‘hot spot’ cannot be explained by differences in regional research intensity alone (Petersen 2009). Even though large climatic changes led to enormous environmental variations and transformations of the landscape in the region during the Late Glacial (Iversen 1954, Björck *et al.* 1998), this ‘hot spot’ was probably mainly due to an enhanced availability of resources.

Pollen-based reconstructions of the Late Glacial landscape from south-eastern Denmark (e.g. Krog 1954, Fredskild 1975, Kolstrup 1982, Kolstrup and Buchardt 1982) have given a well-defined picture of the vegetational development during the Late Glacial period in relation to climate, soil development, succession, etc. In recent years, however, macrofossil-based reconstructions have helped to form a more detailed and sometimes surprising view of the vegetation as compared with those based on pollen alone (e.g. Lidberg-Jönsson 1988, Birks 1993, Birks *et al.* 2005, Mortensen *et al.* 2011, 2014a). Among the major advantages of plant macrofossils over pollen-based reconstructions are their better representation of the local environment and their high taxonomic precision. Pollen assemblages are influenced by many factors, such as pollen source area, vegetation patchiness and a taxonomic precision often limited to

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genus level (Prentice 1985, Sugita 1994, Nielsen and Sugita 2005). Reconstructions including macrofossils are therefore often more diverse and multifaceted than those based on pollen alone (e.g. Birks and Birks 2000, Bos *et al.* 2006, Hofstetter *et al.* 2006).

Plants in treeless, Arctic environments often produce a limited amount of pollen. Pollen can be transported over long distances from other regions, and this ‘exotic’ fraction can therefore represent a large proportion of the total pollen rain and result in misleading interpretations (see Birks and Birks 2000). A classic example of this effect is seen in the immigration of tree birch, where there is often a significant time difference between when tree birch pollen appears relative to when the first macrofossils are seen. Tree birch produces large amounts of pollen and is well dispersed, and the documented difference can most likely be attributed to the long-distance transport of tree birch pollen (Birks 1993, Van Dinter and Birks 1996, Bennike *et al.* 2004a).

One of the most important landscape changes is that between open land and woodland with their associated different flora and fauna. This is especially important in archaeology as hunting strategies differ with the available prey, which in turn is determined by the type of environment. Only one other well-dated environmental reconstruction of the Late Glacial from southern Jutland, Denmark, including both pollen and macrofossils, has been published (Mortensen *et al.* 2011). In southern Jutland, tree birch was first established in the middle of the Allerød period about 13,500 cal. BP (Mortensen *et al.* 2011), much later than previously thought (e.g. Iversen 1954, Kolstrup 1982, Paus 1995). A delay in the expansion of birch is also seen in Schleswig-Holstein (Usinger 1985) but it is not known whether this was also the case in eastern Denmark.

South-eastern Denmark was repeatedly covered by glacial advances from the Scandinavian ice sheet during the last glacial period, the Weichselian. The active period of the final glacial advance, the ‘Baltic Ice Advance’ between 17,000 and 16,000 cal. BP, left a weakly undulating moraine landscape with calcium carbonate-rich, clayey sediments and large quantities of buried dead ice (Bennike and Jensen 1998, Houmark-Nielsen and Kjær 2003, Houmark-Nielsen *et al.* 2006, Houmark-Nielsen 2012). As the climate warmed during the Late Glacial and early Holocene, the dead ice melted, forming depressions filled with water (kettle holes). Kettle holes are a characteristic feature of the Late Glacial and early Holocene in previously glaciated regions such as Denmark, and the landscape was therefore littered with numerous lakes and ponds in various stages of infilling. The Hasselø basin is such a kettle hole and was still a small lake during the Late Glacial. Several Palaeolithic sites have been registered in the area around Hasselø since the late 1970s. Most of these sites are situated on low hilltops overlooking the former freshwater lake of Bredningen. One further low-lying site, Hasselø Tværvej, has attracted attention since its discovery due it being situated by the Hasselø basin. Due to deep ploughing, a rescue excavation was carried out in 1994 (Petersen 2006). The flint inventory at the Hasselø Tværvej site contained several Federmesser points as well as Bromme points (Petersen 2006) and thus confirms the general tendency of Danish Federmesser finds to cluster in two groups of probably different age: an early group associated with late Hamburgian finds (Jels, Slotseng, Sølbjerg) and a late group associated with early Brommian finds (Løvenholm (Madsen 1983), Stoksbjerg Vest (Johansson 2003) and Hasselø Tværvej (Petersen 2006)). Only 50 m separate the kettle hole and the closest of the flint concentrations but, despite an intensive search, only few signs of human activity were seen in a few worked flint pieces, small bone fragments and charcoal which were found in the spoil heaps of the former dead ice lake (Petersen 2006).

The kettle hole was revisited in 2010 to extract sediment samples to reconstruct the environment available for human occupation in the area and possibly to date any human traces in the sediments. This paper focuses on the environmental reconstruction gained from pollen and macrofossil analysis. The results of the occupation site itself will be published at a later date. The environmental analysis of Hasselø is part of a larger research project examining the immigration and establishment of humans in Denmark and southern Scandinavia relative to the climatic and landscape development of the region (Pedersen 2009, 2012, Mortensen *et al.* 2011, 2014a, 2014b, Fischer *et al.* 2013a, 2013b).

Site description

Hasselø is situated on Falster, an island in south-eastern Denmark (Figure 1). The present-day annual average temperature is 8.6 °C (January average 1.4°C, July average 16.9 °C) and the annual average precipitation is 617 mm (Theilgaard 2006). The basin had an original area of *c.* 500 square meters prior to infilling, it was 20–30 m wide and a couple of metres deep and the lake had neither inflow nor outflow. The area is now extensively farmed and the lake sediments are covered by about 2 m of loose, unconsolidated sediments.

Material and methods

Stratigraphy

A profile of around 8 m in width of lake sediments was exposed by excavating a trench from near the lake edge onto dry land. The exposed sediments (Figure 2a+b) were described in detail. No disturbance such as slumping or deformation was observed. Two overlapping sediment

Figure 1. Map of southern Scandinavia showing the Allerød distribution of land and sea. The location of Hasselø is shown in red. Six other localities discussed in the text are shown in black (1. Slotseng, 2. Bromme, 3. Trollesgave, 4. Fensmark Skydebane, 5. Lundby Mose, 6. Sølbjerg, 7. Krogsbølle, 8. Rostocker Heide).

monoliths of 160 x 10 x 10 cm were sampled encompassing the Late Glacial and early Holocene sediments. The field descriptions were supplemented in the laboratory by descriptions of the monoliths using the Troels–Smith system (Troels-Smith 1955). The organic and calcium carbonate content was estimated at continuous 1 cm resolution by loss-on-ignition (LOI); 2 cm^3 of sediment was dried at 105°C for 12 hours (dry weight), and fired at 550°C for 2 hours (to determine organic content) and at 950°C for 2 hours (to determine calcium carbonate content). Organic and calcium carbonate content are important proxies of biological production and erosion. No artefacts indicating human activity were found *in situ* in the sediments, even though the lake is situated close to the Federmesser/Bromme Culture occupation site.

Chronology

Terrestrial plant macrofossils from 10 levels sampled during macrofossil analysis were AMS radiocarbon dated. We used deciduous leaf fragments and fruits or twigs in the absence of the former (Table 1). Remains of aquatic plants, such as *Potamogeton* sp. (pondweed) and *Batrachium* sp. (water-crowfoot), were not used because of potential hard water effects. Seeds of *Menyanthes trifoliata* (bogbean) were dated from one level (AAR-15013) due to the absence of sufficient terrestrial material. *M. trifoliata* is a wetland plant but photosynthesises atmospheric CO_2 and is therefore suitable for dating. Material for ^{14}C determination was selected from the 2 cm contiguous samples and subjected to a standard acid–base–acid treatment to remove possible contaminants, such as carbonates and infiltrating humic acid. The dating results are reported according to international conventions (Stuiver and Polach 1977) as conventional ^{14}C dates in ^{14}C yr BP (before AD 1950) based on the measured $^{14}C/^{13}C$ ratio corrected for natural isotopic fractionation by normalizing the result to the standard $\delta^{13}C$ value of −25‰ VPDB (Andersen *et al.* 1989). The dates were calibrated and an age-depth model constructed using OxCal 4.2 (Ramsey 2009) and the radiocarbon calibration curve IntCal09 (Reimer *et al.* 2009).

Pollen analysis

Pollen was analysed for 34 out of a total of 158 contiguous samples. Pollen preparation followed standard procedures, including KOH, HCl, HF and acetolysis (Fægri and Iversen 1989), and *Lycopodium* (clubmoss) spores were added for the estimation of pollen concentrations (Stockmarr 1971). The residues were mounted in silicone oil. An average of 500 terrestrial pollen grains were

Figure 2. a) Excavation of the Hasselø basin with the late glacial sediments showing in the profile. b) Lake sediment profile. The thin, dark-coloured layers in the lowermost part are in washed macrofossils. Above these are layers of light-coloured, clay- and calcium carbonate-rich gyttja followed by darker gyttja dated to the second part of the Allerød. The Allerød layers are overlain by Younger Dryas sediments and then by dark-coloured Holocene sediments.

counted per sample along with spores, algae and other palynomorphs. All terrestrial pollen and spores were included in the pollen sum. Cyperaceae (sedge) were excluded because of their overwhelming local abundance. Whole slides were analysed to avoid the effects of unequal distribution of pollen under the cover slip. Beug (2004) was consulted for general pollen identification, supplemented by the reference collection at the National Museum of Denmark for problematic grains and specialist works for the following: Punt and Blackmore (1991) and Punt *et al.* (1995) for *Cerastium cerastoides* g. (starwort mouse-ear), *Thalictrum alpinum* g. (alpine meadow-rue) and *Thalictrum flavum* g. (common meadow-rue); Moore *et al.* (1991) for *Oxyria* (mountain sorrel) and *Equisetum* (horsetail); Fægri and Iversen (1989) and Moe (1974) for spores; and van Geel (1976) for non-pollen palynomorphs. Although the grain size of *Betula nana* (dwarf birch) tends to be smaller than that of tree birches, absolute separation is not possible due to their overlapping size distributions (e.g. Birks 1968, Usinger 1977, Andersen 1980). Therefore a fixed threshold of 21.5 µm was used to separate a *B. nana* type from a tree birch type (e.g. Kolstrup 1982, Karlsdóttir *et al.* 2007). These measurements supplement the macrofossil analysis, which is a more powerful tool in the differentiation of *Betula* species. Pollen of thermophilous taxa such as *Alnus* (alder), *Corylus* (hazel), *Picea* (spruce), *Quercus* (oak), *Tilia* (lime) and *Ulmus* (elm) was regarded as redeposited if present in the Late Glacial deposits. Charred fragments >10 µm were counted. The pollen and macrofossil data were plotted using the Tilia program (Grimm 2011). Plant nomenclature follows Wisskirchen and Haeupler (1998). CONNIS was used to determine the local pollen assemblage zones by a square root transformation and Edwards and Cavalli-Sforza's chord distance. Trees, shrubs, dwarf shrubs and herbs were used to determine the local pollen assemblage zones (LPAZ) and these were correlated to the

Table 1. AMS radiocarbon dating of terrestrial remains from the Hasselø sediments.

AAR-	Material (species)	Height (cm)	δ^{13} C (‰ VPDB)	^{14} C age (^{14} C yr BP)	Model age (cal. BP, 95.4% probability)
15014	*Dryas* leaves	5.2	−27.73	12,226 ± 44	14,355–13,941
15015	*Dryas* leaves and *Salix* twigs	17.8	−27.68	12,223 ± 43	14,140–13,903
15016	*Betula nana* leaves	32.3	−27.71	11,945 ± 43	13,960–13,750
15017	*B. nana* and *Salix* leaves	45.8	−26.89	11,955 ± 65	13,890–13,660
15018	*Betula* seeds and leaves	73.5	−26.97	11,741 ± 44	13,685–13,415
15019	*Betula pubescens* seeds and catkin scales	88	−27.94	11,516 ± 45	13,459–13,254
15020	*Salix* leaves	106.3	−28.06	10,707 ± 39	12,710–12,554
15021	*B. nana* and *Salix* leaves	117.0	−25.00	10,340 ± 39	12,415–12,143
15022	*B. nana* leaves and *Salix* buds	135.7	−28.41	10,392 ± 40	12,339–12,051
15013	*Menyanthes* seeds and bud scales	160.8	−27.55	9660 ± 40	11,209–10,868

regional biostratigraphy as described by Mortensen *et al.* (2011).

Macrofossil analysis

Macrofossils were analysed on 17 of the 34 levels analysed for pollen. A sediment volume of 100 cm^3 from the 2 cm samples was measured by water displacement and samples were then wet-sieved through 0.25 mm mesh. Sodium pyrophosphate was added where necessary, to soften the sediment before sieving. Macrofossils were identified and counted at ×6.3–60 magnification. The reference collection at the National Museum of Denmark was consulted for identification, together with identification guides (Katz *et al.* 1965, Nilsson and Hjelmqvist 1967, Aalto 1970, Cappers *et al.* 2006). Frequency of taxa represented by high numbers of fossils was estimated from quantitative subsamples. The amount of remains that could not be counted, including leaf material of *Betula* and *Dryas octopetala* (mountain avens), mosses, twigs and *Characeae* oospores, were estimated and given the following scores in further calculations: present (2), rare (4), occasional (10), frequent (25), abundant (100), very abundant (250). Other fossils are presented as numbers per 100 cm^3 fresh sediment.

Results and discussion

The ages of the 10 ^{14}C dated samples are presented in Table 1 and the age/depth model is shown in Figure 3. The age/depth model was developed by employing the depositional model option (p-sequence) in OxCal 4.2 with a model parameter k = 100 (Ramsey 2009).

The pollen diagram was divided into seven local pollen assemblage zones (HA1–HA7). This zonation is also used to describe the macrofossil results and the LOI results (Table 2). The results of the pollen, macrofossil and LOI analyses are shown in Figures 4a, b and 5a, b.

The open pioneer landscape

Bølling (HA1. Hippophaë–Betula nana, 14,200–14,000 cal. BP)

This zone is characterized by pollen maxima of *Hippophaë ramnoides* (sea-buckthorn) and *B. nana* type and a generally high proportion of light-demanding (heliophile) taxa (e.g. *D. octopetala, Saxifraga* sp. (saxifrage), *Rumex acetosella* (sheep sorrel), *T. alpinum, Artemisia* sp. (mugwort) and Poaceae (grasses). The macrofossil assemblage shows that the local vegetation around the lake was also dominated by light-demanding pioneer taxa such as *Arctostaphylos alpinus* (mountain bearberry), *B. nana, D. octopetala, Salix herbacea* (dwarf willow) and *Saxifraga* sp. These pioneer taxa are adapted to environments with disturbed soils, water stress and minimal

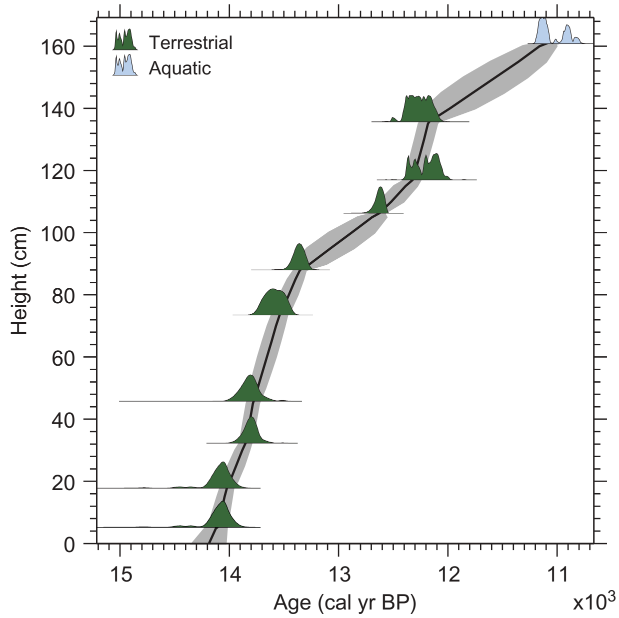

Figure 3. Age/depth model for the Hasselø sediments.

nitrogen content but do not compete well with other plants (Petersen and Vestergaard 2006). The low organic content and high sediment accumulation rate of the sediments show that erosion and soil instability were important factors in the Bølling period (Figure 4a). The distinct dark bands seen in the predominantly minerogenic sediments have a high macrofossil content and were probably formed during the spring snowmelt and/or during heavy rainfall (Figure 2b). This kind of unstable environment, along with associated weak soil formation and water stress, is typical for the early successional phase and is probably one of the main reasons why more competitive taxa such as *Betula pubescens* (downy birch) did not arrive earlier.

The vegetation of the Bølling period has previously been described in detail at only one other site in Denmark, Slotseng (Mortensen *et al.* 2011). Hasselø and Slotseng had similar landscapes with low, open and species-rich vegetation with many dwarf shrubs, herbs and grasses. This would have been an ideal environment for *Rangifer tarandus* (reindeer) which was characteristic of this period (Aaris-Sørensen *et al.* 2007). Southern Scandinavia may have been an important reindeer calving region at this time (Aaris-Sørensen *et al.* 2007) and this was probably the initial reason for human immigration into the region (Petersen and Johansen 1993). With the exception of one, out-of-context, arrowhead belonging to the classical phase of the Hamburg Culture (Holm and Rieck 1992), the first reliable and well-dated traces of humans in Denmark are of the Havelte phase of the Hamburg Culture (e.g. Holm 1993, Mortensen *et al.* 2008) and date to the end of the Bølling period (Weber and Grimm 2009, Mortensen *et al.* 2014b). No traces of the Hamburgian are found at

Table 2. Description of the development of pollen, macrofossils and LOI.

LPAZ	Height (cm)	Age (cal BP)	Pollen	Macrofossils	LOI	Regional period
HA7 *Betula pubescens, Pinus*, Poaceae	155–160	11,350–11,100	Increase in *B. pubescens* t. and Poaceae, most other taxa decline	*B. nana* and *Empetrum nigrum*	Organic content 75%; increasing $CaCO_3$ 0%	Preboreal
HA6 *Betula nana*, Poaceae, *Artemisia*	108–155	12,600–11,350	High percentage of *B. nana* t., along with *Pinus, Juniperus communis, Artemisia sp.*, Chenopodiaceae and Poaceae Maxima of *Dryopteris* and *Gymnocarpium drypoteris* in the first half. Around the middle of the zone an increase in *E. nigrum* and *Ranunculus* sp. Charcoal increases towards the middle of the zone. Wetland: Cyperaceae increase in the middle of the zone and more aquatic taxa are seen. *Pediastrum* and *Botryococcus* increase through the zone	*B. nana, Dryas octopetala, Empetrum nigrum* and *Stellaria media* t., along with *Cenococcum geophilum.* Aquatic: *Potamogeton filiformis*	Organic content decreases from 25 to 5% followed by relatively stable values *c.* 10%. $CaCO_3$ increases strongly through the first half of the zones, followed by a decrease	Younger Dryas
HA5 *B. pubescens*, *Pinus*	85–108	13,400–12,600	Reduction in *B. nana* t., increase in *B. pubescens* type and *Pinus*. Low peak of *J. communis*. Low percentages of heliophile taxa such as *Artemisia* and Poaceae. Towards the end of the zone there is a reduction in *B. pubescens* and an increase in more light-demanding taxa such as *B. nana, Filipendula*, Poaceae, and *G. drypoteris*. In the wetland taxa an increase in *Equisetum* is seen in the middle of the zone but otherwise low values. The proportions of aquatic taxa are generally low but *Pediastrum* increases towards the end of the zone	*B. pubescens* is seen throughout the whole zone. *Populus tremula* and *B. nana* are also seen in the first part of the zone. Heliophile taxa such as *Selaginella selaginoides* and *Thalictrum alpinum* are also seen in the first part together with *Cladium mariscus. A. uva-ursi* found in the last part of the zone. Wetland taxa of *Potamogeton filiformis, Potamogeton natans* and *Myriophyllum alterniflorum* seen	Organic content increases strongly to *c.* 95 cm where a small trough is seen. This is followed by an increase to 100 cm after which it decreases. $CaCO_3$ decreases in the first half of the zone and then remains low	Allerød

(*continued*)

Table 2. (*Continued*).

LPAZ	Height (cm)	Age (cal BP)	Pollen	Macrofossils	LOI	Regional period
HA4 *B. nana*, *B. pubescens*	64–85	13,600–13,400	An increase in *B. nana* and *B. pubescens* types, while *Artemisia* and Poaceae decrease together with other heliophile taxa. Cyperaceae percentages decrease. *Myriophyllum verticillatum* and S*parganium* aquatic taxa are present and a reduction in *Pediastrum* and *Botryococcus* is seen. Charcoal and hystrix are absent	First macrofossils of *B. pubescens*, together with those of *B. nana* and S*alix* sp. Wetland taxa of *Carex rostrata, Eleocharis palustris/uniglumis, Parnassia palustris, Selaginella selaginoides* and *Batracium* sp. Macrofossils of *Chara* sp. *Potamogeton filiformis* and *Potamogeton praelongus* also seen	Organic content *c.* 7–8% until the end of the zone where it increases markedly. $CaCO_3$, ca. 15%	Allerød
HA3 *B. pubescens*, *Helianthemum*	37–64	13,800–13,600	This zone is characterized by a strong increase in *B. pubescens* type which peaks in the middle and then decreases along with an increase in *J. communis*. Decreases in *Salix, B. nana* and *Pinus*. Still many open taxa such as *Dryas octopetala, Helianthemum oelandicum, Rumex acetosella, Thalictrum alpinum* and Chenopodiaceae, along with relatively high *Artemisia* sp. values. The wetland taxa Cyperaceae and *Equisetum* increase. The aquatic taxa *Myriophyllum spicatum, Myriophyllum verticillatum, Potamogeton* and *Sparganium* are seen. Maxima of *Pediastrum* and *Botryococcus*	High counts of *B. nana* macrofossils. *A. uva-ursi, D. octopetala* and *Salix herbacea* are also represented. Also seen are macrofossils of *Carex aquatilis, Juncus, Batrachium* sp.*, Menyanthes trifoliata, Primula (P. farinosa, P. stricta or P. scandinavica), Selaginella selaginoides, Batrachium* sp., *Potamogeton filiformis* and *Potamogeton praelongus*	Organic content, 7–8%; $CaCO_3$, *c.* 15%	Allerød

(*continued*)

Table 2. (*Continued*).

LPAZ	Height (cm)	Age (cal BP)	Pollen	Macrofossils	LOI	Regional period
HA2 Poaceae, *Helianthemum*	22–37	14,000–13,800	Increasing percentages of *Salix* and *Pinus*, along with Poaceae. Many open-ground taxa such as *D. octopetala, H. oelandicum, Rumex acetosella, Thalictrum alpinum, Artemisia*, Chenopodiaceae. Reduction in Cyperaceae, while the percentage of *Sphagnum* spores increases. Maximum for *Pediastrum* while *Botryococcus* declines. Maxima of Hystrix and charcoal	Dominated by *B. nana, D. octopetala* and *Salix* sp. Wetland and aquatic taxa of *Juncus* and *Batrachium* sp., *Chara* sp., *Myriophyllum* sp. and *Potamogeton filiformis*	Organic content generally low at ca. 5%. $CaCO_3$, *c.* 20%	Older Dryas
HA1 *Hippophaë*, *B. nana* zone	0–22	14,200–14,000	Maxima of *Hippophaë ramnoides* and *B. nana* t. High percentages of heliophile taxa such as *D. octopetala, H. oelandicum, E. nigrum, Saxifraga* sp., *Rumex acetosella, Thalictrum alpinum, Artemisia* sp., Poaceae and Chenopodiaceae. Wetland taxa are dominated by Cyperaceae which increase from 20 to 35%, followed by a reduction. Aquatic taxa seen are *Myriophyllum spicatum, Myriophyllum verticillatum, Potamogeton* and *Sparganium*. Two small peaks of charcoal are also seen	Dominated by open-ground taxa such as *Arctostaphylos alpinus, B. nana, D. octopetala, S. herbacea* and *Saxifraga* sp. Wetland and aquatic taxa of *Carex aquatilis, Carex nigra, Eleocharis palustris/uniglumis, P. palustris, S. selaginoides, Batrachium, Callitriche, Potentilla palustris, P. filiformis, P. praelongus* and *Chara* sp.	Organic content generally low at *c.* 5%. $CaCO_3$, *c.* 20% and gently rising	Bølling

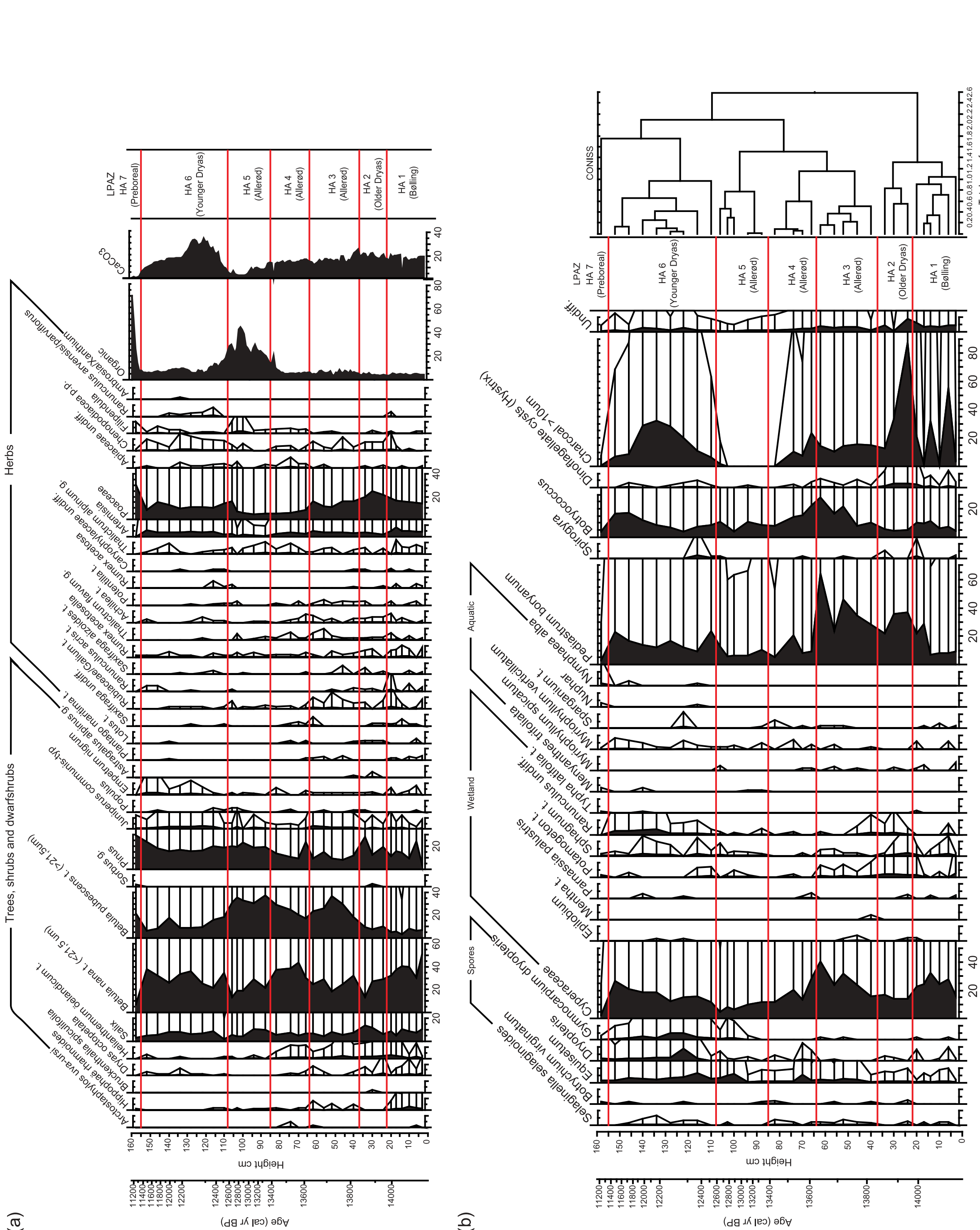

Figure 4. Pollen percentage diagram of selected taxa based on total terrestrial pollen excluding Cyperaceae and spores. ×10 exaggeration is shown by the open outline.

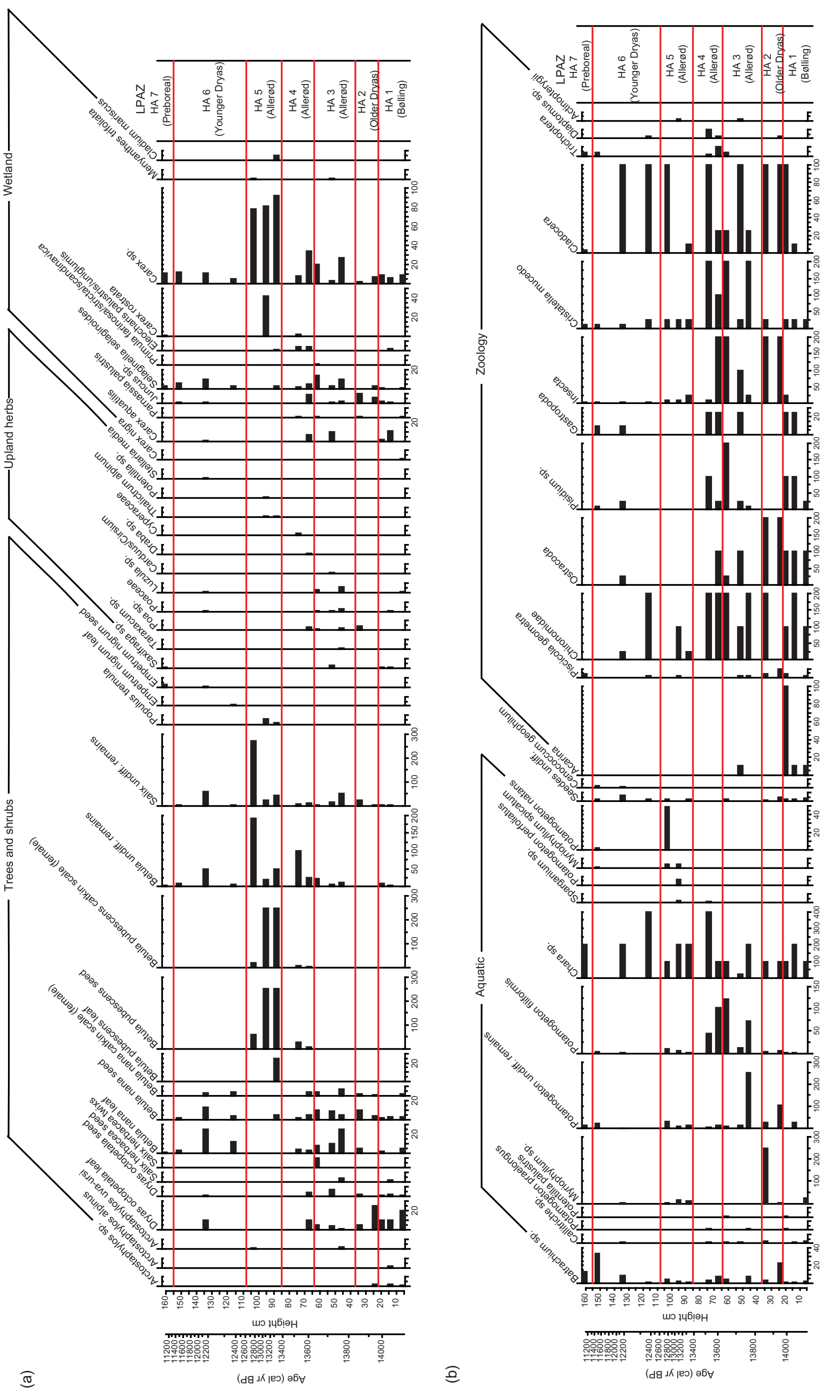

Figure 5. Macrofossil concentrations per 100 ml sediment. The taxa are seeds or fruits unless otherwise indicated. T = macrofossil type.

Hasselø. The nearest occupation sites are situated *c.* 40 km to the west at Sølbjerg and Krogsbølle on the island of Lolland (Petersen and Johansen 1993, 1996, Petersen 2006, Pedersen 2009). The two peaks of charcoal seen in both the pollen percentage and concentration (not shown) diagrams (Figure 4b) could indicate further hitherto undiscovered occupation sites in the area near the lake. However, reworked charcoal from glacial sediments cannot be excluded.

Older Dryas (HA2. Poaceae–Helianthemum, 14,000–13,800 cal. BP)

A continuance of the high proportion of heliophile taxa such as *D. octopetala, Helianthemum oelandicum* (hoary rock-rose), *R. acetosella, T. alpinum, Artemisia* sp. and Chenopodiaceae (goosefoot) is seen, but with an increase in *Salix* (willow), *Pinus* (pine) and Poaceae. The macrofossil assemblage indicates that the local vegetation did not change and continued to be dominated by cold-tolerant pioneer taxa such as *B. nana, D. octopetala* and *Salix*.

The Older Dryas (GI-1d) is shown in the isotopic records of Greenland ice cores as a cold period (Rasmussen *et al.* 2006) and in chironomid and coleoptera records (Brooks *et al.* 2012, Lemdahl *et al.* 2014) from north-western Europe, but this short-lasting period can be difficult to identify in pollen diagrams. Some pollen records are interpreted as showing a temperature decrease (Iversen 1954, Usinger 1985, de Klerk *et al.* 2001) while others are interpreted as a pronounced dry period (Kolstrup 1982, Berglund *et al.* 1994, Mortensen *et al.* 2011). The Hasselø pollen diagram exhibits a strong decrease in *H. ramnoides*, a species which cannot tolerate cooler climates. This occurs at the same time as an increase in arid-tolerant taxa, especially *H. oelandicum,* which is characteristic of the Danish Older Dryas. An increase in dinoflagellate cysts (*Hystrix*) indicates an increase in erosion, undoubtedly due to the partial fragmentation of the vegetation cover, while the decrease in Cyperaceae indicates a drier climate and possibly a lake level lowering.

It is probable that the Older Dryas climate became both colder and drier but since the vegetation was already dominated by cold-tolerant taxa, a temperature decrease would not be clearly expressed in the pollen diagram with the exception of the few warmth-demanding taxa such as *H. ramnoides*. It is likely that this is the reason why the Older Dryas is not more strongly expressed in Danish studies. This is in contrast to northern Germany where the Older Dryas is clearly seen despite being situated only 70–80 km from Hasselø (de Klerk 2002, 2008). This difference also indicates the existence of an ecotone between the two regions with open tundra and pioneer vegetation to the north and a more advanced vegetational development, with the beginning of the spread of tree birch, immediately to the south of Denmark.

The high charcoal content found in several consecutive samples (also seen in the concentrations (not shown)) could, however, be an indication of human activity. Charcoal is present from the beginning of the period (*c.* 14,000–13,900 cal. BP) and is likely to come from the occupation site, since charcoal from local fireplaces is likely to be represented in the stratigraphy close to late glacial and early Holocene settlements (Bos and Urz 2003, Fischer *et al.* 2013b, Tolksdorf *et al.* 2014). The date around 14,000–13,900 cal. BP falls within the period defined for the spread of the Hamburgian and the Federmesser Cultures (Petersen 2006, Grimm and Weber 2008, Pedersen 2009, Riede and Edinborough 2012). The charcoal peak could represent either an undiscovered occupation site from the Hamburgian culture or a very early occurrence of the Fedemesser culture in the Danish area, although neither a natural fire sparked by lightning nor redeposited charcoal can be excluded. However, if humans were present in the Danish region in the Older Dryas and the first half of the Allerød, they would have taken advantage of the available resources in the border regions between the open tundra and the woodlands. The most likely objective would have been reindeer, which was the largest prey available at this time (Aaris-Sørensen 2009).

The open shrub and grassland landscape

Allerød (HA3. Betula pubescens–Helianthemum, 13,800–13,600 cal. BP)

This zone is characterized by a strong increase in *B. pubescens*-type pollen accompanied by an increase in *Juniperus communis* (juniper) and a simultaneous decrease in *Salix, B. nana* and *Pinus*. There are still, even in the presence of a marked increase in tree birch, many open-ground and light-demanding taxa represented in the pollen flora, for example, *D. octopetala, H. oelandicum, R. acetosella, T. alpinum*, Chenopodiaceae and *Artemisia* sp. The macrofossil assemblage still shows a predominance of pioneer taxa, for example *B. nana, Arctostaphylos uva-ursi* (bearberry), *D. octopetala* and *S. herbacea. B. nana* in particular predominates with *D. octopetala* in lower numbers. *D. octopetala* is probably reduced due to competition with the more competitive shrubs and tall herbs which are becoming more dominant in the landscape. The *B. pubescens* pollen type increases to almost 40%, which could indicate a strong increase in tree birch locally. However, in the absence of macrofossils, it is more likely that high percentages are due to long-distance transport of pollen from, for example, northern Germany where tree birch was expanding (de Klerk 2008).

In the transition between HA3 and HA4, *B. pubescens* declines while some of the more heliophile taxa as *D. octopetala, H. oelandicum* and *B. nana* increase slightly. This development has also been recorded in areas further south where it has been related to cooler climatic conditions (Usinger 1985, Litt *et al.* 2001).

The first trees

Allerød (HA4. Betula nana–Betula pubescens, 13,600–13,400 cal. BP)

An increase in *B. nana* and *B. pubescens* types occurs at the same time as a decrease in *Artemisia*, Poaceae and other heliophile taxa. This is a clear indication that more competitive taxa have become locally established in the catchment area. The macrofossil analysis also shows that *B. pubescens* is now locally present for the first time. The time difference between the distinct increase in tree birch pollen in LPAZ HA3 and its first appearance in the macrofossil record is *c.* 200 years. The most light-demanding and least competitive taxa (*D. octopetala* and *S. herbacea)* are now absent while *B. nana*, a species which can grow in the undergrowth of open forest and on wet ground, is still present. During this first phase of woodland development, tree birch probably grew in moist, protected areas with the most developed soils, while the drier and more exposed areas remained relatively open, as has previously been shown at Slotseng in south-west Denmark (Mortensen *et al.* 2011). Similar studies from Germany have shown that birch during the Allerød favoured rich soils (Theuerkauf and Joosten 2012). The low organic content in the sediments suggests that there was still a significant input of minerogenic material (Figure 4a). Towards the end of this zone, increased organic content indicates that a birch woodland proper had become established around the lake and that the roots and undergrowth had stabilized the soils.

It has previously been argued that tree birch immigrated into the Danish region as early as during the Bølling period (Iversen 1954, Kolstrup 1982, Paus 1995). There is some support for this from a study on Kullen in southern Sweden where a few tree birch macrofossils were assigned to the Bølling period (Lidberg-Jönsson 1988). However, these ages are questionable as the sequence was dated using bulk sediment samples with low organic content, and the local presence of tree birch in southern Sweden needs to be confirmed by new studies with the advantage of more modern dating techniques. In Schleswig-Holstein in northern Germany, tree birch is present during the early Allerød period (Usinger 1985). In Denmark, investigations at Slotseng have shown that tree birch arrived much later as the first macrofossils are not found until around the middle of the Allerød period (13,500 cal. BP) (Mortensen *et al.* 2011, 2014a). The similar age of 13,600 cal. BP at Hasselø confirms the late immigration of tree birch into the Danish region, in contrast to what was previously believed. This is also the same time as *Alces alces* (elk) immigrated into the region (Aaris-Sørensen 2009).

Allerød (HA5. Betula pubescens–Pinus, 13,400–12,600 cal. BP)

The beginning of this zone shows a reduction in *B. nana* type together with increases in *B. pubescens* type and *Pinus*. The double peak of *B. pubescens* type might represent a slight reduction in the woodland associated with the cold Gerzensee Oscillation (Andresen *et al.* 2000). Macrofossils of *B. nana, Selaginella selaginoides* (lesser clubmoss) and *T. alpinum* show that the woodlands at the beginning of this zone were still open even though heliophile pollen decreases. The lack of *D. octopetala* and other heliophile taxa from the macrofossil assemblage in zone HA5 indicates a closing of the woodlands, at least in the area around the lake. It is probable that there were open patches on the drier and more exposed areas throughout this period, but that these areas lay outside the macrofossil catchment area. The Allerød woodlands around Hasselø appear to have been denser than at Slotseng in southern Jutland (Mortensen *et al.* 2011).

In addition to *B. pubescens*, the Allerød woodlands in eastern Denmark included *Populus tremula* (aspen) and *J. communis* (Hartz 1902, Fischer *et al.* 2013b), various large willow species such as *Salix* cf. *caprea* (goat willow) (Iversen 1954, Mortensen *et al.* 2011) and most likely also *Sorbus* (rowan). *Sorbus* is found in the Hasselø pollen assemblage and at a number of other Danish sites and, as it is insect pollinated, the pollen probably came from local populations. *Pinus* macrofossils have not yet been found in Danish Late Glacial sediments and even though *Pinus* pollen is abundant in the pollen assemblages, pine was probably not part of the Late Glacial woodlands of Denmark. The closest find of *Pinus* logs lay 60 km south of Hasselø at Rostocker Heide in northern Germany (Terberger *et al.* 2004), and one sample has been dated to 11,220 ± 250 BP (13,600–12,600 cal. BP). This is further indication of an ecotone between south-east Denmark and northern Germany during the second half of the Allerød period (Figure 6). Even though there was a very strong temperature gradient over Europe (Coope *et al.* 1998, Renssen and Isarin 2001), the reconstructed average July temperatures of 13–15°C in southern Denmark (Coope *et al.* 1998) would have been sufficient for the establishment of *Pinus*. Other factors such as dispersion rate and soil formation must account for the delayed immigration of pine to Denmark. The large valley area found between south-east Denmark and north-east Germany may have acted as a barrier. This low-lying region was covered by either the Baltic Ice Lake or large wetland areas during much of the Late Glacial and was subject to large and abrupt lake level changes (Bennike and Jensen 2013). This may have delayed the north-westerly spread of *Pinus* and even though pine can grow on many soil types (Friis-Møller *et al.* 2010), competition with the previously established birch woodlands may also have contributed to the delay.

Figure 6. Map of southern Scandinavia showing the ecotone between the Danish birch forest and the northern German birch/pine forest. The low-lying region between Denmark and Germany was flooded during the maximum extent of the Baltic Ice lake.

The Allerød woodlands

The reconstruction shows that during the second half of the Allerød, south-eastern Denmark was covered by birch woodland with *Populus, Juniperus* and probably also *Sorbus* (Iversen 1954, Fischer *et al.* 2013b, Mortensen *et al.* 2014a). The woodlands were relatively open with *B. nana, Rubus caesius* (dewberry), *Rubus saxatilis* (stone bramble) and *Urtica dioica* (commen nettle) (e.g. Jensen 1985, Fischer *et al.* 2013b). The woodland to the west and north probably had more of a mosaic structure with many open areas (Bennike *et al.* 2004a, Kolstrup 2007, Mortensen *et al.* 2011), while mixed birch pine woodlands were found just south of the Danish region (Usinger 2004, Latałowa and Borówka 2006, de Klerk 2008, Theuerkauf and Joosten 2009, 2012). The coast of the Baltic Ice Lake was found to the east (Bennike and Jensen 1998, Bennike *et al.* 2004b) and the coast of the Yoldia Sea was located near northern Zealand (Houmark-Nielsen and Kjær 2003). The south-eastern Danish region was therefore situated in a zone between several different ecosystems (Figure 6). Such marginal areas are known to have a particularly high biodiversity (e.g. Petersen and Vestergaard 2006) and the numerous subsistence strategies available may explain the especially rich representation of the Bromme Culture in the region. Bones of large game such as *Alces alces, Megaloceros giganteus* (giant deer), *Rangifer tarandus, Ursus arctos* (brown bear) and *Castor fiber* (beaver) have been found from this period and show that the Late Glacial period offered potentially rich hunting grounds (Aaris-Sørensen 2009). However, besides the known availability of large game animals, a range of other resources may have been part of the subsistence. Although the evidence is fragmentary, the coastal areas would also have offered other valuable resources (Fischer *et al.* 2013a). For example, there would have been a rich bird fauna available for both hunting and the collection of eggs and chicks. Additionally, fishing had also been practised during the Palaeolithic (Gramsch *et al.* 2013) and the numerous lakes would have provided good fishing opportunities, for example, for pike and perch whose sticky eggs are rapidly spread by water birds. Lastly, the vegetation itself would have been both a food resource (Tyldesley and Bahn 1983, Aura *et al.* 2005, Revedin *et al.* 2010) and a material for tool production (e.g. Riede 2012), although wooden tools are rarely preserved in the archaeological record.

The change from tundra to birch woodland marks an important environmental change in the vegetation, available fauna, etc. Humans must have responded to these marked changes in resource availability and the existing data suggests that the occurrence of the Bromme Culture in the Danish area is coincident with the immigration of woodland (Mortensen *et al.* 2014a). The nature and speed of the human response to environmental change is difficult to determine and requires that the archaeological and environmental data have rigorous chronological resolution over a large geographic area (Birks *et al.* 2014). With these larger and well-established datasets it will be possible to test different hypotheses of human–environment interactions (e.g. Banks *et al.* 2006, 2011).

The Allerød–Younger Dryas transition

Climatic cooling at the end of the Allerød had a strong impact on the vegetational succession of Late Glacial woodlands. A distinct reorganization of atmospheric circulation over the northern hemisphere followed by a gradual temperature decline is indicated in the Greenland ice cores (Rasmussen *et al.* 2006, Blockley *et al.* 2012). According to the Greenland ice core chronology (GICC05) (Rasmussen *et al.* 2006, Blockley *et al.* 2012), the transition from the warm GI-1a interstadial to the colder GS-1 stadial is dated to 12,896 ± 138 B2 K (12,846 before AD 1950). Temperatures continued to decline until 12,780 B2 K (12,730 before AD 1950), at which time a large and rapid decrease occurred. These changes are seen not only in Greenland ice core proxies but also in records from the whole of the northern hemisphere (e.g. Björck *et al.* 1996, Rach *et al*. 2014). It is important to stress however, that although changes in atmospheric circulation, climate and the biosphere are linked, the responses are not necessarily synchronous (Rasmussen *et al.* 2006).

The temperature decrease between 12,846 and 12,730 cal. BP seen in the ice cores does not appear to have affected the vegetational assemblage at Hasselø, but a decline in the organic content of the lake sediments is seen from 12,879 ± 207. This could be due to a transition to a drier climate which may have led to a lowering of the lake level and associated erosion of minerogenic material from the lake margin. There is, however, a marked and rapid response of the vegetation to the temperature decline at 12,692 ± 130 cal. BP. *B. pubescens* decreases at the same time as an increase in light-demanding taxa such as *B. nana, Filipendula* (meadowsweet), Poaceae and *Gymnocarpium dryopteris* (oak fern). This corresponds to the Allerød–Younger Dryas transition seen at Kråkenes in western Norway, one of the best-dated Late Glacial lake sequences in Europe. Here the transition is dated to 12,711 ± 52 cal BP (Lohne *et al.* 2013). This agrees well with a number of annually layered lake sequences in Germany where the transition is dated between 12,679 ± 30 and 12,606 ± 40 varve years BP (Zolitschka *et al.* 2000, Brauer *et al.* 2001, Neugebauer *et al.* 2012, Rach *et al.* 2014). The Allerød-type environment continued despite the substantial temperature decrease but it became more fragmented with light open woodland. At *c.* 12,575 ± 74 cal. BP, a threshold was reached and the woodland environment and ecosystem collapsed. The fragmentation of the vegetation cover promoted erosion and the deposition of clastic, inorganic sediments.

It has been previously suggested that the Greenland ice core event stratigraphy (Björck *et al.* 1998) can be broadly correlated to the northern European pollen zones (e.g. Terberger *et al.* 2009), as the vegetation often responds immediately to climate changes. The Hasselø record also shows a rapid response, but it additionally shows that the Late Glacial woodlands survived several hundred years into the GS-1 cold period. Younger Dryas-type vegetation is not evident until 12,575 cal. BP, which is cause for caution when interpreting archaeological data. Figure 7 shows the Danish Bromme Culture ^{14}C dates from Bromme, Fensmark and Trollesgave (Fischer *et al.* 2013b) and illustrates that although all the ages lie within GS-1, they belong to an Allerød environment. The transition between Allerød/Younger Dryas and GI-1a/GS-1 is therefore far from synchronous. This demonstrates that the relationship between ^{14}C ages, human occupation sites and ice core data cannot be used directly to define the local environment. Such conclusions must always come from local/regional climate and environmental reconstructions, especially if the ages lie in the transitional zone between two different climatic regimes.

The open Younger Dryas landscape

Younger Dryas (HA6. Betula nana–Poaceae-Artemisia, 12,600–11,350 cal. BP)

A vegetational paradigm shift occurs from the open woodland of HA5 to an open landscape with pioneer vegetation in HA6. *B. pubescens*-type pollen decreases while there are generally higher values of *B. nana* type and *Pinus*. *J. communis, Artemisia sp.*, Chenopodiaceae and Poaceae also reach generally higher percentages throughout the HA6 zone. *Dryopteris* and *G. dryopteris* reach their local maxima in the first half of the zone. *Empetrum nigrum* (crowberry), *Ranunculus* sp (buttercup) and Cyperaceae increase around the middle of the zone.

Macrofossils of *B. nana, D. octopetala, E. nigrum* and *Stellaria media* (common chickweed) show that the vegetation was replaced by more cold-adapted plants. The absence of tree birch indicates an average summer temperature of less than 10°C. The exact limit of tree birch at this time is not known but it probably survived in regions immediately south of Denmark (Usinger 2004, de Klerk 2008). Evidence from lake sequences suggests that the first part of the Younger Dryas was arid and many smaller lakes in northern Germany dried out (Usinger 1981). This was also the case in the southern part of Jutland. In the lake sequence from the Slotseng

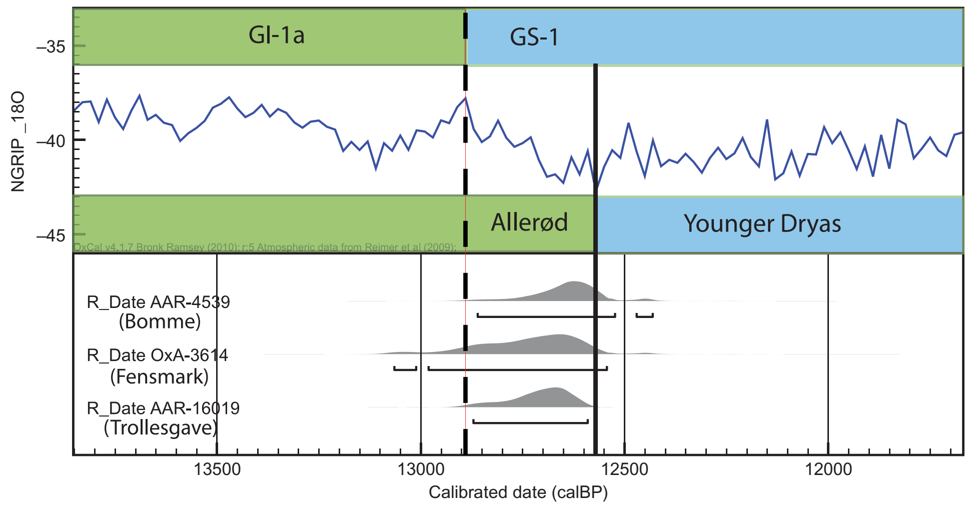

Figure 7. Bromme Culture ages from Denmark (Fensmark Skydebane, Trollesgave, Bromme). The transition from GI-1a to GS-1 (GICC05) is shown by the dotted line. The transition from Allerød to Younger Dryas is shown by the solid line.

kettle hole (Mortensen *et al.* 2011) there is a distinct peak of microtephra from the Vedde ash located directly on top of the Allerød layer (Larsen 2014). This indicates that the Slotseng kettle hole dried out and that there was no sedimentation between the end of the Allerød until the deposition of the Vedde ash, which is dated to 12,140 ± 40 varve years BP (Lane *et al.* 2013). This very dry first part of the Younger Dryas was most likely caused by extensive sea ice in the northern North Atlantic. Extended sea ice would have advected the relatively warm and moist air from the Atlantic further south, promoting prevailing easterly winds over Scandinavia and leading to a colder, drier climate (Bakke *et al.* 2009, Rach *et al.* 2014). A shrinking of the sea ice extent after *c.* 12,150 cal. BP caused the Scandinavian climate to become dominated by westerly, relatively warm and moist winds again pushing the polar front northwards (Bakke *et al.* 2009), and sedimentation in the Slotseng basin resumed.

This shift corresponds with a rise in *E. nigrum* in Hasselø, dated to *c.* 12,100 cal. BP, along with increased percentages of Cyperaceae and *Ranunculus* sp. (probably water-crowfoot as seen in the macrofossils), all of which suggest increased precipitation. The increase in *E. nigrum* is well known in pollen diagrams from Denmark, Germany and The Netherlands (e.g. Iversen 1954, Hoek 1997, Usinger 2004, de Klerk 2008) and is interpreted as a response to a more oceanic climate (Hoek 1997, Usinger 2004). The evidence from Bromme occupation sites suggests year-round presence during the Allerød period while it is thought that the Ahrensburg culture was only occasionally present during the Younger Dryas (Pedersen 2012). This was probably due to the availability of reindeer hunting (Aaris-Sørensen *et al.* 2007, Aaris-Sørensen 2009).

Early Holocene (HA7. Betula pubescens–Pinus-Poaceae, 11,350- cal. BP)

The beginning of the Preboreal shows an increase in *B. pubescens* type and Poaceae pollen while almost all other taxa decrease significantly. These changes are a response to improved growth conditions instigated by the transition to the warmer Preboreal period. The local presence of *B. nana* and *E. nigrum* is shown by the macrofossil analysis but surprisingly, no macrofossils of *B. pubescens* were found. Many pollen records show that the Preboreal period in Denmark began with a marked *J. communis* peak. This lasted for a few hundred years after which tree birch immigrates and rapidly predominates. The juniper peak is not clearly seen in the Hasselø data, but this may be due to low sample resolution in this period. However, a diffuse representation of *J. communis* is also seen in other sites from south-eastern Denmark (Jessen *et al.* 2014) so it may also be due to soil type and associated competitive factors. LOI values indicate continued substantial erosion during the early Preboreal, and the delay in the spread of tree birch after the Holocene warming is probably due to the ongoing instability of soils. This is also seen at other sites (e.g. Trollesgave, southern Zealand) where large-scale soil movements have been documented (Fischer *et al.* 2013b). At Lundby Mose, *c.* 40 km north of Hasselø, pollen data also show a late immigration of *B. pubescens* (Jessen *et al.* 2014). These data from south-east Denmark indicate an actual delay in immigration of tree birch.

Conclusions

Based on the investigation from Hasselø, we have established the first well-dated Late Glacial biostratigraphy from eastern Denmark covering the period from the Bølling to the early Preboreal. It is shown that the vegetation during the Bølling and Older Dryas periods is dominated by pioneer taxa and that eastern and western Denmark had very similar landscapes. The high concentration of charcoal between 14,000 and 13,900 cal. BP could suggest a nearby occupation site. During large parts of the Late Glacial an ecotone existed between south-east Denmark and northern Germany. The large lowland area between these two regions, which was periodically covered by the Baltic Ice Lake, may have formed a barrier to the spread of some plants. In comparison to previous work this study of both local and regional proxies shows a clear delay of more than 1000 years between the first late glacial warming and the immigration of the first tree birch. The first trees (birch trees) did not immigrate to the Danish region until the middle of the Allerød period, *c.* 13,600 cal. BP, and this late arrival appears to be a general feature of the vegetation development in the eastern part of Denmark. This forest existed until the Allerød environment collapsed and was replaced by that of the Younger Dryas at *c.* 12,575 cal. BP, around 300 years after the transition to GS-1. The calibrated ages of the Danish Bromme Culture are positioned within GS-1, but they belong to an Allerød environment. Based on the pollen assemblage, the Younger Dryas can be divided into two phases. The first part is very cold and arid and is followed by a warmer and more humid phase from 12,100 cal. BP initiating the development of *Empetrum nigrum*-rich heaths. During the early Preboreal the landscape was characterized by erosion and soil instability, which may have led to delayed establishment of *B. pubescens*.

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Vegetal grave goods in a female burial on Bornholm (Denmark) from the Late Roman Iron Age period interpreted in a comparative European perspective

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Knowledge about the healing properties of plant substances is probably as old as humankind, and this can be demonstrated by botanical finds in archaeological contexts. Southern Scandinavia has a long tradition of supplying deceased persons with vegetal material for use in their afterlife, as shown by single seeds or processed plants in the form of foods, drinks or medicines. A well-known example is the small container made of birch bark most probably filled with a kind of mead produced from honey, in the Egtved girl's coffin a find which has been dated to the Early Bronze Age. Another fascinating plant discovery derives from the grave of the Fyrkat woman dated to the Viking Age: a handful seeds of the poisonous plant henbane (*Hyoscyamus niger*) was found in a small pocket fixed to the woman's belt. Plant materials enclosed in small amulet boxes are quite common and are frequently attached to necklaces that the deceased had certainly worn during their lives. In this article, we discuss the organic finds from a newly excavated amulet box which was discovered in a woman's grave at the Late Roman Iron Age site of Vellensby, on the island of Bornholm. The box contained two 'chewing gum-like objects' with dental impressions and three vegetal objects. Gas chromatography/mass spectrometry analysis was applied to one of the 'chewing gums' and the results show that it consists of a mixture of birch tar and plant oil. Based on their morphological characteristics, the three uncharred plant parts could be identified as cloves from a wild species of *Allium*, probably *A. scorodoprasum* (sand leek). The traditional medicinal application of sand leek is presented and the symbolic and possible principal meaning of amulet boxes is discussed within a comparative study of related discoveries from female burials throughout Europe.

Keywords: vegetal grave goods; Scandinavia; Late Roman Iron Age; *Allium* cloves; birch tar

The archaeological site Vellensby on Bornholm

An application for a permission to undertake gravel exploitation at the land registry *Vellensby* (BMR 1472) on the island of Bornholm led archaeologists from Bornholm's Museum to inspect the surroundings of the site in 1980 (Figures 1 and 2). Within a low ridge of the terrain surrounding the natural gravel deposit, a soil of a darker colour was observed within the plough layer. A few potsherds dated to the Roman Iron Age were found in this layer. More ceramic artefacts and larger stones came to light during the following years, and consequently, archaeological excavations were performed in 1998. A child grave from the Late Roman Iron Age was subsequently unearthed. The coffin was formed in the shape of a small ship and contained the following grave goods: several fibulas, a knife, six ceramic vessels as well as a wooden bowl, of which, only the cast was preserved. In 2009, excavation activities were completed. In total, this site yielded 19 single and 3 double graves. From their sitting position and the associated grave goods, such as beads, hair needles and spindle whirls, the gender of the deceased was determined to be female. Four of them were adults between the ages of 16 and 30 and three were girls. Seven burials were most probably male individuals that were placed on their backs; among them were four adults of ages between 18 and 35 and three boys. Gender could not be determined for two adult and six child burials.

Some of the female graves were richly equipped, for example burial A5, in which the human remains of a young woman at the age of 17–18 years were found (Figure 2). This grave was excavated and described by Maj Britt Schultz Petersen (2009). The following grave goods were found in burial A5: a ceramic cup, a wooden bowl of which only the cast was preserved, a bone comb, a rosette fibula with silver coat, two fibuli made of bronze, one fibula made of iron and an iron knife. In addition, two bead necklaces were placed around the woman's head. One of the necklaces was fashioned from gold foil, 41 amber and bronze beads, and a silver hook. The second necklace consisted of 17 amber and glass mosaic beads, iron beads, a ring made of silver, several bronze hooks, and an amulet box made of bronze. This box warranted closer examination, and its contents are the principal theme of this article (Figure 3).

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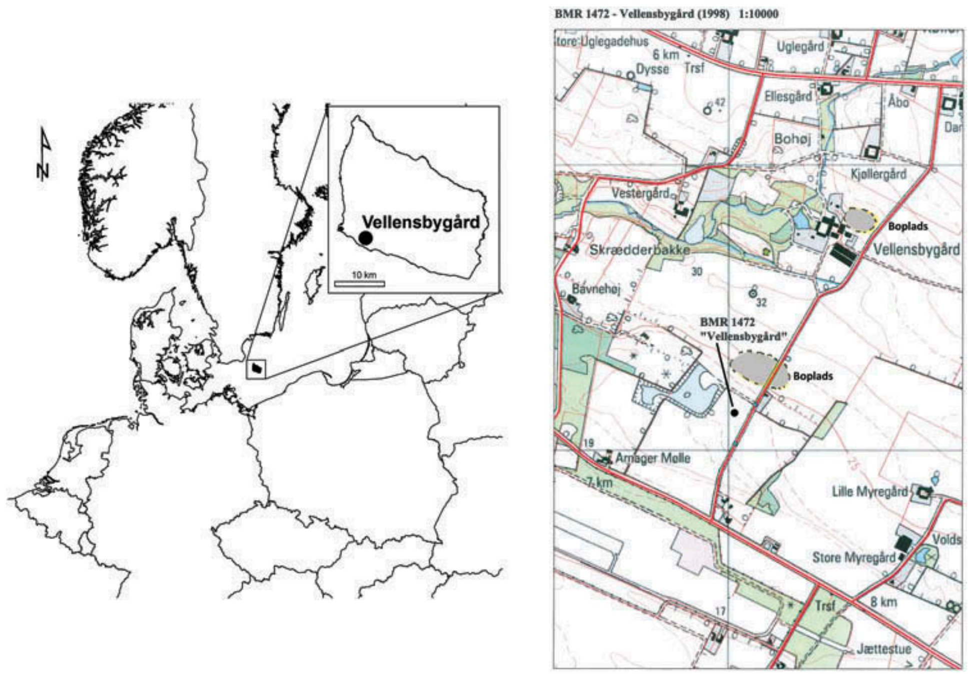

Figure 1. Map with Bornholm and the archaeological site Vellensby (map: Bornholms Museum).

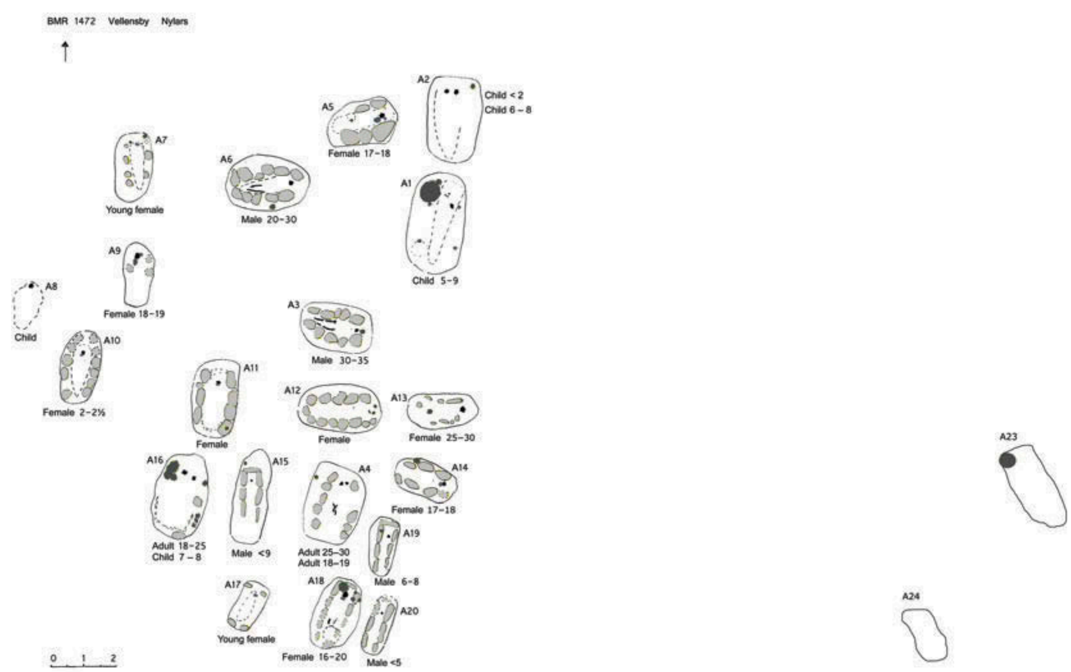

Figure 2. Excavation plan of Vellensby and the graveyard with the healer's grave A5 (illustration: Bornholms Museum).

The organic content of the amulet box from burial A5 at the site of Vellensby

The small cylindrical box made of bronze was opened in the laboratory by Anne Margrethe Walldén. The amulet contained five organic objects which were, in the first instance, analysed by Sabine Karg and Henrik Ærenlund Pedersen, from the Natural History Museum of Denmark (NHMD), with the help of a Leica stereo microscope with 10–40x magnification. Three objects could be determined to be pieces of dried plant, with two objects resembling

Figure 3. The metal amulet box from the Vellensby grave A5 (BMR 1472, A5 x99) (drawing: The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, photos: A.M. Walldén, The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation and P.V. Nielsen).

Figure 4. One *Allium* clove from Vellensby (photo: R. Fortuna).

Figure 5. Modern plants of sand leek on Bornholm (photo: S. Karg).

chewing gum with distinctive dental impressions. With the help of NHMD's extensive reference collection of recent herbarium material, the plant finds were identified as cloves belonging to the genus *Allium* (onions, family Alliaceae, Figures 4 and 5). Cloves are lateral shoots produced from bulbs, representing vegetative reproduction, as they eventually develop into new bulbs themselves.

Identification of the Allium *cloves*

Based on the morphological examination of the cloves from Vellensby we can rule out *A. schoenoprasum* and *A. ursinum* (both of which have thinner, more elongated cloves). Among the *Allium* species documented from Bornholm, this leaves us with *A. carinatum, A. oleraceum, A. scorodoprasum* and *A. vineale* as the possible identity of the cloves in the amulet box. Unfortunately, macromorphological features recognisable from the old cloves did not enable us to unequivocally refer them to one particular species, though our judgement is slightly in favour of *A. scorodoprasum*.

Seven species of *Allium* are usually considered to be indigenous to the geographical region of modern Denmark and adjoining parts of the southern Baltic area (Jessen 1935, Tillge 1981). A number of foreign cultivated species, introduced relatively late, can probably be disregarded within our context. Among the indigenous species, *A. lusitanicum* (syn.: *A. montanum*) has only been recorded once – from a location near the German border in southernmost Jutland – whereas *A. oleraceum* (field garlic), *A. schoenoprasum* (chives), *A. scorodoprasum* (sand leek), *A. ursinum* (ramson), *A. vineale* (wild onion) and the currently rare *A. carinatum* (keeled garlic) are widespread. While the latter six species are all known to be endemic to Bornholm within a modern context, *A. schoenoprasum* and especially *A. carinatum* have only been recorded in a few localities. Coastal populations of *A. schoenoprasum* on Bornholm are believed to be the only naturally occurring populations of this species in Denmark; plants from all other Danish occurrences are morphologically slightly different and are usually found in the close vicinity of gardens.

Gas chromatographical analysis of the chewing gum

Besides the three garlic cloves, the amulet box contained two chewing gum-like objects (Figure 6). The objects were twisted and showed dental impressions, probably derived from teeth of children. Jens Glastrup analysed a small sample from one of the gums using the gas chromatography/mass spectrometry (GC/MS) apparatus at the Danish Nationalmuseum's Conservation department to determine the original content of the material(s) used in preparation. The material was hydrolysed in an alkaline KOH solution (10%) in 50% H_2O/methanol solution. After acidification and extraction of the neutral and acidic components with diethyl ether, the dried residue was derivatised with diazomethane dissolved in methyl-t-butyl-ether. Hereafter, the solution was injected into the GC, and the resulting chromatogram is shown in Figure 7. The chromatogram shows a multitude of peaks (organic material), most prominent being the di-acid series from C_{16}–C_{22} in the 23–35-min region. Also found are peaks within the lupeol/betulin triterpene derivatives in the 38–42-min region. When taken as a whole, this strongly indicates the presence of birch tar, as the combination of the di-acids and the lupeol/betulin derivatives are well known to be present in birch tar (Junkmanns 2001). In addition, the chromatogram shows the presence of palmitic and stearic acids, together with azelaic acid. These components do not normally occur in birch tar and can therefore be surmised that these had been subsequently added to the material. The presence of azelaic acid in the analysed sample indicates that the fatty material added originally contained a high proportion of unsaturated fatty acids, which upon ageing, gives rise to the formation of azelaic acid. It is tempting to speculate that the oil may have been of linseed or hemp origin. However, it is not possible to determine this conclusively solely on the basis of the fatty acids.

Figure 6. Front and back views of the birch tar chewing gums from the amulet box (photos: R. Fortuna).

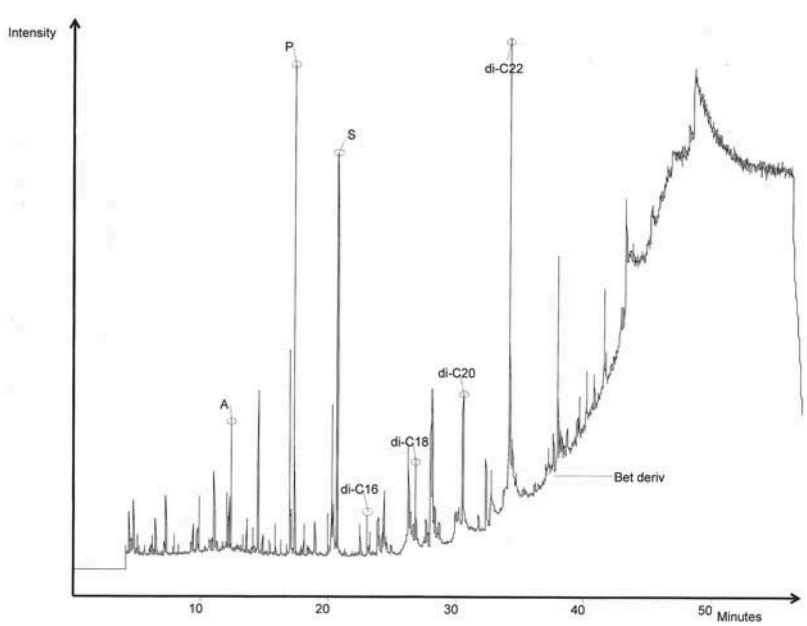

Figure 7. The TIC chromatogram of the analysed material (graph: J. Glastrup).

Interpretation of the organic content in the amulet box of Vellensby and comparative finds

The chewing gums made of birch tar

Birch tar is extracted from the white bark of birch trees by burning it slowly under hermetically sealed conditions (a dry distillation method) at a temperature of *c*. 300–400°C. Birch bark contains up to 25% of terpenes, a kind of resin which begins to soften at a temperature of *c*. 50–70°C. In cold conditions, this black substance reacts in a similar way to modern chewing gum. It has been used as universal glue since early prehistoric times, mainly to fix flint arrowheads to shafts, but also to repair broken ceramic vessels and to caulk leather (Wahl 2007, p. 185). Several experiments illustrate how birch tar is understood to have been produced in prehistoric times (e.g. Czarnowski and Neubauer 1992, Junkmanns 2001).

Small clumps of the raw birch tar exhibiting distinct dental impressions from human teeth are quite frequently detected in archaeological excavations (Fuchs 2012). The oldest known finds from Denmark are the two *c*. 10.500-year-old clumps with dental impressions of a *c*. 11-year-old child from the site of Barmose I, a settlement in South Zealand (Johansson 2011). In this article, Johansson lists additional Scandinavian prehistoric sites at which birch tar is found: Segebro in Southern Sweden, Huseby in West Sweden and Dværgebakken in central Jutland.

Numerous Neolithic finds of so-called 'chewing gum' have been recorded from the lake shore settlements of the circum alpine region. For example, the site of Hornstaad-Hörnle IA, Lake Constance in Southern Germany, where more than 200 birch tar pieces with dental impressions, mainly from children and young adults, were found in a layer that dated to 3918–3902 cal. BC (Fuchs 2012). The taste of birch tar chewing gum shares similarities with the taste from chewing tobacco and smoked meat; Junkmanns (2001) reports that it tastes sweet and aromatic. Birch tar contains the following constituents: tanning agents, salicylic acids and essential oils. It is known that birch tar has antiseptic properties and has, among other applications, been used in traditional medicine to anesthetise toothache, as a cleaning agent and disinfectant for the mouth, a treatment for skin diseases, malaria, dropsy and gout as well as for colic and mange within a veterinary context. Modern medicine assumes, however, that birch tar contains carcinogenic substances (Fuchs 2012).

The Allium *gloves*

The genus *Allium* has a rich ethnobotanical history in Denmark (Brøndegaard 1987), and the use of wild onions may well extend back to prehistoric times. It is particularly interesting that, in some neighbouring areas, the modern occurrence of sand leek is closely related to historical and probably even to prehistoric settlement ruins. Sernander mentions, in 1941, that '*Allium scorodoprasum* on the island of Gotland can often be found in close vicinity to ground plans of old houses and enclosures dating to the iron Age period'. The same observation that the modern distribution of sand leek is tied to old settlements has been made by Naustdal (1945) in his review of finds along the west coast of Norway. This suggests that this species was cultivated in former times as a vegetable for culinary use and as medicinal plant. Based on the references above, Fægri concluded in 1951 that the *leek* (Lauka) mentioned in the Edda sagas and in all the old Nordic literature was *Allium scorodoprasum* (cited from Hjelmqvist 1955, pp. 165–166).

Traditional use of cultivated garlic

Cultivated garlic (*Allium sativum* L.) occupies a special position within the genus *Allium*, as the bulbs can be used for several purposes, including food (vegetable), spices and medicine. The oldest written evidence on the use of garlic is documented in the 22 medical recipes in the famous Ebers Papyrus dated to *c*. 1550 BC (Koch and Hahn 1988). It is not known when cultivated garlic was introduced to Southern Scandinavia as no archaeobotanical finds have yet been made.

Modern scientific analysis and experiments support the abundant information in the antique, medieval and ethnographical literature relating to the pharmaceutical properties of garlic, which seem to be equally present both within the wild species *A. scorodoprasum* and *A. ursinum*, and in the domestic species (e.g. Fritsch and Keusgen 2006).

These various medical applications are attributed to the high antibiotic, anti-sclerotic and anti-carcinogenic effect of the garlic substances. At the same time, garlic acts as a disinfectant which may indicate that the cloves in the amulet were probably used as a remedy for toothache.

Marco Polo reported that in China garlic juice was used to preserve meat (Moule and Pelliot 1938). Biochemical analyses have shown that garlic contains the amino acid alliin which reacts with the enzyme alliinase to form a strong antimicrobial and strong smelling substance (allicin) when cloves are freshly crushed (Melchior and Kastner 1974).

Garlic is associated with vitality and is associated with long lifespans and resistance against cancer throughout the Mediterranean. Garlic has enjoyed (and in some regions even today) the reputation to protect against evil powers, mainly during the dark hours. Until recently, it was a common habit in Southern Europe to place garlic beside women who were due to give birth. Thieves can be threatened and witches warded off by hanging single garlic bulbs or whole garlands below or beside entrances. The legend that vampires detest garlic is known worldwide. One of the oldest written sources on garlic's supernatural attributes is the episode in Homer's epic, the Odyssey, in which the god Hermes orders Odysseus to eat yellow garlic so as not be transformed to a pig by Circe, the daughter of Helios, who was a goddess of magic (Harris 1975).

Amulet boxes from contemporaneous female burials in other European countries

The discovery of botanical parts within the small amulet box from the woman's grave A5 at the site of Vellensby has inspired further investigation of similar boxes from Denmark and abroad. Based on Katarzyna Czarnecka's catalogue (Czarnecka 2010, pp. 234–236), it was possible to compare 16 amulet boxes with the find from Vellensby (Figure 8 and Table 1). All boxes can be dated to the periods C1b and C2 of the Late Roman Iron Age. Five of the amulets were found in Denmark, one in Sweden, five in Germany, four in Poland, one in Hungary and one in Serbia (Figure 8 and Table 1). It is possible to identify some time-related variations within this group. The boxes from Northern Europe, in addition to the find from Serbia, date to the period C1b and differ from the others by not having any decoration. Exceptions, however, include the box from Himlingøje, Denmark, and one of the boxes from Preetz, Northern Germany. The three most extensively decorated amulet boxes are from Himlingøje, Moythienen and Babienten, dated to the period C1b and C2. All 17 amulet boxes belonged to wealthy women whose graves contained objects of both Roman and Germanic origin. The boxes can be described as small cylindrical metal containers with lids, which were attached to a long necklace of beads. A small metal chain connects the lid to the box. Only the amulet box from Stuchowo, northern Poland, differs from the cylindrical boxes by having a round base. The design is most likely a reflection of its intended contents, in this case caused by a large black agate bead. The Stuchowo box is made of silver like the box from Himlingøje. The remaining 15 amulet boxes are made of bronze. The metal chain between lid and box is only apparent on 15 of the boxes. In contrast to the two others from Rebenstorf and Wechmar, Germany, a small cross bar fixes the lid to the box.

An object type that is found in all of the graves is beads, in particular glass and amber beads. In graves outside Northern Europe, beads of semi-precious stones, such as agate, carnelian and rock crystal, are more common. In the Hungarian grave, Szeged Sárgapart, which is interpreted as a Sarmatian grave, many beads were found, especially prismatic carnelian beads. The woman here

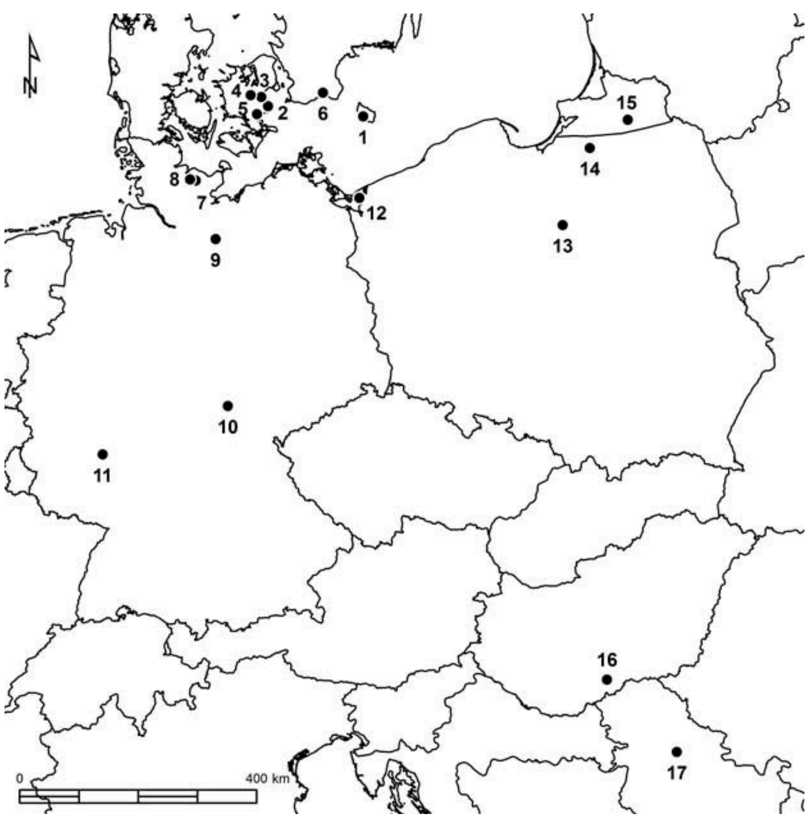

Figure 8. Geographical distribution of the 17 contemporary female burial sites dated to the Late Roman Iron Age in Europe. For site names, dating and descriptions of the amulet boxes see Table 1 (graph: A.M. Walldén).

Table 1. Description of the 17 contemporary sites of female burials with amulet boxes in Europe mapped on Figure 8.

Number on map	Country code	Site name	Dating	Burial type	Age in years	Material	Size in cm height/ width	Decoration	Plant parts	Textile fibres	Ointment	Leather with hair	Silver/iron fragments/ bead	Agate bead with silver thread	References
1	DK	Vellensby	late C1b	inhumation	14–18	bronze	3.5 × 3.9	x	x	x					Karg *et al.* this article
2	DK	Broskov	C1b	inhumation		bronze	2.6 × 2.5								Broholm (1930)
3	DK	Himlingøje	C1b	inhumation	40–50	silver	2.3 × 3.0	x	x	x		x	x		Hansen (1995)
4	DK	Nordrup	late C1b	inhumation	young	bronze	2.0 × 3.4				x				Petersen (1890)
5	DK	Skovgårde	late C1b	inhumation	16	bronze	2.44 × 2.48						x		Ethelberg (1997)
6	S	Balkåkra	late C1b	inhumation	young	bronze	2.6 × 2.8						x		Sundin (1919)
7	D	Preetz, 45	C1b	urn		bronze		x							Brandt and Schäfer (1960)
8	D	Preetz, 123	C2	urn	6–8	bronze	2.6	x							Brandt and Schäfer (1960)
9	D	Rebensdorf	C2	urn		bronze					x				Müller (1893)
10	D	Wechmar	C2	urn	young	bronze	2.8 × 2.7	x	x						Kaufmann (1984)
11	D	Lauffen	late C2	inhumation	14–16	bronze	2.3 × 2.0	x							Schach-Dörges (1981)
12	PL	Stuchowo	C2	inhumation		silver		x						x	Eggers (1938)
13	PL	Crossen	C1b1	inhumation		bronze									Gaerte (1929)
14	PL	Moythienen	C2	urn		bronze	3.6 × 4.7	x							Hollack and Peiser (1904)
15	PL	Babienten	C2	not known		bronze		x			x				Gaerte (1929)
16	H	Szentes-Sárgapart	C1b	inhumation		bronze									Párducz (1950)
17	SRB	Pancsova	C2	inhumation		bronze	4.3 × 5	x							Párducz (1963)

had several necklaces around her neck, wrists, upper arms and ankles; with more than 300 beads used to adorn her ankles alone. The bronze amulet box in this grave is, in fact, two boxes tied together. The upper box has a handle while the lower features a chain. Another point of interest is the two silver rings, which were placed on the woman's temple (Párducz 1950).

The graves of Stuchowo, Babienten and Crossen in Poland, Balkåkra in Sweden and Lauffen in Germany are outstanding, with regard to special grave goods or the characteristics of the deceased. The woman in Stuchowo had a 45-cm-diameter bowl made of bronze placed over her face (Eggers 1938). The Babienten girl had a barbed spearhead, a point of a lance and two sickles in her grave (Gaerte 1929). The grave of Crossen contained spurs and a terminal pendant (Gaerte 1929). The young girl of Balkåkra was missing her left hand while her feet were found tied together. She also had a belemnite in her grave and a large quantity of charcoal had been placed on her body (Sundin 1919). The Lauffen girl had a Roman bronze key, six Terra Sigillata bowls and a 4.8-cm^2 gilded silver plate with a large red/violet glass bead, which had most likely been attached to a belt (Schach-Dörges 1981).

Although the 17 amulet boxes show many similarities, they must have been manufactured in different locations. Their decoration and assemblages differ, as well as the methods by which the metal chain was attached to both the lid and the box. In addition, five of the boxes have a lid that is fixed to the exterior; in the case of the remaining boxes, the lid is fixed to the inside. The small bucket-shaped charms are normally seen in bead necklaces, but are affixed to the amulet boxes at Lauffen and Wechmar.

It has only been possible to identify the contents of nine out of the 17 boxes. The materials can be identified as: plant parts, textile fibres, ointment, leather with hair, silver/iron fragments/bead and one agate bead with silver thread (Table 1).

Summary and conclusions

The Late Roman Iron Age (periods C1b and C2) was a politically unstable period. This is, among other things, reflected in the numerous weapon graves within the archaeological record, and in other evidence for unrest along the Limes during the period. New centres of power and wealth were established, and social networks and alliances between these centres were strengthened. Contact and communication between the centres are, among other archaeological finds, reflected in the grave goods within the previously described female burials containing amulet boxes. The objects in their graves indicate the existence of an extensive social network that is, for example, also reflected by the glass finds of the Eggers Type 189, found among the Late Roman Iron Age (C1b) graves of Himlingøje, Nordrup and Crossen. The glass is of Roman origin and had been transported from Cologne to Zealand and Bornholm, and from there onwards to Poland (Kokowski 2004, p. 38). The distribution of the fibula types Almgren VII 196 and Almgren IX 217 also reflects the existence of trading a network across the Baltic Sea.

The richness of the grave goods within the female burials at each of the 17 archaeological sites described reflects the fact that these women belonged to the Late Roman Iron Age elite. It can be hypothesised that some of these women entered into marriages with members of other tribes (Przybyla 2011, p. 321), while others maintained different forms of social networks especially those buried in the large female cemetery in Preetz or those, whose graves were not placed on an actual burial ground, such as the women of Babienten, Stuchowo, Balkåkra, Pancsova and Lauffen.

One possible explanation for the outstanding characteristics of each of these female burials may be that all these women, as with many other women in Late Roman Iron Age Barbaric Europe, shared a common knowledge of the healing properties of natural medicines, such as birch tar, that can be used against tooth pain, and *Allium* cloves, which are known for disinfectant properties. The woman from Vellensby was herself part of this body of knowledge.

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BRIEF COMMUNICATION

On the mystery cloud of AD 536, a crisis in dispute and epidemic ergotism: a linking hypothesis

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In AD 536, some kind of natural catastrophe(s) darkened the sun by what has been called a mystery cloud or a dust veil. The darkening of the sun lasted for over a year and initiated dramatic changes of the climate in the Northern Hemisphere, resulting in a series of cold 'years without summer'. This climatic disaster has been linked to the so-called Migration Period crisis in Scandinavia, a time of population decline and reforestation of agricultural land. The extent of these changes and the relative importance of possible factors involved are matters in dispute; failed harvests and famine, plague, war and social changes have been discussed so far. The present comment puts forward the hypothesis that epidemic ergotism due to widespread contamination of food and fodder by poisonous ergot (*Claviceps purpurea*) also may have been a contributing factor. The main reason being the extreme weather conditions, which became exceptionally favourable for growth and spread of this highly toxic fungus in crops and pastures for several years in a row after the AD 536 event. It is pointed out how the ecological and toxicological characteristics of ergot are consistent with an irregularly distributed depopulation, a need of several generations for recovery, an extensive reforestation of agricultural land and migration of settlements from lowlands to higher grounds. It is also argued for the possibility that the wording in two verses of the Old Norse poem *Völuspá* actually was inspired by long-time memories of illness due to ergotism.

Keywords: Migration Period; Scandinavia; AD 536; *Claviceps purpurea*; ergot; ergotism; archaeobotany; osteoarchaeology; *Völuspá*

Introduction

In AD 536, some kind of natural catastrophe(s) initiated a decade of exceptionally cold climate in the Northern Hemisphere, as will be discussed more in detail below. This event, at the end of the Migration Period, has been linked to a demographic decline in Scandinavia. Failed harvests and famine, the Justinian plague, war and social changes have been put forward as possible elements in the much debated picture of what some call the Migration Period crisis. Not only the nature but also the extent of this demographic decline is a matter of debate, and there are scholars being sceptical as regards the use of 'crisis' as a proper designation for the changes taken into consideration (Näsman 2009, p. 107, 2012). Uncertainty about what may have happened is reflected by a conclusion in the proceedings from a joint Scandinavian conference on this topic: 'From the debate […] it is obvious that we have not yet reached any consensus as regards the understanding of the archaeological source material – neither its representativity nor its interpretation' (Näsman 1988, p. 228, our translation). There are still questions to be answered (Näsman 2012). Due to what is known about the Scandinavian climate and agriculture at the time in question, we want to draw attention to a hitherto overlooked factor worth including as a hypothesis in the ongoing debate – epidemic outbreaks of ergotism, i.e. food poisoning by ergot. Why and how ergot may have played a role even more serious than plague in a possible demographic crisis at the end of the Migration Period will be discussed in detail after a brief background on the ecological and toxicological characteristics of this highly poisonous organism.

Ergot

Ergot is a plant disease caused by the parasitic fungus *Claviceps purpurea*, which infects the developing grains of cereals and grasses. Rye is especially vulnerable, but the disease also affects barley and wheat and some 300 other plant species. The infected kernel is replaced by a seed-like sclerotium – the ergot (Figure 1) – containing fungal mycelium surrounded by a dark rind (Johnson 2013, Anon 1). The ergot is a 'chemical factory' producing more than 200 compounds, which include many different alkaloids with various powerful physiological properties (Lee 2009). The mix of components in this 'drug cocktail' and the ensuing toxic effects on humans and animals are influenced by a number of factors including the type of host plant, the soil and topography where the host plant grows and the climate during ergot formation (Matossian 1989, p. 13).

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Figure 1. Ear of rye with two toxic black ergots (Greenish 1920, p. 219).

One of the most important facts pertaining to the following discussion about a Scandinavian demographic crisis in the sixth century is the climate requirements for optimal growth of this fungus. It thrives when a freezing winter is followed by an overcast wet spring and cool summer (Matossian 1989, pp. 13f, Anon 1).

Ergot poisoning

It is beyond the scope of this brief communication to describe in detail the bewildering array of symptoms caused by ergot poisoning, ergotism. Suffice it to say that they include – among many other things – hallucinations, convulsions, miscarriage, reduced fertility and gangrene causing digits or hands or feet and even entire limbs to blacken, mummify and fall-off (Schumann 2005, Lee 2009). Written accounts of ergot poisoning are on record back to the 900s AD, and epidemics of the disease were common during the Middle Ages when gangrenous ergotism was known as the frightening 'Saint Anthony's fire' (van Dongen and de Groot 1995). It shall be underlined that ergot poisoning often was a lethal disease. During 10 epidemics of ergotism documented in the 1800s, the mean mortality rate among those who were taken ill was over 40%. The danger from ergot is compounded through its alkaloids being both potent and hardy. Disease occurs when the harvest of grain and the food prepared from it is contaminated by a certain share of ergots; as little as 2% in the grain used for bread can cause community-wide ergotism. Ergot alkaloids are also very stable and can retain their toxicity in the harvest for more than a year. In addition, their toxicity is not neutralized by baking at low heat or boiling for up to 3 hours (Matossian 1989, pp. 7, 12, 14).

Another point of importance to the following discussion is that children and teenagers are especially susceptible to food contaminated by ergot, since they – compared to adults – consume more food and thereby more toxins per unit of body weight. Furthermore, ergot toxins can pass into mother's milk, as well as the milk of domestic animals feeding on contaminated grass (Matossian 1989, pp. 9, 12).

Prehistoric ergot in southern Scandinavia

Occurrence of ergot in Scandinavia during the Migration Period has been demonstrated by archaeobotanical analyses of carbonized material from burnt houses in Sorte Muld on Bornholm and in Vallhagar on Gotland (Helbæk 1957, p. 272). Earlier presence of ergot is known from Jutland through the gut contents of the world famous bog body Grauballe Man, who had his throat cut some time 400–200 cal BC (Harild *et al.* 2007, pp. 175f, Heinemeier and Asingh 2007, p. 201). An even older find of ergot is on record from Vårgårda in south-western Sweden. The carbonized material in question – associated with a presumed harvest offering – has been dated to *c*. 630–550 BC by ^{14}C-analysis (uncalibrated, Regnell 2006, p. 50). Thus, at least 2500 years have passed since ergot first occurred in Scandinavia – where it still is present (although not much heard of due to control and counter-measures).

Since rye (*Secale cereale*) is especially vulnerable among the many host plants affected by ergot, the cultivation of this cereal in the 6th century AD is of particular interest regarding the hypothesis presented in this paper. In Denmark cultivation of rye appears to have been a fundamental component of the agriculture, at least locally, from the Roman Iron Age onwards (Grabowski 2011). A telling example is the gut contents of the Huldremose Woman, one of the famous bog bodies from Jutland; rye was a main ingredient in her last meal before she died around AD 100 (Asingh 2007, p. 296). Furthermore, the composition of carbonized straw in the remains of fillings from iron-smelting furnaces constitutes evidence of well-tended rye fields on Jutland at the end of the Roman Iron Age (Henriksen 2003). At that time, cultivation of rye was also established in Halland and Scania in southern Sweden, as well as the islands of Bornholm, Öland and Gotland in the Baltic Sea (Helbæk 1957, p. 264, Grabowski 2011). In southern Norway, the cultivation of rye has been traced back to the 5th century AD in Vestfold and Rogaland. It is not for nothing that the etymology of the county Rogaland

– and its inhabitants called *ryger* – can be traced back to words used for rye (Alm and Elvevåg 2012). To summarize: both ergot and one of its preferred hosts, rye, were part of the landscape being cultivated in southern Scandinavia in AD 536.

The climate change in AD 536 – perfect for ergot

In March of AD 536 people saw 'a most dread portent'; the sun darkened, became bluish and lost its brightness. It reminded of a solar eclipse, but the dimming of the sun lasted for over a year and was followed by unseasonable chill and failed harvests – all according to surviving records from several contemporary writers in the Mediterranean region and the Middle East (Stothers 1984, Arjava 2005, Gräslund and Price 2012). The cause(s) of this so-called 'mystery cloud' or 'dust veil' of AD 536 remains unclear. Volcanic eruption, meteorite impact or exploding comet, singular or plural – possibly in combination – are alternatives put forward (Stothers 1984, Rigby *et al.* 2004, Abbott *et al.* 2008, Gräslund and Price 2012). In order to put the magnitude of what happened into perspective, it can be mentioned that estimates of the atmospheric dust load caused by the AD 536 event(s) indicate that this was about twice as large as the one caused by the explosion of Tambora in 1815 (Stothers 1984), which is considered to be the last millennium's greatest volcanic eruption on Earth and the cause of a 3-year period with drastic global changes of the climate, resulting in worldwide failure of crops and famine (Wood 2014, pp. 2, 9–10). Although it remains unclear what exactly happened in AD 536, it is unquestionable that some kind of natural catastrophe(s) had dramatic effects on the climate in the Northern Hemisphere. Physical evidence is provided by dendrochronology (for references, see Gräslund and Price 2012). It is of particular interest that tree rings show a period of very slow growth for Scandinavian pines, beginning in AD 536 and continuing for the next 10 years. Since the growth of pine is determined by July temperatures (Arjava 2005), this finding indicates a series of exceptionally cold summers in Scandinavia at the end of the Migration Period. Furthermore, the event(s) under discussion also led to a period of colder winters and increased humidity (Gräslund and Price 2012). In other words: the extreme climate change beginning in AD 536, with a darkened sky, colder winters, wet springs and cold summers, constituted optimal conditions for growth of ergot.

In addition, it is quite possible that the cultivation of rye was accelerated in Scandinavia by the climatic catastrophe of AD 536. Rye, being the most frost-resistant of the cereals, could still be harvested when the crops of barley and wheat failed due to unfavourable weather conditions (Tvauri 2012, p. 104). The ability to grow on poor soils is another factor making rye highly competitive vis-à-vis other cereals (Behre 1992).

Long-term demographic effects of epidemic ergotism

Thus, we have so far established that the preconditions for food poisoning by ergot – the fungus itself, vulnerable foodstuffs and ideal weather – all coexisted in Scandinavia in the mid-sixth century. In the following, we will outline the hypothesis presented in this paper by discussing *how* widespread, epidemic ergotism may have contributed to the so-called Migration Period crisis, when the population of Scandinavia was reduced, perhaps by as much as half, and large areas of agricultural land returned to forest (Gräslund and Price 2012). We will elucidate this from several points of view: acute mortality, reduced birth rate, affected livestock and religious reactions.

As to acute mortality, we have already mentioned the experience from epidemics of ergotism recorded in the 1800s, when the death toll among those being affected averaged around 40% and could be as high as 70% in some places. For comparison, it can be mentioned that these figures are quite similar to the case mortality from bubonic plague before the era of antibiotics (Walløe 2008). There is, however, one important difference between ergotism and plague: those who survive poisoning by ergot do not develop any immunity to the disease – unlike survivors of plague. On the contrary, those who once have been affected by ergotism are, for unknown reasons, more sensitive to the poison at repeated exposures (Matossian 1989, p. 12). This constitutes a significant risk factor to keep in mind in a long-term perspective since ergot can be expected to have shown exceptionally abundant growth for several years after AD 536 due to the continuation of harsh weather and a probably increasing share of rye in the crops, as outlined earlier.

Regarding depopulation, reduced birth rate is an important effect of ergotism with several long-term aspects worth taking into consideration – not the least in perspective of the estimation that it took up to seven generations before the cultural landscape had recovered from what is called the Migration Period crisis (Gräslund and Price 2012). First, as mentioned earlier, women in childbearing age and younger girls – the next generation – belonged to those at highest risk to die from ergotism. Second, abortion can be induced by ergot alkaloids. In a Russian report from an outbreak of ergotism in 1896, it was concluded that 'if a pregnant woman got ergotism when she was in her first trimester, she aborted; if in her sixth or seventh month of pregnancy, the child died after birth'. It can be added that initially surviving infants born by mothers with ergotism also run a high risk of being affected and eventually die, since ergot toxins pass over in the mother's milk (Matossian 1989, pp. 9, 23). Alternatively, the babies soon died from starvation, if the ergot eaten by their mothers contained a certain alkaloid inhibiting milk production (Lee 2009). Finally, on top of all the other negative effects, ergot toxins also suppress fertility – the very ability to become pregnant (Matossian 1989, p. 9, Schumann 2005). Thus, if there were repeated epidemics of ergotism during the years without summer after AD 536, they can be expected to have had marked demographic effects for several generations.

As regards the livestock, there is a fundamental difference between epidemics of plague and epidemics of ergotism. Whereas plague spares livestock (Anon 3 2009, p. 5), ergotism affects cattle, pigs, horses, sheep and any other domestic animal (including poultry) feeding on grass or grain contaminated by ergot. The disease has also been documented in wild animals, e.g. moose and roe deer (McMullen and Stoltenow 1998, Uhlig *et al.* 2007). The effects are the same as in humans, including convulsions and gangrene. Even small amounts of ergot fed to cows may result in loss of milk and abortion (McMullen and Stoltenow 1998). Thus, infestations by ergot affect not only the utility of cultivated land for crops but also the utility of meadows and pastures to feed the livestock. Thus, if there were repeated epidemics of ergotism following the change of climate in AD 536, they may apparently have contributed to a widespread return of agricultural land to forest during the so-called Migration Period crisis.

In view of what is told in historical records from Scandinavia, we think that the possibility of religious beliefs connected to ergotism also deserves a comment – despite the duly noted lack of source material from the sixth century itself. Although it is questionable to generalize between societies separated in time by more than a millennium, it does not seem entirely unreasonable to assume that people in the mid-sixth century were affected by ideas about supernatural dangers like people in the 1600s – a century ravaged by witch hunts. A noteworthy aspect of this dark chapter in history is that some of these persecutions most likely were caused by ergot poisoning believed to be witchcraft, a felony punished by death. General economic crises then aggravated these responses (e.g. Behringer 1999, Pfister 2007). Extensive and detailed contemporary trial documentation from Norway provides strong support of the ergot hypothesis (Alm 2003). It is not unthinkable that people in the sixth century may have drawn the same conclusion – i.e. that the frightful symptoms of ergot poisoning were caused by black magic – resulting in the search for scapegoats and death sentences on top of the casualties from ergotism. Judging from the irrational reactions among people during the Black Death in the mid-fourteenth century, the death toll among such designated scapegoats may have been considerable. At that time, Jews were collectively accused of poisoning the water used by Christians and thereby causing the plague. The result was horrible pogroms with many casualties, especially in Germany (Harrison 2000, pp. 237ff). Another atrocity – practised in Sweden and Denmark – was ritual sacrifices of children, who were buried alive to avert the plague (Harrison 2000, p. 234). It cannot be excluded that reactions similar to those caused by the plague in the fourteenth century also were triggered by possible epidemics of ergotism 800 years earlier. What we definitely do know from contemporary written sources is that Mediterranean people interpreted the long darkening of the sun in AD 536 as a most dreadful omen of disaster (Arjava 2005). Scandinavians looking at the same darkened sun may have reacted in much the same way, as has been discussed on the basis of numerous gold deposits thought to be offerings to higher powers in order to have a dying sun restored (Axboe 1999, 2007, pp. 117ff, 156ff, Bondesson and Bondeson 2012). Another example of strong religious impact in this context is the conception that memories from the cold period of years without summer, following the darkening of the sun in AD 536, eventually were incorporated with Norse mythology as the terrible *Fimbulvinter*, which will foretell the end of the world in *Ragnarök* (Axboe 2007, pp. 121, 157, Gräslund and Price 2012). Interestingly enough, one of the earliest known written accounts concerning Norse mythology – the poem *Völuspá* in the Icelandic *Codex Regius* from the thirteenth century (KL 1976) – does not end with *Ragnarök*, but instead with a short comment on the subsequent rising of a new world. In one of the latter verses, there is a passage of particular interest regarding the hypothesis presented in this paper: *Muno ósánir akrar vaxa, bǫls mun allz batna* (Brøgger 1994, p. 114). Translations of this wording basically say that unused arable land will prosper and evil things will cease – e.g. 'On unsown acres the ears will grow, all ill grow better' (Hollander 1990, p. 12). One possible interpretation of this passage is that fields being prosperous in the new world had been unusable in the old one because of illness and therefore had been unsown, i.e. they had been lying in fallow. In line with this interpretation, one may speculate if the poet was influenced by longtime memories of devastating illness caused by something coming from the fields – like ergot. In fact, the passage about a '…wolf age ere the world crumbles…' in a previous verse of *Völuspá* (Hollander 1990, p. 8) dealing with the prelude of *Ragnarök* may well refer to ergot instead of the animal. Based on Germanic mythology, it has been suggested that the wolf was a symbolic embodiment of ergotism in ancient times, being reflected in the folklore by a name for ergot meaning wolf-tooth, and a demon living in the grain fields called the rye-wolf (Bové 1970, p. 5, Gerstein 1974, p. 148).

Ergotism, demographic irregularities and local migration

Archaeological data indicate that the depopulation of Scandinavia and the Baltic countries discussed here had a quite irregular distribution. Some settlements seem to have been more or less deserted, whereas others appear to have remained fairly unaffected (for discussion on source material and references, see e.g. Näsman and Lund 1988, Gräslund and Price 2012, Löwenborg 2012, Tvauri 2014). There is not yet any generally accepted explanation of such an irregularity (Näsman 2012). Epidemic ergotism is hereby introduced as a potential factor in the probably multifaceted background. As already mentioned, the toxicity and effects of ergot may show considerable differences from one time to another and from one place to another due to a number of factors in the environment (Matossian 1989, p. 13). Since rye is especially vulnerable to infestation by ergot, the share of rye in the crops obviously is an important factor from a quantitative point of view; the greater share of rye, the greater risk of ergot intoxication. Geological differences also have influence from one area to another. Soils with low content of certain trace elements, e.g. copper and boron, favour the growth of ergot (Johnson 2013, Anon 2 2008). Furthermore, the soil also influences the synthesis and the mix of various ergot alkaloids, and thereby the effects and the toxicity of the fungus. In addition, not only the weather in general but also local differences in the microclimate regarding both temperature and humidity is important to the growth and the toxicity of ergot (Matossian 1989, p. 13). In summary, it is conceivable that epidemic ergotism might have contributed to a significant Scandinavian depopulation on the whole, but the effects can be expected to have varied considerably from one place to another.

Environmental preferences of ergot also provide a clue to the origin of another observation regarding population geography. Following the AD 536 event(s), it appears that settlements in eastern central Sweden situated near wetlands and watercourses were abandoned and moved to higher and drier grounds nearby. It has been suggested that these relocations were triggered by rising ground water and overflowing rivers causing damage to wooden buildings due to spread of mould facilitated by increased humidity (Gräslund and Price 2012). We think that ergot adversely affecting people and livestock can be added as a possible contributing factor since marshy land with constant dampness favour the growth of ergot as well as mould (Matossian 1989, p. 14). In other words, to move to drier grounds was to move where most survivors lived in times of ergotism.

Concluding remarks

Based on what has been put forward, we suggest that epidemic ergotism should be added to the list of factors discussed concerning the background of demographic changes in Scandinavia linked to the so-called mystery cloud of AD 536 and its effects on contemporaneous climate. Contemporary records and dendrochronology indicate that the weather conditions following the AD 536 event became exceptionally favourable for the growth and spread of ergot in cereals and grass for as long as a decade. Through archaeological finds, it is also known for certain that this highly toxic fungus was an integral part of the mycological flora long before the sixth century in Scandinavia. Regarding the mortality among people taken ill, ergot poisoning equals untreated bubonic plague. For an agricultural society, however, epidemic ergotism can be expected to have an outcome even worse than plague, since ergot poisoning – contrary to plague – affects livestock in addition to the people. This factor, in conjunction with the complex and long-term toxicological effects of ergot, helps to explain certain currently unresolved aspects of the so-called Migration Period crisis in Scandinavia.

As regards future archaeological research dealing with this ‘crisis’ in dispute, it is of interest that physical evidence substantiating our hypothesis – that epidemic ergotism may have been a contributing factor – can be looked for in two ways. One involves archaeobotanical analyses aimed at elucidating the presence and relative proportion of ergot in finds of grain from the time in question. Considering the scarcity of data on prehistoric ergot published so far, however, one may question if the information being obtainable by macrofossil analysis ever will permit any conclusion as to the possible occurrence of epidemic ergotism in Scandinavia at the end of the Migration Period. On the other hand, the hypothesis discussed here may inspire future research focused on this particular issue, not only in the form of new excavations but also using already collected archive material. The same reasoning applies to the second line of investigation in this context, namely osteoarchaeological analyses. Although not entirely specific as to aetiology, skeletal lesions caused by gangrenous ergotism are sufficiently different from a number of other bone-affecting systemic diseases (Lefort and Bennike 2007) to be of potential value in the search for support of our hypothesis.

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DISCUSSION ARTICLE

Four churches and a lighthouse—preservation, 'creative dismantling' or destruction

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A presentation and discussion of the heritage dilemmas, which appear, when the medieval churches of Mårup, Rubjerg, Lyngby and Furreby and the modern lighthouse of Rubjerg Knude in Northern Jutland, Denmark, all are threatened by dunes, drifting sands and the North Sea. The churches of Rubjerg and Lyngby were taken down and rebuilt further inland in, respectively, 1904 and 1913–1914, while the church of Furreby is still functioning. The lighthouse is standing as a ruin waiting to be taken down around 2020. The church of Mårup was made redundant, when a new church was built further inland in Lønstrup in 1926–1928.

A great dispute emerged on the future of Mårup, when it became threatened by increasing sea erosion in the 1980s. The church was investigated and partly taken down 2008 and 2011. The dispute on Mårup has been seen as a conflict between nature and culture, periphery and centre, experience and knowledge – preservation and destruction. First, to understand the debate the author introduces the concept 'creative dismantling'; a concept in between preservation and destruction. Second, the author argues that the unspoken core of the dispute has been the assumed irrelevance of the church to the national canon of art and history by all disputants. The creative dismantling lifted the church into the canon thereby creating a new, but also problematic consensus.

Keywords: heritage; preservation; destruction; creative dismantling; medieval church; modern lighthouse; cultural canon

At the edge of Jutland

The sky, land and sea meet stories of the past, present and future at Lønstrup Klint in Northern Jutland in Denmark. Along the 15-kilometer long cliff open to the North Sea between Lønstrup and Løkken four medieval churches and a modern lighthouse have been or are still threatened (Figure 1). Nature with its waves hammering the coastline, dunes and shifting sands are threatening the survival of the cultural remains up on the cliff.

The cliff is a popular destination visited by hundreds of thousands of people every year. The visitors are attracted by the ruined church of Mårup, close to the edge of the cliff, and by the lighthouse of Rubjerg Knude standing alone among the dunes (Figure 2).

Lønstrup Klint is itself partly protected as a unique erosion cliff creating a conflict between priorities of either nature or culture. Also development and antiquarian actions have been perceived as posing threats to the cultural remains. Thus, the four neighbouring churches and the lighthouse are an excellent case study to discuss being or not being of heritage.

Why did an intense debate emerge on the destiny of the church of Mårup in the 1980s, while other churches long ago have been taken down, moved and rebuilt and few cares about the future of the lighthouse? How may we understand the different perspectives on the church and the lighthouse and what might we learn from them? The author here emphasizes the importance of the stories we tell about the heritage for its preservation and questions the new consensus for valuing heritage.

Destination Mårup and Rubjerg

Within sight of each other and with only half an hour's walk between them lie the church of Mårup and the lighthouse of Rubjerg Knude, both within the area of nature protection. The medieval church and the modern lighthouse are deserted after having been superseded by development and the forces of nature, but are now popular tourist destinations close to seaside hotels and cottages.

Both the church of Mårup and the lighthouse of Rubjerg Knude are threatened by the North Sea. The question is, if it was or is desirable and also possible for the church and lighthouse to be preserved? Is destruction unavoidable? Or is there a third way?

During the decades, as the sea has approached and made a solution more urgent, the debate over this question has been vigorous and involving many institutions and people. The debate is not concentrated on one place or one moment, but has to be discovered in scattered official reports, articles, correspondence and webpages, in media, pamphlets and lectures and also in local activities over the course of several decades (e.g. documents in the archive of the National Museum, www.maarupkirke.dk, www.naturstyrelsen.dk).

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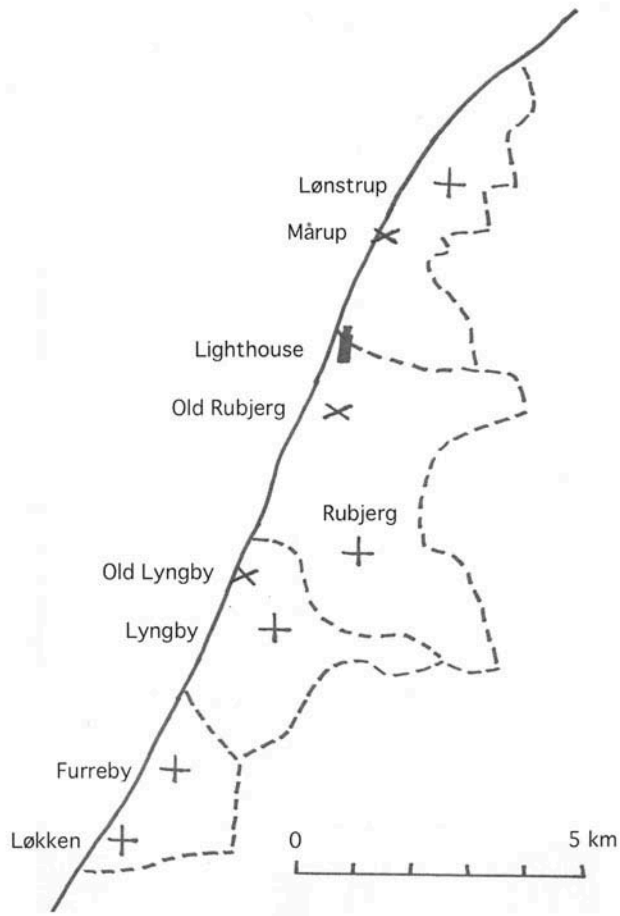

Figure 1. Four parishes along Lønstrup Klint in Northern Jutland with the localization of the churches of Lønstrup, Mårup, Old and New Rubjerg, Old and New Lyngby and Furreby and also the lighthouse of Rubjerg. Redrawn after rubjergknude.dk.

Figure 2. Lønstrup Klint with the lighthouse of Rubjerg Knude among the dunes and the medieval church of Mårup further away. Photo Per Lysdahl, the Historical Museum of Vendsyssel in Hjørring, 3 July 2008.

Different competing stories have been debated in which to fit the church and lighthouse. Depending on the story that would come out from the debate as a winner the consequences for the remains would be different. The stories have actualized a number of classical dichotomies – nature versus culture, the Middle Ages versus Modernity, periphery versus centre, experience versus knowledge and protection versus destruction.

However, in the shadow of the famous destinations, the church of Mårup and lighthouse of Rubjerg Knude, there are the stories of three additional churches along the cliff. South of the lighthouse are the foundations of the two medieval churches, one at Rubjerg and one at Lyngby, which both were moved and rebuilt further inland in presumed safety of the sea, dunes and drifting sands. Further south is the still standing church of Furreby.

Even though all four were Romanesque buildings, the church of Mårup remained protected for decades, only recently to be reduced to a ruin, whereas the churches of Rubjerg and Lyngby were taken down and rebuilt on new sites. Finally, the church of Furreby is intact. Why such different strategies in handling the ecclesiastical heritage? And what will happen to the lighthouse?

Recognizing heritage in Scandinavia

During the Romantic period in the first half of the nineteenth century medieval churches were gradually being recognized as heritage worth preserving and studying in disciplines such as art history and medieval archaeology (Wienberg 2006, pp. 62ff, Wienberg, in print). The newborn consciousness of the medieval heritage arose in a paradoxical coexistence with the replacement of hundreds of original medieval churches with neo-Romanesque or neo-Gothic churches in Scandinavia and also abroad (Clarke 1928, Grandien 1974, Fernlund 1982, Wienberg 1993, pp. 192ff).

In the decades around 1900, when the need for new and larger churches ceased, there was a change in the antiquarian perspective. From here on it became unthinkable to demolish a medieval church, at least in Scandinavia. And with the increased secularization during the twentieth century also churches belonging to post-medieval periods were gradually perceived as valuable heritage. At present, demographic shifts and a continuous decline in those attending church have caused a debate on the future of disused churches from all periods. However, the supposed sacredness of the place, emotional ties to buildings and the existence of burials often prevent alternative use, movement or demolition (Wienberg 2006, 2010).

The recognition that industrial buildings and constructions could also be considered as heritage came more than a century later. With de-industrialization commencing in the 1980s the interest in remains of the modern industrial society has increased. This interest has had two manifestations, as follows:

Either a story is told about the transformation of the factory and other remains into heritage and the reuse of the space as a cultural centre, a museum, as offices or housing. It is a story of progress, of the success of transforming society from industrial to post-industrial (e.g. Storm 2008, Willim 2008). Or deserted and decayed factories, office blocks, machines and cars are presented in photo books and on websites, which are permeated by melancholic aesthetics and existential reflection (e.g. Burström 2004, Edensor 2005, Jörnmark 2007). The ruins should remind us of the consequences of capitalism, of the failures of progress and of the perishability of Modernity.

Both the story about successful transformation and the story on inevitable impermanence are trying to deal with the consequences of the conjunctures of Western capitalism; however, perceived very differently. In the first case, the threat of decline is turned into a possibility for action and recovery, and in the second case the threat is accepted as a condition only open for experience and reflection.

Heritage and threats

The turning point in development by which both churches and industrial remains are transformed into heritage is the emergence of a threat. It is destruction, or the threat of destruction, that creates a certain category named heritage (cf. Arrhenius 2003). This may be recognized all the way from the efforts at the Abu Simbel in Egypt in the 1960s to the establishment of UNESCO's list of World Heritage sites with the convention of 1972 over the destruction of the Bamiyan-statues in Afghanistan in 2001 and to the present discussion at Mårup on preservation versus destruction. Threats are a vital part of the rhetoric in the heritage sphere, but also a reality to face (e.g. whc.unesco.org/en/danger).

Threats are basically in my view about changes, which are perceived as negative: perishability, oblivion, vandalism, iconoclasm, destruction or erasure. Changes with positive connotations might then be development, modernization, renewal, innovation and creation. Thus, the paradoxical concept of 'creative destruction' introduced by Joseph Schumpeter, which has had a renaissance in interpreting the transformation of living industries into industrial heritage (Schumpeter 1912, cf. Jörnmark 2007), is fascinating in its ambiguity, both positive and negative.

At Mårup and Rubjerg nature poses a genuine threat. There is heavy sand drift, and the coastline is eroded between 1 and 3 metres every year. The medieval church of Mårup was initially built around 1 kilometre from the coast, but stands today (2014) less than 7 metres from the edge of the cliff; parts of the cemetery are already lost to the sea (Figure 3). As it has been expressed in a newspaper headline: 'The church of Mårup is waiting for the sea' (*Politiken*, 29. December 2008). When the lighthouse was erected it was 200 metres from the cliff; now the distance is around 60 metres (rubjergknude.dk).

Figure 3. The church of Mårup threatened by the sea. Photo Per Lysdahl, the Historical Museum of Vendsyssel in Hjørring, 3 July 2008.

Nature poses a threat however at the church of Mårup even antiquarian authorities, which are expected to work for protection of heritage, have been seen as a threat to the church, as they opposed its preservation. At least this was the view raised by a local opinion, when the waves of the debate rose high. The regional and national heritage authorities on their side argued that continuous preservation of the church was either impossible or too expensive. Furthermore, from my point of view, heritage authorities and local people, respectively, were telling different stories about the church.

Church of Mårup

Mårup church was probably erected near a village. The Romanesque church was built in brick with rich articulated details. According to a dendrochronological investigation, it dates from 1200 to 1204. An eastern sacristy, a porch and a large western tower were added in the late Middle Ages. From the decades around 1700 it was reduced to the familiar church consisting only of a chancel, a nave and a late porch. Many of the original details were covered or lost. The settlement moved away. From the elaborate medieval building central in a probably wealthy parish the church were transformed into a simple building with an inadequate location (Bertelsen 2009).

In 1926–1928, a new and larger church was erected further inland in the nearby expanding fishing village of Lønstrup. The parish wanted to demolish the old church and sell the lead roof; however, the National Museum in Copenhagen took over responsibility for its maintenance.

The building was abandoned, while burials on the cemetery continued.

After several coastal collapses in the 1980s, where the sea advanced 25 metres in 3 years, it became obvious that the church and the cemetery were threatened. An intensive debate started, which involved many individuals, societies and heritage authorities – for example, The Danish Coastal Authority, The Danish Agency for Culture, The Danish Nature Agency, the Danish Parliament, The Danish Society for Nature Conservation, the society Friends of Maarup Church, Hjørring Municipality, Lønstrup Tourist Society, the Ministry of Culture, the Ministry of the Environment, the Ministry of Transport, the National Museum of Denmark, the North Jutland Region, the parish council and Vendsyssel Historical Museum. Mårup church here totally overshadowed the lighthouse at Rubjerg.

Under threat the church of Mårup now also became one of the most popular tourist destinations in Denmark. Mårup fascinated and still fascinates with its risky location close to the edge of the high cliff and with a spectacular view to the North Sea.

The threat from the sea transformed the church into a symbol of vanity, an illustrative example of unavoidable downfall and also a local symbol of a coastal region dominated by poor fishermen. In 1993, the year after the disappearance of 12–14 metres of the coast in one day, the local 'Friends of Maarup Church' society was founded aimed at the protection of the church.

Several future scenarios were possible: A movement on rails further inland was suggested, but the national antiquarian authorities saw this as a temporary solution and furthermore too expensive. A transfer to a museum was not an option, as Hede Open Air Museum in Jutland already has a (reconstructed) Romanesque church (Petersson and Wienberg 2007), and as the Open Air Museum in Copenhagen was not interested in a church from Jutland. Coast protection was also considered, but rejected, as this part of Lønstrup Klint is protected as nature, where erosion and dune formation can rage freely. Friends of Maarup Church collected signatures from 40,000 people arguing for coast protection, and there were both illegal and later also legal attempts of coast protection, however in vain.

The national authorities chose to give priority to the natural environment over culture, to the eroding coast over the church. The furniture of the church was gradually secured by being moved, and an archaeological investigation was conducted. The protection of the church was repealed in 2005. The Ministry of the Environment, the Culture Heritage Agency (now the Danish Agency for Culture) and the National Museum agreed on a plan, which hereafter has been followed in the main lines: when the church was only 15 metres from the edge, it would be dismantled under supervision and followed by an antiquarian documentation (www.naturstyrelsen.dk).

Figure 4. The church of Mårup after a second phase of dismantling. Photo Thomas Bertelsen, the National Museum in Copenhagen, 2011.

In 2008, this plan was put into effect and the last service was conducted under the church roof. The National Museum had the church investigated and taken down halfway creating a minor ruin with standing walls in the height of 2 meters without a roof. The churchyard would not be investigated, as there are relatively recent burials; the last coffin was buried in 1961 and the last urn in 1994. The bones, which are allowed to fall down the cliff, are collected at the beach (Trap 1960, VI, 1, pp. 227ff, Wienberg 1999, 2006, 2010, Bertelsen 2009, rubjergknude.dk).

Three years later, in September 2011, it was time to take down also the western end of the nave further reducing the man-made ruin. The distance to the cliff was then only 7 meter (Figure 4).

Three more churches—Rubjerg, Lyngby and Furreby

The site of the old church of Rubjerg is still visible. The cemetery is overgrown, but preserved with some tombstones standing. There are the remains of the core of the western wall of the church building. Moreover, the layout of the church is marked by turf walls.

Folk stories tell that the parish once was rich and densely populated. The church from the twelfth century should have been located at a large now vanished village. However, the parish and the church were tormented by sand drift as forests were overused. From the seventeenth century the church was standing almost isolated in a sand desert and gradually decayed. The distance for attending high mass was rather long. It might even have been necessary to dig the way into the church. The increasing problem with sand drift and the distance to the settlement of the parish led to the idea in 1881 of moving the church (Riber 2004, rubjergknude.dk).

After years of discussion and planning the Romanesque church was finally taken down and rebuilt in 1904 ca. 2 kilometres further inland using the old granite ashlars, which were numbered during the process of rebuilding. Also some of the furnishings were moved to the new church and reused. The last burial on the old cemetery was in 1910 (Riber 2004, rubjergknude.dk).

A memorial mound was set up over the last remains of the old church with a Romanesque stone cross. The site was then left to decay until 1966–1967, when the Historical Museum of Vendsyssel cleansed the site and marked the layout of the church. Today the cemetery lays relatively safe ca. 360 metres from the cliff (Trap 1960, VI, 1, pp. 224ff, Riber 2004, rubjergknude.dk).

Also the site of the old church of Lyngby is visible with burial plots and a belfry. The sea has already taken the western part of the cemetery. Coastal erosion threatened the dilapidated Romanesque church and also other buildings from the 1880s. A new cemetery was consecrated 1 kilometre further inland in 1901, and the last burial on the old cemetery was in 1910. It was considered to close down the parish and let people attend to the new built church of Rubjerg. However, in 1913–1914, when the distance from the cemetery to the cliff was only 20 metres, a new church of Lyngby was erected on the new cemetery. Again, old granite ashlars were numbered and reused in building the chancel and some of the furnishings were moved (Trap 1960, VI, 1, p. 331ff, Jensen 1987).

Finally, the Romanesque church of Furreby is still functioning. The distance to the cliff is ca. 270 metres, so it is not yet under threat. The neo-Gothic church of Løkken in the same parish, which was built in 1898, is in fact closer to the sea. It stands only 195 metres from the cliff. Now we go back to the lighthouse at the once highest point of the cliff, 60 metres above sea level.

Lighthouse of Rubjerg Knude

The lighthouse of Rubjerg Knude was built in 1899–1900. From the beginning there were problems with dunes and shifting sands. In the 1920s, when Mårup church was abandoned, a sand dune between the lighthouse and the sea had to be reduced every year, so the sound of the foghorn and the light could reach the ships. In 1953, the horn was taken down, as it was no longer heard and in 1968 even the light was turned off (rubjergknude.dk). The first struggle against the sand was lost.

The lighthouse became a tourist destination. A museum of sand drift was established in the adjacent buildings in 1980, and the nearby dune became a popular attraction for paragliders. However, the dune gradually covered the buildings surrounding the lighthouse, and the museum had to close in 2002. The roofs of the buildings were taken off in 2003 to avoid accidents and they were gradually filled with sand (Figure 5). Instead a museum on the culture and nature of Rubjerg was organized in a nearby farm called 'The wreck master's house' (rubjergknude.dk).

Figure 5. The lighthouse at Rubjerg Knude in the dunes. Photo Nikolas Becker, 18 March 2005, Wikipedia Commons.

Today, the dune has encroached further inland, beyond the lighthouse, which stands alone as a ruin in a desert of sand. The present plan is to take down the lighthouse around 2020, to avoid it falling into the sea (rubjergknude.dk). Thus, the lighthouse would wait for the sea in vain.

From conflicting dichotomies to consensus

The four churches and the lighthouse at Lønstrup Klint apparently highlight a number of classical dichotomies in discussion of history and heritage: nature versus culture, the Middle Ages versus Modernity, periphery versus centre, experience versus knowledge and finally preservation versus destruction. However, at a closer look these dichotomies are revealed as false or at least problematic.

At the cliff of Lønstrup, nature protection was given priority over culture protection, the erosion of the coast over the protection of the church and lighthouse. This might have a pragmatic economic explanation. However, it might also refer to a political context, where the Ministry of Environment had a strong position in Denmark giving priority to questions concerning nature over culture, at least until the political turn of 2001, where a new right-wing government took power. This government instead gave priority to a national cultural canon (*Kulturkanon* 2006, cf. Wienberg 2007, pp. 241–242). But the concepts of nature and culture are slippery, as the dunes and drifting sands are the consequence of both an earlier climate change and of human action. When the churches were built, the area was probably dominated by forest. Drifting sand however was proven to be a problem already in the late Middle Ages at the church of Mårup according to the archaeological investigation (cf. Bertelsen 2009, p. 88). Cultivation exploited the soils and requirements of timber for shipbuilding and for fuel in time of war exploited the forest leading to erosion and drifting sands (rubjergknude.dk).

The four churches and the lighthouse might also be seen as examples of older heritage being given priority over younger, the Middle Ages over Modernity, as there is no discussion of the lighthouse being protected or moved. It is only gradually and hesitatingly that modern remains have been included in what is considered worth protecting. However, it might be claimed, with words from Walter Benjamin, that every present has seen itself as modern (Benjamin 1982, p. 2, 677). Thus, the Middle Ages and Modernity are not mutually exclusive as also the Middle Ages once have been modern. And all modern periods will become old.

In the debate on the future of the church of Mårup the national authorities apparently have been up against the local inhabitants, the capital of Copenhagen up against the periphery of Jutland and experts and politicians up against ordinary people. The local society has struggled in vain for the protection of 'their' church. A compromise by moving the church to an open-air museum was rejected by both parties. National authorities considered a relocation of the church as too expensive and locals as simply out of the question. The local self-confidence was expressed by the author Knud Holst, who wrote about the idea of transferring the church to the Open Air Museum at Copenhagen: 'The Open Air Museum? Then rather let it be blown into the air' (Holst 1984).

However, I do not think geographical location is essential. It is not the location of the churches far from Copenhagen, the capital and centre of political, bureaucratic and also antiquarian power in Denmark, which has decided their fate. The churches of Mårup, Rubjerg and Lyngby, as also the lighthouse of Rubjerg Knude, are peripheral to the national canon of history. If the churches had been associated with stories of royal individuals, as is the case at the three Danish World Heritage sites – Jelling with its mounds, runic stones and church, the Roskilde Cathedral and the Kronborg Castle, or if the lighthouse had been connected to some famous scientist, then I am convinced that all possible resources would have been mobilized to keep them alive.

At Mårup, there seems to have been a partly hidden conflict of values between experience and knowledge. On one side, the locals and their society viewed the church of Mårup as a symbol of local identity, the peripheral and poor fishermen of the coast, and also as a tourist destination important for their economic income. Without the actual experience of the authentic church 'in situ' at the edge of the cliff it would all be meaningless to them. On the other side, the national antiquarian authorities looked at the church as a source material. A demolition was acceptable if the site was properly investigated and documented so it might be reconstructed in the future. The church as a source might be turned into texts and pictures in an archive; however, the church as an experience demands the sky, land and sea. Here a digital reconstruction would not work.

Where archaeological excavations normally attract great public interest as a performance (cf. Holtorf 2005), in the case of Mårup the antiquarians and archaeologists were undesired, as their work was perceived as a part of the destruction. Moving of furnishings and excavations were seen as an early warning of the coming end. However, this conflict of values changed as new knowledge gained from the investigation by the National Museum resulted in a rewriting of the history of the church.

To all parties the church had stood out as architecturally insignificant: a typical, but not archetypical, Jutlandic medieval church, as so many others. Now it changed from silent to speaking, from poor to rich, from average to exclusive and delivered new insights into the medieval building process (cf. Bertelsen 2009). The church of Mårup was no longer insignificant, but has had a rich brick architecture, has been considerably larger and can now be dated with accuracy. It can now be mentioned with local pride as an extraordinary church; no longer associated with poor fishermen, but with medieval aristocracy and noblemen.

After the investigation, the church of Mårup has raised to the level of the national canon of art and history, up to the level, where it might be mentioned in the art historical overviews and the history books. Mårup has been lifted up to the level of outstanding Romanesque architecture built by the mighty of the Middle Ages. Hereby, some of the conflict between the Jutlandic periphery and the centre in Copenhagen could be downplayed or settled. Even if the church will be totally dismantled within a few years, the story has been rewritten with an almost happy ending for the disputants now meeting each other in a consensus on the importance of the church. However, what bothers me, and ought to bother others too, is if the conventional canon of art and history, outstanding architecture and the presence of the mighty, still is important or even necessary for granting value to heritage.

Finally, the four churches and the lighthouse raise the question of protection versus destruction, where I will introduce a new concept in between.

Preservation, 'creative dismantling' or destruction

What stories are told is essential for the survival of a place. It depends on the stories themselves and where, by whom and when they are told. Stories are decisive for the classification and evaluation of places, deciding whether remains are to be preserved as heritage, discarded as garbage, just left for oblivion or simply destroyed. Thus, it might be crucial whether a place has been characterized as either belonging to nature or to culture, to the Middle Ages or to Modernity, belonging to the centre or to the periphery of the national canon, either contributing with experience or knowledge. Positive and negative connotations of words are important as also the social context of stories meaning the authority of the storyteller.

The choice between preservation and destruction depends on the object and the context in time and space, where tourism has become a significant factor. Seemingly the example of the church of Mårup reaffirms the thesis of threats creating heritage; the more threatened, the more efforts on preservation as heritage. However, the concept of a threat depends on context. If the church of Mårup had been seriously threatened back in the nineteenth century it would simply have been demolished or rebuilt in a new location without hesitation.

One way of preserving a church is by moving it piecemeal as at Rubjerg and Lyngby. The churches were moved in the years when there was an 'antiquarian turn'. A few decades before they might just have been demolished, and replaced by new churches. A few decades later, it would probably not have been possible at all to take down the medieval churches. Thus, the last medieval church of Scania in Sweden to be demolished was at Röke in 1906, and the hitherto last medieval church in Denmark to be taken down before Mårup was at Kolind in 1918 (Wienberg 2006, pp. 64–65).

The years around 1904–1914 were a period where several Norwegian and Swedish old stave or timber churches were carefully taken down, moved and rebuilt in the new established open-air museums as a strategy to save them from destruction. Also the ruin of St Mary Minor, a medieval stone church in Lund in Sweden, was moved in 1914 to the nearby Cultural Museum after an archaeological excavation (Petersson and Wienberg 2007, p. 112).

Another way of preservation is to move a church in one piece. Thus, St Emmaus in Heuersdorf in Saxony in Germany weighing 660 ton was moved 12 kilometres on a truck in 2007, when the whole village was threatened by brown coal mining.

However, there exists a compromise between preservation and destruction. The church might be investigated and taken down – by what I would call a 'creative dismantling' cf. the concept by Joseph Schumpeter of 'creative destruction'. The 'creative' element in the process is the investigation, which gives birth to new knowledge and storytelling. When remains such as building materials and furnishings are stored for future use, it would be wrong to talk about 'destruction' as in the concept by Schumpeter. Also the moving of the churches of Rubjerg and Lyngby might be labelled 'creative dismantling' as past remains were reused in new contexts.

The National Museum chooses its words with care. The church of Mårup was not vandalized, destroyed, eradicated or demolished, but 'dismantled under supervision'. As is well known, all archaeology is both destructive and constructive. Something disappears, and something else turns up instead. At Mårup, the archaeological investigation created a new story. Furthermore, the building materials are stored in the nearby town of Hjørring making a reconstruction possible in the future.

The last part of the church of Mårup, the man-made ruin, will soon be taken down. However, it is an open question, what will happen to the modern lighthouse. Would a 'Friends of Rubjerg Knude lighthouse' society appear struggling eagerly for its survival? Would it be taken down by a 'creative dismantling' making a new story or a future reconstruction further inland possible? Or would it just be allowed to fall, when it wants to? It might depend on the stories we choose to tell about the lighthouse in the future.

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DISCUSSION ARTICLE

Ancient monuments on the brink

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The coastline of Denmark has a total length of 7314 km. Due to isostatic subsidence and marine erosion of the coast, some of the country's 32,000 scheduled ancient monuments are always in danger of being destroyed by coastal collapse. Then there are rivers and watercourses that, either in an original or in a restored state, create new courses or erode away the sides of river valleys where there are also ancient monuments.

This risk has always existed and will continue to do so in the future – especially under the influence of current climate change. The scheduled ancient monuments that are primarily in the danger zone are, for example, megalithic graves from the Stone Age, Bronze Age barrows, churches and castle mounds from the Middle Ages, coastal defences from the wars of the seventeenth to nineteenth centuries and more recent fortifications from the Second World War.

Since 1937, scheduled ancient monuments have in general been covered by legislation that fundamentally forbids any change to their state and which has traditionally been applied in restrictive fashion. Exceptionally weighty grounds are required for permission to be granted for changes to or, more drastically, actual removal of a scheduled ancient monument. For example, the entire network of natural gas pipelines was established without a single scheduled ancient monument being affected, and the motorway network has sinuously avoided all scheduled barrows that otherwise stood in the way. Damage caused, for example, by agriculture, forestry and tourism is taken seriously, and on reinstatement – often at the perpetrator's expense – efforts are made to preserve respect for ancient monuments and thereby preclude future destruction.

It is therefore a paradox that well-preserved ancient monuments located along the coast have for decades slowly but surely been allowed to degrade without this unique source material being secured through archaeological investigation. There are several reasons – both formal and practical – for this situation.

Until 1969, the costs of archaeological excavations were included in museums' running costs and other activities or were met by grants from foundations and special funding arrangements. With a change to the Nature Protection Act of 1969, a modification was introduced whereby public contractors and the state were obliged to pay for the investigation of non-scheduled ancient monuments that would otherwise be destroyed by development works. As for scheduled ancient monuments, funding was only earmarked for restoration – not for archaeological investigation – as the intention was of course that these monuments should be preserved. In the 1970s, 1980s and 1990s, archaeological investigations were increasingly carried out at public expense and, because there was no provision in the legislation that permitted the financing of investigations of scheduled ancient monuments, these investigations were by and large not carried out when monuments were undergoing destruction due to coastal erosion.

It was not until a change in the legislation in 2006 – in the form of the Museum Act – that it became possible for statutory public funds allocated to archaeological investigations also to be used for the investigation of scheduled ancient monuments. Even so, it is still not common for this action to be undertaken in the case of monuments threatened by coastal erosion.

There are several reasons for this. One is that the degradation often takes place over many years and the situation is therefore not immediately perceived as being acute. Even though experience clearly demonstrates that the monument will, at some point, inevitably collapse into the sea, there is a major obstacle to the recognition of the problem in that other types of sites are seen to be of a more acute character. As a consequence, ongoing processes and an autumn storm can suddenly result in a situation where the monument lies so close to the coastal cliff that – in practical and safety terms – an investigation would involve technical problems that in turn increase the costs involved.

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Another obstacle is that an archaeological excavation will inevitably result in the monument being to some degree erased from the landscape. This is something to which local people are often opposed. Denmark's coasts are subject to strict legislation aimed at retaining them in as undisturbed a state as possible, unaffected by anything other than nature itself. Nevertheless, extensive measures are taken in some places to delay, or even directly prevent, marine erosion of the coast. The removal of a barrow is very visible testimony to the fact that this negative process will continue nevertheless, merely at a slower pace. Moreover, the excavation of a barrow on a coastal slope may accelerate its degradation.

In continuation of this line of thought, it is often argued that 'nature must take its course'. This applies for example when wild animals such as badgers take up residence in a barrow and perforate it with their burrows. That is to say, some things are, from the hand of nature, unavoidable and we just have to accept this. Associated with this argument is perhaps also a hint of romantic decay and a fascination with the drama of nature. This was seen for example in discussions about whether the Jelling rune stones should be protected from further damage, resulting from the climate and vandalism, by being moved or covered up or whether they should simply be allowed to remain standing as they had done for centuries.

In order to illustrate the problem of ancient monuments on the brink, three cases are presented below, each exposed to the same threat but with three different outcomes.

On the island of Langeland, a long dolmen on a *c.* 5-m-high coastal cliff at Tryggelev nor was suffering ongoing degradation due to coastal erosion (Skaarup 1985, p. 174, no. 222). The kerbstones along one side of the dolmen had fallen down on to the beach many years previously and, following a fierce storm in 2007, the ortholiths and capstones of the chamber looked likely to follow them. In the interests of the safety of bathers on the beach, a local wish was expressed that the dolmen chamber be removed. The solution found was to move the actual chamber to a suitable site located 36 m away, 13 m back from the edge of the cliff, while the remnants of the mound around it were investigated (Figures 1 and 2).

On Asnæs, in western Zealand, one end of a long dolmen was suffering degradation above a 4-m-high coastal cliff, and in 1986 half of the 23.5-m-long remaining part was investigated and reconstructed (Gebauer 1990). Despite consolidation of the coast, the outermost part of the reconstructed section is now, almost 30 years later, again close to collapsing on to the beach. However, it will be still many years before the original parts of the dolmen come under threat (Figure 3).

On a 7–8-m-high coastal cliff on the Hindsholm peninsula in northeast Funen stands less than half of a

Figure 1. Until 2008, the chamber in a long dolmen at Tryggelev Nor on the island of Langeland stood on the very edge of the coastal cliff. The kerbstones had fallen down on to the beach long ago. The remnants of the mound were investigated and the chamber was moved 13 m back from the cliff edge. Photo: T. Dehn.

Figure 2. Manipulated photograph showing both the original and the new position of the dolmen on Langeland. Photo: T. Dehn.

Figure 3. Long dolmen on Asnæs, Zealand. The outer end was investigated and reconstructed in 1986. The inner, intact part of the dolmen will not come under threat for many years. Photo: T. Dehn.

Bronze Age barrow: Lars Jens' Høj (site no. 080112-88). At the end of the eighteenth century, it was still possible to plough between the barrow and the edge of the cliff, and its ongoing destruction has been recognised for 130 years. By 1884, half of the barrow had been eroded away. In 1938, there was a wish to investigate the barrow, although no such action was taken. In 1952, the barrow was not considered suitable for scheduling because it was on its way into the sea. In 1960, an investigation was once again considered, but this was not carried out due to the barrow's poor state of preservation. In 1974, it was estimated that 3/5 of the barrow remained. Back then – as now – kerbstones and remains of a grave platform of water-rolled stones at the base of the barrow were observed. In 1989, the barrow was scheduled.

The investigation in 2002–4 of an intact, well-preserved Bronze Age barrow, Skelhøj, yielded significant new information on the construction of Bronze Age burial mounds (Holst and Rasmussen 2013). In research terms, this paved the way for a further investigation of Lars Jens' Høj, whereby the structure of the barrow could be read in section. Despite the fact that funding was made available for an exploratory investigation in 2011/2012, the barrow, complete with its stone platform, kerbstones etc., is still undergoing degradation today, in 2014. As a consequence of this, parts of a bronze sword and two other bronze artefacts were found on the beach below the barrow in summer 2014. On this occasion, part of the coffin platform, made of small water-rolled stones, was investigated. Wood from the coffin was preserved around the *in situ* remains of the remainder of the sword. It was concluded that this represents remnants of the barrow's central grave (Figure 4).

Figure 4. Lars Jens' Høj on Funen. The degradation of this Bronze Age barrow has been acknowledged for 130 years, but in 2014 a passer-by found a piece of a bronze sword on the beach below. An investigation of the barrow revealed that wood from an oak coffin still lay *in situ* around the remainder of the sword. Photo by drone: M. Nielsen.

Lars Jens' Høj illustrates the paradox that half of a 3–4-m-high barrow, which – in research terms – can potentially contribute to solving an interesting problem complex, can be allowed to slowly degrade, while every year, as a consequence of development works, several ploughed-down barrows are investigated where only a maximum of 0.5 m of mound fill remains.

The above three examples – like those provided by the churches Mårup Kirke and Lyngby Kirke – illustrate the fact that in Denmark there is not as yet an established procedure for how ancient monuments subject to the negative effects of the powers of nature should be dealt with.

The different courses of events evident in the destruction of Mårup Kirke and Lyngby Kirke show that the opinions of the local community are important in respect to how the scientific resource that these ancient monuments represent is administered. A comparison between the two localities reveals the important difference that Lyngby Kirke was demolished as early as 1913 and some of the materials reused in a new church, while Mårup Kirke was left intact after a new church, Lønstrup Kirke, was built in 1928 to take over the parish church function. Back then, the parochial church council in Mårup wanted the church to be demolished, but the National Museum of Denmark took on the maintenance of the building in order to preserve it for as long as possible. In 1952, the church and churchyard were transferred to the National Museum as a scheduled ancient monument. As a consequence of the administration of scheduled ancient monuments being moved from the Ministry of Culture to the Ministry of the Environment in 1988, the Forest and Nature Agency took over the National Museum's properties that included scheduled ancient monuments; among these was Mårup Kirke. In both Mårup and Lyngby, the churchyards were taken care of, and also occasionally used, even after the churches ceased to function as such.

For many years, it was the practice at Lyngby Kirke that the receiver of wrecks and the sexton from the new church gathered up the skeletal remains that fell down on to the beach due to erosion of the coastal cliff and reburied them in the new churchyard. In 1946, the churchyard was scheduled as an ancient monument and in 1976 – by which time only a small corner of the churchyard had been lost – the question was raised in a feature article (Thomsen 1976) of whether the churchyard should be investigated archaeologically before it disappeared. In 1981, the author of this feature article asked the Minister for Ecclesiastical Affairs to promote an investigation before it was too late. In the light of this, Aalborg's diocesan authorities held a meeting in Rubjerg vicarage, at which all the ecclesiastical authorities, museums and scheduling authorities were represented. There was broad support at the meeting for the parochial church council's wish that there should be no disturbance of the graves in the abandoned churchyard – either for the purposes of an archaeological excavation or for the relocation of the graves. Behind this view lay an acceptance of the fact that degradation of the cliff and, as a consequence, the churchyard was a natural condition of the place and part of its history. Despite the fact that, from an anthropological point of view, it was desirable to secure the skeletal material for scientific analysis, it was decided to respect the views of the local community.

The argument at Mårup Kirke has been slightly different. In the prolonged process that has taken place since the cliff approached the churchyard boundary in the 1990s (Dehn 1990), local groups have worked hard in support of the installation of coastal defences that could prevent or delay the disappearance of the church and its churchyard into the sea. The Danish Coastal Authority, the body responsible for coastal defences in Denmark, was however not willing to carry out this work. In 1994, the costs of partial coastal defences were estimated at 6.5 mill. DKK, with annual maintenance costs of 730,000 DKK. It was judged that this work would be able to secure the locality for 10–15 years. Nobody was interested in the dismantling and relocation option and, as mentioned earlier, there were no funds for a (buildings–)archaeological investigation, because this is a scheduled ancient monument. It is not the author's understanding that the dismantling of Mårup Kirke was the result of an intentional prioritisation of nature over culture by the Ministry of the Environment. Economic resources for a 'cultural solution' were simply not available, and the 'natural solution' was therefore the only one possible. It was even in accordance with the wishes of local people, with Mårup Kirke seen as a spectacular tourist destination, with associated opportunities for income. Neither is it the author's understanding that there was any conflict between Jutland and Copenhagen. The church was administered by the Forest and Nature Agency's local department, northern Jutland's state forest district, which set up a contact group with local interested parties.

Regardless of the course that events took in this process, posterity will undoubtedly appreciate that the matter nevertheless concluded with a successful buildings–archaeological investigation that considerably increased knowledge of medieval churches and, furthermore, made it possible for the church to be rebuilt in another location (Bertelsen 2009).

One of the crucial factors with respect to whether an ancient monument is simply allowed to be destroyed on the coast without intervention is the current antiquarian legislation. The two abandoned medieval churches are covered by the Museum Act, while the lighthouse Rubjerg Knude Fyr, which is of a later date, is not covered by any such legislation – not even the Building Preservation Act. One might therefore be tempted to believe that society has made a choice with respect to the monuments it wishes to preserve and those it does not.

But this is not always clear-cut. The Cold War fortification Stevnsfortet was cut into the chalk cliffs of eastern Zealand in 1950–3 and comprises 46 rooms and 1.7 km of passageways running about 18 m below the surface. It was armed with cannon and had the function of controlling the southern part of the Oresund. Following the collapse of the Berlin Wall in 1989, this coastal fort lost its military significance and it was abandoned by the Danish Defence in 2000 (Pedersen 2013). Maintenance of the fort in an intact state involved expensive running costs relating to pumps and ventilators. There did not seem to be a willingness to meet this expenditure, so it appeared as though the fort would be sealed off and abandoned. However, in political quarters an interest was developing in the Cold War as history. A right-wing government had been elected in 2001 and the Minister for Culture at that time, Brian Mikkelsen, led the way in obtaining funding for the fort's preservation. In 2008, the fort reopened as one of several museums with a Cold War theme.

This is an example of 'the choice between preservation and destruction depends on the object and the context in time and space'; similarly, the narrative can be significant (Wienberg 2014, pp. 9–10). However, if the decisions that have been made in Denmark in recent decades with respect to ancient monuments threatened by destruction, including those affected by coastal erosion, are considered from a more general perspective, the author sees no evidence that nature has been prioritised over culture – rather the opposite (see below).

The examples presented above can give the impression that it has only been possible in exceptional circumstances to carry out the securing or investigation of ancient monuments threatened with destruction by coastal erosion. In spite of the deficiencies in the legislation and the lack of economic provision, this has, however, been achieved in a few cases.

A research project involving the systematic investigation of 24 medieval castle mounds, executed between 1982 and 2004 on the islands off southern Funen, was in part initiated because five of these sites were undergoing destruction as a consequence of coastal erosion (Skaarup 2005, p. 8).

The directly threatened part of a dolmen located in southern Funen, Damsbo Skjoldmose, was recorded in 1984 for private funds in conjunction with Niels H. Andersen's investigations in the Sarup area (Andersen 1985). Destruction has continued in the intervening period, but the initial investigation has unfortunately not been followed up (Figure 5).

The castle mound of Vesborg on Samsø, of which almost half has disappeared since its construction in the fourteenth century, was investigated in 2009 as part of the Danish National Museum's research project on Samsø's medieval fortifications (Etting *et al.* 2010).

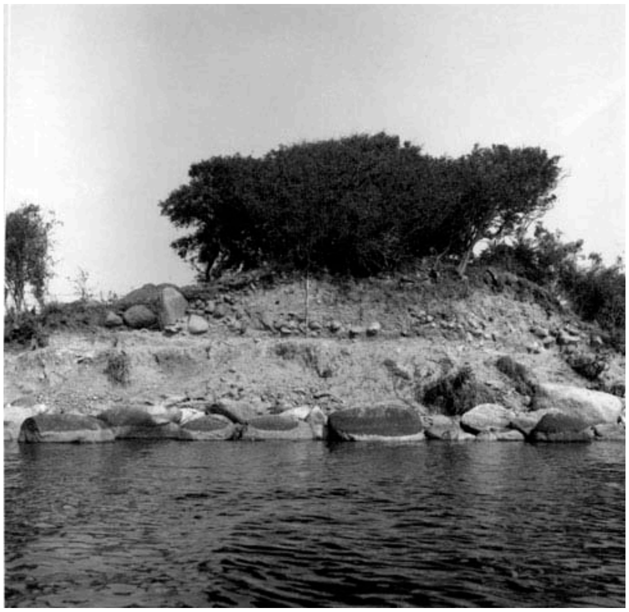

Figure 5. The cleaned section in the coastal cliff, showing the most threatened part of the dolmen Damsbo Skjoldmose on Funen, 1984. Photo: J. Jeppesen.

None of these three investigations involved total excavation, merely limited investigations of the directly threatened parts in order to secure important information with respect to date, extent and construction. The arguments made in favour of granting investigation/excavation consent included the fact that these sites were undergoing degradation.

Archaeological excavation of threatened sites is, however, not the only option with respect to securing information. Another possible solution is to consolidate the coast along the critical stretch. This was carried out on Stevns Klint in 1928, after the chancel of Højerup Kirke collapsed into the sea. The cliff was reinforced with a supporting concrete wall and a pierre-perdue (rubble mound) at its foot. These measures were subsequently repeated and extended in 1954, 1962, 1974 and 1981 (Vesth 1991).

There is another example from Årup Hede, near Gram. In 1983, a barrow standing on the bank of the river Fladså was about to be undermined due to a change in the course (meanders) of the river (site no. 200201-113). The area was subject to a nature protection order, according to which no inference with natural developments, such as altering the course of the river, was permitted. The conflict was, therefore, clearly between obvious nature interests and the preservation of a virtually intact prehistoric monument. In this case, the relevant conservation authority – the Nature Conservation Board – granted a dispensation from the protection order, allowing work to be carried out to consolidate the river bank such that the barrow was not undermined.

A third case is that of the castle mound Hindsgavl Borgbanke, located on the Funen coast of the Little Belt (site no. 080713-29). The first mention of the castle is in the thirteenth century, but it was abandoned when a large part of the site was destroyed by the sea in 1695. Since then, the castle has been a ruin. However, in conjunction with an initiative launched in 1987 to begin management works and allow public access, the possibility of consolidating the coast was also raised. Despite opposition from nature conservation interests in the form of complaints about a dispensation relative to Danish coastal protection legislation (*Strandbeskyttelseslinjen*), coastal defences were established in 1991. However, by 2004 these defences had already been destroyed by shipworms and unfortunately no economic resources were available for their replacement.

The consolidation of coasts and river banks is unfortunately not a sustainable solution. As a rule it merely postpones the decision to be taken by future generations. The actual works involved are expensive and it can be difficult to predict and evaluate their effects and consequences. For example, it is generally accepted today that coastal defences are degraded and non-scheduled settlement sites from all periods are also allowed gradually to disappear without being consolidated or investigated. It is the author's view that the value of these threatened ancient monuments as source material should be evaluated on an equal footing with all other ancient monuments and that they should be included in the prioritisation of economic resources for archaeological investigations, if long-term consolidation of these sites is seen as being unrealistic. The argument in favour of this is that these sites often hold the potential to yield completely different information from that provided by ploughed-down sites. Equally important is the fact that allowing destruction of these monuments without investigation has a negative effect on the general respect for other ancient monuments and efforts to preserve them as monuments in the landscape.

In spite of the cases outlined above, where archaeological investigations have been carried out or protective measures against erosion have been undertaken, it is not possible to speak of a generally accepted procedure with respect to dealing with ancient monuments in danger of being undermined by erosion of coasts and riverbanks. Over the years there appears to have been a somewhat haphazard approach to the question of how the degradation of an individual monument is dealt with: investigation, protection or complacency. However, experience shows that taking account of nature in the otherwise restrictive Nature Protection Act's coastal protection legislation is, in practice, not an obstacle to the securing of the information held in these monuments through acute investigation or protective measures.

In the author's view, 'creative dismantling' does not only take place in conjunction with cultural heritage sites that are degraded by the forces of nature. Is not every archaeological investigation a form of 'creative dismantling', if the investigation is carried out to save information from destruction, regardless of whether this destruction results from natural forces or society's wish to build for example a motorway? Preservation of the original components of the cultural heritage and displaying them in another location – for example artefacts or a dolmen chamber – is also a possible option. Essentially, the academic or research-related result of an archaeological investigation is not dependent on whether the investigation was prompted by coastal erosion or another instigator of rescue excavation. One difference could, however, be the economic resources that are or are not available for this intervention. Their presence or absence is determined by the legislation and its administration, as well as the potential to avoiding destruction by making changes to the development works that present the threat.

Another difference relates to whether there is a visible monument that is part of the landscape, but this is also not always clear-cut. During the construction of a stretch of motorway between Fredericia and Vejle in 1992, an unrecorded, ploughed-down Bronze Age barrow with a diameter of 57 m was encountered; it had been built over a round dolmen (Holst 2006). It was too late to change the route of the motorway, so following investigation both the barrow and the dolmen chamber were rebuilt some distance away in conjunction with a motorway service station. This can be referred to as 'creative dismantling' or simply an ordinary example of an archaeological excavation followed by presentation of the results at a scale of 1:1.

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DISCUSSION ARTICLE

Conservation of historic buildings along the eroding coastline of Northern Jutland

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Introduction

The erosion of the western coast of Northern Jutland, in Denmark, has generated an extremely challenging environment for the preservation of architectural heritage. This phenomenon causes the loss of approximately 2–4 m of shore per year, and tends to become more and more severe, leading to the loss of as much as 11 m of shore in a single year. This constitutes a major threat to important historic buildings close to the coast. Jes Wienberg's article describes how the early thirteenth-century church of Mårup, in Lønstrup Klint, recently had to be 'dismantled under supervision', in anticipation of the erosion of the ground below the church and the historic cemetery surrounding it. This astonishing decision was preceded by a fierce debate, an account of which has been provided by Casper Bruun Jensen and Randi Markussen (2001, pp. 795–819). Although this decision was controversial, it was not unique in the history of the region. As Wienberg reminds us, in the early twentieth century, similar natural phenomena led to the dismantling and rebuilding of other monuments in the same area, such as the late medieval church of Rubjerg and the church of Lyngby. But, as the above article points out, erosion is not the only threat to the coastal heritage of north-western Jutland. Sand drift has led to the accumulation of sand around historic buildings hindering access to them, and, sometimes, covering part of their fabric. The intensity of this phenomenon is reflected in the gradual redundancy of the 1900s lighthouse of Rubjerg Knude, which started only half a century after its construction.

Counteracting coastal erosion and sand drift has proven to be more complex than it may seem at first sight. This is not only because of the elevated cost of coast protection, but, mainly, because coastal decomposition and sand dune formation also enjoy legislative protection as the generators of a uniquely significant coastal landscape. The decision that these natural phenomena should continue unhindered sealed the destiny of Mårup church. This implies that the protection of nature was given hierarchical priority over the protection of the church.

Wienberg has analysed the decisions affecting the dismantling of the churches. His article has investigated the influence of the debate concerning Mårup church on the evaluation of its significance, and interpreted the divergence of perceptions of the building by local societies (such as 'the Friends of Mårup Church'), archaeologists and the central government. This interesting study raises questions about the future of architectural heritage along this coastal region. The cases of Mårup, Rubjerg and Lyngby show that the dominant approach to the problem of preservation in this region involves the dismantling of buildings that had stood in their site for centuries while the sandy landscape they are built upon is claimed by the sea. One might ask whether this approach constitutes the best compromise between the preservation of architectural heritage and nature. To answer this question, it is necessary to consider the implications of this approach for the durability of the built environment as well as for the interaction between architecture and nature in this region. Considering these implications is essential to answer the questions regarding what should be preserved and how.

Durability and architectural heritage

The decision to destroy or relocate coastal monuments threatened by coastal erosion challenges the right of coastal communities to create and preserve buildings with a commemorative role. Not only are their historic monuments disappearing, but their loss also discourages long-term planning: with the coastline receding at this pace, it is very difficult to envisage any new public monument built less than 500 m from the sea. These conditions are hardly favourable for the preservation and creation of monuments durable enough to be shared by different generations. Yet, such durable monuments fulfil an important social role: they constitute lasting points of reference and essential elements of the local cultural identity. As Hannah

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Arendt has observed, the existence of a community that gathers people together and relates them to each other ‘depends on permanence’. Public space ‘cannot be erected and planned for one generation, but must transcend the lifespan of mortal men’ (Arendt 1998, p. 55).

Small churches like the ones of Rubjerg and Mårup have played this role for centuries. Their survival until the twentieth century suggests that their poor, provincial communities, in spite of their limited resources, found the materials, expertise and energy required to preserve buildings that acquired a commemorative role. The church of Mårup, for instance, kept playing a memorial role long after the settlements that originally surrounded it disappeared. Indeed, the church and its graveyard commemorated the loss of three British ships nearby. The anchor of *HMS The Crescent*, which sank during the Napoleonic wars, was placed prominently in front of the west elevation of the church. These memorials constituted the visual manifestation of major episodes in the history of the local community. Thanks to them, historical events became rooted in local traditions and narratives that now form part of the local culture.

The loss of such buildings will make it more difficult to remember and understand the history they were associated with. This history, from now on, will be only accessed through publications and museum exhibitions.[1] Still, one might ask whether these sources of information can substitute everything a monument has to offer in this respect. However informative a publication may be, it lacks the presence and permanence of a local monument. Unlike museum exhibitions, monumental buildings constitute the only source of information that allows the observer to interact with the site of historic events. Looking at the giant anchor of *The Crescent* with the sea in which the frigate sank in the background provides a memorable learning experience that cannot be replaced by other media. The above observation naturally leads us to examine another quality of durable monuments like Mårup church: their interaction with an environment subject to constant change.

Architecture and nature

The Danish Government claimed that the dismantling and eventual removal of specific historic monuments along the coastline was necessary to maintain the natural decomposition of the coastal cliffs and the sand dune formation process (Jensen and Markussen 2001, p. 810). At a time when the dune areas elsewhere Europe are being threatened (Jensen 1994, p. 268), and great parts of the Mediterranean coastline are disrupted by speculative touristic development, the decision of the Danish Government may be interpreted as a sign of environmental consciousness. On the other hand, this same decision also reflects the belief that building preservation is incompatible with ecology. This seems to overlook the efforts of the last 50 years to incorporate environmental data in the planning process, reconciling planning and ecology, built and the natural environment (McHarg 1992, p. iv). The possibility of reaching a compromise between natural process and heritage preservation does not seem to have been adequately evaluated when the decision to dismantle the churches was taken. The following paragraphs cannot hope to fill this lacuna. This requires systematic, site-specific study and collaboration between conservation architects, planners and landscape urbanists (Feilden 2003, pp. 191–202, describes the role of these disciplines). However, it is possible to give the brief outlines of an alternative approach to the problem of reconciling natural process and heritage preservation.

This approach suggests that the maintenance of historic structures in a landscape subject to constant change may enhance our ability to evaluate, measure and experience this change (Kostof 2010, p. 10). Thanks to their durability, historic monuments constitute ‘golden threads’ that link different stages in a site’s history. Their continued presence provides the datum points necessary to understand the development of their changing context. In the case of Jutland, the local protection of the coast around monuments such as Mårup church should be viewed not only as an obstacle to coastal erosion and dune formation but also as a means to understand these processes better. If soft landscaping was developed to prevent coastal erosion around Mårup church, the church could become an ideal vantage point from which to observe this natural phenomenon. Experiencing the increasing distance between the protected church and the receding shoreline outside the protected zone could have raised our awareness of the phenomenon of coastal erosion.

Coastal protection depends largely on our ability to model the formation of dunes and to anticipate the coast’s reaction to human intervention. Comparable examples such as the Dutch defences against the violent sea may be particularly useful here, as they involve ‘soft’ measures that preserve the elements of the natural landscape. These techniques include the stabilisation of dunes with appropriate plants and their protection from human activity, the preservation of the littoral drift, this sea-induced transportation of sand that nourishes the dunes, as well as the building of natural dikes with layers of twigs, sand and clay (McHarg 1992, p. 7–17). These techniques are friendlier to the environment than the techniques employed elsewhere in Jutland, such as shore revetments and groynes (i.e. artificial barriers constructed perpendicularly to the coast). The expertise accumulated from these ‘soft’ interventions shows how the maintenance and reinforcement of dunes can serve to preserve the coast, its morphology *and* its monuments. This method could be used to prevent coastal erosion along the entire coast.

Alternatively, it could focus on zones of coastal protection outside which erosion can continue unimpeded.

An inclusive approach to architectural heritage

One of the most iconic confrontations between the man-made and the natural in Northern Jutland is found in the lighthouse of Rubjerg Knude. Periodically submerged in sand dunes and redundant, the elegant 1900s building seems condemned: it will be destroyed prior to the erosion of the ground it is built upon. As Wienberg has observed, although the lighthouse is a fine example of the region's industrial heritage and a memorial of Denmark's naval history, its scheduled destruction has not been met with the same public opposition as the one organised for the church of Mårup. The public's discrimination between the two buildings may reflect the way in which their significance is perceived today, on the basis of their age, uniqueness and social role. Similar discrimination and different degrees of protection between different 'classes' of buildings characterises most conservation legislations, including that of Denmark (Skovgaard 1978, p. 520–3).

Discrimination between monuments may prove to be problematic when the criterion is not the significance of the monuments but their association with the most popular aspects of a community's history. This kind of discrimination favours only one aspect of an area's heritage, the one that fits better with the dominant perception of history; buildings that represent less popular narratives are lost. There are countless examples of this selective approach to architectural conservation in recent European history. Every one of them was marked by the loss of the architectural vestiges of entire periods: a large part of the medieval tissue of many European cities was lost during the urban regeneration of the nineteenth and the twentieth centuries; the emergence of new nation-states in the Balkans and Asia Minor was detrimental to the preservation of monuments that did not serve the new religious, cultural and political agendas. Similar phenomena distort our current understanding of several historic sites that have lost entire phases of their history.

We realise that discrimination *between* buildings can often lead to discrimination *against* buildings. In the case of Mårup church, one might ask whether the focus on a single significant landmark represents the best strategy to preserve the region's architectural heritage. Indeed, even if this strategy had proven to be successful it would have only guaranteed the preservation of only one part of this heritage. Focus on key monuments makes it difficult to justify the preservation of theoretically 'lesser' buildings, such as the lighthouse, which are very likely to become vulnerable. Yet, these buildings and their interaction with their surroundings may prove to be essential components of the site's character, history and identity. Their disappearance may therefore create a far greater loss than a simple assessment of their individual significance may initially suggest.

The above observations suggest that the campaign for the preservation of architectural heritage may be more convincing if it focuses on broader areas instead of isolated buildings. This ensures that what is preserved is a true reflection of the history of a community and representative of the full spectrum of its architectural achievements. Reflecting the deliberations of the 1975 Congress on the European architectural heritage, which led to the famous 'Amsterdam Declaration', this inclusive approach to heritage makes it possible to preserve a wide variety of historic buildings in a given site and to avoid the meaningless and artificial isolation of key monuments.[2]

The practice of 'creative dismantling'

The concept of 'creative dismantling' seems to have marked the preservation of church architecture in the region. The National Museum started dismantling the church of Mårup in August 2007. 'Dismantling' was preceded by detailed investigation and was carried out methodically, stage by stage. The removed parts were stored in order to be reassembled in an open-air museum in the future.

This was not the first time that a monument is treated in this way in Jutland: the churches of Rubjerg and Lyngby were relocated in a similar manner in the early twentieth century. This is a recurrent phenomenon in Denmark: several buildings of Aalborg were moved to an open-air museum; a large farm building which is now at Hjerl Hede was originally built in the village of Vinkel, near Viborg (*ibid.*, 535). This practice is also encountered outside Denmark. Spon Street, in Coventry, UK, is partly lined by medieval timber buildings that were relocated there from elsewhere in the city, during the post-war redevelopment of the war-torn city centre (Charles 1984, p. 59, 224, 229).

At first sight, this technique may seem to protect buildings by taking them away from sites that compromise their chances of survival. One could also claim that open-air museums facilitate access to the buildings and provide an environment suitable for their study. On the other hand, relocation risks 'fossilising' historic buildings, emptying them from the function that once animated them. Another disadvantage of similar relocations is the loss of archaeological evidence during dismantling. However careful the latter may be, not all the fabric can be moved intact, nor are modern craftsmen always able to reproduce every aspect of the original structure. In the case of Mårup church, for instance, none of the internal arches had a regular tracing. Like most medieval structures, they were non-geometric, the products of a 'free-hand' method of construction. The future reconstruction risks erasing irregularities that constitute essential elements of the building's medieval character. Considering a building's relocation one should note the caveat expressed by one of the most important architectural historians of the twentieth century. For Spiro Kostof, 'no building is sufficient unto itself'. Its character partly derives from the building's interaction with its changing setting (Kostof 2010, p. 10). To remove a building from its setting is to deprive it from part of its character.

Both the practice of relocating buildings to open-air museums and the perception of their maintenance as antagonistic to natural processes reflect a static perception of architectural heritage. Placing buildings in static, contrived environments overlooks the potential of their character to evolve due to the changes in their setting. Had the churches of Northern Jutland been preserved *in situ* they would have constituted an excellent illustration of how a dynamic landscape can affect a buildings' character. The dismantling of Mårup church brought an end to the fascinating interaction between this building and its surrounding landscape. To profit from a similar interaction in the future, further efforts need to be made to reconcile the preservation of nature with the preservation of architectural heritage.

Notes

1. This instance seems to confirm the prediction expressed in Victor Hugo's *Notre Dame de Paris* concerning the undermining and replacement of architecture by the printed word. See E. V. Ellis (1997), p. 37.
2. The Amsterdam Declaration can be accessed through the site of ICOMOS. It states that 'the architectural heritage includes not only individual buildings of exceptional quality but also their surroundings as well as all areas of towns or villages of historic or cultural interest'.

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DISCUSSION ARTICLE

Transience and the objects of heritage: a matter of time

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Introduction

Let me start by briefly recapitulating Sigmund Freud's short but seminal essay from 1915 on 'transience' (Freud 1957b). In this essay, Freud relates a conversation with two friends as they are strolling in a beautiful countryside setting. Freud describes how one of his companions – a poet – admires the beauty of the scenery, but how he cannot feel any real joy in the beauty of the landscape, because he knows that the beauty will vanish some day and be doomed by the transience of all things material. For the poet, the transience – or *Vergänglichkeit* – of whatever is beautiful means that it loses its worth. In the essay, Freud advocates an entirely opposite attitude. He argues that the temporal limitations of an object do not devalue the object, and that transience may indeed increase the importance of the object. Seeing things perish may of course be difficult – as in all cases of true mourning – but if we are not capable of letting go, Freud argues, then we end up in the pathological state of melancholia (Freud 1957a).

Freud's position on mourning and melancholia has been challenged by more recent research on bereavement and grief (Klass *et al.* 1996, Howarth 2007, see also Bjerregaard *et al.* in prep.), yet I believe that it is worthwhile – if not necessary – to return to Freud's praise of transience in light of the widespread paranoia of losing material culture characterising much contemporary heritage management and heritage politics. In the present issue of *Danish Journal of Archaeology*, Jes Wienberg offers a very stimulating and for some readers probably also provocative perspective on the dismantling of heritage objects. Wienberg makes the interesting suggestion that certain heritage sites – in his case architecture – can be 'creatively dismantled'; a managerial practice located somewhere between 'preservation' and 'destruction'. I believe that Wienberg's discussion of four churches and a lighthouse on the coast of north-western Denmark needs to be set in a greater conceptual discussion, relieving the architecture of the limited geographical and thematic confines within which Wienberg has chosen to delimit the scope of his article. I would argue that two aspects of Wienberg's argument in particular hold the potential for further elaboration and critique: first the notion of 'creative dismantling' and second the notion of threat. In the following, I explore these issues through a critique and an example.

Dismantling destruction

The notion of 'creative dismantling' of course already forms a key concept in Wienberg's discussion, but Wienberg fails, in my opinion, to do full justice to the concept by not developing it conceptually and by not reflecting more substantially on the origins of the term. As Wienberg points out, the idea of 'creative dismantling' is a paraphrase of economist Joseph Schumpeter's notion of 'creative destruction'; yet, I find it worthwhile to clarify that 'creative destruction' was introduced by Schumpeter as a description of the disruptive mechanisms of economic growth and capitalism. In an ever-intensifying market economy, Schumpeter argues, the cycle of innovation, expansion and downsizing will lead to a constant reconfiguration of the socio-economic order and, hence, result in a process that is both creative and destructive at the same time:

> The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory (…) illustrate the same process of industrial mutation – if I may use that biological term – that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism (Schumpeter 2003, p. 83).

Wienberg's notion of a creative reconfiguration may at an elementary and rather under-theorised level share certain characteristics with Schumpeter's critique of capitalism. However, Wienberg's choice of changing the vocabulary from 'destruction' to 'dismantling' in fact disarms the most compelling and radical potential in

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translating Schumpeter's concept into the field of heritage management, namely the destructive element itself.

For Wienberg, 'dismantling' is preferred to 'destruction', because it may assume a position between preservation and destruction, whereas destruction is about changes 'perceived as negative', such as perishability, oblivion and erasure. So, while creative *destruction* is associated with the negative and chaotic demolition of a building, creative *dismantling* is synonymous with a controlled, supervised and seemingly more gentle deconstruction of the architectonic unit, where as much as possible of the building material is damaged as little as possible. 'Dismantling' furthermore implies the potential for knowledge production and future reconstruction, whereas destruction results in the erasure and loss of the architectonic unit. The implication seems to be that a dismantled architectonic unit is never *really* lost, because it may be reconstructed in a different location and context.

In this distinction between destruction and dismantling, I believe that a crucial quality of Schumpeter's original point is lost, as he argued that the destruction of one object or condition would lead to the creation of something new, which is, in fact, at sacrificial logic (cf. Hubert and Mauss 1964, see also Willerslev 2009). Wienberg does indeed observe that 'all archaeology is both destructive and constructive', recognising the very sacrificial principle of common archaeological research methods, such as field excavation or laboratory analyses, where cultural layers or samples are destroyed in order to achieve knowledge. However, Wienberg does not fully extend the consequences of this observation to the five buildings on the coast of Jutland. Instead of embracing the archaeological sacrificial logic wholeheartedly, he seeks to preserve the dismantled building for potential future reconstruction. This means that he does not even consider the possibility that Mårup church could be allowed to vanish (yet this possibility has been aired in an older article, see Wienberg 1999, p. 199).

Disappearance as a cultural artefact

Let us consider for a moment what might be gained if Mårup church had been left on the verge of the Jutland, accompanying the graves that are for some reason allowed to remain in place, and gradually tumble down the cliff as the erosion progresses. Had Mårup been left in place to gradually be consumed by geological erosion, we would need to face, and potentially accept, the very *process* of destruction and disappearance as a cultural artefact in its own right, allowing us to rethink more critically the relationship between nature and culture, time and change, perishability and history. This form of disappearance through the forces of geological erosion would indeed have had disruptive material and culture–historical effects, but it would also contain the potential for an increased awareness of the temporality of heritage and the constant changeability of the material world, redirecting the narrow, parochial focus on Mårup in favour of a deeper consideration of materiality, duration, pastness and futurity.

My point is not simply to roll back to a Romantic attitude to ruins and decay (not that I see anything inherently wrong in that attitude), but rather to voice a critique of conservation and protection as the unquestionable norm and ideal for whatever phenomenon is designated as 'heritage'. When objects, places or buildings are canonised (formally or informally) as 'heritage' they currently seem to be circumscribed, automatically, by a popular and institutional paranoia of disappearance and decay, and any recognition of perishable qualities in the object is entirely lost. However, I would argue – following Freud – that it is only by observing and appreciating the transience of things that we can truly begin to cherish objects and human life with objects, whether extant or vanished.

I thus advocate decay and demolition in certain cases, not because the past or history is a burden that can be relieved by disappearance and forgetting (cf. Wienberg 1999, p. 184), nor because decay is 'the story on [sic] inevitable impermanence' created by the conjunctures of Western capitalism (Wienberg, this issue), but because the very process of decay and disappearance – including acts of demolition and destruction – is to be considered as an object of heritage in its own right, allowing us to reflect on materiality, time and being (see also DeSilvey 2012, DeSilvey and Edensor 2013).

Threatening heritage

This brings me to the second issue in Wienberg's article that I see as particularly worth pursuing as a potential critique of current heritage agendas. Wienberg argues that threat is a dominating principle in the production of heritage, and he contends that threats are about changes perceived as negative. A threatened heritage object is thus an object in danger of disappearing, because, following Wienberg, disappearance is perceived as negative. For me, however, threat is not so much about negative effects, but rather about perceived vulnerability, emergency and precarious futurities (cf. Anderson 2010, Massumi 2010, Adey and Anderson 2012, McCarthy 2012), and I would like to explore threat and heritage from this perspective.

If Wienberg had scaled the cliffs and strolled the shores further south in Western Jutland in the summer and autumn of 2013, he might have added yet another dimension to the discussion of threats, protection, conservation and destruction. During the German Occupation, thousands of military fortifications were built in Denmark, the majority along the west coast of Jutland as part of the Atlantic Wall. A total of approximately 600 concrete bunkers are registered in the coastal landscape (Andersen and

Rolf 2006), yet others have already disappeared into the sandy beaches or the ocean since the Occupation. Some bunkers have been conserved and turned into formal culture-historical museums, for instance at Hirtshals and Hanstholm, while other concrete remains of the Occupation heritage are scattered along the coast in various states of deterioration.

In the spring of 2013, the Nature Agency and The Coastal Authority (under the Danish Ministry of the Environment) decided in collaboration with the Ministry of Transport and five municipalities in Western Jutland that around 120 bunkers should be demolished as they pose a threat to visitors and tourists, strolling the beaches and swimming in the water. After 70 years of exposure to the environment, the concrete is deteriorating in many places, and its iron reinforcement becomes exposed. The problem is that concrete fragments and iron bars are partially or entirely hidden under the water, which has resulted in a number of accidents, when swimmers have made close contact with the architectonic heritage of the Second World War. The removal of the undesired bunkers has proven very popular, and when the first bunker was demolished in July of 2013, the Minister of the Environment made her appearance in front of media and popular attention, celebrating the initiative to demolish the bunkers (Gade 2013, Lundsgaard 2013), which in effect eradicates a part of the national and international cultural heritage. This case brings out an unresolved tension between the protection of cultural heritage against people and the protection of people against cultural heritage, produced by ambiguous notions of 'threat'.

Taken at face value from the most pedestrian perspective, the bunker fragments on the shore are a threat because they can hurt people physically, but I believe that there is more to the definition of threat and damage than meets the eye in this case. I would argue that the bunker fragments are managed as dangerous waste and not as heritage, not so much because they are hazardous, damaged or, for some, ugly. Rather, they are defined as waste because of what they *do*: they possess a particular material and temporal capacity for emergence or to be emergent in uncontrollable ways, suddenly, unavoidably and with undeniable immediacy.

The emergence of the bunker fragment and its iron reinforcements is rapid and unforeseen, surfacing suddenly and violently, exposing the vulnerability of the human body and corrupting the possibility for reflecting calmly on heritage that is definitively 'past' (González-Ruibal 2006). While other bunkers, such as those organised as museums, are cherished as formal heritage sites, the decaying and corroding bunkers in the water do not obey the laws of tangible heritage by refusing to remain passive and inert media for retrospective historical contemplation as they continue to exert an agency and thus remain unfinished (Hetherington 2004).

So, somehow it seems that tangible heritage must remain conserved, unchanging, inert and passive, not confusing the borders of past and future, nature and culture (Edensor 2005, DeSilvey 2006, Harrison 2012), which is constantly what the bunker fragments on the beaches are doing: they are seamlessly interwoven in the rhythms of rolling waves and tidal change, and they merge into the gradual movements of gravel and sand grinding the concrete down, thus exposing and sharpening the iron reinforcements. In this perspective, the canonised cultural heritage object reveals itself as a truly modernist construction, setting up a wide range of strict dichotomies between nature and society, humans and non-humans, agents and patients (Sørensen 2013, but see also Simmel 1959).

Instead, the decaying bunkers force themselves onto us in their own time and at their own bidding, regardless of whether we want their presence or not. I would argue that this is the reason why the corroding and disintegrating bunkers cannot maintain their default status as heritage, because 'ordinary' or 'proper' heritage – at least in Denmark – needs to be controlled and controllable, domesticated, and brought under the regulation of the cultural system (see also Smith 2006). *Cultural* heritage, it seems, needs to be at our disposal, at our convenience, and it needs to be safe in order to deserve safeguarding.

Letting go

And the Danish ideal of a complacent and receptive heritage is presumably also the reason why Mårup church had to be taken down and why the lighthouse at Rubjerg Knude will also be removed in 2020, so that visitors to the sites or the shore will not be threatened by the tumbling debris of collapsed heritage. Just like the graves emerge in the profile of the cliff, exposing the vulnerability of human existence, so would a collapsing historical architecture give us reason to rethink the uncompromising conservationist agenda that produces an impotent and immobile heritage. It would, in my opinion, be more poetic and more intellectually challenging to allow the ruins to disintegrate and collapse to the rhythms of coastal erosion, celebrating the more brutal aesthetics of the relentless metamorphosis of all material phenomena.

Interestingly, unlike the local opposition to the dismantling of Mårup church, bunker destruction has been widely welcomed by municipal politicians, local stakeholders, residents and tourists, and only a few voices have questioned the removal of the 120 'dangerous' bunkers (Maressa 2013, Pedersen 2013). This also testifies to Wienberg's observation, constituting the fundamental subtext in his argument; that the choice whether to conserve or destroy is a matter of the narratives that are told about objects from the past (echoing Waterton and Smith 2009). I agree with Wienberg that the critical issue is not so much *if* the four churches and the lighthouse should be conserved or removed, but *how* either action should materialise. I am, however, not convinced that 'creative dismantling' really achieves anything different than conventional heritage management, and I believe that there are compelling reasons to explore the possibility for a more radical creativity that allows for an exposure of the decaying process, leading to the ultimate disappearance of the material traces of the churches and the lighthouse (see also Holtorf 2006, Sørensen 2007, Harrison 2013).

In the light of the political initiative to remove bunkers on the West coast of Jutland, the question furthermore arises if the process of decay (or for that matter deconstruction and dismantlement) could be turned into truly creative components of heritage management. Might it be possible to establish a temporary and contemporary space for exploration, reflection and intervention on heritage, temporality and pastness (Varvantakis 2009) by allowing people to participate in the demolition of architecture and the creation of narratives, by actively inviting processes of departure with things as cultural events?

As Freud observes, departure and separation is often difficult, but nevertheless indispensable. So the question is, in terms of heritage, not necessarily what is lost when things vanish, but maybe, rather, what is lost when we fail to let things go in favour of a compulsion to conserve. Would it be possible not always having to conserve things as physical objects, but instead to sustain them as memories and narratives, and maybe then to cope with departure and disappearance, and remind ourselves that tears will, eventually, let up? In conclusion, we may recall a few lines from a song that was probably well known to the occupants of the bunkers on the West coast of Jutland 70 years ago (performed by Lale Andersen, music by Fred Raymond, lyric by Max Wallner and Kurt Feltz, 1942):

> Es geht alles vorüber, es geht alles vorbei
> Darum fällt der Abschied doppelt schwer, doch sie sagt:
> 'Jetzt wein ich nicht mehr!'

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DISCUSSION ARTICLE

Back to the edge – heritage management, landscaping or contemplation

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The quest

Heritage at the edge of Jutland, and especially the destiny of the deserted medieval church of Mårup, evokes thoughts and feelings. Mårup has become a controversial icon of perishability, a 'memento mori', appealing to almost everybody. The image of the church and cemetery just a few metres from the edge of the cliff fascinates: What ought to happen? Should the church be saved and if so, how is it possible? The viewpoints have been and still are many and divergent.

Over the years when I have lectured and been writing about the church of Mårup (and now also three other churches and the lighthouse at Rubjerg), my words, texts and pictures have constantly been met with strong reactions. Mårup seems to be a contested example of heritage, and everybody seems to have their own opinion of what ought to happen. Over the last 15 years, I have received critical comments from listeners, readers, session leaders, editors and peer reviewers, where the comments together far exceed my own output. However, these reactions are only a small portion of the greater debate at the place, between locals and different authorities and in the media.

Even if the debate has been extensive, there are no clear-cut answers to the questions that Mårup and other sites raise; one must always look for other solutions. Therefore, I will thank three colleagues for adding new layers to this never-ending debate and contribute a few comments in reply to the comments in our common quest.

Heritage management

Not surprisingly, Torben Dehn from the Danish Agency for Culture, which is responsible for the process at Mårup, finds the present management impeccable. He cannot identify any contradictions or conflicts and sees no need for new concepts. The only matter that worries him is the arbitrariness observed in the management of threatened heritage at the coast, where different strategies have been applied; the sector of heritage management like all rational agencies always looks for uniform rules. According to Dehn, the church of Mårup and other monuments threatened by slow decay ought to be treated like other threatened objects, namely by conducting rescue archaeology.

If new and better antiquarian practices can be a consequence of the experiences from Mårup, it would surely be an improvement. Thus, there is now an official heritage strategy concerning the many deserted medieval churches in Denmark (cf. The Ministry of Environment www.kulturstyrelsen.dk, 'Middelalder ødekirker') and much debate on the future of churches, caused by the plan to put a number of closed nineteenth-century churches in Copenhagen on sale since 2013.

However, reducing the destiny of Mårup to a question of rules and statutes and ignoring the different values involved means giving up any attempt to understand why this monument has become a contested heritage, why there have been and still are different opinions. If anything has had an effect on the outcome of the process, it has not been rules or statutes, but the engagement and enthusiasm by which representatives of the National Museum in Copenhagen since 2008 have conducted and not least mediated the dismantling process. By telling how outstanding the church once was architecturally – and now also how unique in having become the best-known medieval church in Denmark. They have created a new best-selling story, which has the potential to settle the conflict between centre and periphery, authorities and locals. As the conflict partly originated in the top-down rejection of Mårup from the national canon of art history, it indirectly tells the locals that 'their' church was of no or very low interest. Thus, a different attitude from the archaeologist or antiquarians working in the heritage sector might be of greater importance than a future fine-tuning of administrative procedures in the name of a uniform treatment of monuments.

Soft landscaping

Nikolaos D. Karydis is not happy with the actual heritage management or way of compromising between nature and

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culture at Mårup meaning the loss of the medieval church, the lighthouse and memorials such as the large anchor from *The Crescent*. The British frigate was shipwrecked in 1808, and the anchor was recovered in 1940 and placed at the western gable of the church as a memorial to the buried dead. However, the anchor is safe for the time being as it was moved in 2008 to a new location just east of the chancel.

I agree with Karydis when he argues that the protection of a landscape with its different elements is better than a focus on individual key monuments, but it is difficult to be consistent. A more holistic protection might mean a 'fossilizing' of the landscape, which Karydis sees as a risk, when monuments are relocated to open-air museums.

His concern for the management is justified, when the plan for the dismantling of the church was described as 'The future of Mårup church is secured' (Himmelstrup 2008, p. 36), a kind of newspeak known from the political sphere. However, when Karydis proposes a 'mild landscaping', for example, dune interventions to protect the monuments, I have my doubts. 'Landscaping' along the western coast of Denmark and in other areas with drifting sand has a long tradition and was actually used in vain, for example, at the lighthouse of Rubjerg Knude. The conditions on the coast are simply too tough for 'soft' actions to have any lasting effect; at least it is too late.

Contemplating destruction

Tim Flohr Sørensen adds a number of new perspectives to the discussion. First of all, he is critical of what is called the 'paranoia of losing material culture'. In line with this critical attitude, he prefers to keep the destructive part of the concept of 'creative destruction' by Joseph Schumpeter; creation yes, but he would also like to see some destruction. While referring to Sigmund Freud, he emphasizes the importance of the transience or perishability of all things. Instead of seeing threats against the heritage, he sees a threatening heritage, a heritage exposing our own vulnerability. A demonstration of this was the seemingly popular demolition of around 120 bunkers from World War II along the western coast of Jutland in 2013; their hidden concrete and iron reinforcements were perceived as a threat to bathers. According to Flohr Sørensen, when heritage cannot be controlled, when it is no longer passive, people want to get rid of it. Finally, he calls for a 'letting go' attitude. Permit the church to disappear, confronted with the forces of nature and let us use this opportunity to contemplate the passing of time.

First of all, I would characterize Flohr Sørensen's diagnosis of preservation as 'paranoia' a viewpoint typical for followers of David Lowenthal, who for many years has defined heritage studies as a very critical approach (e.g. Lowenthal, 1997), even though there is no reference to his publications in this contribution. The hypercritical thinking by Lowenthal has become a concealed paradigm in heritage studies since the 1980s.

Secondly, I deliberately constructed and chose the concept of 'creative dismantling', not 'creative destruction' by Schumpeter, because I find the first to be the most adequate description for what actually has happened at the cliff; it is a concept in an attempt to understand the process. I never 'seek(s) to preserve the dismantled building for potential future reconstruction', as it is claimed in the comment; that is nowhere to be read. In fact, I suppose that the storing of material from the church is only a calming action to prevent criticism. And to put it plainly, I have no ambitions to persuade others about how things ought to be done, if the church ought to go or not. My quest is rather to try to understand why the destiny of Mårup has been so controversial, to understand the creation of heritage; there is no shortage of people promoting heritage politics under the label of doing heritage studies, trying to persuade others what to think and do.

Thirdly, I am not against letting material or immaterial culture disappear in all cases, how could anybody be that? Whatever the ambition, it would be an impossible task. For the same reason, I wondered years ago why the church of Mårup was not allowed to fall:

> Let the church fall! Let the old church fall into the sea. The church on the cliff is only one of many superfluous deserted churches. Impossible to preserve on the spot, difficult to move, out of use as a church, architecturally insignificant, historically of little interest and economically an embarrassment. Let it fall, just as the sea has taken numerous other churches through time. Why not just let it disappear from the cliff? (Wienberg 1999, p. 183, also p. 199)

However, the questions, and the following vision, which is not quoted, of the fall of the church in the future, are only means for an investigation and rethinking of the motives for the preserving of heritage. And my conditions proved to be wrong, as the church, with the 'creative dismantling' and a new narrative, later turned out to be both architecturally significant and historically interesting.

Fourthly, yes, I am also convinced that the fate of the church of Mårup has become so sensitive and controversial as an icon of 'memento mori', or as Flohr Sørensen puts it, our own vulnerability. The threatening bunkers are of course a fascinating example of heritage, which can be drawn into the discussion; the four churches and the lighthouse are only chosen because they (also) are good to think with. As a child I played in the abandoned bunkers in the forest near my hometown Silkeborg, which functioned as the German military headquarters in Denmark during World War II. Sunday outings by the family often went to the coast, where bunkers were impossible to avoid as they were scattered everywhere. By the way, the bunkers at Silkeborg were open in my childhood, partly water-filled dark rooms to investigate, but are now closed precisely for security reasons except for a bunker museum; Dehn also mentions a dolmen on a cliff as a potential threat to bathers. However, I find it surprising that the political implications of the bunkers are not mentioned at all. The bunkers of the Atlantic Wall are probably the largest building complex in Denmark, but also an example of contested heritage. The bunkers are a reminder of the problematic Danish collaboration policy during the occupation. They are normally called 'German bunkers', even though they actually were built using a Danish workforce. Thus, the bunkers are not directly a national heritage to be proud of and there are good reasons, other than 'vulnerability', why politicians and others want to get rid of them. It's the narrative!

Fifthly, protected or investigated heritage such as Mårup is still an exception. The overwhelming majority of human creations disappear silently around us every second – and some of the creations are even aggressively destroyed, for example, at present in Syria. Thus, there is no lack of examples of 'letting go', if we are looking for places where we can contemplate the decaying process, nature and culture, time and change, perishability and history. And if we ask for places where people are allowed to participate in the demolition of a monument and the creation of narratives, we only have to travel back in time to the Berlin Wall in 1989, an event being celebrated as I write these lines.

Continued dismantling

While we are discussing here which attitudes are the best towards heritage, the edge comes closer. Waves continue to hammer the coastline, erosion of the cliff goes on and the antiquarian management continues as planned. The first phase of dismantling the church of Mårup was conducted in 2008, the second in 2011 and now the third in August 2014 with a fourth and last probably soon to follow. Thereafter, we would be left with stories to tell, memories to recall or ruminate about and maybe even some stored debris of the heritage to refit in the future.

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RESEARCH ARTICLE

Repeating boundaries – repertoires of landscape regulations in southern Scandinavia in the Late Bronze Age and Pre-Roman Iron Age

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Towards the end of the Late Bronze Age, linear boundaries such as enclosed farmsteads, field divisions, and pit zone alignments emerged and gradually permeated the landscapes of southern Scandinavia on multiple scales. This article suggests the concept of a 'repertoire' as a way of approaching this phenomenon. The repertoire consisted of different topological operations (e.g. plot definition, demarcation, and enclosure), constructed by different materials (e.g. fences, pit zones, and earthen banks) on different scales (e.g. farmstead, settlement, and landscape). Such linear boundaries were applied as technological solutions to the new social and economic problems that occurred at this time in prehistory. A number of chronological and regional preferences can be demonstrated within this repertoire, and during the Late Bronze Age and Pre-Roman Iron Age, a range of new applications and combinations were developed in a creative exploration of the repertoire of linear boundaries.

Keywords: Late Bronze Age; Pre-Roman Iron Age; settlement archaeology; landscape regulation; social organisation; boundaries; fences; field systems; repertoire

Introduction

Research history

Southern Scandinavia is characterised by a long and comprehensive settlement archaeological research tradition, which can be traced back to the pioneering excavations of Iron Age houses (Kjær 1928, 1930, Hatt 1930, 1938, 1954, 1957, Brøndsted 1936) and the later introduction of mechanised area excavations (Becker 1966, 1969, Voss 1976).

In many ways, this research tradition developed along its own lines, generally staying outside the major theoretical discussions of the 1960s (Binford 1965, Binford and Binford 1968, Clarke 1968, cf. Hvass 1992). However, it clearly incorporated many of the ideas from the processual discourse more implicitly such as a clear behavioural–economic focus. This was, for example, reflected in a strong tradition of considering settlement structure and development in the light of demographic, climatic, and socio-economic conditions (Becker 1966, 1976, Kristiansen 1975, 1978, Nielsen 1982, p. 138, Champion *et al.* 1984, Hedeager 1990, Jensen 2003, p. 244). Similarly, it tended to focus on a few key archaeological sites, which could be fit into social-evolutionary lines of development, for example, from loosely structured to rectilinear field systems (Hatt 1949, Sørensen 1982) or from simple towards increasingly complex settlements (Hansen 1984, p. 65, Hvass 1993, p. 190, Jensen 1994, p. 118 ff., Ethelberg 1998, pp. 259–60, Webley 2007, p. 456). The model below implies that one principle of settlement enclosure builds upon and eventually replaces another with a relatively clear development from open settlements towards common-fenced villages, towards an increasing internal differentiation, which eventually results in an individual farmstead parcelling (Figure 1).

This type of evolutionary explanatory model received relatively little criticism in a Danish research context compared to the British (Hodder 1982, 1986, Tilley 1990, Shanks and Hodder *et al.* 1995). A critique was nevertheless raised, which insisted on the multiplicity of interpretations as well as ahistorical variation being part of the nature of prehistoric societies. This provided an alternative view that considered each site on its own premises without relating it to courses of evolutionary progression (Ejstrud and Jensen 2000, Jensen 2005; also see Hedeager 1993, p. 172). A recent contribution was made by Herschend (2009), who similarly engaged in interpretations and research themes across the established archaeological periods. This critique was raised at a time where development-led archaeology was in a radical intensification and which increasingly has made it obvious that a number of explanatory models (cf. Figure 1) no longer can be maintained in proportion to the immense variation in the data: fenced villages which were previously unique for the sandy soils of western Jutland are now discovered in eastern Jutland (Skousen 2010), new types of large-scale areal demarcations appear from a much earlier point in time than previously thought (Bentsen 2011), and tightly fenced farmsteads are discovered both before and after the emergence of common-fenced villages (Isler 2012, Jørgensen 2011).

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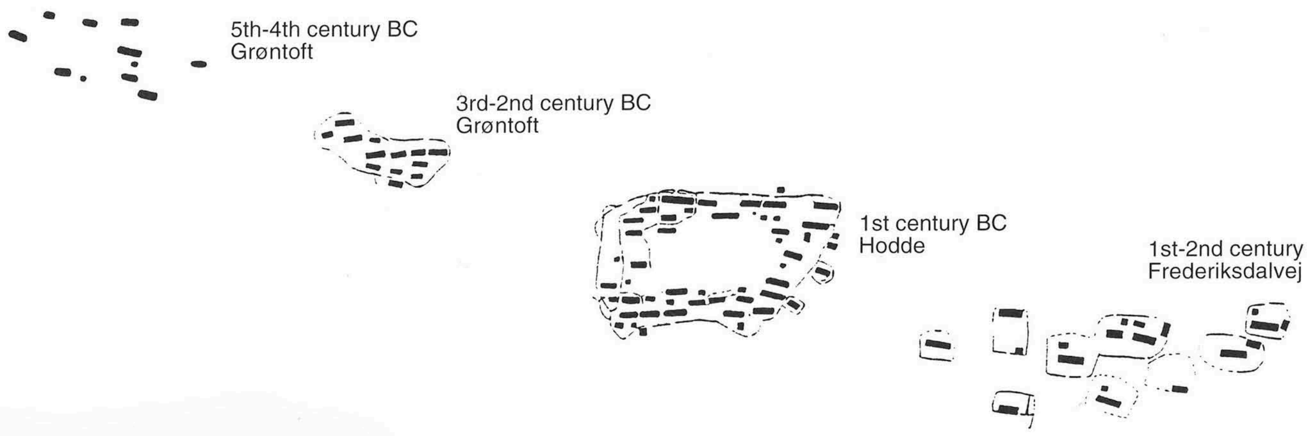


Figure 1. Model of the development of the Iron Age village in southern Scandinavia (after Mikkelsen 1999, fig. 11, 191).

However, the evolutionary model has still continued to dominate settlement and landscape studies, and the interpretation of landscape and settlement demarcations refers to overall long-term narratives. This has sustained a particular understanding of the definition and delimitation of the archaeological feature types and their social bearing: the classical fence around 'farm 1' at Hodde as the ultimate symptom of a power structure in which the village chieftain has an unequivocally dominant position, the common-fenced village of Grøntoft as the ultimate symptom of a normative and egalitarian community, the Celtic field systems as the ultimate symptom of private property and agricultural intensification, and so on.

We wish to propose a pragmatic approach where the variation in the archaeological material is considered in the light of the concept of a repertoire, the definition of which is unfolded in the section below. On the one hand, the repertoire was not introduced as a package nor does it imply a development from one stage to another. Instead, the analyses demonstrate how different principles of operation were transferred across different materials and spatial levels, together forming a dynamic and flexible set of solutions to interrelated problems. On the other hand, different elements and combinations in the repertoire emerged in geographical concentrations and at particular times, of which some disappeared again while others became part of an increasingly formalised and institutionalised application ('Landscape technologies in a long-term perspective').

An emerging repertoire

The Late Bronze Age/Pre-Roman Iron Age is generally understood as a period of societal fragmentation and regional variation. Graves became increasingly anonymous, and there were strong culture–geographical differences in burial forms, including covered cremation [hillock] burial sites, burial pits, stone cairns, and reburials in barrows (Becker 1961, pl. 124, Jensen 1966, Jørgensen 1972). The settlement patterns as well as the strategies of livestock management and landscape exploration varied considerably between regions and even within local areas (Haue 2012, pp. 288–291). This is, for example, reflected in the village mounds of northern Jutland (Jensen 1976), the densely settled, more dynamically explored compounds (Becker 1969), whereas other areas appear to have been much more sparsely settled until mid-Pre-Roman Iron Age or later (Møller 2013).

The longhouse architecture was dominated by a new type of house, which was significantly shorter than in the preceding centuries, averaging ~75 m^2, only leaving room for smaller families (Becker 1982, Rasmussen and Adamsen 1993). Although some variation can be recognised (cf. Hvass 1985, Rindel 1999, Haue 2011), the homogeneity in construction principles as well as the internal layout is striking. The stall now made a consequent element, which was normally situated in the eastern half of the longhouse (Fokkens 2003, Herschend 2009). Thus, an integrate quality of this schematic architecture was also associated with new economic regulations where cattle and livestock were explicitly kept within the walls of the individual houses. This form of architecture was so widespread that it dominated the entire lowland area from Scania to the southern Netherlands (Tesch 1993, Theunissen 2008, Webley 2008). The houses bear witness to far-reaching architectural regulations associated with the individual farmsteads in spite of regional variations, such as paved floors (Frandsen 2011), wall-ditches in the east end (Mikkelsen and Jensen 1996), turf-built walls (Hatt 1957), preference of orientation (Webley 2008, table 4.1, p. 57), as well as variations in subsistence strategies.

The farmsteads were generally situated in an open landscape; however, towards the end of the Late Bronze Age (*c.* 700 BC), a number of linear, physical boundaries began to appear in their surroundings, such as linear ditches, fences, pit zones, and earthen banks. Over the following centuries, many houses became enclosed or partly enclosed by often fragile and ephemeral fences (Nielsen and Mikkelsen 1985, Pedersen 2007, Jørgensen 2011). Such fences created a new element on the settlement sites forming an explicit boundary between the farmstead and its surroundings or between neighbouring farmsteads. Similar kinds of fences and ditches also occurred less explicitly tied to individual farmsteads, separating larger areas within the settlement sites or connecting houses. From *c.* 250 BC, fences became more common and sometimes enclosed entire settlement sites, either as common-fenced villages or as boundaries demarcating the limits of much larger (inhabited) areas (Becker 1966, Andersen 1984). Other boundaries again were constructed as belts of open holes, the so-called pit zone alignments, that obstructed traffic corridors or cut off larger pieces of land and which appeared from the very beginning of Pre-Roman Iron Age (Mauritsen 2010, Løvschal in press b). Thus the introduction of linear boundaries created very tangible and indisputable boundaries between farmsteads, groups of people, and parts of the landscape and are hence expected to reflect new forms of regulation on multiple levels.

Although these physical boundaries demonstrate an almost inexhaustible range of variation (including construction material, morphology, size, and demographic association), certain principles repeated themselves across different contexts. The parcel-shaped plots that characterised the enclosed field systems (Celtic fields/ Danish: 'digevoldinger') also reoccurred in the fences surrounding farmsteads forming plot-like structures. The pit zone alignments that were typically constructed as hindering of access outside the intensively explored areas were also surrounding aggregated settlement sites (Becker 1969, 1971, Eriksen and Rindel 2001, Mauritsen 2010). And principles of nearness to the houses that were characteristic for the farmstead fences also reappeared in the common fences that surround nucleated villages.

As a result this period was characterised by the introduction of a number of new elements, giving evidence to an increased formalisation and standardisation within multiple domains. Furthermore, it saw the emergence of new physical principles which were selected for in particular situations. These regulatory elements were apparently not fixed or well defined. Instead the material suggests an incredible breadth of variation as well as a significant creativity in how they were used and combined. These elements could be characterised as a set of very basic spatial principles or a kind of 'repertoire', which will be explained in the section below.

The idea behind the concept of a repertoire

The 'repertoire' is understood here as a form of toolbox comprising both concrete types of structures (e.g. fences, ditches, earthen banks, and pit zones) and more abstract principles of regulation (e.g. parcelling, plotting, add-on, compound, demarcation, and enclosure). They have parallel existence and can potentially be combined freely on multiple levels.

The concept of a 'repertoire' has been given particular attention within cognitive neuroscience and behavioural psychology (Delgado and Hayes 2007, Palmer 2009, Carey 2011). Here, a 'conceptual repertoire' is (often implicitly) taken to cover the sets of acquired procedures or behavioural responses that either consciously or unconsciously fit the expectancies of people and their surroundings. A repertoire is something that accumulates and gradually builds up and which therefore also, with time, gains certain inertia: in a long-term perspective, certain representations as well as behavioural responses are more likely to become evoked than others, depending on how well they fit with the general cultural schemes they appear in. Similar to the notion of a cultural schema (D'Andrade 1995, Nishida 1999), a repertoire is constituted by the generalised procedures of social life that are passed down from one generation to the next, transformable and applicable to different contexts. Such conceptual and behavioural categorisations and competencies are obviously not developed in isolation, but are both caused by and a cause to particular categorisations in the environment.

Therefore, although the term is originally geared towards a range of (verbal) concepts and not for handling prehistoric spatial behaviours, a 'spatial repertoire' could be understood along the same lines: a repertoire representing the sets of solutions and technological choices that people gradually develop, know about, have access to, and can choose to implement, modify, or ignore. Such a repertoire is not considered a universal human trait available to everybody but rather as dynamic, emerging spatial technologies learned, transmitted, and developed through a dynamic feedback relationship between micro- and macro-level processes. Therefore, a spatial repertoire is perhaps best described as a set of technological choices and horizons of possible operations that can be applied onto a wide range of tasks for social communication, coordination, distribution, landscape regulation, and allocation and which is deeply embedded in decision making processes and social concepts of organisation.

This repertoire does not emerge on a blank slate but operates on a particular culture-historical and topographical surface (cf. Figure 4), which has already been subject to preceding concepts and practices of landscape organisation and regulation and thus naturally hold certain affordances. In the archaeological material in focus of this article, such a repertoire would appear as articulations of similar spatial regulatory principles appearing across larger geographical areas, archaeological periods, materials, demographic scales, or commonly used feature types.

This is a different view than previous models of evolution and chronological horizons based on fixed combinations of types of structures and usage and isolated developmental courses (Sørensen 1975, cf. Rogers 2003). Opposite a repertoire, horizons are characterised by phases of rapid innovation or diffusions (Willey and Phillips 1958, p. 32; also see South 1972). They also imply a degree of similarity across the given variables that can be distinguished from each other and which links different cultures to the same chronological phases. This is different from the repertoire, which is triggered by certain similar conditions that cannot necessarily be coupled to discrete cultural periods or unilinear developments. At the same time, the many varied forms of boundaries within the repertoire are not just random variation and unique expressions. They refer to a limited set of more abstract principles. It is these principles which should be identified to understand the development of the boundaries.

The repertoire as method

A repertoire, as used in this article, comprises a set of operations, which include plot definition, demarcation, and enclosure. Plot definition includes either a parcelling of a defined space or an application of rectilinear enclosures with particular stackable and repeatable morphologies. Demarcations consist of open lines that cut off particular spaces from their surroundings, often in a visible relation to a certain direction of movement. Enclosures consist of closed, curvilinear lines, which enclose a particular space into singular entities. These operations are applied on various spatial levels, which in principle constitute a continuous scale. However, they are here classified as household/farmstead, settlement, and landscape (Figure 2). These scales are functionally selected, but are associated with different cultural logics to specific use patterns, for example, landscape level comprises both boundaries regulating traffic on a territorial scale as well as boundaries regulating an economic aspect such as fields and pastures. Furthermore, the operations materialise as fences, ditches, palisades, earthen banks, stone banks, and pit zones. The different operations and materials have parallel existence and can potentially be combined freely.

The classifications have been applied on a data set consisting of a systematic collection of sites with physical linear boundaries from the Late Bronze Age–Pre-Roman Iron Age across north-western Europe (Løvschal 2014a) with additions from Fund og Fortidsminder, Jensen (1976), and Runge (2009). The categories are not necessarily clear-cut but imply topologic overlaps. For example, plot definition on landscape level also includes elements of parcelling, demarcation, and alignment. There is also a, primarily discursive, drift between demarcation and enclosure, and enclosure and plot definition). However, they are still considered meaningful categories, which, in their combination with particular materials, partly relate to established archaeological feature types (e.g. pit zone alignments, common-fenced villages, and Celtic fields). Their development will be explained and synthesised in the following section, which aims to contribute to a more holistic understanding of the archaeological record.

Synthesis: manifestations of landscape technologies

In this section, we present seven different scenarios where the most dominant combinations of 'operation' and 'scale' are represented in various combinations with different materials; they distribute geographically according to Figure 3a–g.[1] The purpose of the section is to explore the observable manifestations of the repertoire in the archaeological record that embrace an extremely wide variety of ways in which similar operations and materials are combined across multiple scales. Similarly, they do not cover the entire repertoire but combinations that are particularly evident in the archaeological material.

Figure 3a–g demonstrates a geographical overlapping between the different selections of the repertoire although

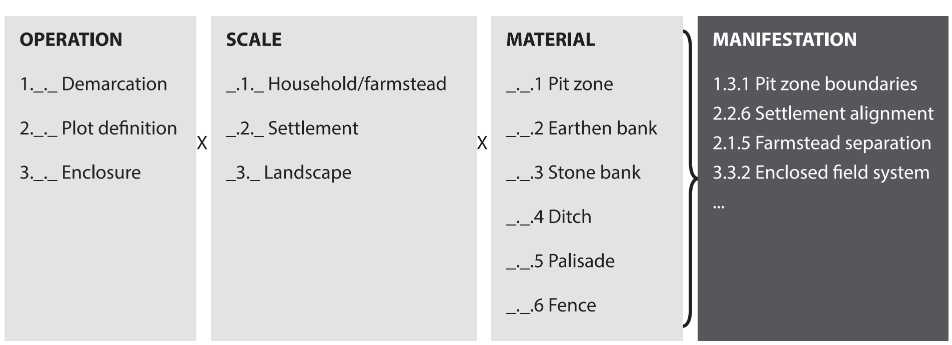


Figure 2. Diagrammatic outline of the main components involved in the definition of the repertoire.

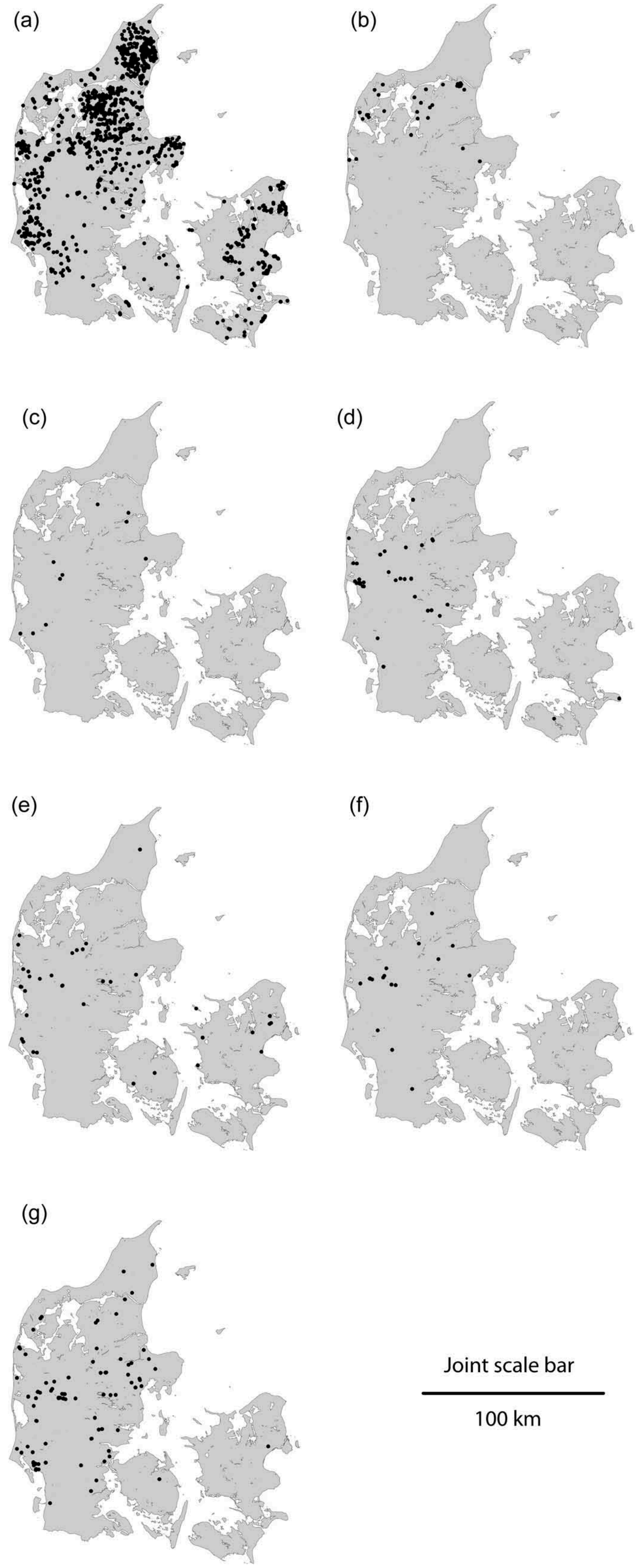


Figure 3. (a–g) Distribution map of the landscape technologies that figure in the analyses (No. 1-7), dated to 1100 BC–AD1. (a) Plot definition on landscape level. (b) Plot definition on settlement level. (c) Plot definition on farmstead level. (d) Demarcation on landscape level. (e) Demarcation on settlement level. (f) Enclosure on settlement level. (g) Enclosure on farmstead level.

with clear geographical concentrations for the different principles. Plot definition on landscape level (enclosed field systems) was mainly concentrated on the sandy soils in northern and western Jutland. Plot definition on settlement level (aligned settlement and village mounds) concentrated in northern Jutland with few occurrences in the rest of Jutland. Plot definition on farmstead level was a rare phenomenon with sporadic occurrences in north-eastern and western Jutland. Linear demarcation on landscape level (pit zone alignments) was mainly distributed in western Jutland with few coincidences in southern, northern, and eastern Jutland. Demarcation on settlement level appeared widely across southern Scandinavia, particularly in western and eastern Denmark. Enclosure on settlement level (common-fenced villages) was almost exclusively situated in western Jutland. And finally, enclosures on farmstead level were distributed widely but particularly in western and eastern Denmark.

These concentrations partly relate to culture-geographical regions (Figure 4). Although dominated by a flat terrain with a short distance to coast and waterways, the landscapes of southern Scandinavia also hold some fundamentally different qualities, spanning from the sandy-loamy moraines and ice-pushed ridges, the sandy heath plains and marshes in southern and western Jutland to the heavier, loamy soils in eastern Jutland and on the islands (Figure 4). These differences also formed an underlying basis for different faunal developments and economic preferences (Odgaard 1994, Odgaard and Rasmussen 2000, Vinter 2011). Furthermore, the different culture-historical developments and landscape uses in these regions have clearly affected the preservation conditions of archaeological traces of physical boundaries that are vulnerable to cultivation and modern building works (cf. Baudou 1985).

TECHNOLOGY No. 1: plot definition on landscape level

In the Late Bronze Age/Early Pre-Roman Iron Age, large areas were subject to a plot definition where the individual field plots became surrounded by earthen banks, lynchets, or banks of field stones (Celtic fields). The changing horizons underneath the banks indicate that the field systems were sometimes applied onto land already allocated for heath and pastures. In other cases, forest appears to have preceded them (Hatt 1949, Becker 1971, Rindel 1999, Nielsen 2007). The sizes of the individual plots as well as these allocated areas reflected a significant variation where some can be proven never to have exceeded a few hectares, others exceeded several hundred hectare (Figure 5) (cf. Nielsen 2000, fig. 170, p. 185, Egeberg 2011).

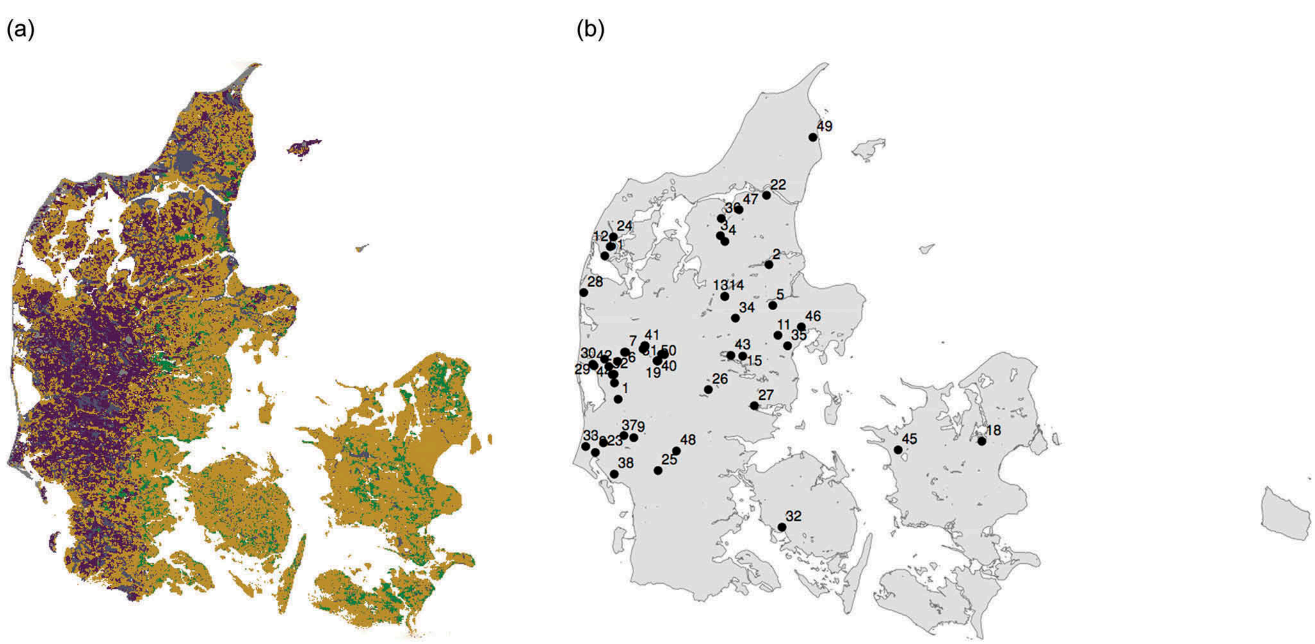


Figure 4. (a): Main landscape types of Denmark according to the VSK economic map (heathland; forests; and cultivated land). (b): the distribution of all sites mentioned in this article. 1: Agerhøj, 2: Alstrup Krat, 3: Baunehøj 3, 4: Borremose, 5: Frederiksdalsvej, 6: Grøntoft, 7: Grøntoft Hede, 8: Hesselmed, 9: Hodde, 10: Holing, 11: Humlehaven, 12: Hurup, 13: Hvilmose Nord, 14: Hvilmose Syd, 15: Højlund I, 16: Lyngsmose, 17: Lysgård, 18: Margrethehåb, 19: Munksgårdkvarteret, 20: Møgelhøje, 21: Norgesvej, 22: Nr. Tranders, 23: Nybro, 24: Nørre Hedegård, 25: Nørre Holsted, 26: Nørre Snede, 27: Priorsløkke, 28: Rammedige, 29: Rindum Ny Skole, 30: Rindumgård Nord, 31: Rosenholmvej, 32: Sarup, 33: Selager, 34: Skallegård Syd II, 35: Skejby, 36: Skørbæk Hede, 37: Snorup, 38: Solbakkegård, 39: Spjald Syd, 40: Stenbjergkvarteret, 41: Sverigesvej, 42: Sønder Brorstrup, 43: Torslund Bakke, 44: Troldebanke, 45: Ubby, 46: Vendehøj, 47: Vokslev Hede, 48: Vorbasse, 49: Øksenhede, 50: Ørskovvej, 51: Øster Helligsøgaard, 52: Øster Lem Hede.

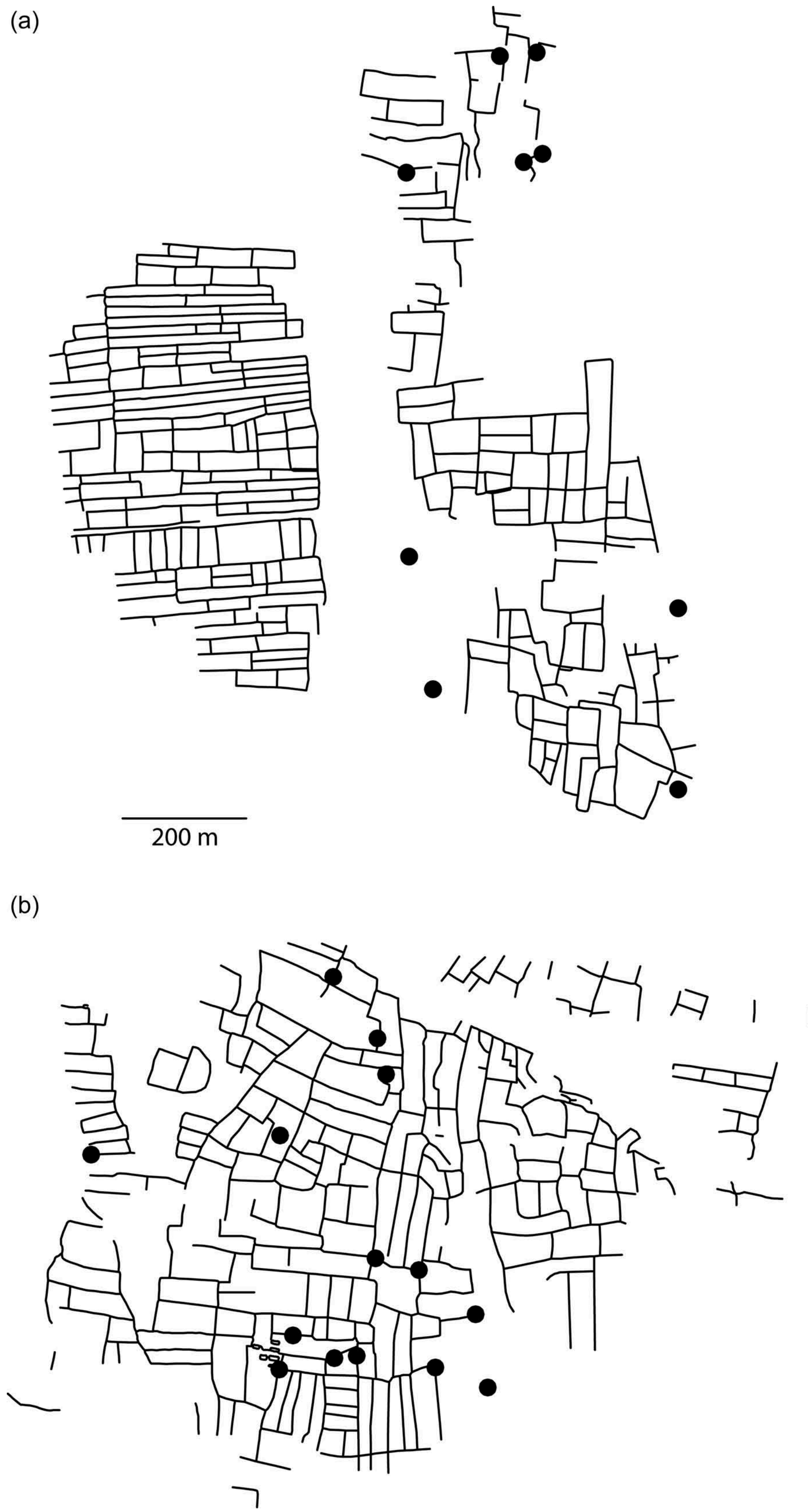


Figure 5. Examples of plot definition on landscape level (Celtic field systems); black dots are round barrows. (a) Byrsted Hede (Hatt 1949). (b) Skørbæk Hede (Hatt 1949). In none of these examples does 'plot definition/parcelling' occur as a single topological principle. Rather, different parts or chronological horizons within the systems relied on different topological principles, such as the arrangement according to one dominating line, juxtaposition of individual plots in piecemeal fashion, or filling-in of superior compounds and empty areas.

The topological principles upon which these field systems were based were extremely wide ranging and complex.[2] However, some comparable principles can be identified. These included so-called aggregate or add-on principles where individual plots adjoined and accumulated in a piecemeal fashion. Others divided up already naturally delimited areas into parcelled areas (Vinter 2011, fig. 7, p. 142). Others were based on one or several dominating axes that were laid out in the initial phases of the field systems and along which the individual plots accumulated (Hansen 1980, fig. 4, p. 142, Hatt 1949, pl. IX). Others again were applied as large compounds, subject to later adjoining and disintegration into smaller units. It has been suggested that these different principles reflect a successive development of organisational principles from the unorganised organic systems with ad hoc adjoining to the regular organised systems, for example, represented in Sørensen's categorisation of A–B–C types of field systems (1982, fig. 2–4). However, this is unsubstantiated by the available dates, and rather it appears that parcelled field systems developed from multiple topological principles (also see Nielsen 2000, p. 376).

As a spatial technology, the parcelled field systems represented a physical delimitation of the cultivated soils, which in some cases obtained an obvious time depth. The parcelling also worked as a distribution of the landscape among people, who thus became increasingly associated with the local area: if you had an enclosed field plot, you were likely to be living and buried close to it. The individual field boundaries often took a starting point in older barrows or encircled them within individual plots. The field systems are assumed to have been associated with a fallow-system, which implied a continuous and cyclic return to the same plots and as such entailed a place-specific spatial continuity, demanding new, more explicit regulations and ways of dealing with rights to land. Furthermore, this physical landscape parcelling naturally entailed that extensive areas were confiscated and the landscape became increasingly 'filled-in'.

As a social technology, the plot definition on landscape level allowed a new coordination of people beyond the household level and the creation of a common sense of purpose as well as common spatial strategies. Furthermore, the distribution of land in relatively uniform pieces could have been a way of making an equal distribution and downplaying social differences.

These enclosed field systems were particularly concentrated in northern and western Jutland (Hatt 1949, Sørensen 1975), but also present in large numbers in southern and eastern Jutland, Bornholm, and the islands (Sørensen 1982, Nielsen 2000, 2010), which is likely to be related to the different geographical preservation conditions.

TECHNOLOGY No. 2: plot definition on settlement level

The second principle of landscape regulation appeared from the transition to Pre-Roman Iron Age and onwards with a strong concentration on the heavier, loamy soils in northern Jutland. In the archaeological record, it is expressed through settlement parcelling and houses situated in systematically arranged or conspicuous spatial alignments (Figure 6). This was pronounced on settlement mounds but also on sites without any demonstrable culture layer, often combined with parcel-shaped fences (see No. 3). Similar to the landscape parcelling (No. 1), settlement parcelling and plot definition demonstrated a significant topological complexity. It involved aggregate principles where individual enclosures were applied in an add-on, piecemeal fashion (Frederiksdalvej (ERIA), Vendehøj). Others appeared as a parcelling of already delimited areas (Nr. Tranders). Others again were arranged in a linear fashion or along a road (Øster Helligsøgaard, AUD 1999, no. 329).

As a technology, the settlement parcelling worked along similar lines as the landscape parcelling (No. 1). They divided up already bounded 'islands' or relatively fixed and demarcated areas, which explains the symmetrical shapes and the continuous maintenance of the same parcel-shaped plots. In some cases, this involved a gradual establishment of defined plots that, over time, accumulated and came to define an increasingly distinct parcelling. In northern Jutland, in particular, settlement parcelling did not articulate as constructed boundaries but appeared as spatial separations, which, however, did not exclude the possibility of being marked in other ways with, for example, hedges or stone rows (Runge 2009, fig. 95, 86 and fig. 119, 96). Accordingly, there were also dynamic differences between the often unmarked, however, apparently very stable parcelling of the village mounds and the more dynamic, physically marked, settlement parcelling of eastern/mid Jutland.

Whatever the manifestation, the parcelling constituted a chronologically stable subdivision of particular areas within which the settlement obviously aligned according to relatively fixed plots. Their regular appearance, as well as the combination with conservatism in the alignments and individual plots, suggests that settlement on these sites was aggregated and kept within specific areas rather than spread across the landscape. Initially, this grid afforded a spatial freezing and less freedom to manoeuvre, displace, or expand (cf. No. 5–7). At the same time, it outlined a spatial separation of each social unit or plot, which concurrently were included in a subdivision dependent on larger groups of people. Therefore these examples of parcelling appeared to build on the same principles as the landscape parcelling that similarly covered and subdivided entire demarcated areas. Furthermore, there is a classificatory slipping slope between settlement parcelling

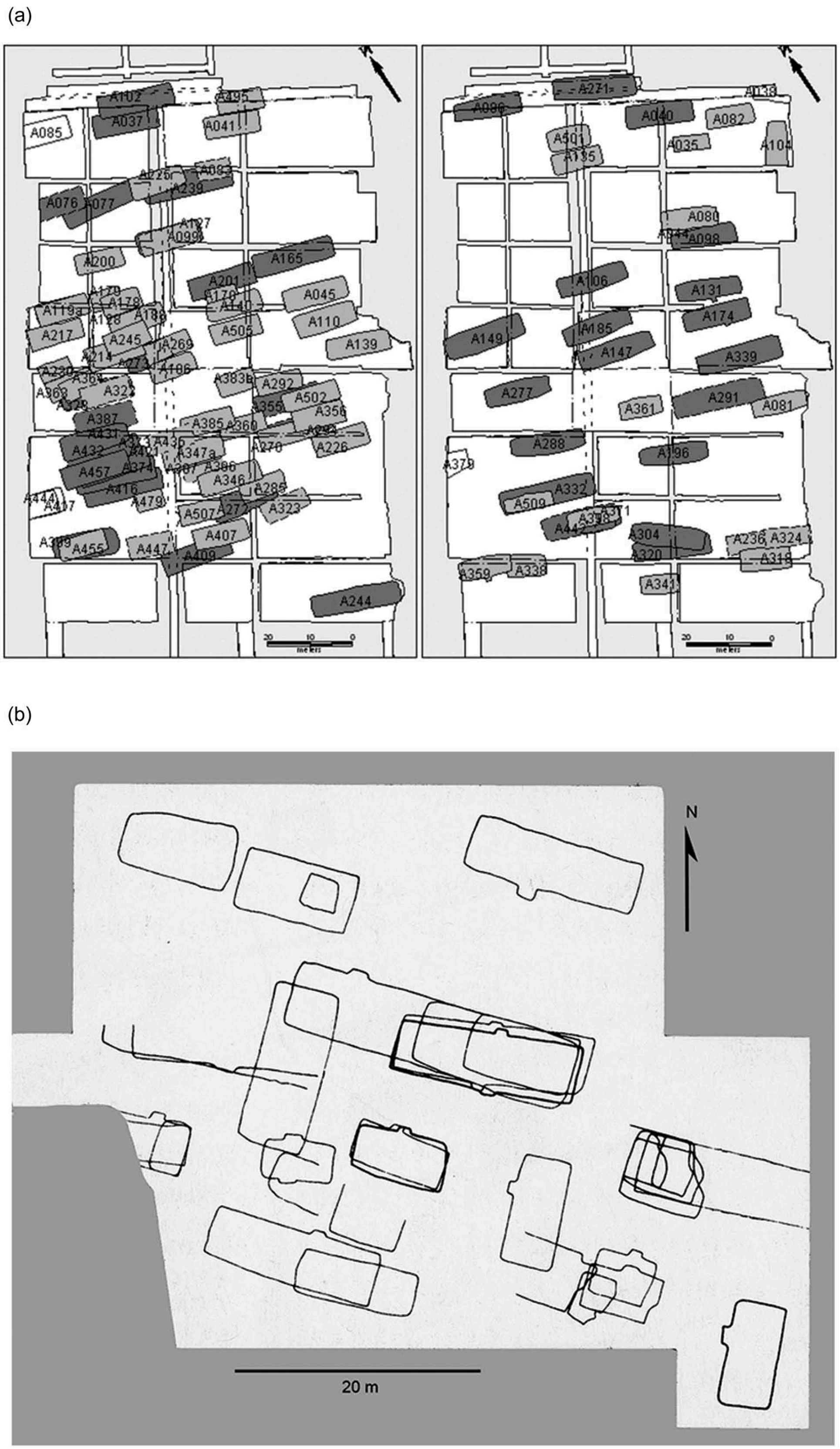


Figure 6. Examples of plot definition on settlement level (village mounds). (a) Nørre Tranders (Haue 2012, fig. 116, p. 144). (b) Hurup (Jensen 1976, fig. 4, p. 68).

and houses situated directly within field systems, as known for example from Grøntoft, Skørbæk and Øster Lem Hede (Hatt 1949, 1957).

TECHNOLOGY No. 3: plot definition on farmstead level

Comparable features were expressed as parcel-shaped fences that surrounded the longhouses and their associated outbuildings. Such features can be identified from the transition to Late Pre-Roman Iron Age, but were primarily a post-1 AD phenomenon. In northern Jutland, such farmstead parcelling most often appeared in isolation with a fortified appearance, for example Baunehøj III (Terkildsen and Clemmensen 2005), Alstrup Krat (Bech 2003), and Øksenhede (Andersen 2005).[3] On Mid- and East Jutish settlement sites, it was more common to have multiple parcel-shaped enclosures, which adjoined in an aggregate manner (Figure 7). In this way, the plot definitions appeared as a kind of template-like formalisation of enclosed space with stackable affordances, which seemed morphologically related to the banks surrounding the fields.

The plots showed a significant size-wise differentiation from smaller enclosures at, for example, Vendehøj (~200 m^2) to larger enclosures at, for example, Rosenholmvej (~1700–2200 m^2), Øksenhede (~1800–2300 m^2), and the recently discovered enclosed village at Skejby (~10,000 m^2) (Skousen 2010). Concurrently, there were trends towards a standardised size, averaging 550 m^2 (Hvass 1985, Jöns 1993, Terkildsen and Clemmensen 2005, Haue 2012, p. 265).

In this way, parcelling and plot definition occurred on multiple levels, here described at

- Landscape level, as Celtic field systems (No. 1)
- Settlement/'house owners' association' level, as aligned settlements (No. 2)
- Farmstead level, as individually fenced farmsteads (No. 3)

The expansion in spatial parcelling and plot definition bears witness to an explicit regulation of particular areas, which in some cases must have reached a maximum capacity in population density and resource exploitation. For example, the regular orientation and dense character of the settlement at Grøntoft together with environmental evidence and new estimations of the extent of the field systems indicate a densely settled area with an extensive parcelling (Rindel 1999). Similarly, case studies which include various mapping methods such as has been carried out at St. Binderup and Gundersted show that the parcelled field systems almost entirely filled in the available land (Vinter 2011).

The morphological regularity and conservatism in the field plots indicate a well-defined and relatively fixed landscape zoning between fields and pastures. These parcelled up areas built on a principle of self-organisation through mutual regulation: fitting each plot into a defined areal parcelling entailed an integration of independent social units, such as farmsteads and family groups, into an interdependent spatial network of physically interconnected plots. And unlike the closely set fences (No. 7), the parcel-shaped fences created standardised spaces outside the longhouse, where one at one and the same time could be outside the house and still within a private sphere.

TECHNOLOGY No. 4: demarcation on landscape level

A very different form of landscape regulation appeared in Late Bronze Age per. VI and Early Pre-Roman Iron Age in western Jutland, in particular. Such features were predominantly represented by pit zone alignments, which at present have been dated to no later than the middle of the Pre-Roman Iron Age. There are, however, still only few absolute dated sites, and thus a general ascription to the Early Pre-Roman Iron Age cannot be taken for granted. For example, the pit zone alignment at Rammedige was situated along an undated 'folkevold', suggesting that there could be a temporal overlap between these different material constructions (Olesen 2003, Eriksen and Mauritsen 2011, p. 163). Furthermore, comparable technologies are the field systems organised according to one dominating axis, which equally related to particular communication lines (Løvschal in press), just as fence-like structures and ditches have been discovered along pit zone alignments (cf. Olesen 2009, fig. 2, 76).

Pit zone alignments were built as closely set open holes, sometimes accompanied by pointed sticks. Labour divisions as well as their often several kilometre-long courses indicate that they were probably not built by or for individuals but coordinated by larger groups of people (Rasmussen 2007).[4] Since none of them have yet been excavated in their entirety, very little is known of the exact nature of this feature type. Also, they were rarely associated with concurrent archaeological traces (cf. Olesen 2009) and equally cannot be coupled to specific farmsteads or settlement sites.

Since they were probably almost invisible in the landscape, they primarily appear to have reflected a need of a common defensive and regulatory technology rather than an explicit social symbol of a particular group of people. Such features have been proposed to be strongly connected with the communication lines, which were indicated by the linear arrangements of barrows as well as extensive traces of hollow roads, trackways, and historical roads and fords (Steen 2006, Olesen 2009, Løvschal in press). Also, the pit zone alignments were mainly situated in the transition zones between the moraines and the marshland and flat heath plains (Løvschal in press). They lack the same explicit landscape distribution as Celtic fields; instead, their linear course entailed that they demarcated and separated areas but did not define the precise extent of a certain 'piece of land'. Thus, culture-topographically, they were situated in ways that made them likely as obstructions of access to the less intensively cultivated and

Figure 7. Examples of plot definition on farmstead level (combined with plot definition/parcelling on settlement level). (a): Vendehøj near Hornslet, Late Pre-Roman Iron Age (Ejstrud and Jensen 2000, fig. 30, p. 44). (b): Frederiksdalvej near Randers, ERIA (Christiansen 1996, fig. 1, p. 104).

settled areas. Here they appeared as short-term regulations on a territorial level in a kind of 'no-man's-land'. Such regulations would have made sense in landscapes where access to particular areas was important and with movement by people (and livestock) who were not necessarily familiar with the landscape. If these landscapes were relatively marginal, then there is also reason to believe that there existed another, more 'loose' understanding of who owned this land or particular parts of it.

Accordingly, linear pit zone alignments were situated at central positions on some of the main communication lines and at the same time in transition areas between different kinds of landscape where claims to land were less settled and where the definition of community ties were still relatively fluid. Such landscape technologies probably reflected informal, intergroup, and landscape regulations in highly competitive environments.

TECHNOLOGY No. 5: demarcation on settlement area level

Another related form of landscape regulation appeared in Late Bronze Age–Early Pre-Roman Iron Age and concentrated in Late Pre-Roman Iron Age. It was expressed as curvilinear pit zones that were explicitly, spatially associated with settlement sites, as well as other morphologically composed settlement demarcations that enclosed larger inhabited compounds (Figure 8).

The demarcated area far exceeded the inhabited area and thus appeared to demarcate not only the extent of a settled area (as No. 6–7) but also a substantial area beyond it. The early constructions of these boundaries with, for example, pit zones were primarily concentrated in western Jutland. They suggest that such linear boundaries were very flexible and easily subject to adjustments. Later demarcations had a more equal geographical distribution and are known from, that is, Sarup (Andersen 1984, fig. 1, p. 83), Kirstinebjerg (Henriksen 2005), Margrethehåb, Rindumgård Nord (Egeberg and Posselt forthcoming), and Ubby (Bican 2004), where they appeared with a much more elaborate and stable expression, consisting of up to several courses of deep ditches and/or palisades (also see Fonnesbech-Sandberg 1990, Madsen 1999, Andresen 2007, Martens 2007).

In this way, principles of demarcation occurred on

- landscape level, as pit zone alignments and access regulations (No. 4)

and

- settlement level, as pit zone demarcations, ditches and areal boundaries (No. 5)

TECHNOLOGY No. 6: enclosure on settlement level

Another regulation principle involved settlement enclosure concentrated from the transition to Late Pre-Roman Iron Age and onwards. It was expressed as common-fenced settlement enclosures situated closely around the inhabited space and were often only restructured in their entirety (Figure 9).

What differed from the curvilinear farmstead enclosures (No. 7) and the landscape enclosures (No. 5) is that the construction of these enclosures was deeply dependent on collective labour investment and signalled social collaboration and affiliation. For example, very elaborate constructions such as palisades (Hodde, Lysgård) and moats with pointed sticks (Lyngsmose), combined with very broad or numerous entrances indicate a social symbolism and collective association rather than primarily a practical purpose (cf. Becker 1976, Martens 1990, 2007, p. 96, Rindel 1993, p. 23).

Common-fenced settlements remained a predominantly western Jutish phenomenon throughout the entire period. Offshoots, however, are known from, for example, Borremose near Aars in northern Jutland (Martens 1990).

These sites were primarily concentrated on the boundaries between typical agrarian and grazing land, such as the edges of moraines facing the flat surrounding heath or in the vicinity of grassable wetlands (Møller 2013, Løvschal in press). They were situated in areas with short access to apt pastures (Hvass 1985, 184) and, consequently, appear to reflect a landscape technology connected to a form of community-based cattle management.

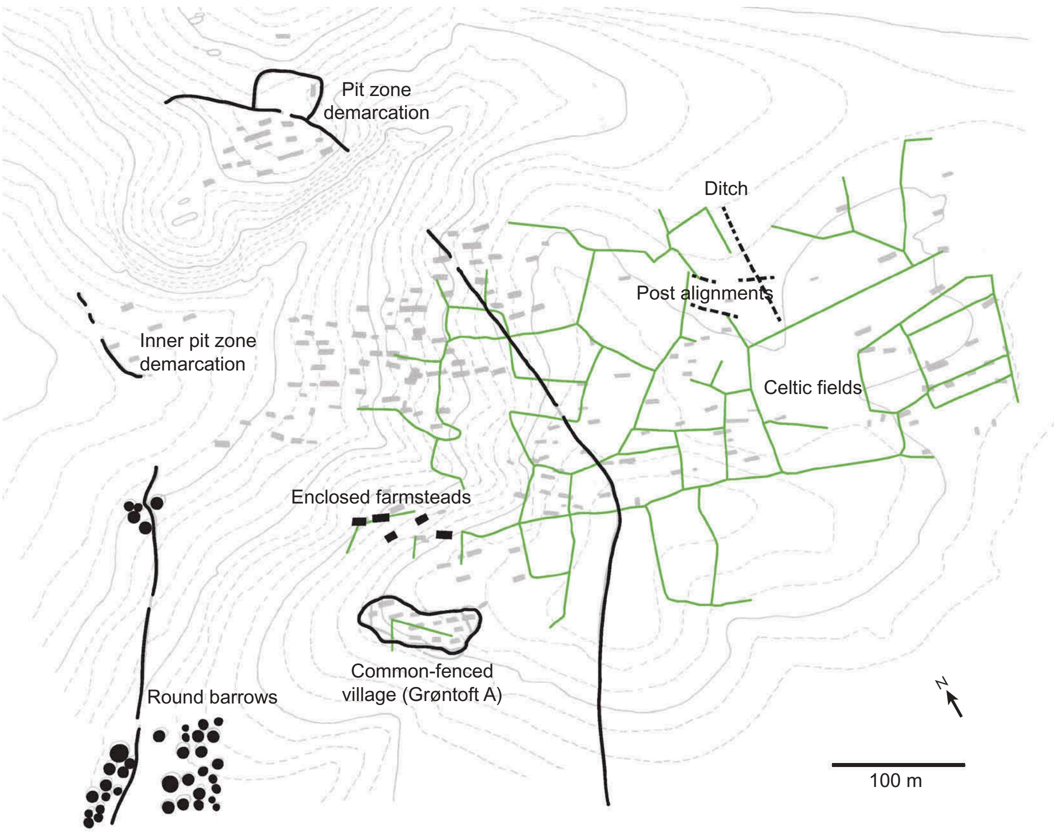
The enclosed settlements were associated with a significant morphological complexity and varying expressions of household autonomy ranging from no internal divisions (Grøntoft, Lyngsmose), to a combination of regular farmstead enclosures and more scattered barriers of specific buildings and areas (Hodde), to a consequent enclosure of each farmstead (Lysgård). As a result there was a sliding transition from common-fenced enclosures to curvilinear-farmstead enclosures (No. 7) as well as a pronounced inter-site, size-wise differentiation.

TECHNOLOGY No. 7: enclosure on farmstead level

Another form of curvilinear enclosure was more specifically coupled to the level of the individual household. Such enclosures were initially based on the same morphological principles as the closely set fences surrounding villages (No. 6). In the archaeological record, such regulations occurred from Late Bronze Age and throughout the Pre-Roman Iron Age as irregular farmstead fences running closely around the walls of the longhouses.

There were two main morphological variants of this kind of enclosure: one where the fences enclosed the longhouse and (potential) outbuildings separately and another where both longhouse and outbuildings were kept within the same enclosure. Examples of such features are known from, for example, Agerhøj (SKJ 839), Hodde (Hvass 1985), Munksgårdkvarteret (Pedersen 2007), Nybro (Nielsen and Mikkelsen 1985), Rosenholmvej (Møller-Jensen 2006), Selager (Knudsen and Rindel 1989, Møller 2011), and

(a)



(b)

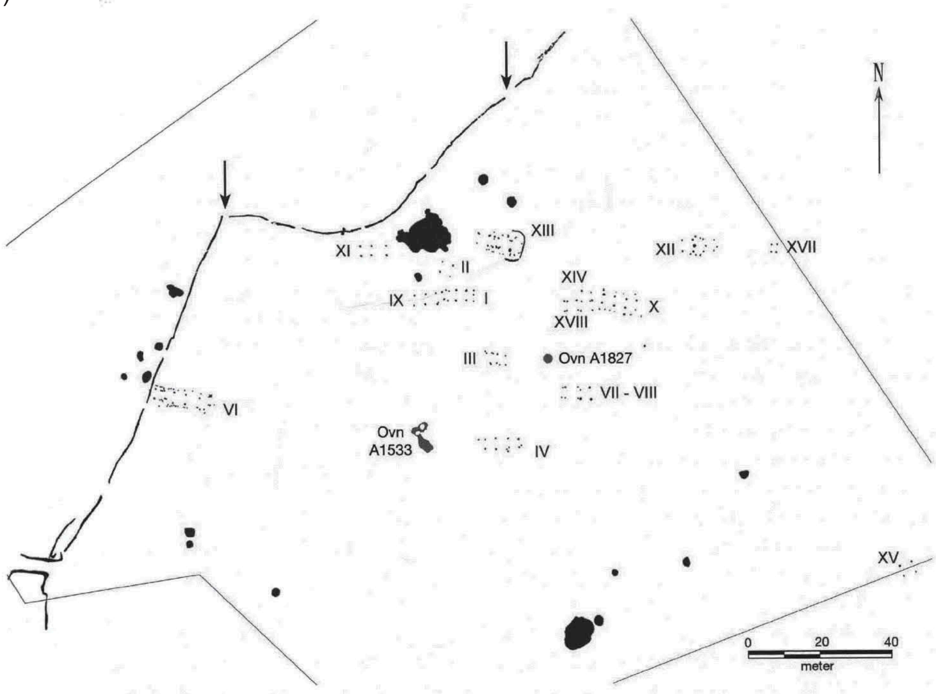


Figure 8. Examples of demarcations on settlement level. 8 (a) The pit zone boundary at Grøntoft, demarcating an area of min 130,650 m^2 (Løvschal 2014a, fig. 1, p. 726, author's elaboration of an excavation plan kindly provided by P. O. Rindel, University of Copenhagen). 8(b) The ditched boundary at Lysehøj, demarcating an area of ~74,200 m2 (after Meistrup-Larsen and Moltsen 2011, fig. 13, p. 109).

Figure 9. Examples of enclosure on settlement level (common-fenced settlements with inner divisions). (a) Hodde between Varde and Grindsted, Late Pre-Roman Iron Age (Hvass 1985, pl. 92, p. 309). (b) Lysgård near Herning, Late Pre-Roman Iron Age (plan kindly provided by Museum Midtjylland, light grey colour indicate modern disturbance).

Spjald Syd (Jørgensen 2011). This was also the most widespread kind of fence-enclosure outside western Jutland. A third way of fencing the farmstead was by using fences as demarcations which did not fully enclose the farmsteads but adjoined the corners of longhouses or outbuildings, making parts of the farmsteads directly exposed to the surrounding landscape, which was particularly common in southern Jutland (cf. Knudsen and Rindel 1989, Eriksen and Rindel 2003, fig. 3, p. 126, Møller 2011, 2013, fig. 5.40, p. 123, Løvschal 2014b, fig. 7).

As a social technology, these fences were oriented 'outwards' (opposite No. 3): they did not mark out a significant area within the fences and thus primarily appeared as a demarcation against livestock, people, or other farmsteads. Since the fences were not allocations but situated close to the walls in a curvilinear fashion, they were primarily coupled to the houses rather than a specific matrix for form or size such as the farmstead parcelling (No. 3). These fences held a double-edged quality, in that they facilitated both proximity and distinction. Most of them were situated within settlement concentrations where they made it possible for people to live closer together while still maintaining their status as individual farmsteads.

Enclosed farmsteads often emerged in areas which showed no or few traces of preceding Bronze Age settlements, for example, along the western edge of Skovbjerg Moraine. Furthermore, their organic layout indicates that they emerged in areas which had not been explicitly divided into equally sized pieces according to a fixed boundary of the area allocated for settlement (cf. No. 2). Rather, they accumulated in a piece-by-piece manner, taking up as little space as possible (Figure 10). Being situated closely around the farmsteads, these fences expressed no explicit wish to expand the size of the individual farmstead plot, and they were rarely repaired or re-erected on the same spot. This suggests that although these areas showed evidence of dense settlements, they were also characterised by a highly dynamic landscape appropriation and settlement pattern. Primarily, the shape of the enclosures would have made sense if livestock were put out to pasture in the surroundings of the houses with no pressure from a boundary that forced a formalised subdivision.

Comparable examples of farmstead enclosure are rediscovered at Humlehaven (150603-34), Agerhøj (SKJ 839), and Højlund I (160105-273).

In this way, principles of enclosure (curvilinear) occurred on:

- settlement level, as common-fenced villages (No. 6) and
- farmstead level, as individually fenced farmsteads, sometimes adjoined in an aggregate manner (No. 7)

Sites representing these technologies were probably situated in areas that would have been characterised by a large degree of flexibility and openness in the organisation of land which it was possible to draw advantage of by introducing another kind of order such as the new physical boundaries. They were characterised by a more labile and informal regulation than the parcelling (No. 1–3). Regarding their size, there appeared to be a sliding transition between multiple spatial levels varying from the individual long-house to larger, nucleated villages.

A new technology: variation and constriction

The above section has outlined a number of scenarios, involving the application of artificial lines in southern Scandinavia during the Late Bronze Age and Pre-Roman Iron Age. In contrast to previous landscape approaches

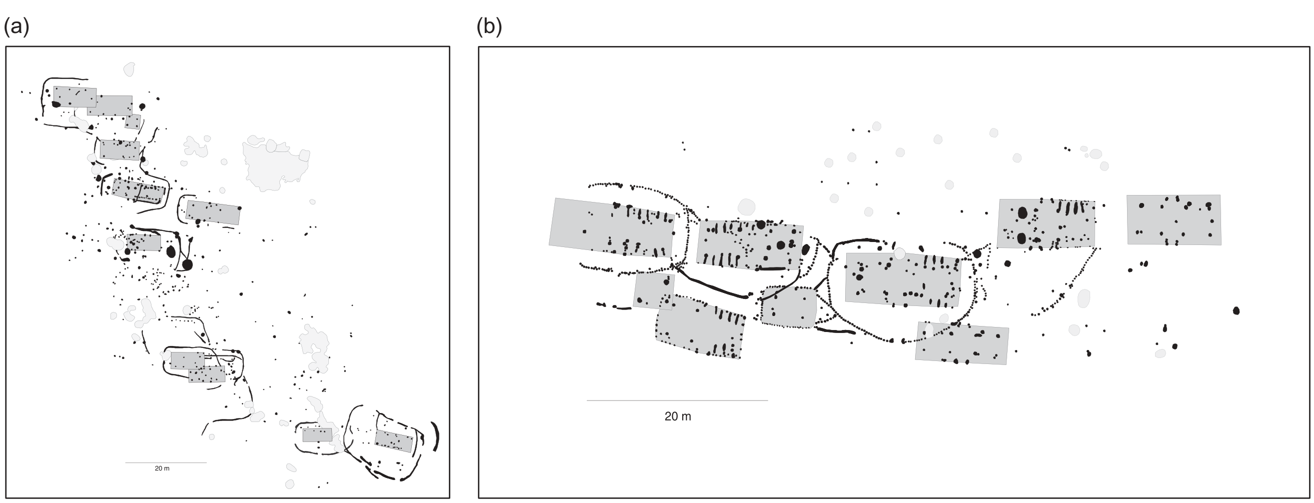


Figure 10. Examples of enclosure on farmstead level (tightly fenced farmsteads which are hypothetically situated in open pastures). (a) Torslund Bakke, Early Pre-Roman Iron Age (after Isler 2012; light grey colour indicates larger pits). (b) Spjald Syd near Videbæk, Late Pre-Roman Iron Age (after Jørgensen 2011).

(cf. Introduction - Research history), the section exposes a technological creativity that questions the way in which typical feature types such as settlement fences and pit zone alignments are defined and delimited and suggest the existence of much more dynamic, transferable principles. Furthermore, it exposes the existence of a number of conflicting approaches to and ambiguities in landscape and settlement organisation in Pre-Roman Iron Age societies, which are rarely studied in the material. The operation of fences, ditches, and earthen banks are characterised by a significant social ambiguity, organisational autonomy, and economic flexibility. It hints at other underlying dynamics than the consolidated village chieftain, egalitarian communities, or agricultural intensification and identifies a focus for considerable social attention, which must have required significant efforts to establish, align, and maintain.

The repertoire involved a palette of new different material technologies, including fences, ditches, palisades, stone banks, earthen banks, moats and pit zones. They were also applied in different ways, including parcelling/plot-definition, demarcation, and enclosure and on several spatial and demographic level, including farmstead/household, settlement, and landscape (Figure 11). These lines would, with time, have created a landscape where both visual appearance and general mobility changed significantly.

In this sense, this repertoire afforded a *technological opening* generating a very flexible system with multiple material applications that opened up for significant margins for variations in the material. This variation was manifested in pronounced differences in size, shape, building material, duration, demographic association, as well as scale. For example, parcelling was not only associated with a segmentation of the landscape but also involved in the internal regulations of settlement sites as well as demarcating the extent of the individual farmsteads. As a result, different principles of spatial regulation diffused into multiple scales and created an association between different parts of the repertoire, such as the landscape parcelling that farmsteads sometimes moved within and the parcel-shaped fences that were built explicitly according to farmsteads. Furthermore, there appeared to be a clear correlation in the operations from small scale to large scale. Some of this combinatory openness was probably intimately associated with the emerging character of the repertoire.

However, the data show certain preferences in the selection and combinations of components, which are outlined as the seven landscape technologies: No. 1–7. These are, as already emphasised, considered stereotyped combinations within the repertoire that were not clearly delimited as topological principles. One technology, for example, landscape parcelling/plot definition (No. 1), could involve numerous different topological principles, such as alignment, enclosure, compound, and parcelling, just as the farmstead parcelling (No. 3) could involve principles of proximity similar to the farmstead enclosures No. 7. Besides from the listed principles, there were numerous other ways of using linear demarcations such as fences connecting different parts of the settlement sites, for example as seen at Kjærsing (Christiansen 1985), Mellanbyn (SE) (Friman 2008), and Selager (Møller 2011) or settlements which were aligned on an existing road or an apparently unmarked line. Still, there appeared to be certain constrictions as well as chronological and culture-historical causalities implied in this repertoire (Figure 11).

Second, there appears to be causality in the chronological development of the operations and combinations. The boundaries were introduced and intensified at different points in time; however, they were all present in the data from *c.* 400/200 BC. Accordingly, the application

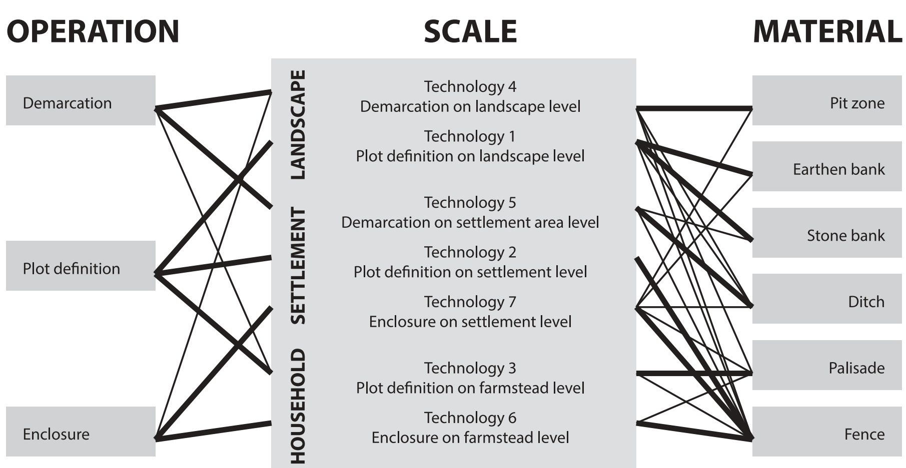


Figure 11. Schematic exemplification of all known combinations in the repertoire (thin lines) and the regional preferences in the combinations (thick lines), outlined as TECHNOLOGY No. 1–7.

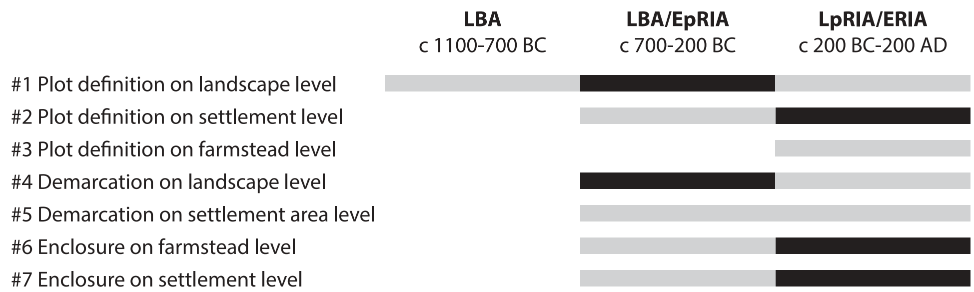


Figure 12. Generalised overview of the time at which the outlined landscape technologies occur in the archaeological material. Lines indicate chronological centres of mass, dotted lines indicate early stages with few occurrences, often connected with dating or interpretative uncertainties.

principles and their materialisations developed in a highly generalised chronological sequence (Figure 12).

Third, there were some clear preferences in the interpretation and selection of landscape technologies according to particular ecological circumstances and culture-historical trajectories and which consequently appeared in regional 'centres of mass'. In the centuries predating the Late Bronze Age (*c.* 1100 BC), the societies of southern Scandinavia were generally characterised by a dispersed habitation pattern, sometimes occurring as very large longhouses (Boas 1993, Bertelsen *et al.* 1996, Earle *et al.* 1998). Such longhouses were probably an important focus for the institutional regulation of extended households (also see Boric 2007, 2008). Activities connected to the building of barrows would equally have constituted important mechanisms of social coordination in an otherwise dispersed settlement pattern as well as regulation of the access and rights to the landscape (Holst and Rasmussen 2012). The stripping of the soil for turf naturally created certain visible patterns in the landscape, for example, 'heath corridors', as well as vegetation differences in the surrounding landscape dependent on labour divisions (Doorenbosch 2013). Furthermore, a boom in barrow building has been demonstrated *c.* 1450 BC with approximately half of the 86.000 preserved and recorded barrows in Denmark having been built or extended within less than two centuries; this would have accentuated these trends and had radical impact on the landscapes (Thrane 1984, pp. 152–153, Holst *et al.* 2013, pp. 270–271).

The arrangement of barrows in linear distributions was particularly strong in western and southwestern Jutland.[5] As far as these barrows were situated along roads (Müller 1904), the majority of these communication lines probably continued in the last millennium BC. Although linear arrangements of barrows are clearly discernible in other parts of southern Scandinavia, they tended to be shorter and less consistent in, for example, northern and eastern Jutland and on the Islands. In these areas, linear arrangements were superseded by more dispersed patterns, local clusters, scattered distributions, as well as trends towards more centralised landscape organisational patterns (Jensen 1983, Thrane 1984).

The understanding of these variations remains limited and the covering of their complexity is far from fully exploited. Some were inevitably the result of source-critical circumstances and historical uses of the landscape. However, they probably also reflected regional ways of appropriating these landscapes, which formed very different backgrounds for the described infrastructural and organisational long-term trajectories.

Thus, on the one hand, the landscape technologies appeared as (partly) concurrent but sometimes conflicting solutions (spatial and chronological mutual exclusion as well as regional preferences), which conflict with a picture of a succession of principles in a unilinear development. On the other hand, there were clear chronological causalities in their emergence, for example, the articulation of landscape parcelling predated the emergence of other technologies, which conflict with a purely ahistorical explanation. In the following section, we wish to discuss these aspects of the concept of a repertoire in relation to previous approaches introduced in the beginning of the article.

Discussion

Elements of development

As the boundaries were operated with different layout principles, they also provided the basis for a complex associative repertoire of different spatial solutions to associated problems that appeared on the settlement sites as well as in the surrounding arable land, such as maintaining access to valuable soil and marking insiders from outsiders (also see Thomas 1997). At the same time, there are some clear elements of development between the different technologies. For example, the principles of articulated landscape parcelling appeared, at least chronologically, to form an underlying basis for the articulated farmstead and settlement parcelling. Several centuries probably passed where the materialisation of linear boundaries was restricted to a landscape level. Landscape parcelling did not only constitute explicit separations of two or more field plots but also induced an increased juxtaposing of the landscape: it created a kind of equivalence and a physical framing of certain areas wherein certain social rules applied and people necessarily had to agree on what they meant. Furthermore, it built on principles of allocation by means of axes, add-ons, parcelling, or compounds, which allowed a large degree of flexibility and variation. The often symmetrical morphology would have made it easy to copy and created new possibilities of equalisation, local standardisation, and formalised comparison.

Different elements that formed part of the repertoire held some clear, intrinsic communicative potential: the boundaries were easy to apply and potentially they had a very broad social and regulatory applicability. When people started recognising and negotiating these generative potentials, they could be applied and developed within other contexts as well, which probably was part of what opened up for the immense variation that unfolded and escalated at the transition from Early to Late Pre-Roman Iron Age.

Compatible and incompatible technologies

The landscape technologies entailed a break in the organisational logic that was incompatible with previous ways of organisation: they defined enclosed margins within which certain rules applied and were difficult to combine with non-boundaries because they created an expectation of reciprocity; if a neighbour's field was marked by banks or walls, others were likely to follow his example and do the same.

Many of these new explicit principles of landscape regulation appeared compatible with one another, and on many sites, multiple forms of regulation existed side by side. Grøntoft contained a palimpsest of boundaries, including a common-fenced village, Celtic fields, pit zone demarcation, dispersed fences, and ditches, as well as possible farmstead enclosures, of which at least some of them must have been contemporaneous. At Øster Lem Hede, the Celtic field system, Late Bronze Age/Pre-Roman Iron Age, was situated next to an adjacent settlement site with enclosed farmsteads, Late Pre-Roman Iron Age (Møgelhøje), and a pit zone alignment, possibly Early Pre-Roman Iron Age (Sønder Brorstrup). The common-fenced site Borremose was equally situated within a landscape surrounded by parcelled up areas (Jensen 2003, p. 220).

Other applications appear to have had mutually excluding effects. The construction of common fences sometimes directly excluded previous farmstead enclosures. Taking Grøntoft as an example again, single-fenced farmsteads were probably erased shortly before the common fence was built (Rindel 2010). Another example is Lyngsmose (Late Pre-Roman Iron Age) where two separately enclosed farmsteads were possibly removed shortly before the construction of the common enclosure (Eriksen and Rindel 2003).[6] Thus, in some locations, these particular landscape technologies would have represented incompatible institutional realities (for a counter example, see Hodde cf. Hvass 1985). This trend increased during the last centuries BC and significantly during the following centuries, which will be discussed briefly below.

Landscape technologies in a long-term perspective

Towards the end of the Pre-Roman Iron Age, there appeared to be a gradual narrowing down of combinations and an increasing alignment between principles applied in landscape and intra-site settlement regulation. Similar to the landscape parcelling, the parcel-shaped farmstead enclosures were built with a consistent morphology in standardised sizes (p. 12). Farmstead enclosure became a more consequent principle on the settlement sites, and fences were increasingly maintained on the same spot (Løvschal 2014b). This indicates a growing conceptual alignment between the explicit regulations associated with plot definition and parcelling on a landscape and settlement level.

In a long-term perspective, applying these different principles of spatial regulation can be followed far into the Iron Ages and possibly later. On the Early Roman Iron Age settlement sites, the parcel-shaped layout developed into a highly formalised regulation principle (Holst 2010). Similar to the Pre-Roman Iron Age, parcel-shaped farmstead enclosures appeared within a limited area with an even more regular and standardised morphology. This phenomenon can be traced on numerous well-preserved sites in the Herning area, such as Stenbjergkvarteret (Olesen 2007), Holing, Norgesvej, Sverigesvej, and Ørskovvej (Olesen 2012), as well as the classical sites from western and southern Jutland, including Vorbasse (Hvass 1978, 1983), Nørre Snede (Hansen 1988, Holst 2010), Snorup (Mikkelsen and Nørbach 2003), and, in the extreme, in the newly excavated Rindum Ny Skole (RSM 10013, Posselt 2012) (Figure 13).

Later elements such as the 'langvolde' (Jørgensen 1988) can be considered an articulation of a comparable technology as the linear landscape demarcations (No. 4). Dates from such features appear from the first centuries AD and throughout the Iron Ages. They too related to communication lines and were probably, in several cases, constructed with a situation-specific purpose. However, their material configuration in much more lasting rampart constructions made them consequently obtain very different long-term effects.

Therefore, it is likely that principles of spatial regulation from much younger sites, that is, Roman and Germanic Iron Age, drew on principles that had already been introduced and tested during the Late Bronze Age and Pre-Roman Iron Age.

Figure 13. (a) Nørre Snede, mid Jutland, Early Iron Age. (b) Ørskovvej, western Jutland, Late Pre-Roman Iron Age-Early Iron Age (plan kindly provided by Museum Midtjylland).

The relevance of the concept of a repertoire

Following the above arguments, the landscape technologies No. 1–7 worked as part of a 'repertoire' of spatial solutions, characterised by a multi-layered application as well as, sometimes, mutual geographical exclusion. Different elements in this repertoire could be applied in a wide range of situations, that is, as means of regulating access to particular areas, controlling and channelling movement of livestock and humans, making territorial claims to the landscape, reorganising and allocating landscape, providing solutions to drainage and land erosion, aggregating otherwise dispersed social units, coordinating labour, as well as defending farmsteads and communities against raids and animals. Thus, the repertoire was associated with a number of social, regulatory processes that evidently did not have a 1:1 association. However, over a significant time span, the repertoire was increasingly merged with institutionalised principles and ideas contributing to its standardisation and localisation.

This repertoire was not characterised by a package-like introduction or diffusion. Rather, it emerged during the Late Bronze Age–Pre-Roman Iron Age and was formed, formalised, and redefined over several centuries. It originated in specific landscapes, however, with a degree of alignment in the culture-historical trajectories and feedback dynamic with broader culture-historical developments of north-western Europe (Løvschal 2014b). Therefore, the concept of a 'repertoire' did not implicate a clear cultural coherency across time or space. People did not necessarily have equal access to it and it did not necessarily develop in an evolutionary fashion. Instead, the different sets of solutions to particular problems may have occurred at different places at different times during the Pre-Roman Iron Age. Parts of it were forgotten, became redefined, or were used in other ways.

The suggested process of transferring or aligning regulation principles from one domain with another, for example, from landscape regulation to farmstead regulation, naturally demanded that spatial structuring increasingly became a known concept and a repertoire of spatial solutions that, at given points in prehistory, could be applied detached from their local landscape. By doing so, it became possible to actively and purposely act through these structures to establish, modify, and transform new forms of organisation. In a long-term perspective, this meant that applying linear boundaries as a spatial response to different issues became increasingly more likely to be evoked than other solutions. And that regional preferences in the selection and application of the repertoire formed the basis of the geographic concentrations (Figure 3a–g), which too became increasingly pronounced in the succeeding centuries (cf. Ringtved 1988).

Conclusion

This article has provided a study of how, in the Late Bronze Age and pre-Roman Iron Age, an increasing part of the landscape was confiscated by means of linear boundaries. In this period, people began to organise according to new regulations on architecture, economy, burials, as well as an increased zoning of the landscape. These regulations sometimes manifested as linear, physical boundaries when certain relations were somehow challenged; a boundary was not constructed unless there was a particular need for it. These concretisations held a double-edged quality. On the one hand, they were based on extremely normative principles and principles of equality, equal distribution, and disintegration of hierarchical differences. On the other hand, they created a new material condition for social and spatial differentiation. We suggest a gradual development of principles of spatial regulation of which the earliest are probably associated with landscape parcelling, which form a repertoire of spatial solutions to different social and economical issues. This development was probably part of what opened up for the variation in the material that was pregnant during the pre-Roman Iron Age and of which certain elements became part of an increased formalisation, the long-term social and juridical effects of which can be traced far into the Late Iron Age societies.

Acknowledgements

We sincerely thank Folmer Christiansen, Kroppedal Museum, Lea Meistrup-Larsen, Museum Midtjylland, and Silkeborg Museum, for contributing with material and excavation plans.

Notes

1. A recent discovery has been made of yet another pit zone alignment at Rødby Havn, Lolland by Museum Lolland-Falster (personal communication Anders Rasmussen, August 2014), which is not on this map.
2. The genesis of the British rectilinear field systems has been subject to a similar discussion by several authors (cf. Fleming 1987, Johnston 2005, Roberts 2013, p. 538).
3. Also see Rosenholmvej near Herning (Møller-Jensen 2006) and Skallegård Syd near Viborg (VSM 08938).
4. Also see Hvilmose Nord (131208-90) and Hvilmose Syd (131211-125) near Viborg, which possibly constituted an interconnected pit zone alignment, running for several kilometers across a ridge.
5. It has recently been suggested that the distinct linear arrangements were associated with regulation of the landscape based on long-distance herding (Holst and Rasmussen 2013) where pastoral resources potentially were situated a large distance from the settlement sites. If we accept this suggestion, obviously it would have left parts of the landscape particularly vulnerable to intervention.
6. Also see Priorsløkke, AD 0 to AD 180 (Kaul 1985, 1989).

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RESEARCH ARTICLE

First evidence of lime burning in southern Scandinavia: lime kilns found at the royal residence on the west bank of Lake Tissø

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In connection with investigations of the aristocratic residence at Tissø from the Viking Age, the earliest evidence so far of lime burning in Denmark has been excavated. The excavations unearthed traces of up to five lime kilns which were subsequently dated to the end of the ninth century. This corresponds well with the dating of the erection of the hall in the third construction phase at Fugledegård. Finds of mud-and-wattle with whitewashing show that the lime was used to whitewash the halls at Tissø in both the Germanic Iron Age and the Viking Age. Analyses of lime from the lime kilns and the whitewashed mud-and-wattle demonstrate that the raw material for the lime burning was mainly travertine deposited in spring water, but that bryozoan limestone was also used. The lime kilns were just under 2 m in diameter with stone-built edges, and there are indications that the superstructure may have been built up with clay. This resembles the corresponding parallel finds from the Iron Age in the German area.

Keywords: lime burning; lime kilns; whitewash; Viking Age; Iron Age; aristocracy; Tissø

Introduction

In Danish archaeology, lime burning has always been dated to the Early Middle Ages, when the first stone churches were built with fieldstone masonry, calcareous tufa and mortar. The present finds of lime kilns from the Viking Age are the first in the southern Scandinavian context where lime-burning units from prehistoric times have been excavated. The find has afforded us the opportunity to gain insight into the constructional aspects and processes that lie behind the final product: whitewash. What follows below is a review of the function and construction of the lime-burning units and the perspectives of the find.

The archaeological investigations

Excavation history

In the mid-1990s, archaeologists from the National Museum of Denmark and the Kalundborg Museum (today the West Zealand Museum) conducted excavations of what was later to turn out to be one of northern Europe's richest sites from the Late Germanic Iron Age and the Viking Age (Jørgensen 2013). The excavations took place on the western bank of the Lake Tissø in western Zealand (Figure 1). Two presumed royal residences with related ritual areas as well as workshops and gathering places were investigated there (Jørgensen 2009, 338 ff.). The first royal residence lay at Bulbrogård (*c.* 550–700) and when it was closed down a new residence was built 600 m further south at Fugledegård (*c.* 700–1050). The latter site is contemporary with the lime kilns. The royal residence at Fugledegård could be traced through four phases, and in all phases consisted of a hall building, a smaller fenced-in area with a cult building, a smithy in the northern part of the residence and a larger enclosure of the whole complex (Figure 2). When the smithy area was investigated in the 1990s intact culture layers were identified, only some of which were excavated; at the same time the topsoil was drawn off down to the subsoil around the preserved culture layer, and towards the east there emerged a large irregular ash-grey fill-layer with an area of 4 × 6 m. At the time it was interpreted as an ash layer and was not investigated in more detail.

In the spring of 2013, the National Museum returned with assistance from the Kalundborg Archaeological Society to the smithy at Fugledegård, and opened up the intact culture layer once more. The aim was to clarify the relationship of the culture layer with the smithy through their various phases. During clearance, parts of the large ash-grey fill-layer came to light, partly beneath the culture layer. In connection with the excavation, the overlying culture layer was water-sifted to find any objects and here emerged small lumps of cemented-together material with solid-fired charcoal and bone fragments in the sieve residue from the top of the grey layer (Figure 3). Because

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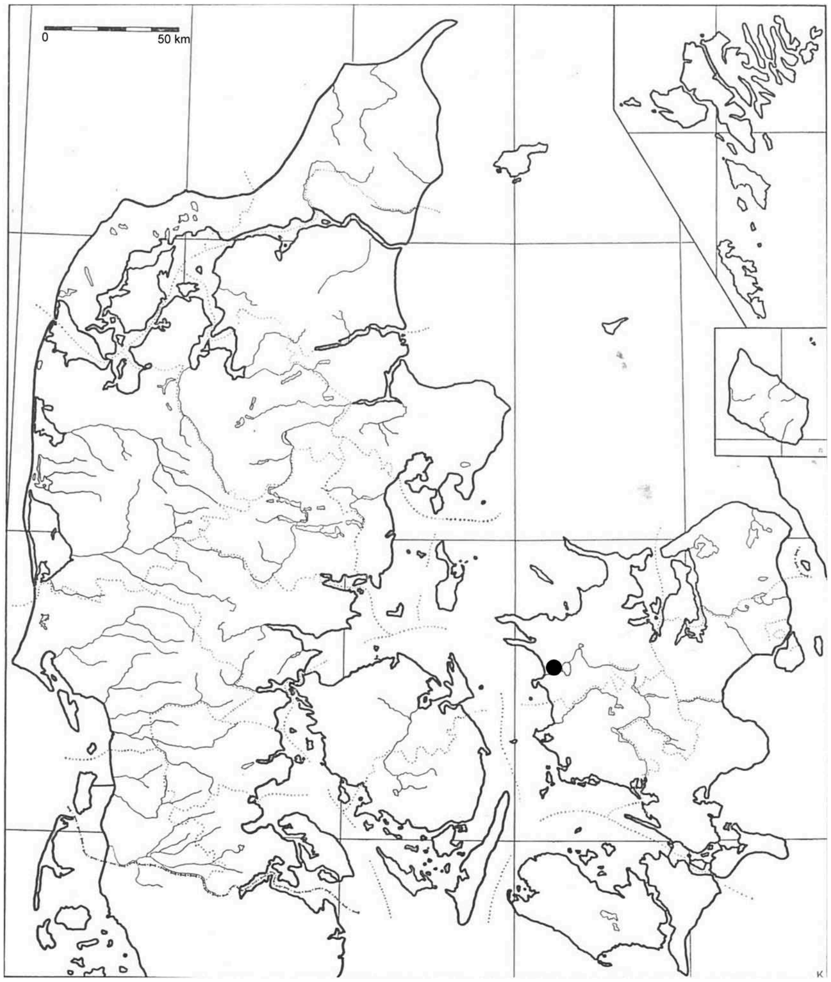

Figure 1. Location of the Tissø-complex in Western Zealand.

of the solid-fired material, the cemented lumps were examined in the microscope and it now became clear that they could be pieces of lime. In a subsequent test with hydrochloric acid, it was confirmed that the lumps did consist of lime.[1] At this time, the fill-layer was only partly uncovered, and an interpretation based on the character of the layer and a profile of the excavation boundary to the east was that this might be the bottom of a lime kiln – in that case, the earliest known lime kiln in the southern Scandinavian area.[2] Later the layer was radiocarbon-dated to the ninth century. Because of the special nature of the find, the remains of the layer were subsequently uncovered and excavated. This resulted in the find of three round-to-oval lime kilns as well as what are thought to be the remains of a further two to three kilns.

Construction of the lime kilns

Three of the lime-burning units were so well preserved that their original size and contour could be observed, as can be seen on the excavation plan (Figure 4). However, only the bottom 5–15 cm of the units was preserved. The units were 170–190 cm in diameter and almost circular. Before the establishment of the kilns the whole area had been dug down to pure subsoil sand, and the kilns were then dug down a further 5–10 cm. No stratigraphic distinctions could be observed between the various kiln units. In two of the kilns, remains were found of a stone-built ring around the edge of the unit, which indicates that the kilns were built with a stone-built mantle at the top. In the westernmost part of the lime and ash layer, this is overlaid by a *c*. 6 cm thick layer of clay. By two of the kilns, FG-A117 and FG-A119, possible stoking holes and/or flues were found in the form of small buried channels coming out of the circular units.

In the feature FG-A118, which was the best preserved, two layers of lime were found in the kiln (Figure 5). Just above the sand subsoil there was a thin greyish-brown layer of ash and charcoal overlaid by an almost white lime layer, which was up to 5 cm thick and surface-covering. Above this was

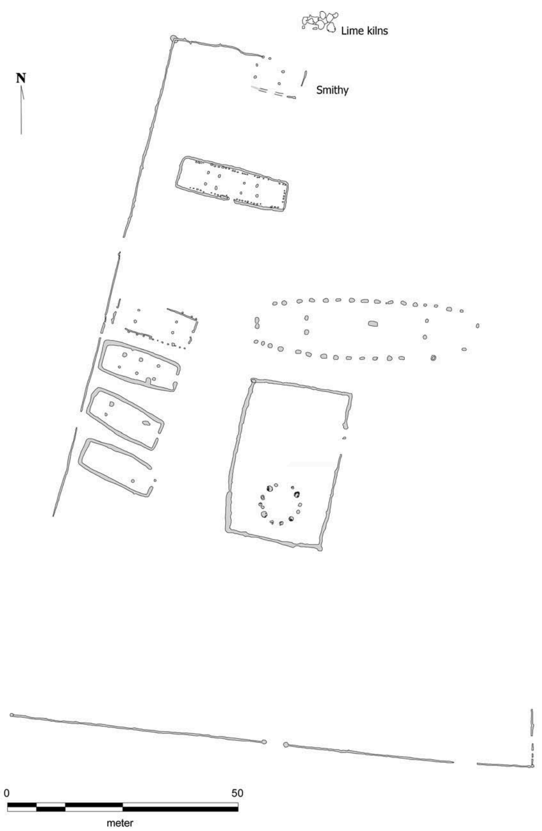

Figure 2. The royal complex in phase 3 with the lime kilns marked to the north.

Figure 3. Lump of lime from kiln FG-A118 with charcoal and bone fragments. Photo: P.S. Henriksen.

found yet another layer of ash and charcoal which was in turn overlaid by a more reddish lime layer, similarly several centimetres thick, but not present throughout the area of the kiln.

The subsoil sand beneath and around the kilns was particularly hard as a result of the precipitation of slaked lime after the lime burning. This shows that the whole kiln area was covered by burnt lime, presumably in the form of crumbled lime scattered in connection with the emptying of the kilns after the lime burning.

In the area around the lime kilns, the excavations of the 1990s registered a number of post-holes at the edges of the two lime kilns. The excavation of the two lime kilns FG-A118 and FG-A119 registered a further two post-holes around the edges which may have belonged stratigraphically to the kiln units.

Datings

From the three best preserved kilns, charred material embedded in the lime was AMS radiocarbon dated. From each of the three features FG-A117, FG-A118 and FG-A119, a grain specimen and small pieces of charcoal were dated; the results of the datings can be seen in Figure 6.

All the datings fall within the Viking Age, unfortunately with a high degree of uncertainty because of wiggles in the radiocarbon curve. If the lime kilns are more or less contemporary, as the stratigraphy suggests, the most likely dating is at the end of the ninth century, which corresponds to the start of phase 3 of the royal residence at Fugledegård.

Finds of mud-and-wattle and pottery with whitewashing

During the excavations of the Tissø complex in the 1990s and at the beginning of the 2000s, mud-and-wattle with whitewashed surfaces was found in both Germanic Iron Age and Viking Age structures. From the halls at Bulbrogård, kilograms of mud-and-wattle with whitewashing emerged. This find has been dealt with in detail by Bican (2007). At Fugledegård, only smallish pieces of mud-and-wattle with whitewashed surfaces were found in the hall area, but it is assumed that there too the halls had whitewashed walls. Moreover, in the phase 2 hall, a single potsherd was found with painting on the outside, and investigations and microscopy demonstrated that burnt lime had been used there too.

The lime-burning process

The process of making slaked lime that could be used to whitewash mud-and-wattle walls began with the burning of limestone in a lime kiln. The limestone could come from many different sources. Lime in the form of chalk, bryozoan limestone and coral limestone exists in the Danish and Baltic subsoil and in certain places the limestone layers are exposed in cliff formations such as those at Stevns and Møn. During the Late Baltic Glacial at the end of the last Ice Age, limestone from these layers was deposited in the moraine of the whole eastern Danish area

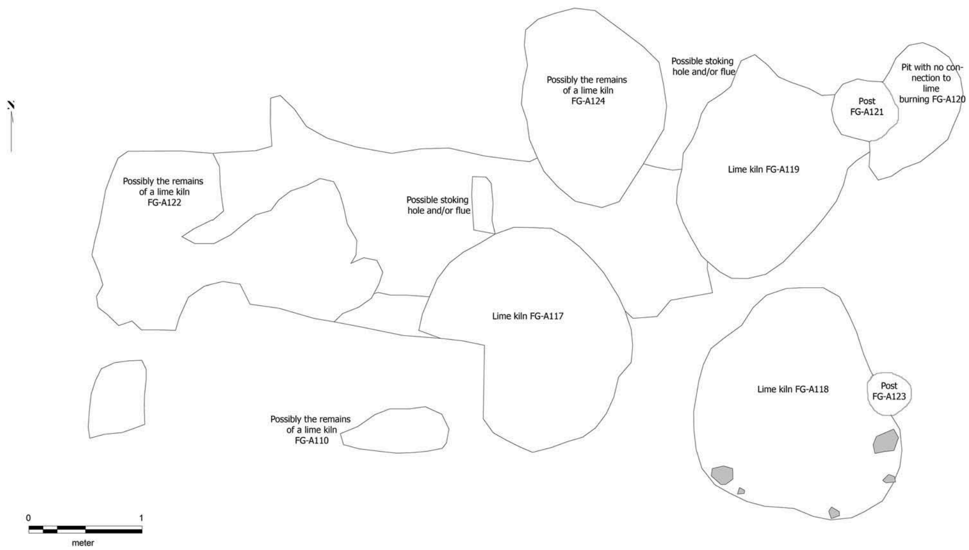

Figure 4. Excavation plan.

Figure 5. Profile of lime kiln FG-A118 (note that the A-number on the blackboard has later been changed), showing two lime burning layers. Photo: S. Holst.

(Houmark-Nielsen and Sjørring 1991), where it can now be gathered from fields and along the coasts.

In many parts of the country, lime can also be found as travertine, which can form metre-thick layers (Nielsen 1967). The deposits are formed in springs where CO_2-rich groundwater that has dissolved lime in the soil comes up to the surface, where the carbon dioxide evaporates and the lime is re-precipitated, usually together with iron and manganese (Larsen and Surlyk 2012).

Other possible sources of lime are oyster shells and other seashells since the mineral elements of these consist exclusively of calcium carbonate (Petersen 1971). The shells can be gathered along the coast, often washed together in large concentrations.

In lime burning the limestone has to be heated to above 850°C. At this temperature, the limestone, which

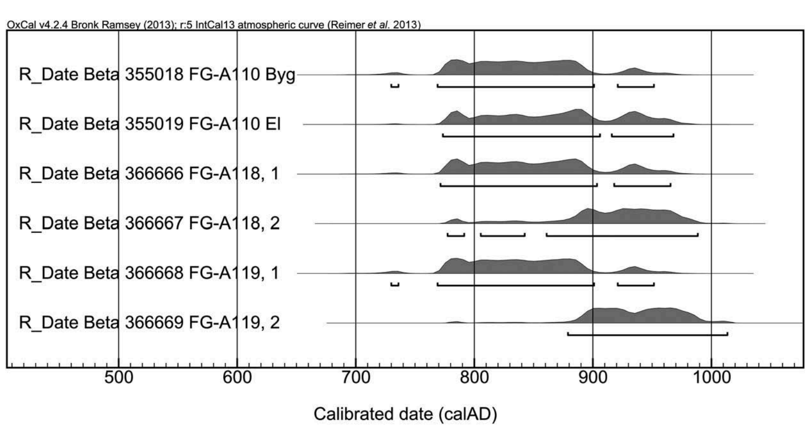

Figure 6. AMS radiocarbon dates of the lime kilns calibrated with OxCal v4.2.3 (Bronk Ramsey 2013) and IntCal13 (Reimer *et al.* 2013).

$$CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2 \xrightarrow{H_2O} CaO + H_2O \rightarrow Ca(OH)_2 \xrightarrow{CO_2} CaCO_3 + H_2O$$

Figure 7. The chemical process of lime burning and slaking.

consists of calcium carbonate, sheds carbon dioxide to become calcium oxide (see Figure 7). Subsequently, the calcium oxide is mixed with water. This is called slaking, and forms calcium hydroxide, also called slaked lime. When the slaked lime comes into contact with air, for example when used to whitewash house walls, it re-absorbs carbon dioxide and then becomes calcium carbonate/limestone again.

Scientific investigations

Microscopic investigations of lime from the lime kilns

A number of specimens were taken (3–4 l/specimen) from the lime layers in the various kilns for more detailed analysis. The composition of the layers varied from almost pure lime to layers with equal proportions of lime, ash and sand. From the kiln FG-A118, two specimens were analysed in more detail; one specimen from the lower, almost white lime layer, and one specimen from the upper, reddish lime layer. Parts of the specimens were passed through a sieve with a mesh size of 0.5 mm to remove fine sand prior to the microscopic examination.

Microscopic analysis of the specimens at a magnification of 8–100× showed that they mainly consisted of lime in which many pieces of charcoal were embedded, as well as some sand, fragments of bones and shells of swollen river mussel (*Unio tumidus*) and a few cockle and snail shells.

The lime took the form of a cemented mass of microcrystalline grains around 1–10 μm in size. In among the lime grains were varying amounts of reddish-brown particles of iron of 1–5 μm. In the lower lime layer from FG-A118, the percentage of iron particles was low, while the upper lime layer contained so many iron particles that the layer looked reddish-brown (see Figure 5).

XRF analysis

Specimens from the lower and the upper lime layer in FG-A118 were investigated at the National Museum's Environmental Archaeology and Materials Science Unit with an XRF scanner.[3] This scanning analysed the material for element composition; however, small elements such as oxygen and carbon cannot be demonstrated with XRF. The scanning showed that the specimens were dominated by calcium, as expected, since calcium is the main element in lime. The specimen from the lower layer also contained iron, while the specimen from the upper layer

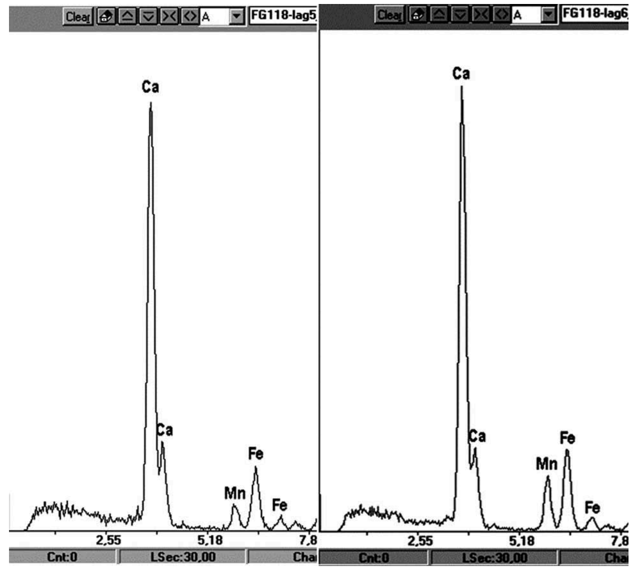

Figure 8. Results of XRF analysis of the lime layers from FG-A118. Left: the lower lime layer. Right: the upper lime layer. Both layers contain iron and manganese.

contained both iron and manganese (see Figure 8). The XRF analysis shows that travertine was used as raw material in the lime burning since travertine is rich in iron and manganese, whereas bryozoan limestone and seashells, the other locally occurring lime types, do not contain these elements.

Thin-section analysis

A specimen from the bottom layer of the feature FG-A117 was subjected to thin-section analysis[4] (Seir 2013). Around 70% of the specimen consisted of lime crystals formed by the slaking of burnt lime. The remainder of the specimen consisted of sand and a small amount of unburnt lime, most of which was a very fine-grained sedimentary limestone without impurities and in places with structures from bryozoa-like fossils. This suggests that the point of departure for this specimen was Danian lime, which is the limestone found at the cliffs of Stevns Klint, but which can also be found as loose blocks in the moraine of among other places Zealand. In the specimen, there were at one point clearly contoured traces of hexagonal calcite crystals, which may indicate that there was also travertine in the specimen analysed (Seir, personal communication).

Microscopic analyses of the whitewash

A piece of mud-and-wattle with lime from Bulbrogård was analysed at the National Museum's Conservation Department. The analysis showed that this was whitewashing done with slaked lime. The lime layer was 0.2–0.5 mm thick and in a few places layers from two whitewashings

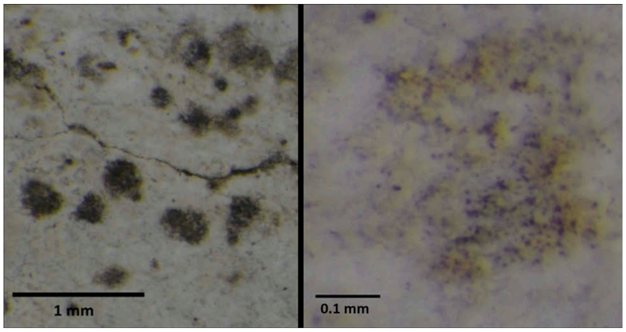

Figure 9. Microscopic images of the lime layer with the many black areas 0.2–1 mm in size identified as manganese (left), along with scattered 2–5 μm red spots of iron (right). Photo: P.S. Henriksen.

could be observed. Beneath the lime layer, a layer of a similar thickness was found, consisting of a mixture of lime and clay. This may have been formed when the first whitewashing was done on the still-wet mud-and-wattle (Christensen and Schnell 2006).

On other pieces of whitewashed mud-and-wattle from Bulbrogård, a layer of clay up to 5 mm thick was found with lime mixed in between the mud-and-wattle and the outer lime layer. This suggests that a plaster layer of clay mixed with lime was added before the final whitewashing, presumably to get better adhesion of the lime to the underlay.

XRF analysis of whitewash from Bulbrogård showed that the lime layer, besides calcium, also contained iron and manganese, which shows that travertine was used as a raw material. The iron could also be examined microscopically since innumerable small red grains were found scattered through the white lime layer.

The mud-and-wattle with lime from Fugledegård resembled the find from Bulbrogård; here too there was a plaster layer of lime, clay and sand as an underlay for the whitewash. On one of the preserved pieces of whitewashed mud-and-wattle, the plaster layer was around 2.5 mm thick.

The lime layer appeared as a white groundmass with many black areas 0.2–1 mm in size, which XRF analysis was able to identify as manganese, as well as scattered, 2–5 μm red spots of iron, very numerous in some places, corresponding to what was also seen in the lime from the lime kilns (see Figure 9).

Experimental lime burning

In order to test how different lime types are suited to the production of whitewash and what the lime looks like, bryozoan limestone, mussel shells and travertine with different iron contents were heated to 1000°C in a muffle kiln and then slaked. The lime was then painted on clay slabs that could be compared with the original whitewashed mud-and-wattle from Bulbrogård and Fugledegård.

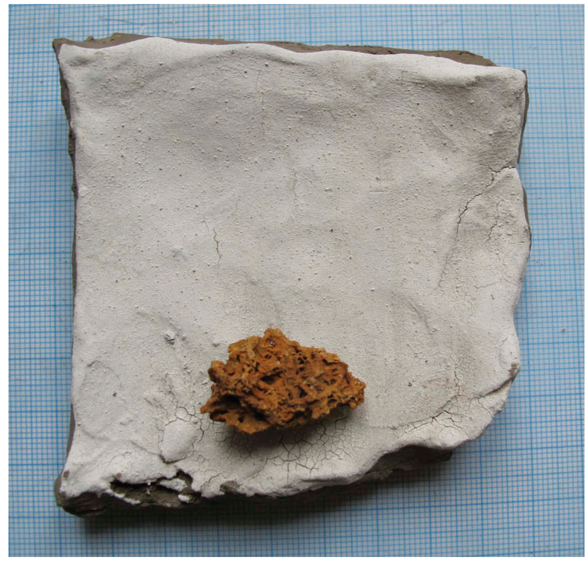

Figure 10. The result of experimental whitewashing based on lime with high content of iron as described in the text. A piece of the iron rich lime is placed on top of the whitewashed clay slab. Photo: P.S. Henriksen.

All the whitewashing appeared more or less white – even the lime that was made on the basis of dark, rust-red travertine (see Figure 10). Under the microscope, small red and black iron and manganese particles could be observed embedded in the lime made on the basis of travertine, while the lime made of bryozoan limestone and seashells did not contain any of these impurities. The lime made from travertine thus corresponded best to the lime found on the mud-and-wattle.

Parallels from abroad

The early development of lime-burning technology

The earliest signs of the use of burnt lime come from pre-pottery Neolithic settlements in the Middle East dated to the 7th century BC (Garfinkel 1987); the earliest known lime-burning unit was found in the Mesopotamian city of Khafaje, and has been dated to the middle of the third millennium BC (Williams 2004, p. 3). However, it was not until later, for example in the Middle Minoan period on Crete around 1800 BC, that lime in the form of mortar was used as a construction material. And not until the Roman Empire did lime mortar come into common use in construction (Dix 1982, p. 339, Harrington 2000, 4 f.). The Romans' use of lime for construction and other purposes is particularly well known since besides the archaeological finds there are several contemporary written sources that describe in detail the processes leading from limestone to usable construction materials. A detailed account was written by the Roman statesman Cato[5] in the work *De agri cultura*, in which he reviews everything from the construction to the operation of various kilns (Uschmann 2006, p. 95).

In the northern European area, the first reliable find of lime burning is a chalk layer at the bottom of a kiln dated to the Late Bronze Age and found in eastern Pomerania around 1880 (Uschmann 2006, p. 12). Since it is likely that the lime-burning technology came to the Scandinavian area from the south, it seems reasonable to look at the parallels from there.

Northern European parallels

A large number of lime kilns from the period around the 3rd century BC until the 4th century AD have been found in the present-day German area, with concentrations around Hamburg and in the lower Elbe area (Uschmann 2006). The early kilns, dated to the Pre-Roman Iron Age, were typically round with a diameter of 1–2 m, but in the course of time the shape of the kilns changed to oval. Most kilns had a stone-built funnel-shaped bottom with a depth of 0.5–1 m, in some cases a stoking duct in the side, and in connection with many of the kilns one could see remains of a clay superstructure that was broken down after each burning. At many of the kilns, traces have also been found of covering constructions (Uschmann 2006, 38 f. & 75, diagrams 25 & 26). In the German material, several kiln units occur which are very similar to the Fugledegård kilns, round-to-oval constructions with traces of stone rings around them (Figure 11). This applies, for example, to finds from Printzen and Herzsprung II as well as Osterrönfeld from Brandenburg and Schleswig, respectively (Jöns 1993, Abb. 3, Schuster 2000, 96 f., Uschmann 2006, plate 4, 1).

In the transition to the Early Middle Ages in the German area (*c.* AD 490), lime burning changed its character. This happened when the need for burnt lime for mortar increased dramatically in connection with the spread of monasteries and other stone-built houses. Large stone-built lime kilns were set up at monasteries and in towns, while small-scale production in the countryside took place in simple charcoal stacks covered with turf, built directly on the ground surface (Uschmann 2006, 111 ff.).

In the northwestern German area, the raw material for the lime burning was mainly lake and bog lime, found there in layers up to several metres thick at the bottom of lakes and under the peat in some bogs (Uschmann 2006, p. 20). Lake and bog lime are lime layers precipitated in lakes with highly calciferous water (Galsgaard 1998, p. 32). In many German lime kilns, there are also remains of burnt bones (Jöns 1993, p. 68), as was the case in the find at Fugledegård.

Discussion

Construction and placing of the lime kilns

The lime kilns from Fugledegård recall the German kilns with stone-built edges and stoking ducts. However, the Fugledegård kilns were not constructed with a depression in the middle as most of the German kilns were. There was only a small layer of clay which could be the remains of a superstructure of the kind known from Germany. However, since only the very lowest layers were preserved, it is not possible to establish how the superstructure looked. In the kiln unit FG-A118, there were two separate layers of burnt lime, which indicates that the kiln was used for at least two burnings. It could not be ascertained whether the other kilns had been used several times since only a thin bottom layer was preserved in them.

At Fugledegård the lime kilns were situated just outside the large paddock enclosure in phase 3, associated with the smithy, which was situated close to the fencing with an outlet through the fence (see Figure 3). In a number of German cases, the lime kilns were also associated with smithies, but isolated from the built-up areas (Jöns 1993). It is thus likely that it was the smith that was responsible for lime burning. Whether the lime burning was isolated from the surroundings with a covering, as described from the German area, is hard to say, since the post-holes around the lime are so irregularly placed that one cannot directly distinguish a structure.

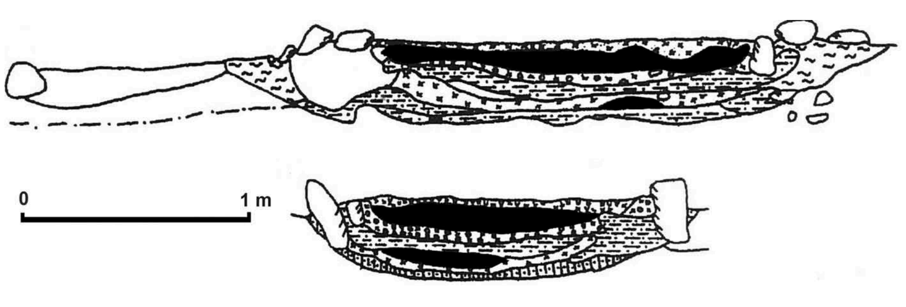

Figure 11. Profile drawings of a lime kiln from Printzen, Germany, which are very similar to those at Fugledegård. The lime layers are marked with black. (Redrawn after Uschmann 2006).

At Fugledegård, the kilns were placed less than 70 m from the hall building despite the fact that the lime-burning process would have created a nuisance in the form of smoke and highly corrosive lime dust. One explanation may be that the kilns only functioned during the establishment phase of the hall from phase 3, which is supported by the datings to the end of the ninth century, when this hall phase was built.

Raw materials for the lime burning

The analyses show that the primary raw material for the lime burning was travertine, but that bryozoan limestone was also used. The closest travertine deposits are found just a kilometre west of the royal residence at Fugledegård in the former bog area Maderne. Drillings in the low-lying surfaces in this area showed signs of removal of the lime since thin lime layers could be observed at a depth of 40–50 cm, overlaid by re-dug layers. On slightly higher-lying surfaces, there are moreover areas of up to several hundred square metres with ploughed-up travertine layers. On the surface there one can see many travertine fragments up to 15 cm thick. Drillings have further shown that beneath the plough layer travertine can be found down to a depth of at least 70 cm.

The bryozoan limestone could be gathered in small quantities from the surface in the landscape and along the banks of Tissø and at the Great Belt coast. However, it is not possible to ascertain how much of the raw material for the lime burning consisted of bryozoan limestone.

To a lesser extent, shells were also used, primarily from swollen river mussel, a freshwater species that could be gathered in Tissø and Halleby Å.

In the lime layers, there were also many fragments of burnt bones, which indicate that there were also attempts to exploit the lime in the bones. However, only a small part of the lime can be used since only a few per cent consists of calcium carbonate (Biltz and Pellegrino 1969), while by far the greater part is calcium phosphate, which cannot be converted into calcium oxide by burning. Despite this, it was apparently common to add bones in the lime burning, as can be seen in the German material (Uschmann 2006). Whether it was believed at the time that lime from bones could be exploited or whether there were ritual reasons behind this can hardly be determined. Some researchers do think, however, that lime burning in prehistoric times was used as a means of consolidating social and cultural identity, and that lime burning was therefore assigned a ritual meaning (Dillehay *et al.* 1997, 46 f.). Since travertine is easily accessible in large quantities close to Fugledegård, it was not because of a scarcity of raw materials that bones were used. This may suggest that bones were added for other reasons, for example, ritual ones. Unfortunately, the bone remains from Fugledegård are much fragmented and it is not possible to identify their species.

Whitewashing in prehistory

It is uncertain how long whitewashing with burnt and slaked lime was practiced in the Danish area. Finds of mud-and-wattle with whitewashed surfaces have earlier been traced all the way back to the Bronze Age with the finds from Voldtofte, Skamlebæk and Ledreborg Golfbane[6] (Lomborg 1979, Thrane 1979, Jensen 2002, p. 351, Andersen 2012) and to the Early Iron Age with the find from Ginderup (Kjær 1928, Høy and Kaul 1995), but analyses of the 'whitewashed' mud-and-wattle pieces from the four sites in connection with these investigations have shown that on the whole there was no lime in the light-coloured coatings of the mud-and-wattle. It is instead likely that this was painted with a layer of very light-coloured clay with a small lime content. From Voldtofte we know of early painting with red and black colours (Berglund 1982). From Fosie IV in Scania, there is a similar find of mud-and-wattle painted with chalk in a pit in a Bronze Age house (Björhem and Säfvestad 1993, p. 86) and in the present-day German area painting of the Bronze Age houses was also widespread (Knoll *et al.* 2013).

Painting with lime has also been described on a number of house-shaped urns from the Bronze Age (Broholm 1946, pp. 129 & 132–133, 1949, pp. 146–148). Investigations of these house-shaped urns showed that burnt lime was not used to colour these urns either, but that they were painted with a greyish-white clay. On a few house-shaped urns, the light-coloured coatings were not painted at all, they were mineral precipitation found both on the inside and the outside. The oldest known occurrences of whitewashing with burnt lime are therefore in the find from the Late Germanic Iron Age from Bulbrogård as well as a contemporary find from Fredshøj in Lejre (Tom Christensen, personal communication). The structures at this site (Christensen 2010) were presumably parallel in status to those at Bulbrogård. From Scania we also know of a contemporary find since mud-and-wattle with whitewash was found around the burnt-down cult house at Uppåkra (Karl Magnus Lenntorp, personal communication, 24 April 2014).

Finds of mud-and-wattle with whitewash are very few in the Danish archaeological material. However, it can be hard to tell whether this is because whitewashing was uncommon or whether it was due to the preservation conditions. If mud-and-wattle with whitewashing is to be found preserved, it has to have been subjected to strong heat so that the clay has been fired, but the lime must not have been heated to over 850°C, at which point the carbon dioxide is split off.

Whitewashing: practical and social function

The whitewashing of mud-and-wattle walls has been widespread until recent times. The whitewashing was absolutely necessary to the durability of mud-and-wattle outer walls since without whitewashing they would very quickly be destroyed by driving rain, which can soften the clay surface, making it fall down. Whitewashing forms a thin film of waterproof limestone on the outside of the wall, which thus becomes more weatherproof.

In several of the phases of the royal residence at Tissø, the posts were of such large dimensions that we must presume that the buildings had more than one floor (Lars Jørgensen, personal communication, 3 July 2014). This means that the walls must have been so high that the roof construction was unable to protect the walls, so whitewashing would have been essential to the preservation of the mud-and-wattle.

It is also possible that the inside walls were whitewashed since white walls reflect light better than clay walls, which would have considerably improved the benefit of the poor lighting of the period. The very widespread use of mud-and-wattle with whitewashing at Bulbrogård makes it likely that the walls there were whitewashed both outside and inside (Bican 2010, p. 152). Whitewashing of inside clay walls was certainly known as far back as the 1500s (Steensberg 1974).

Besides the practical function, whitewashed walls may also have had a social function. The halls at Fugledegård were situated on a plateau down towards Tissø and given the sizes of the halls, both at floor level and at the presumed heights, whitewashed walls would have been highly visible in the landscape, whether one sailed into the complex or arrived by land. It has therefore earlier been suggested that whitewashed walls were in fact an element in the manifestation of social power, and that they should be seen as part of the demonstration of power by the elite (Bican 2010). This may be supported by the fact that the finds from the Iron Age and Viking Age so far all come from the buildings of the elite. This gives us a picture of lime burning as something associated with the higher levels of society, suggesting that the actual lime-burning technology was perhaps reserved for the aristocracy.

Summary and perspectives

Lime burning and whitewashing with burnt and slaked lime appears with certainty from the Germanic Iron Age in Denmark since older finds of presumed whitewash have proved not to be lime based. Instead, they are examples of painting with light-coloured clay. The present finds of whitewash in prehistory are all from high-status sites – whether this is the true picture of the occurrence of whitewashing or whether it was more common cannot be established with certainty with the present small amount of data.

The kiln structure found at Fugledegård in many ways recalls parallels from the present northern German area during the Iron Age, but also differs from most of these in not having a sunken middle. This is probably because kiln construction changed over the centuries from the type of kiln developed in the German area to the type used in the Danish area in the Viking Age.

The analyses of lime from the lime kilns and of whitewash on mud-and-wattle show that in the Germanic Iron Age and Viking Age a number of raw materials were used in the production of whitewash. The main ingredient was travertine or bryozoan limestone, but to a lesser extent shells and bones were also used.

The lime kilns were placed just outside the fencing, associated with the smithy, which may indicate that the lime production was connected with the smith, a situation we also know from many German finds from the Iron Age (Jöns 1993, p. 75).

Lime kilns have hitherto been a neglected find group in Danish archaeology. The feature type can however easily be identified by simple means: one has to pay attention to round or oval stone-surrounded features with ash layers with possible white or reddish lime layers, which can be identified with diluted hydrochloric acid. One must moreover be alert to hardened subsoil layers in connection with the features. By many of the lime kilns from the German area, traces of coverings were found. With future finds of lime kilns one must therefore be very aware of post-holes which may come from such covering structures.

Notes

1. The presence of lime can be demonstrated with hydrochloric acid. When one pours diluted hydrochloric acid (10%) on lime, it fizzes powerfully since the acid decomposes the calcium carbonate, emitting CO_2.
2. On Gotland, a possible Viking Age lime kiln has been excavated in 2013. The interpretation as a lime kiln is however uncertain since the kiln itself is built of limestone. The burnt lime at the bottom of the kiln may therefore come from the actual casing of the kiln, without having anything to do with the function of the kiln (Carlsson *et al.* 2014).
3. The XRF analyses were conducted at the Environmental Archaeology and Materials Science, National Museum of Denmark by Conservation Scientist Michelle Taube using a Bruker Tracer III-V+ hand-held X-Ray Fluorescence apparatus. With XRF one bombards a specimen with an X-ray. This boosts some of the atoms to a higher-energy level, after which they decay again while an X-ray characteristic of each element is emitted. From an X-ray spectrum, one sees the elemental composition of a specimen since the position of the peaks shows which element they come from and their areas indicate the amount of the element in question. With the National Museum's XRF, all elements with a higher atomic number than magnesium (no. 12 in the periodic system) can be detected. The X-ray tube in the apparatus contains rhodium (Rh), which means that peaks for Rh are shown in the spectrum.
4. In thin-section analysis, the specimen is first impregnated with epoxy treated with fluorescent pigment. Then a 0.02 mm thick slice of the specimen is made. At this thickness, mineral grains and other components are translucent and can thus be identified with so-called refraction or polarization microscopy.
5. Cato lived from 234 until 149 BC and was a Roman statesman and theoretician of science (Uschmann 2006, p. 95 note 450).
6. Thanks to Roskilde Museum and Ole Thirup Kastholm for kindly making the Ledreborg Golfbane material available for detailed investigation.

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RESEARCH ARTICLE

Galgedil: isotopic studies of a Viking cemetery on the Danish island of Funen, AD 800–1050

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Galgedil is a Viking Age cemetery located in the northern part of the Danish island of Funen. Excavations at the site revealed 54 graves containing 59 inhumations and 2 cremation burials. Previous study of the remains to date has included light isotopes of carbon and nitrogen in collagen (10 samples) and the radiocarbon determination of the age of 8 samples. In addition, aDNA was investigated in 10 samples from the cemetery. Here we report the analysis of strontium isotopes in human tooth enamel as a signal of place of birth. Some 36 samples have been measured and non-local outliers identified. Baseline levels of strontium isotope ratios in Denmark are discussed and documented. Our study also includes an in-depth consideration of the bioarcheology of the skeletal remains in terms of demography, paleopathology, and taphonomy. The burials are evaluated in light of the available archeological, chronological, anthropological, and isotope information available.

Keywords: bioarcheology; Denmark; strontium isotopes; mobility; archeology; prehistory; Vikings

Introduction

In the last 25 years, the chemistry of human bone, both at the molecular and atomic level, has become an important means for studying past human behavior and activity. Studies of ancient DNA, for example, provide important information on the genetic ancestry and kin relationships of past humans. The isotopic chemistry of skeletal remains is employed for the study of past diet and mobility. The use of light isotopes of carbon and nitrogen provides information on paleodiet, while isotopes of strontium, oxygen, and sometimes lead are used to study residence changes in the past. These methods provide a means to examine both the individual and the group in terms of prehistoric behavior and kinship and have the potential to open new windows into the study of the human past.

The study reported here will focus on the investigation of human movement in the past at the molecular and atomic level. We examine a skeletal population from the Viking Age cemetery of Galgedil in Denmark using various indicators. A thorough description of the cemetery and the graves is provided for the context of the skeletal remains and the cultural materials associated with them. The biological anthropology of the skeletons is presented with details of age, sex, stature, and pathology to define the biological characteristics of these individuals. A previously published aDNA study of the same skeletal material is briefly summarized to include those results (Melchior *et al*. 2008a, 2008b).

Strontium isotopes are used to examine the place of origin of the burials from Galgedil. Discussion of the characterization of the strontium isotope baseline in the local area is an important component in order to be able to distinguish local and non-local individuals. A study of carbon and nitrogen isotopic of the bone and dentin collagen was conducted some years ago (Kanstrup 2006). These data are briefly summarized and offer some information on the diet of the cemetery inhabitants. Carbon and oxygen isotopes in dental enamel provide dietary and locational information, respectively, from the early childhood of these individuals. Our summary integrates the results from the various molecular and chemical investigations in the context of the Viking cemetery. In the end, we learn more about the lives of these individuals who lived a millennium ago in northern Europe.

The Viking cemetery at Galgedil

A cemetery with 54 graves from the Viking age was excavated in 1999–2005 near Galgedil (Figure 1) in the northern part of the Danish island of Funen.[1] The total number of interred individuals was 61 as some of the graves contained more than one burial. Fifty-four of the graves had inhumations and there were two cremations. Originally more graves had been present, but sand quarrying in the 18th and 19th centuries destroyed an unknown number. Five of the excavated graves had

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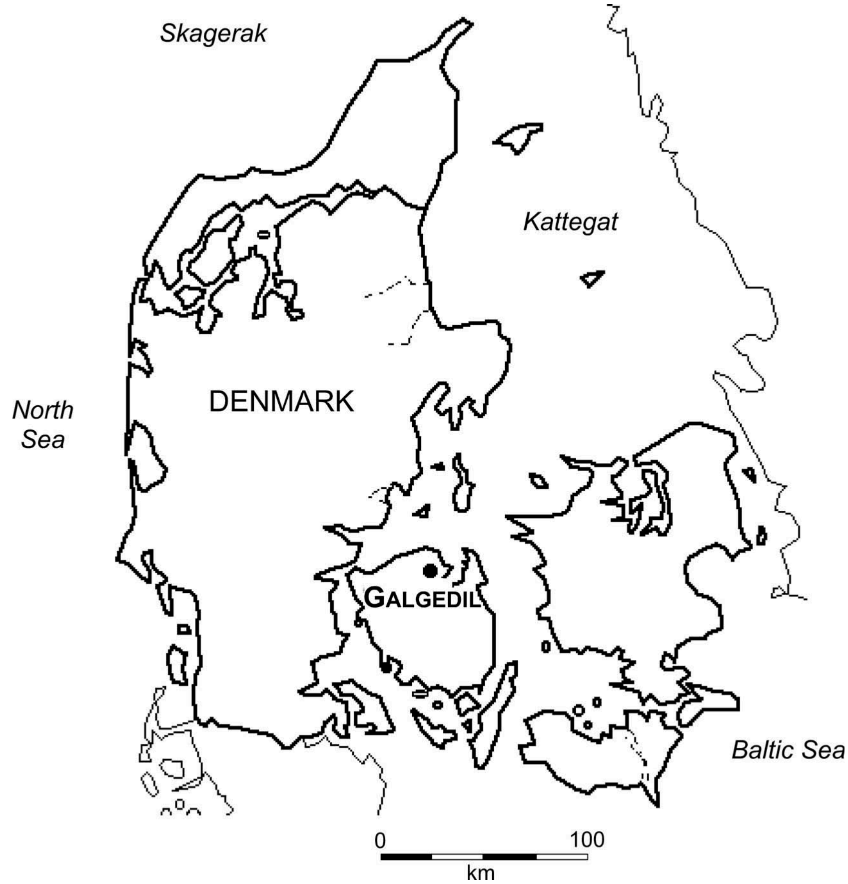

Figure 1. The location of the Galgedil cemetery on the island of Funen, Denmark.

been badly disturbed by the earlier sand quarrying. Preservation of the skeletal material in the intact graves was generally very good. As part of the excavation recording procedures, the graves and other features at the site were registered and numbered sequentially from A to BGE (Table 1).

The interments are generally described as pagan, or pre-Christian, because of the irregular orientation and the contents of the graves. The cemetery can be divided into two main phases, groups can be observed in the distribution of the graves, and a change in burial rites occurs during the lifespan of the cemetery. Artifacts document contact to a wider world, but the archeological finds give few clues regarding the mobility of the inhabitants of the burial ground.

The cemetery is situated on the top and down the southern and western slope of a small hill in a rolling, moraine landscape 5 km from the former seacoast (Crumlin-Pedersen *et al*. 1996). The distribution of the graves is, unlike a Christian cemetery, more or less random, although some groups and individual burials apart from the main group(s) can be observed (Figure 2). The graves have an irregular alignment. Some are orientated east-west, some north-south, and yet others in various directions. It is likely that the location of the grave was originally marked on the ground surface. Only in one case was a grave dug into an older one. In two cases, large stones were found on top of graves. Wooden grave markers may have been used as well, but they have long since disappeared.

Dating

There are eight ^{14}C dates available from Galgedil (Table 1), seven on human bone and one was made on charcoal from a cremation, with four dates from each of the two phases.[2] The range in the eight dates is between AD 770 and 1210. The majority of the dates fall between approximately AD 880 and 1060, with three slightly later measurements.

Fifteen of the 54 graves have been dated by association with the grave goods.[3] Five of the graves dated by association belong generally to the period from AD 800 to 1050, and 10 of these graves could be dated more specifically to shorter intervals within that time frame. Nineteen of the graves contained no grave goods and 16 held only an iron knife or a knife and one other artifact and could not be dated more specifically than Iron Age/Viking Age.

Table 1. Radiocarbon dates from the Galgedil cemetery.

Grave - sample	AAR-number	^{14}C Age (BP)	Reservoir corrected ^{14}C age (BP)	Calibrated age (1 and 2 sigma ranges)	$\delta^{13}C$ (°/$_{00}$)
KO - bone	AAR-11099	1214 ± 37	1110 ± 37 (Res. age: 0.26 x 400 years)	68.2% probability 890AD (68.2%) 980AD 95.4% probability 820AD (1.6%) 850AD 860AD (93.8%) 1020AD (intCal04)	−18.38
SB - bone	AAR-11100	1170 ± 34	1092 ± 34 (Res. age: 0.20 x 400 years)	68.2% probability 895AD (24.2%) 925AD 9400AD (44.0%) 990AD 95.4% probability 880AD (93.8%) 1020AD (intCal04)	−19.34
UD - bone	AAR-11101	1207 ± 37	1135 ± 37 (Res. age: 0.18 x 400 years)	68.2% probability 875AD (68.2%) 980AD 95.4% probability 770AD (93.8%) 990AD (intCal04)	−19.35
AKJ - bone	AAR-10569	1061 ± 35	988 ± 35 (Res. age: 0.18 x 400 years)	68.2% probability 990AD (38.0%) 1050AD 1080AD (30.2%) 1150AD 95.4% probability 980AD (95.4%) 1160AD (intCal04)	−19.44
AXE - bone	AAR-10568	995 ± 36	909 ± 36 (Res. age: 0.22 x 400 years)	68.2% probability 1040AD (68.2%) 1170AD 95.4% probability 1030AD (95.4%) 1210AD (intCal04)	−19.17
AYR - charcoal (Fagus)	AAR-10760	1101 ± 33		68.2% probability 895AD (25.9%) 925AD 935AD (42.3%) 985AD 95.4% probability 880AD (95.4%) 1020 AD (intCal04)	−24.26
BEW - bone	AAR-10570	993 ± 33	967 ± 33 (Res. age: 0.08 x 400 years)	68.2% probability 1020AD (25.8%) 1050AD 1080AD (42.4%) 1160AD 95.4% probability 1010AD (95.4%) 1160AD (intCal04)	−20.33
BFQ - bone	AAR-10571	1057 ± 30	985 ± 30 (Res. age: 0.18 x 400 years)	68.2% probability 1010AD (38.5%) 1050AD 1090AD (29.7%) 1150AD 95.4% probability 980AD (51.0%) 1060AD 1070AD (44.4%) 1160AD (intCal04)	−19.48

Notes: Bone samples are human. The wood comes from a cremation grave.

There are settlements from the Neolithic through the Older Iron Age in the same location at Galgedil, and this settlement waste in the graves in some cases confuses the dating of the contents. The overall characteristics of the graves and the cemetery and the grave goods, along with the radiocarbon dates, however, confirm the general Viking Age attribution, probably in use from around AD 800 to 1050.

Distribution and contents of the graves

Two phases can be observed in the horizontal stratigraphy of the graveyard (Figure 2); Phase 1 with 39 graves and Phase 2 with 15 graves. The dates from both artifact association in the graves and from radiocarbon provide chronological information on 22 of the 54 graves. Eighteen of the 39 graves were dated from Phase 1 and four of the 15 graves from Phase 2.

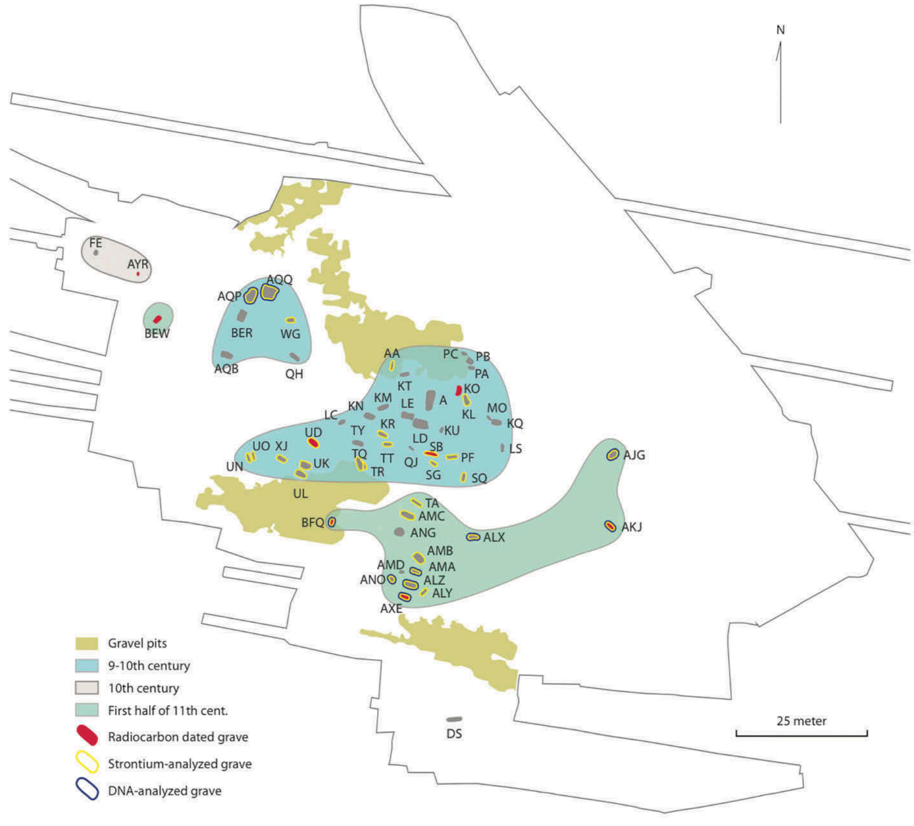

Figure 2. The cemetery at Galgedil with graves, various samples, and periods of use. Structures from Neolithic to the Older Iron Age settlements are not shown.

During Phase 1, in the 9th and 10th century, the first burials took place on the top of the hill and slightly down the southern slope. Thirty of the 39 graves are placed more or less together in one group with no clear subdivision. Very early in Phase 1, a single grave (DS) was placed in isolation at the bottom of the slope as the southernmost burial in the cemetery. Slightly later, but still in the first phase of the cemetery, a minor group of six graves were placed on top of the western part of the hill. Four of these graves (AQB, AQP, AQQ, BER) appear unusual, with wooden coffins, extraordinary artifacts, and deeper graves then other burials in the cemetery. On basis of the artifacts, for example, a trefoil brooch and belt garnish ornamented in Borre style probably inspired by the acanthus plant, these graves are dated between AD 850 and 950. Further west of this group, away from the inhumation graves, the two cremations (designated as FE and AYR) were found, the northwestern-most graves in the cemetery. On the basis of a single ^{14}C measurement, at least one of them (AYR) is from the 10th century.

The graves of Phase 2 were placed south of the main group of Phase 1 graves (Figure 2). This second phase of the cemetery presumably begins some time near the end of the 10th century. The youngest graves in the cemetery are from the first half of the 11th century. Most of the graves in Phase 2 cannot be accurately dated. Only one grave is dated by artifact association to the late Viking Age. However, ^{14}C dates place four of these graves (AKJ, AXE, BEW, BFQ) in the early 11th or early 12th century. According to the archeological context, a dating to the early 11th century seems most probable. Statistical probabilities for the dates indicate a tendency for the older date as well. Two graves (AJG, AKJ) from Phase 2, to the east, were placed separately from the other graves. An unusual isolated grave (BEW) to the northwest belongs to Phase 2 as well, based on a ^{14}C date, but close to the previously mentioned six graves and the two cremation graves from Phase 1. BEW contained only the lower half of an individual, from the hips to the feet with a knife and a whetstone. Two huge stones were placed on top of the grave as if to insure that the person would not rise up.

In general, the cemetery seems to have expanded from north to south in both Phase 1 and 2, with a few isolated graves placed away from the main group. Specifically, the area to the northwest was occasionally used throughout the life of the cemetery. For the most part, the graves were simple pits with no indications of a coffin (Figure 3). Some of the graves were so narrow that there would

Figure 3. Grave UO at Galgedil.

seem to have been no room. Only the four graves from Phase 1 (AQB, AQP, AQQ, BER) had coffins, as evidenced by the iron nails, rivets, and brackets that survived. In the main group of Phase 1 burials, one undated grave (LD) containing two individuals was of a size that might indicate a chamber grave.

The bodies were placed either on their back or side with flexed legs (a sleeping position) with their heads oriented in various directions. This lack of patterning reflects the general randomness of grave placement noted earlier. Of the 52 graves where the position of the dead could be determined, 40 individuals were placed on their back and twelve individuals in sleeping position. The latter position was apparently reserved for women and children. Out of these twelve graves, six, or perhaps seven, contained women and two out of three children were buried in sleeping position. Gender could not be determined for the three remaining individuals in sleeping position. It is tempting to suggest that they were women as well, give the ubiquity of this practice. Excavated Viking Age cemeteries on the island of Langeland, southeast of Funen, show a similar pattern (Skaarup 1976, Grøn *et al*. 1994).

While majority of the graves contain simple inhumations, there are two cremations and seven double graves. The double graves contain a mix of individuals. There are two double graves with an adult and an infant. There are five double graves with a male, two with a female, one with a male, and two indeterminate. There are also two pairs of closely adjacent graves with a male and a female that may represent the burials of couples. The double graves with two males may well represent a situation of master and slave, evidenced by the wealth differences, the location in the graves, and a contrast in the diets of the individuals. The diet information is discussed in more detail in the section on carbon isotope ratios at Galgedil.

The double graves all belong to Phase 1. Two examples (WG, XJ) involved adults with infants. The two adults were a 25-year-old woman and a 50 year-old whose gender could not be determined. The young woman may have died in childbirth, as the baby was a newborn. There was at least one man in each of the five remaining double graves (KL, LD, TR, UD, AQQ). In two cases, a man was buried together with a woman, in another case with a man, and in two cases it was not possible to determine the gender. Two bodies were placed next to each other at different levels in one grave, while the individuals in the other graves were buried one on top of the other.

Three of the double graves are located on a northwest-southeast line roughly in the middle of the main group (KL, LD, TR). The last two double graves (UD, XJ) are located in a group of six easternmost graves within this main group. The other four graves in this group are in two pairs placed exactly side-by-side only 40 cm apart and are thought to be contemporary (UK-UL, UN-UO). In both cases, the buried individuals are male and female. They might be interpreted as couples. Thus, these graves might be seen as a variation of double graves. From this perspective, the eastern group of graves consists entirely of double graves.

Double graves have often been interpreted as master and slave (e.g. Grøn *et al*. 1994). It seems reasonable to assume that this was sometimes the case at Galgedil. In one of the double graves (AQQ), a man more than 45 years of age was buried in a wooden coffin, maybe an old wagon bed. Most of the graves were shallow, but in this case, the coffin was placed about 1.2 m beneath the surface. A 25–30-year-old man was buried 25 cm above this level, parallel to the coffin, possibly on a wooden stretcher. The older man – presumably the master – had two knives, a whetstone and a belt with buckle and bracket with ornamentation inspired by Carolingian *archenthus*. The younger male – the slave – had only a knife. In this case, there appears to be a marked social difference between the two individuals. In the other examples, the difference between the two buried individuals is not so obvious and grave goods are not always present. Master and slave are difficult to identify. None of the potential slaves show evidence of cause of death. Analysis of carbon and nitrogen isotopes may provide a clue as there are striking differences in the diets of the two individuals in the same grave in several cases (discussed later).

As noted, the cemetery reveals a society with social classes. This is most obvious in Phase 1. Over time there was an overall reduction in the number of artifacts in the graves, and as the graves became more uniform with fewer artifacts, social differences are harder to see in the archeological record. If one disregards graves with only knives, 20 graves contain other artifacts. Several are related to dress and clothing, including belt buckles (six graves), belt brackets (two graves), oval brooches (two graves), trefoil brooches (two graves), and a ringed-pin. Other kinds of personal items are beads of glass, amber, and an unusual kind of rock crystal (seven graves), one Thor's hammer, and one comb. The rest of artifacts include one axe, seven whetstones, two keys, and one awl. A few iron artifacts could not be identified.

It is difficult to know what artifacts reflected social prestige, but some of the graves with several artifacts are clearly distinct. Coffins, which are rare, might also indicate a certain social status. There is an even distribution of males and females among the wealthier burials; with one or two possible exceptions all are adults.

Sacrificed animals are another category of grave offering. As the cemetery is located in an older settlement area, it was difficult to distinguish between grave deposits and settlement waste in the grave fills. In nine, perhaps twelve, of the inhumation graves (AA, KO, KR, LS, SB, TA?, TT, UD2, UL, UO, XJ?, AQP?), animals were intentionally included. It is always only a part of the animal, which was found in the grave lying next to the feet (4 graves), the thighs (2 graves), the torso (3 graves), at the stomach (1 grave) or by the face (1 grave). The identified animals are ox, sheep/goat, pig, horse and red deer.

With one possible exception (TA), all of these graves belong to Phase 1. Where gender is known, it is predominately male. In two cases with females (XJ, AQP), the interpretation of animal offerings is uncertain. Only in one case (UD) was an animal sacrifice definitely placed with a woman. She was in a double grave with a male. Perhaps both she and the animal should be seen as a sacrifice.

None of the artifacts help identify migrants to the area. The artifacts are of general well-known types in the Viking Age of South Scandinavia. The ornamentation on oval brooches, trefoil brooches, belt buckles and brackets are presumably all of local or regional origin. A generic connection to the southwest from Western Europe into Scandinavia can be seen in the two trefoil brooches. These Carolingian sword strap-tags were transformed in Scandinavia into female jewellery (Skibsted Klæsøe 1999). In a couple of cases, inspiration from Carolingian *archenthus* ornamentation can also be seen. The only artifacts definitely traded into the area were seven whetstones of slate from Norway and one bead of rock crystal, possibly from the Orient or Byzantium. Only one of the whetstones is from a grave (TA) with an individual with a high strontium isotope value, identified as non-local in the strontium isotope analysis described later. The whetstones are a common item of trade and do not provide indications of human movement. The burial with the crystal bead (XJ) was one of the richest in the cemetery, and this individual was also identified as non-local in the strontium isotope study.

All the graves in the cemetery are likely pagan. The graves and the individuals within them have random orientations, and one of the youngest graves (BFQ) from the first half of the 11th century contains a Thor's hammer, recognized as a pagan symbol. Although there are fewer artifacts and perhaps only one animal sacrifice in Phase 2, there are no definite indications of the arrival of Christianity.

From a general Danish and regional perspective, Galgedil seems to be a rather late pagan cemetery. A letter from the German emperor in AD 988 describes a bishop in Odense, 15 km south of Galgedil (Madsen 1988). In 2006, another Viking Age cemetery with 50 graves from the 10th century was excavated at Kildehuse south of Odense, 19 km from Galgedil (Runge *et al*. 2010). The orientation of the graves and the limited grave goods in this cemetery argue that it was early Christian. It appears that the conversion to Christianity in Denmark was locally variable.

No nearby Viking Age settlement is known at Galgedil. With a uselife for the cemetery of 250 years and more than 60 burials, approximately one individual was interred every four years on average. This number suggests either a sizable, nearby settlement or the use of the cemetery by several smaller settlements. If the latter we might expect family groupings of graves at the cemetery. This is not clearly visible in Phase 1, although there are the northwestern group of graves and the eastern group in the main series. In Phase 2, it seems more likely as the graves are lying in two groups of seven graves and three graves, each placed more or less separately. In both phases, but especially in Phase 2, a smaller number of graves are in an isolated location.

Contemporary with Phase 2 at Galgedil, there was another small cemetery of six graves in use only 850 m to the south.[4] It may be that the changes from Phase 1 to 2 at Galgedil and the use of the small cemetery contemporary to Phase 2 to the south indicate a change in the organization of the local settlement from larger to smaller units at the end of the 10th century.

Although no settlements are known, there is other evidence for the presence of the Vikings in the area. Contemporary with Phase 1 at Galgedil, a runic stone, with the longest inscription in Denmark, was raised between AD 900–950 some 6 km to the southwest at the present place of Glavendrup. About the same time, a wealthy and mighty chieftain was buried in a ship at Ladby, 17 km southeast of Galgedil (Sørensen 2001). In both cases, we are dealing with the traditions of a pagan society and an upper level in that society that had contacts with the larger world. The individuals buried at Galgedil were, to a greater or lesser extent, part of this way of life. Even though they must have lived primarily as local farmers, they would have been aware of and actively participated in that larger world. The presence of non-local individuals in their midst is witness to this larger realm of interaction.

Physical anthropology

The investigated skeletal material from Galgedil consisted of the human remains from 57 inhumations with varying degrees of preservation. The number of male and female skeletons was almost the same. There were 24 males (48%) and 19 females (38%). Sex could not be determined in six of the adult skeletons (14%) or for the eight subadult individuals of various ages.

Preservation and demography

The number (8) of subadults – only 16% of all preserved skeletons – cannot be considered as an accurate reflection of the mortality of infants, children and juveniles in the local population. The number is far too small. Children may have been buried elsewhere or perhaps the graves were not recognized during excavation. However, the number is similar to what has been found in other cemeteries of the same time period, between 0 and 23%, with an average of approx. 10% (Bennike 1993). Even though other factors should not be ignored, the main reason for this may be the taphonomy of small and fragile bones that have completely disappeared.

Preservation conditions may also be the reason why the males outnumber the female skeletons. In contrast to the male skeleton, the bones of the female skeleton are in general smaller and more fragile with less bone mass. It therefore seems reasonable to suggest that the six unsexed skeletons that could not be determined because of bad preservation may be female. Even though the difference in the number of male and female skeletons is seldom very high, it is not unusual to find more male than female skeletons in a Viking skeletal population (Bennike 1993). Only in places like Trelleborg (Price *et al*. 2011) were many more males than females found, probably because the site was related to some kind of military organization.

Stature

Comparative studies of Danish skeletal material reveal some periods with a decrease in stature and others with an increase. The changes seem to occur simultaneously in males and females, and the average height of women is usually about 93% that of men (Bennike 1985). It has been of special interest to examine whether the tall stature of the Vikings usually described in popular literature can be confirmed. Some studies have shown that the stature was reduced during the Viking period in Denmark compared to the previous lron Age and the later Middle Ages (Sellevold *et al*. 1984, Bennike 1985). Variation is naturally seen in skeletal material from different sites. The average stature of 20 male skeletons and 13 female skeletons from Galgedil is 172.6 cm and 161.4 cm, respectively, not very different from the calculated average stature of the Viking Age period which for males is 172.5 cm and for females is 159.0 cm. While the male stature was almost the same, it seems that the women from Galgedil were slightly, but not significantly, taller than their peers at other Danish Viking sites.

Dentition

The status of the dentition was complete or partial depending on preservation. Almost all of the sexed skeletons had preserved teeth (23 males and 18 females). A significant finding was that a much more pronounced frequency of caries was present in the female dentition (67%) than in the males (17%). Caries may be related to various factors, but the most important seems to be nutritional – the amount and type of carbohydrates – and hygiene. Nutritional differences between males and females were not revealed in the carbon and nitrogen isotope analysis (see below). The higher frequency of caries might be explained by more carbohydrates in women's diets or a possible difference in the level of hygiene.

Three burials in simple graves (AA, PF, ALX) had modified incisors with horizontal furrows, a characteristic known as filed teeth, a possible marker of social group membership (Arcini 2005). There were no goods in one of these graves, in another one iron knife, and in the last an iron knife and a sacrificed animal. Two of the graves belong to Phase 1 and the third to Phase 2. In two out of the three graves, the individual was determined to be an adult male. The third individual was an adult of unknown sex. All three persons were identified as local from the strontium isotope analysis.

aDNA investigations

Melchior *et al*. (2008a, 2008b) conducted an aDNA study of tooth dentin from ten individuals in the Galgedil cemetery. The results of their published investigations are briefly summarized here. Measures to avoid contamination included field excavation of the human remains by laboratory staff in full decontamination body suits. Teeth were removed from each mandible and taken immediately to the lab for analysis. Widely accepted guidelines for the aDNA analysis were followed in the lab (Gilbert *et al*. 2005, Melchior *et al*. 2008b). mtDNA extracted from the dentin samples was amplified, cloned, and sequenced. Haplogroup affiliations were assigned following established rules and definitions (e.g. Richards *et al*. 1998), and population affinities by haplotype/group frequencies were determined by comparison with published data for extant populations of Europe and Near East.

The results of the study indicate that the Viking burials from Galgedil are similar to other Viking and Iron Age samples from Denmark in their haplogroup frequency distribution (Table 2). However, five of the ten haplotypes in the Galgedil samples either have not been observed before or are infrequent in modern Scandinavians. In particular, haplotype X2c in Burial AJG is interesting. Haplogroup X is rare (0.9% in Scandinavians), but has a very wide geographic range, and X2c is a rare subgroup of X accounting for only 5% of 175 Hg X samples surveyed in 2003 (Reidla *et al*. 2003). Hg I occurs at less than 2% among modern Scandinavians, but markedly higher (10–20%) in Danish Iron Age and Viking population samples (Rudbeck *et al*. 2005, Melchior *et al*. 2008b). In sum, the mtDNA evidence from Galgedil points only to Burial AJG as potentially unusual.

Strontium isotope analysis

Strontium isotope analysis provides a robust means for examining questions regarding human mobility in the past. The method is straightforward and described in detail in a number of publications (e.g. Price *et al*. 1998, 2001, 2011, Montgomery et al. 2003, Price and Gestsdóttir 2006). The strontium isotope ratio of $^{87}Sr/^{86}Sr$ varies among different kinds of rocks. Because the ^{87}Sr is produced by the decay of an isotope of rubidium (^{87}Rb) in a radiogenic process over time, older rocks with more rubidium have a higher $^{87}Sr/^{86}Sr$ ratio, while younger rocks with less rubidium are at the opposite end of the range with lower ratios. Sediments reflect the ratio of their parent material. Strontium moves into humans from rocks and sediment containing nutrition for vegetation through the food chain. Strontium substitutes for calcium in the formation of the human skeleton and is deposited in bone and tooth enamel. Tooth enamel forms during early childhood and remains unchanged through life and commonly after death. The incidence of diagenesis in tooth enamel is low because of the hardness and density of this material (Hoppe *et al*. 2003, Lee-Thorp and Sponheimer 2003, Sponheimer and Lee-Thorp 2006). Values of $^{87}Sr/^{86}Sr$ in human tooth enamel that differ from those of the place of burial indicate that the individual was not buried where he/she was born.

A total of 36 individuals were sampled for strontium isotope analysis from the Galgedil cemetery. We selected a premolar from the majority of individuals; other teeth were used if a premolar was not available, and this information is provided in the table. Preparation followed conventional methods described in detail in Frei and Price

Table 2. Results of mtDNA analysis of 10 individuals from the Galgedil cemetery (Melchior *et al*. 2008a, 2008b).

Grave	Age	Sex	Haplogroup	Comment
AMA	50+	F	K	No exact match in European or in haplogroup K database
ALZ	45+	M	H	Common haplotype throughout Europe
AKJ	40–50	F?	H	No exact match in the database.
ANO	35–40	M?	H	Rare but widely spread haplotype throughout Europe
ALX	30–40	M?	U5a1a	Common haplotype throughout Europe
AXE	50+	M	I	Common haplotype throughout Europe
AJG	20–30	F	X2 c	Rare but widely spread haplotype throughout Europe
BFQ	50+	F	H	Rare type observed in Eastern Europe
AQQ	25–35	M	T2	Common haplotype throughout Europe
AQP	45+	F	H	Rare but widely spread haplotype throughout Europe

(2012), Price *et al.* (2001), and Sjögren *et al.* (2009). Small pieces of clean tooth enamel were dissolved in weak acid. Elemental strontium was isolated using an ion-specific resin, and the resulting pure strontium was placed on a filament for instrumental measurement. Strontium isotope ratios in the samples were measured on a VG Sector 54 Thermal Ionization Mass Spectrometer at the Institute of Geography and Geology, University of Copenhagen.

Results of the isotopic analyses are presented in Table 3, a large data set listing strontium, carbon, and oxygen isotopes from tooth enamel and carbon and nitrogen isotopes from bone collagen and tooth dentin for many of the same individuals. The $^{87}Sr/^{86}Sr$ values range from 0.7092–0.7155. The mean value is 0.7105 ± 0.0012. The enamel values from Galgedil are presented in graphic form in Figure 4. In this graph, the $^{87}Sr/^{86}Sr$ values are ordered from lowest to highest, left to right.

In order to determine if individuals analyzed in this study were non-local, it is essential to know the local baseline strontium isotope values at Galgedil and the surrounding area (Price *et al.* 2002). Two of us (Frei and

Table 3. Isotopic data for Galgedil enamel samples.

Grave	Sex	Age	Bone	C_{col}	N_{col}	C:N	Dentin	C_{col}	N_{col}	Tooth	87Sr/86Sr	C_{ap}	O_{ap}
SQ	M?	>45	Femur							4+	0.7092	−15.0	−2.5
SG	F	>40	Femur	−19.7	10.3	3.24				5-/ 4-	0.7093	−11.9	−4.8
WG	F	50	Femur	−20.4	11.0	3.33	−5	−20.1	11.4	−5	0.7093	−12.5	−4.3
UK	F	35–45	Femur			3.45				5+	0.7094	−11.9	−4.2
AKJ	F?	40–50	Femur	−19.9	10.8	3.36				3-	0.7094	−13.1	−5.8
AQP	F	>45	Femur	−19.4	11.3	3.19				2	0.7094		
AJG	F	20–30	Femur	−19.9	11.2	3.30	−4	−19.9	10.7	−4	0.7095	−12.7	−3.7
UN	F	30	Femur	−20.0	11.5	3.27	5	−19.5	13.2	5	0.7097	−13.5	−2.9
AMA	F	>50	Femur	−19.7	11.2	3.26				5	0.7098		
ALZ	M	>45	Femur	−19.7	12.0	3.49				5	0.7099	−14.5	−4.1
AMC	F?	>45	Femur	−19.2	11.3	3.19	4	−20.0	11.9	4-	0.7099	−15.1	−4.5
AA	M	25–35	Femur	−19.5	11.6	3.27	5-	−19.7	11.7	5-	0.7100	−13.4	−4.3
KQ	?	late 50s	Femur	−19.6	11.7	3.47				−5	0.7101	−12.9	−4.1
ALY	F	30–40	Femur	−20.2	10.7		4	−19.4	12.1	4	0.7101	−14.2	−3.3
PB	M	25–35	Femur	−20.1	11.6	3.31	5+	−20.0	10.5	5+	0.7101	−15.2	−3.3
TT	M	30–40	Femur	−19.8	11.9	3.27	5-	−19.8	12.5	5-	0.7102	−13.3	−4.6
KM	F	>50	Femur							−5	0.7102	−13.8	−4.2
TR 1	F	>30	Femur	−20.0	9.2	3.33				5+	0.7103	−12.4	−4.3
UL	M	30	Femur	−19.7	11.6	3.38	−5	−19.7	11.0	−4	0.7103	−14.5	−4.1
AXE	M	>50	Femur	−19.7	11.5	3.31				−3	0.7104	−14.3	−4.3
KR	M	late 40s	Femur	−19.5	12.3					−5	0.7105	−13.9	−4.5
BFQ	F	>50	Femur	−20.0	11.4	3.33	−5	−19.5	12.2	−5	0.7105	−14.5	−4.3
ALX	M?	30–40	Femur	−20.4	10.4	3.24	−4	−19.6	10.9	−4	0.7105	−14.4	−4.3
AQQ	M	25–30	Femur	−19.3	10.9	3.19	4-	−19.9	11.4	−5	0.7106	−15.8	−4.3
ANO	M?	35–45	Femur	−19.2	12.2	3.18	−5	−19.8	12.0	−5	0.7107	−14.4	−4.0
KL 2	M	50	Femur	−19.5	9.1	3.19				3-	0.7108	−13.5	−5.1
KL1	F?	25–35	Femur	−19.3	12.1	3.13	−4	−19.6	9.2	−4	0.7109	−11.4	−6.0
SB	M?	35–45	Femur	−19.3	12.2					−7	0.7109	−13.5	−3.7
AQQ	M	>45	Femur	−19.4	11.7	3.17				5	0.7109	−12.9	−3.9
TQ	F	35–45	Humerus	−20.4	11.6	3.28	4+	−20.1	12.3	−4	0.7109	−14.5	−4.2
UD 2	F?	>45	Femur	−19.9	10.6	3.41	−4	−19.7	11.6	−4	0.7111	−11.8	−4.4
UD 1	M	30–35	Femur							5-	0.7114	−13.9	−5.4
XJ	F	25	Femur	−19.8	10.5	3.25	4-	−19.2	10.8	4-	0.7115	−13.7	−4.4
TA	M	40–45	Femur	−19.2	10.8	3.31	4-	−18.4	11.7	4-	0.7119	−10.8	−3.2
UO	M	30	Femur	−20.5	11.8	3.40	max.	−20.4	11.7	max.	0.7130	−14.0	−3.9
AMB	F	35–45	Femur	−20.0	10.6	3.29				5	0.7155	−13.4	−4.2
LS	M	35–45	Femur	−19.4	12.4	3.27							
LD 1	?	Adult	Femur	−19.8	10.7	3.20							
LD 2	M	30–35	Femur	−18.9	11.5	3.24							
BEW	M	Adult	Fibula	−20.0	11.3	3.26							
BER	M	>40	Femur	−19.3	11.6	3.17							
ANG	M	35–45	Femur	−19.2	10.6	3.17							
KU	?	9	Femur	−19.7	10.8	3.20							
TR 2	M	25–35	Femur	−20.0	9.2	3.30							

Notes: C_{ap} = apatite carbon, O_{ap} = apatite oxygen, C_{col} = collagen carbon, and N_{col} = collagen nitrogen. Samples are ordered by the strontium isotope ratio.

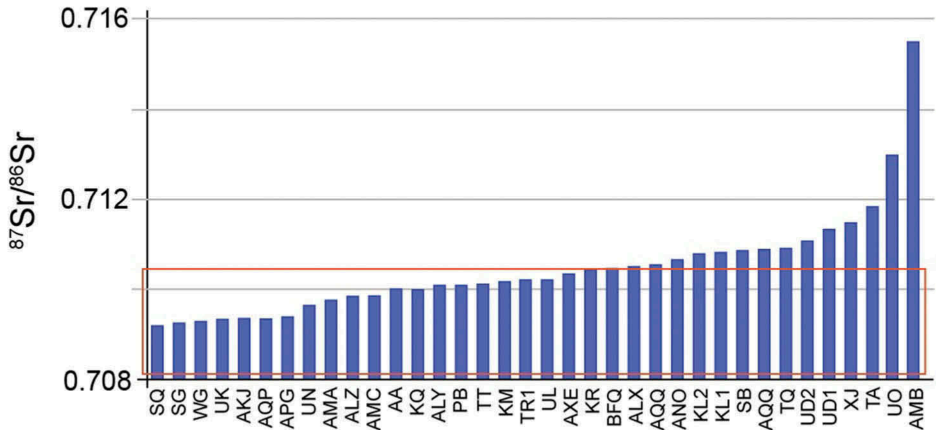

Figure 4. Bar graph of the ranked strontium isotope ratios from 37 graves at Galgedil. The red box defines the local ranges for this part of Denmark, 0.7081 to 0.7103. Grave numbers are listed. (This figure is presented in colour online.)

Price 2012) have been involved in a long-term project to develop a baseline map of strontium isotopes across Denmark. This project is summarized briefly here, and the results are presented to place Galgedil in the larger context of Danish strontium isotope sources.

The sea and the land are two major sources of food and isotopes for human consumption. Marine foods everywhere share the same isotopic value of 0.7092, which is also the value of seawater (e.g. Veizer 1989). Terrestrial sources vary according to bedrock and surface sediments. In actual fact, however, levels of strontium isotopes in human tissue may vary somewhat from local geology for various reasons (Sillen *et al*. 1998, Price *et al*. 2002). It is necessary to measure *bioavailable* levels of $^{87}Sr/^{86}Sr$ in a region to determine local strontium isotope ratios. Bioavailable strontium isotope ratios are those ratios actually available in the food chain.

We have measured a variety of materials to determine bioavailable levels of $^{87}Sr/^{86}Sr$ from throughout Denmark, including small rodents in modern owl pellets, modern snails, modern wool, and archeological fauna. The results of our study indicate that there are two major terrestrial sources in Denmark from two different lobes of ice that covered most of Denmark in the last glaciation. The island of Sjælland and the eastern quarter of the island of Funen were covered by a lobe from the east that brought rock and sediment from Sweden and the Baltic Basin into Denmark. Western Funen and Jutland were covered by another lobe coming from the north, bringing sediments from Norway and the North Sea Basin.

Our baseline measurements show slightly higher $^{87}Sr/^{86}Sr$ values on Sjælland and eastern Funen. We have suggested that a range from 0.7072 to 0.7119 likely defines the local bioavailable values for this area (Frei and Price 2012). For the rest of Funen and Jutland, values were slightly lower and a range of 0.7081 to 0.7103 should define the bioavailable $^{87}Sr/^{86}Sr$ in this western part of Denmark. Although these sources differ somewhat, they also overlap significantly and cannot be used to ascertain mobility between the two regions of the country, except perhaps in the most extreme cases. For Denmark as a whole, except for the island of Bornholm, any human $^{87}Sr/^{86}Sr$ values above 0.7119 are considered non-local. Galgedil lies in western Funen and should fall in the 0.7081 to 0.7103 baseline range of values.

We can use this baseline range (i.e. 0.7081 to 0.7103) to distinguish local and non-local individuals at the site. This range is plotted on the graph in Figure 4. This less cautious baseline range would suggest that between 12 and 16 of the individuals at Galgedil with $^{87}Sr/^{86}Sr$ values outside the range were probably non-local to the area. There are four values just at the cutoff line that may or may not belong in the non-local group. The proportion of non-local individuals is quite high, 12/36, or 33%. Individual AGJ, with the unusual haplotype in the aDNA analyses, is identified as a local individual in the strontium isotope analyses.

The samples measured for baseline values were completely terrestrial, without marine input. Human diets in Viking Denmark, on the other hand, often included a marine component. Kanstrup's study of carbon and nitrogen isotopes in bone collagen, dentin, and enamel (2006), summarized in a subsequent section of this article, documents the diet of the individuals buried at Galgedil. Tηε $\delta^{13}C$ values ranged from −20.5‰ to −18.9‰. In prehistoric Danish human remains, this value ranges from approximately −21‰ for a completely terrestrial diet to −12‰ for a fully marine diet. The values for the individuals at Galgedil suggest the consumption of some marine foods in the diet of these individuals, up to as much as 30%, assuming a linear relationship between $\delta^{13}C$ and the proportion of marine food in the diet.

Consumption of marine foods will pull higher or lower terrestrial $^{87}Sr/^{86}Sr$ values toward the marine value

Table 4. Individuals with highest strontium isotope values, context data.

Grave	Orientation	Grave size	Position	Sex	Age	Grave goods
TA	ESE-WNW	240 x 75 x 15 cm	On back	M	40–45	X933 mica whetstone
UD 2 (Double Grave. Upper)	NW-SE	233 x 123 x 8 cm	Hocker on left side Hocker is in the text called sleeping position	F?	Over 45	X781 iron rod X782 iron masses X784 iron masses
UD 1 (Double Grave. Lower)	NW-SE	233 x 123 x 10–18 cm	On back, lightly flexed legs	M	30–35	X794 iron knife
UO	NW-SE	180 x 63 x 45 cm	On back, legs spread	M	ca. 30	X714 iron masses X715 iron belt buckle X716 iron knife X717 food offering. sheep
XJ	ESE-WNW	200 x 100 x 5 cm	On back	F	ca. 25 with newborn infant	X826 glass bead X827 crystal bead X828 silver bead with filigree X829 glass bead X836 iron knife with possible silver wire
AMB	NW-SE	260 x 150 x 38 cm	On back, legs spread	F	35–45	X1361 iron knife

(0.7092) in tooth enamel, in proportion to the amount of seafood in the diet. For this reason, we would suggest that the terrestrial baseline values for Galgedil are generous in defining local individuals and cautious in distinguishing non-local persons.

Because there is a possibility that the higher $^{87}Sr/^{86}Sr$ values of eastern Funen extend into the area of Galgedil, we will take a more cautious approach to identifying non-local individuals. We will focus on the six individuals with the highest $^{87}Sr/^{86}Sr$ values, above 0.711, as definitely non-local and likely not from Denmark. A summary of these burials and grave contents appears in Table 4. Of these six non-local individuals, four are female and two are male. Females appear to be slightly more mobile than males in the Galgedil population. There are $^{87}Sr/^{86}Sr$ values for 18 females and 17 males from the cemetery. The mean and s.d. for females is 0.7104 ± 0.0015 and for males is 0.7107 ± 0.0009. While the average value for males is slightly higher yet still local, the s.d. is much higher for females suggesting more variability in places of origin.

There is no observed difference in the proportion of non-local graves between Phase 1 and 2 at the Galgedil cemetery. Spatially, the non-local graves appear scattered among the others with the exception of the western corner of the larger Phase 1 burial area (Figure 2). Here there are several adjacent graves (UD, UO, XJ) with non-locals present. Grave UD is a double grave with a male and female, both of whom are non-local and have very similar $^{87}Sr/^{86}Sr$ values.

It is important to remember that the non-local designation does not imply a specific distance or place of origin. Determining the place of origin for non-local individuals is difficult and often not possible. The key utility of strontium isotope analysis is identifying non-locals, not place of origin. Often several different regions may share the same $^{87}Sr/^{86}Sr$ values, and distinguishing a homeland among these is not feasible with strontium isotopes alone. Examination of the non-local values at Galgedil suggests that there are several different non-local strontium isotope ratios, indicating several different places of origin for these individuals. The place of origin of some of the non-locals may not have been so distant. Eastern Funen has a somewhat higher strontium isotope source and values up to 0.711 could come from that region.

Values higher than 0.711 are very rare in Denmark. Values of 0.712, 0.713 and 0.715 are unknown in Denmark (outside of Bornholm) and must come from older terrains, such as the rocky areas of western Sweden or southern and western Norway. To the south, there are few high $^{87}Sr/^{86}Sr$ sources across the North European Plain from the Netherlands across northern Poland. Some older rock outcrops with higher values are known to the south from Central Europe such as the Mittelgebirge in central Germany, the Black Forest region of southern Germany, and in the Carpathian Mountains. Given the location of Galgedil, close to the Kattegat, it seems most likely that the three high ratio non-local individuals may have come from Norway or western Sweden.

Light isotopes: carbon, nitrogen, and oxygen

Analysis of the stable isotopes of carbon and nitrogen in human bone collagen is standard practice in the study of past diet. This analysis provides an index ($\delta^{13}C$) of long-term average diet and of certain dietary patterns. For northern Europe, carbon isotope ratios are used largely to distinguish between marine and terrestrial foods. Collagen carbon is largely produced from ingested protein (Ambrose and Norr 1993). Carbohydrates are not well represented in the collagen, so that a somewhat biased view of diet is provided. Nitrogen isotopes provide information on the trophic level of the individual and reflect the importance of meat in the diet.

In this study, three separate tissues have been used for isotope analysis: bone collagen, dentin collagen, and tooth enamel. Each tissue provides somewhat different information. The measurement of carbon isotope ratios in bone collagen is well known in the study of marine resources or C_4 plants in human diets. Dentin collagen is similar to bone collagen, but turns over more slowly and may provide a measure of diet from the younger years of life. Carbon also is present in the mineral, or apatite, portion of bone and tooth enamel and also contains information on diet (Ambrose and Norr 1993, Ambrose *et al*. 1997, Sealy 2001). Although there are potential problems with contamination in apatite, this carbon isotope ratio can provide substantial insight. Apatite carbon is discussed more thoroughly in a subsequent section.

Oxygen has three isotopes, ^{16}O (99.762%), ^{17}O (0.038%), and ^{18}O (0.2%), all of which are stable and non-radiogenic. Oxygen isotopes are much lighter and highly sensitive to environmental and biological processes. Oxygen isotopes, which are commonly reported as the per mil difference (‰ or parts per thousand) in ^{18}O/^{16}O between a sample and a standard, can be measured in either the carbonate $(CO3)^{-2}$ or phosphate $(PO4)^{-3}$ ions of bioapatite. This value is designated as δ^{18}O. In this study, we have measured carbonate as a component of tooth enamel. Different standards are also used in oxygen isotope studies, usually either ‘Standard Mean Ocean Water’ (SMOW) or PDB belemnite (a fossil from the Cretaceous Pee Dee Formation in South Carolina). PDB was the standard for this study.

Oxygen isotope ratios in the skeleton come from body water (Luz *et al*. 1984, Luz and Kolodny 1985), which in turn predominantly reflects local rainfall. Isotopes in rainfall are greatly affected by the enrichment or depletion of the heavy ^{18}O isotope relative to ^{16}O due to evaporation and precipitation. Major factors affecting rainfall isotope ratios are latitude, elevation, and distance from the evaporation source (e.g. an ocean) – i.e., geographic factors. Like strontium, oxygen is incorporated into dental enamel – both into carbonate and phosphate ions – during the early life of an individual where it remains unchanged through adulthood. Oxygen isotopes are also present in bone apatite and are exchanged through the life of the individual by bone turnover, thus reflecting place of residence in the later years of life. Thus, oxygen isotopes, although non-radiogenic, have the potential to be used like strontium to investigate human mobility and provenience.

Carbon and nitrogen isotopes in collagen

This study was undertaken several years ago by Marie Kanstrup (2008) and is briefly summarized here. Isotopic analysis of bone and dentin collagen from the Galgedil skeletal material provides direct evidence for diet and permits an assessment of the homogeneity of Viking diet. Dietary variability at Galgedil is examined at three different levels: (1) intra-individual (life history), (2) inter-individual (in relation to sex, height and status), and (3) the population.

Standard procedures were followed in the preparation of collagen (Ambose 1990, van Klinken 1999, Jørkov *et al*. 2007). The isotope analysis was performed at the radiocarbon facility at Aarhus University using a GV instruments IsoPrime mass spectrometer in combination with a Euro Vector 3024 continuous flow Elemental Analyzer.[5] The results are presented in Table 3.

A total of 40 individuals were analyzed for bone collagen carbon and nitrogen isotopes. The ratio of carbon to nitrogen abundance was measured as an index of preservation and the quality of the sample (DeNiro and Weiner 1988, Ambrose 1990, van Klinken 1999). The percentage of collagen recovered from a sample and its C:N ratio are common measures of sample integrity. Collagen percentages were routinely high in these samples. Collagen samples from preserved bone or dentin are considered largely unaltered if their C:N ratios fall in the range of living bone, i.e., 3.22 to 3.45 (Schoeninger *et al*. 1989). The average C:N ratio in the Galgedil samples was 3.3 ± 0.1. There were 2 samples with values greater than 3.45 (3.47 and 3.49) and several lower than 3.22 but above 3.10. The mean δ^{13}C for bone collagen was −19.7 ± 0.4 with a narrow range from −20.1 to −18.9. The mean δ^{15}N for bone collagen was 11.3 ± 0.8, with a range from 9.1 to 12.4. The samples generally exhibited good integrity and all were used in the analysis discussed below.

Nineteen of the same individuals were sampled for tooth dentin. The mean δ^{13}C for dentin collagen was also −19.7 ± 0.4, with a range from −20.4 to −18.4. The mean δ^{15}N for dentin was 11.6 ± 1.0, with a range from 9.2 to 13.2. The bone and dentin collagen were generally highly correlated. For this reason, most of the discussion below focuses on the bone collagen results.

Although there was relatively little variation in the carbon and nitrogen isotope ratios, there are clear differences between male and female diets. Carbon vs. nitrogen isotope ratios for bone collagen in males and females are plotted in Figure 5. The differences in isotopic signatures and hence diet between adult men and women are statistically significant when δ^{13}C and δ^{15}N are combined in a paired student's *t*-test (p = 0.0023). Comparison of the means and s.d. of δ^{13}C and δ^{15}N for men and women, respectively, suggests that women had a more

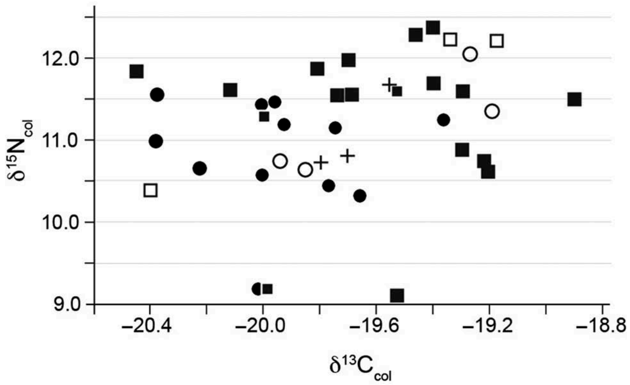

Figure 5. Carbon and nitrogen isotope ratios plotted for men, women, and children at Galgedil. Square = male, circle = female, hollow = sex uncertain, triangle = child.

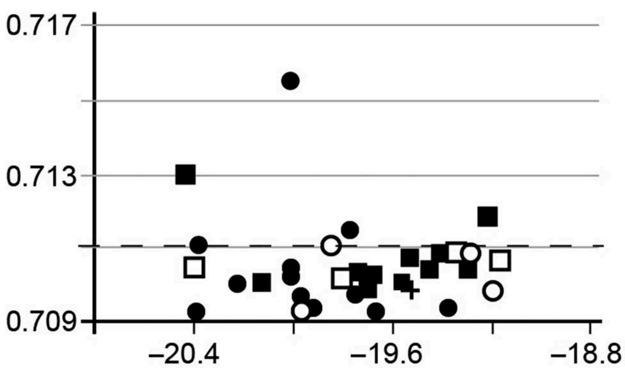

Figure 6. Carbon and strontium isotope ratios plotted for burials at Galgedil.

homogenous diet than men. Three individuals have markedly low $\delta^{15}N$ values. Burials TR1, TR2, KL2 were all from the double graves. The low $\delta^{15}N$ values suggest less carnivorous diets, perhaps a reflection of status.

Comparison of bone $\delta^{13}C_{col}$ and $^{87}Sr/^{86}Sr$ values is of interest (Figure 6). The individual (UO) with the most negative $\delta^{13}C_{col}$ value has the second highest $^{87}Sr/^{86}Sr$ and is very clearly non-local. This individual likely came from an inland region where marine foods were rare or absent in the diet. The remainder of the non-locals fall within the same $\delta^{13}C$ range as the local individuals. The difference in male and female diets appears again in the carbon isotope data.

The tooth dentin from the individual in grave UN has a very high $\delta^{15}N$ value. The bone value falls within the normal range of the Galgedil population. This difference appears to reflect a change of diet from childhood, due perhaps to preferences, illness, or a change in residence. However, the strontium isotope ratio does not suggest mobility for this individual. A similar difference is evident in $\delta^{13}C$ in the bone and tooth sample from the individual buried in grave TA. In the dentin that may represent diet at a younger age, this individual consumed a good bit of marine food, whereas the adult diet represented in the femur collagen resembles the low marine input more typical of the general population. The $^{87}Sr/^{86}Sr$ value (0.7119) indicates mobility.

The relatively high values for $\delta^{15}N$ in the Galgedil population should represent a diet that is largely carnivorous (e.g. Ambrose 1993, Bocherens and Drucker 2003). The variation observed in these values reflects the normal dietary differences that existed among Viking individuals. The combination of carbon and nitrogen isotopes in bone collagen suggests a diet that is largely carnivorous. Comparative data from other periods in Denmark can be found in Jørkov *et al*. (2010) and Yoder (2010).

The isotopic data and archeological findings do not indicate any clear relationship between stature and diet or status and diet. A few individuals are, as noted earlier, clearly outliers. These individuals have often been interpreted as slaves, based on their presence in double graves and general lack of grave goods. A $\delta^{15}N$ offset of 2.5–3‰ between the presumed master and slave and is seen between the two individuals in grave KL and in a comparison of the individual buried in grave TQ just next to a double grave (TR) with two possible slaves. These individuals were eating less meat and may represent a segment of the population otherwise often anonymous in the archeological record.

Oxygen isotopes in enamel

Oxygen isotopes in dental enamel reflect water sources in early childhood. Apatite enamel $\delta^{18}O$ values from Galgedil have a mean of −4.2 ± 0.7, with a range from −2.3 to −6.0. Fricke *et al.* (1995) reported a $\delta^{18}O$ phosphate value of 18.1 for tooth enamel from medieval Risby, Denmark. This value, converted to a carbonate scale, is very similar to the average measured at Galgedil.[6] A scatter plot of $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$ (Figure 7) shows very little pattern, suggesting that oxygen values are not varying geographically among the non-local individuals. Two of the lowest $\delta^{18}O$ values, and one of the highest, occur with local individuals. Only three of the non-local individuals exhibit higher oxygen isotope ratios. The fact that a local individual has a similar value suggests that variation in $\delta^{18}O$‰ values is high and that little geographic variation is being recorded. Oxygen isotopes are often problematic as a marker of geographic variation.

Conclusions

Excavations of a Viking Age cemetery near the town of Galgedil in Denmark uncovered some 54 graves containing 61 buried individuals. These burials have been the focus of anthropological, aDNA, and isotopic

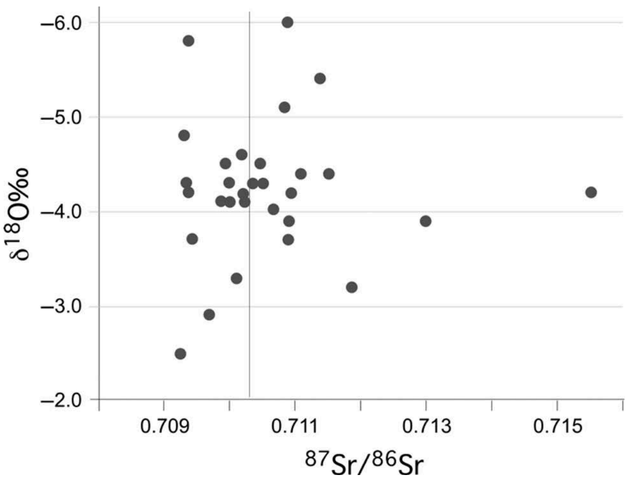

Figure 7. Scatterplot of $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$ for enamel samples from Galgedil. The vertical line marks the upper limit of the local baseline in this part of Denmark (0.7103).

investigation to learn about the life histories of the deceased individuals. Based on the typology of the grave goods and radiocarbon dates, this pre-Christian cemetery was in use from approximately AD 800 to 1050. Of the 57 skeletons analyzed for age and sex, there were 24 males, 19 females, and six indeterminate individuals. Only eight subadults were found among the largely adult population of the cemetery.

Several lines of inquiry have been pursued in the investigation of the human remains from Galgedil. An aDNA study (Melchior *et al.* 2008a, 2008b) involved a sample of 10 individuals. Only burial, AJG, was recognized as genetically unusual and perhaps exotic to the population at Galgedil. The isotopes did not distinguish this individual.

A multi-isotope approach was employed in the investigation of these burials. Strontium isotope ratios were used to identify non-local individuals in the burial population. Light isotopes of carbon and nitrogen in bone collagen provided information on diet (Kanstrup 2006). Dentine collagen isotopes were generally similar to the bone collagen results. Oxygen isotopes in tooth enamel were also measured as a potential index of mobility, but there was no patterned variation in these data and no clear relationship with the $^{87}Sr/^{86}Sr$ values.

Carbon isotope ratios in samples of bone collagen averaged −19.7‰ ± 0.4, documenting a largely terrestrial diet with marine foods comprising approx. 10%–30%. Nitrogen isotope ratios show a pronounced difference between male and female diets. Males were significantly more carnivorous. Nitrogen isotopes also revealed three individuals with markedly low $\delta^{15}N$ values, all from the double graves and all non-local individuals. These individuals were local based on $^{87}Sr/^{86}Sr$, but their diets were much less carnivorous than the rest of the population.

Comparison of the carbon isotope data with the local/non-local information from the strontium isotope analysis provided some insight. The individual (UO) with the most negative $\delta^{13}C_{collagen}$ (least marine) had the second highest $^{87}Sr/^{86}Sr$ value, clearly non-local and likely from an inland region of older rocks in central or northern Scandinavia. In general, however, there was little difference in the diets of local and non-local individuals.

Strontium isotopes identified a number of non-local individuals. The proportion is quite high, 6/37, or approximately 16% of the burials. Several patterns were observed. Four of the individuals buried during Phase 1 have high strontium isotope values (UD1, UD2, UO, XJ). They are located more or less together at the edge of the cemetery in the southwestern part (Figure 2). Here there were several adjacent graves (UD, UO, XJ) with non-locals present. In Phase 2, the two non-locals from 15 burials in this group were placed in separate groups. This might indicate a change over time in the status of and/or the integration of newcomers. In Phase 1, the individuals in double graves are often of non-local origin. For example, grave UD is a double grave with a male and female, both of whom are non-local and have very similar $^{87}Sr/^{86}Sr$ values. There are no double graves in the Phase 2 cemetery. As the practice of double graves ends, they are buried in ordinary single graves in Phase 2.

The graves with more contents were more likely to contain non-local individuals. The grave with one of the highest strontium isotope value (XJ) was one of the richest with four valuable beads, two of glass, one of rock crystal and one of silver with filigree ornamentation, and an iron knife possibly with silver wire. A few beads of rock crystal are known from Denmark, but they are more common in Sweden (Jansson 1988), a potential place of origin for the woman buried in grave XJ.

Animal sacrifices may have been more common with non-locals, but this association is uncertain. Three of the graves with sacrificed animals (UD2, UO, XJ) from Phase 1 have high strontium isotope values indicating non-local origin. The only grave from Phase 2 with a possible animal sacrifice (TA) also has a high strontium isotope ratio, indicating the male burial as non-local. He is lying on his back with a whetstone and a bird next to his face. The bird bone may have been accidentally or intentionally included in the grave.

In sum, the investigation of Galgedil has revealed a number of new aspects in the lives of its Viking inhabitants. Information on place of origin, diet, and social organization are apparent in the context and contents of the graves, in the physical skeletal remains of these individuals, and in the molecular and isotopic chemistry of their bones and teeth.

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Notes

1. The excavation was conducted for Odense Bys Museer by Susanne Clemmensen and Mogens Bo Henriksen in 1999-2001 and by Lisbeth Christensen and Kirsten Prangsgaard in 2005 under the file number OBM 4520.
2. Five of the ^{14}C AMS measurements were made at the Department of Physics and Astronomy, University of Aarhus, AMS ^{14}C Dating Laboratory, by Jan Heinemeier in connection with the excavations in 2005: AAR10568, AAR10569, AAR10570, AAR10571, AAR10760; and three of the ^{14}C AMS dates in conjunction with Marie Kanstrup's work on diet: AAR11099, AAR11100, AAR11101.
3. The dating of the artifacts is generally based on Calmer (1977), Arwidson (1984, 1986, 1989), Skibsted Klæsøe (1999), Eisenschmidt (2004), and Maixner (2005).
4. This excavation was conducted in 1998 by Susanne Clemmensen under the file number OBM 8532.
5. Precision for this system is ±0.2‰ and ±0.3‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively. The samples are at a minimum measured in duplicate with the exception of GAL 46 where there was insufficient material. All of the collagen samples extracted using the Longin method with ultra-filtration (30 kDa) fulfilled conventional quality criteria (Ambrose 1990, p. 438, Brown et al. 1988, Longin 1971, p. 241, van Klinken 1999, p. 689).
6. Conversion of $\delta^{18}O$ phosphate to $\delta^{18}O$ carbonate is fairly straightforward. The formula $\delta^{18}O_c = 1.2^* \delta^{18}O_p + 8.3$ can be used (Coplen *et al.* 1983, Bryant *et al.* 1996, Hoefs 2004), where Op and Oc are phosphate oxygen and carbonate oxygen, respectively. Calculating $\delta^{18}O_c = 1.2^*18.1\ \delta^{18}O_c+8.3$.

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RESEARCH ARTICLE

A ritual site with sacrificial wells from the Viking Age at Trelleborg, Denmark

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The promontory facing Storebælt with the well-known circular Viking Age military fortress of Trelleborg erected by Harold Bluetooth in AD 980/981 seems to have been an important ceremonial space prior to the erection of the fortress and contemporary with a nearby high status settlement dated to the seventh to the eleventh century. This study presents new cross-disciplinary investigations focusing on three sacrificial well-like structures (47, 50 and 121) from the pre-Christian Viking Age at Trelleborg. Two of the sacrificial wells (47 and 121) included the only skeletal remains of four children hitherto recovered from Danish Viking Age wells. The strontium isotope results of the four children point to local provenance. However, the results of each well seem to pair up in a systematic way pointing to that the children might come from two different key surrounding areas at Trelleborg. Furthermore, the three wells contained animal remains of primarily domestic livestock partly representing consumption waste from either profane or ritual meals deriving from, for example, *blót* activities. Well 47 produced a young he-goat and well 121 a hindlimb of an above-average-size young horse, a large part of a young cow and a large dog. Altogether intentional offerings deposited while still enfleshed and interpreted to have served as propitiatory sacrifices to honour or appease the gods and to ensure fertility. This research provides new information that enlightens the formation processes underlying accumulation of cultural deposits in features such as ritual wells, in the period prior to Christianity.

Keywords: human sacrifice; animal sacrifice; ritual well; strontium isotopes; pre-Christian Viking Age; paganism

Background

The circular Viking Age fortress of Trelleborg on the island of Zealand in Denmark is well known as a military fortress built by Harold Bluetooth in AD 980/981. The site is of utmost importance for the understanding of the beginning of the Danish state formation and has therefore been intensively investigated (Nørlund 1948, Price *et al*. 2011). Trelleborg is situated at a promontory bordered by the rivers Tude Å and Vårby Å in southeastern Zealand with a view towards the Great Belt (Figure 1). It was excavated in the years 1934–42 by Nørlund from the National Museum who a few years later published a comprehensive treatise on the results (Nørlund 1948). In the same publication, Degerbøl published the faunal material, hereby providing important and at that time new zoological information on our common domesticates and on husbandry and hunting practices at a Viking Age military garrison (Degerbøl 1948, p. 241ff). The fortress functioned as a military garrison for a short period and probably only a few decades. Strontium analyses indicate that the buried garrison population in the cemetery by the fortress consisted of individuals of both foreign and local origin (Price *et al*. 2011). Some of the axe types in the graves could indicate that the individuals came from the Slavonic areas in the southern Baltic area and thus providing further support for the results delivered by the strontium analyses.

However, it is important to note that when the fortress was built in 980/81 there already existed a larger settlement only 300 m east of the promontory where the fortress was erected (Figure 1). The settlement, which covered *c*. 4 ha, has produced more than 200 finds from the seventh to the eleventh century by metal detector surveys. Several are high-quality objects, and they indicate the presence of an elite residence. Among others, the find material consists of brooches and pendants of silver and bronze, strap mounts, dirhams, silver ingots, weights, etc. An unpublished survey carried out by the regional museum by magnetometer has also indicated activity areas and traces of other constructions. The large settlement both predates and succeeds the military garrison on the promontory. It is obvious to link this settlement with a number of unique ritual features and finds on the promontory from the period prior to the construction of the fortress. Nørlund also dealt with this unique material in his publication, and he identified the features as forming a sacrificial site from the

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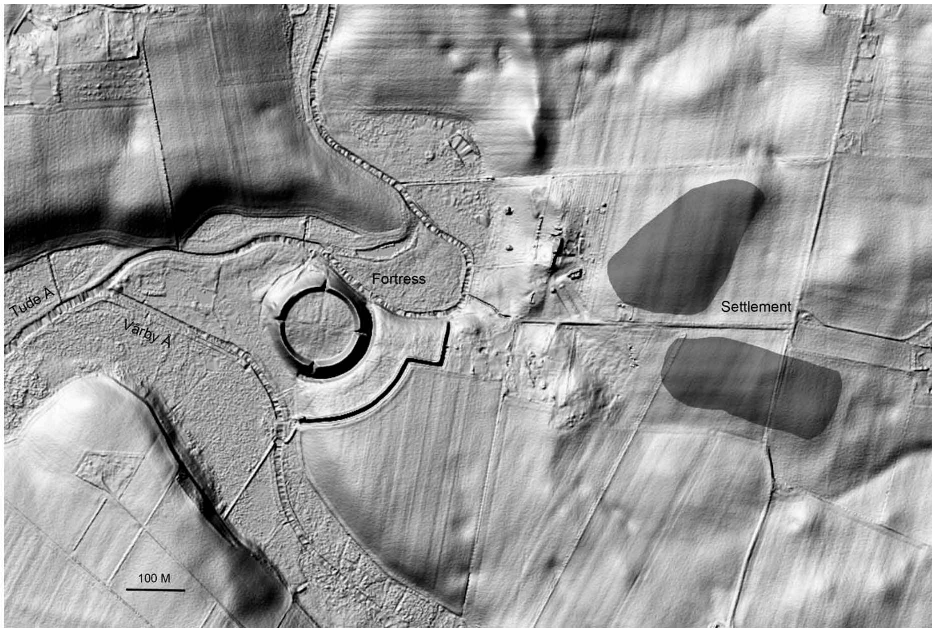

Figure 1. Lidar scan showing the location of the Trelleborg fortress on the promontory bordered by the rivers Vårby Å and Tude Å. To the east of the fortress is marked the extent of the settlement area (Trelleborggårde) producing rich metal detector finds from the seventh to the eleventh century. The settlement thus existed both before and after the fortress. Map: Danish Ministry of the Environment and Cultural Heritage Agency.

period before the fortress was erected (Nørlund 1948, p. 36ff). In our paper, we will elaborate further on the highly interesting ritual features and finds.

During the excavation of the fortress, Nørlund noticed several wells and pits partly due to their unusual contents, for example, human skeletal parts, and partly their construction and location (1948, p. 36ff) (Figures 2 and 3). In particular, two wells or well-like structures from the ninth to the tenth century, well 20/36 gr. 47 and well 12/37 gr. 121 (in the following designated wells 47 and 121), attracted attention by holding children's skeletons and some nearly complete animal corpses (Degerbøl 1948, p. 243ff, Nørlund 1948, p. 41f). Also, well 21/36 gr. 50 (= well 50) including skeletal parts of an adult person and a more ordinary assortment of animal remains was described in more detail by Degerbøl (1948, p. 243f). Nørlund suggested that prior to the erection of the fortress at least five out of six wells may have served as sacrificial wells, of which three (117, 121 and 123) were clearly associated with special horseshoe-shaped trench features (1948, p. 44). A similar trench feature has recently been excavated at the contemporary residential complex at Lake Tissø (Jørgensen, unpublished). Here, two entrance posts and a row of posts in the trench marked the construction. The trench construction was not associated with a well. However, the feature was probably associated with uncertain activities that took place inside the trench feature. Other circular ditch features have also been presented and discussed recently (Henriksen 2015, p. 201ff).

The two other wells 125 and 123 seem to have been cleaned and contained only few finds, more or less contemporary with the closing of the wells. However, there is also the possibility that well 125 was not filled with ritual depositions during the function. In the fill layers of well 117, fragments of soapstone vessels, a few iron fragments and an antler comb from the tenth century were found (Nørlund 1948, p. 40f). In well 123, an axe from the Viking period was found close to the bottom and an iron key in the upper fill layer (Nørlund 1948, p. 40). Well 117 is clearly older than the fortress as the supporting posts of the building were placed in the fill of the well. As we probably can associate well 123 with the adjoining horseshoe-shaped ditch, it indicates that this well also belonged to the period before the construction of the fortress.

Purpose of the study

As already suggested by Nørlund, the finds attest the importance of the area as a ceremonial space. The present investigations focus on the finds from the pre-Christian Viking Age by re-examination of especially wells 47, 50 and 121 in order to shed light on their formation process and to improve our knowledge of the offering rituals that took place at the promontory.

The human remains have been examined to provide an overview of the ages, health conditions and possible injuries. Moreover, the taphonomical approach aims to shed

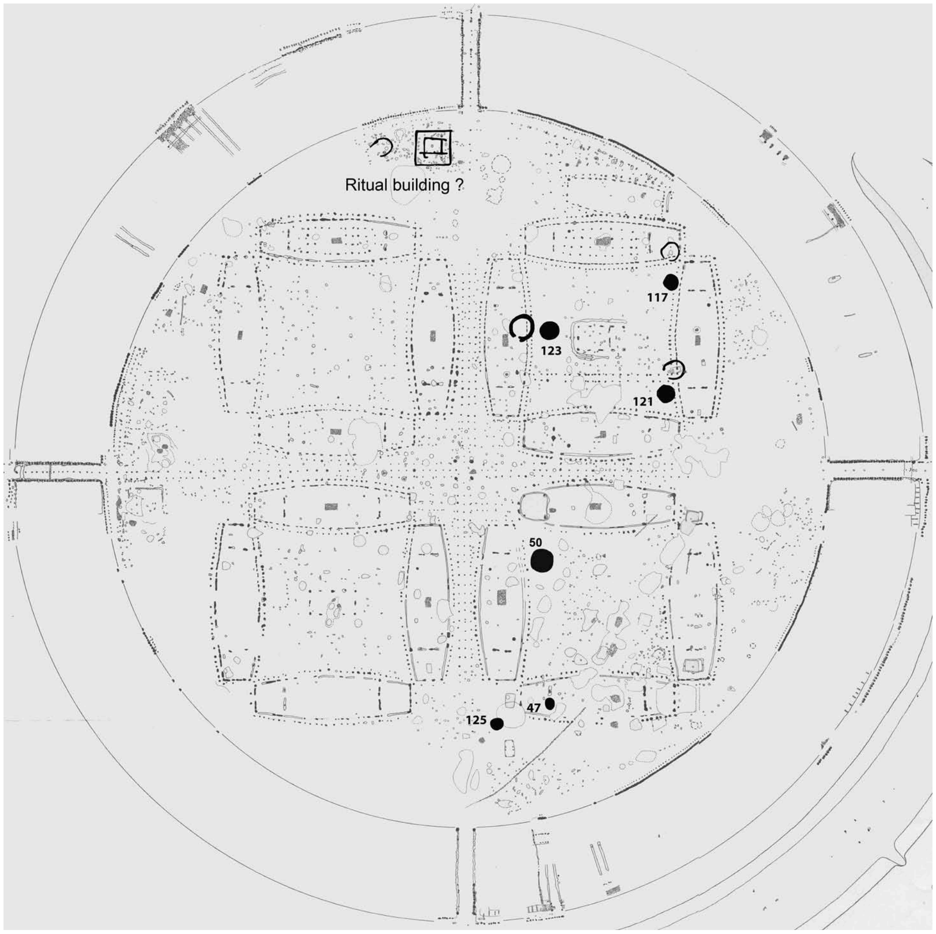

Figure 2. Nørlund's plan of the excavation. The six wells and the four horseshoe-shaped ditches are marked. A possible ritual area with a special building, a horseshoe-shaped trench and several pits and/or postholes is located immediately west of the north gate. Plan: Nørlund (1948) with additions.

light on whether it can be stated how the humans died and were treated post-mortem. Additional strontium isotope analyses of the four young individuals from two of the wells were conducted in order to reveal their provenance. Moreover, new ^{14}C analyses of the four children, a semi-complete goat and a part skeleton of a cow have been conducted in order to identify the time relation between the human and animal remains.

The study of animals in ritual use is often hampered by the difficulty in distinguishing between animal bones being the leftovers of ritual feasts and/or ordinary meals (cf. Lauwerier 2004). It is thus difficult to evaluate the archaeozoological evidence of ritual activity in settlement waste dumps, whereas special areas such as bogs, funerary sites (Magnell and Iregren 2010, Gotfredsen forthcoming) or special features such as wells or so-called shafts (e.g. Nilsson 2003, 2009, Grimm 2008, 2010, Serjeantson and Morris 2011) may offer better opportunities. Since beliefs and associated practices can shape the zooarchaeological assemblage, it is essential to pay attention to the spatial distribution and contexts of faunal remains (cf. Russell, 2012, p. 50). Moreover, in order to understand the processes of deposition and subsequent destruction and loss, it is of outmost importance to study the natural destruction and human-made modifications inflicted on the bones (Serjeantson 1991, Morris 2008, Magnell and Iregren 2010, Magnell 2012). Consequently, the archaeozoological part of the present study will focus on taphonomic analyses, peri- and post-mortem practices but also include contextual considerations.

Materials and methods

The three wells

Well 47 was located within house 4 in the southeastern building complex (Nørlund 1948, p. 41f). It was oval and measured 1.8 × 2.35 m at the surface and narrowed down to 0.90 × 1.20 m at the bottom. It was 2.13 m deep as measured from the surface of the subsoil. It was unclear

Figure 3. Trelleborg. The sacrificial well 121 and the associated circular foundation ditch during the excavation in 1937. The ditch shows weak traces of posts or planks. The well contained skeletons of two 4-year-old children and parts of three horses, two cows, four pigs, three sheep, a dog, a red deer and a peregrine falcon. Photo: Roar Skovmand, National Museum.

whether the shaft was in fact a well since no traces of stone setting or planks were detected (Nørlund 1948, p. 42). Among the artefacts in the fill was a tortoise brooch from the tenth century (Nørlund 1948, Pl. XXVII 1a–c), bronze bowl, arrow head, Slavonic pottery (Nørlund 1948, fig. 108b), two whetstones, spindle whorls, fragments of weaving weights, etc. The finds were, however, all located in the upper fill layers. The deepest lying object was the tortoise brooch in a depth of 1.59 m. The finds seem primarily to be related to the closing of the well. Nørlund (1948, p. 39ff) dates the well to the period before the fortress.

Well 50 was located in the southeastern building complex (Nørlund 1948, p. 39). At the surface, it had a diameter of 4.10 m and from a depth of 1.5 m it narrowed down to measuring 1.4 × 1.4 m. The well was approximately 3.6 m deep measured from the top of the subsoil. Traces of wooden planks were documented. At the bottom level was found fragments of a knife, iron fragments, a quern stone, three wooden bowls, bowl handle, fragment of a possible sledge runner, several wooden fragments and a wooden spoon (Nørlund 1948, Pl. XVIII 4–6). Nørlund (1948, p. 39) suggests that the well was in function during the fortress period.

Well 121 was located in the northeastern building complex (Nørlund 1948, p. 41). It was circular with a diameter of 3–3.75 m and reached a depth of *c*. 3 m below the surface of the subsoil. In the upper fill layers, fragments of pottery, semi-finished antler for combs, whetstone, a bone skate and iron fragments were found. The lower layers provided three belt buckles, a knife fragment and various iron objects. However, none of the finds seem to be associated with the primary function as a sacrificial well as they derive from the secondary fill material. Both well and the adjoining trench are cut by the building wall and thus from the period before the fortress.

The human bone analysis

The human bones were examined at the Laboratory of Biological Anthropology (LBA), Department of Forensic Medicine, University of Copenhagen. The human material from wells 50 and 121 is currently curated at the LBA, and the material from well 47 is on exhibition in the museum at Trelleborg. The bones were examined macroscopically as well as using CT images for teeth development and pathologies. Bone lengths were measured using an osteometric board. The age of the individuals was determined from dental development by the method according to Ubelaker (1989). Bone growth was examined according to Scheuer and Black (2000) and Primeau *et al*. (2012). Sex cannot be determined for children as young as the material present here, and for the adults too little material was available for sex assessment.

The faunal bone analysis

The animal bones[1] were examined and identified by use of the comparative collection of the Natural History Museum of Denmark, University of Copenhagen. The bone material was recovered by shovels and not sieved. Further, no systematic registration of the *in situ* position of the animal bones was undertaken, although Nørlund made a few observations in the field. Consequently, bones which are considered to be articulated joints were actually rearticulated in the laboratory. The faunal material had suffered a substantial taphonomic loss since the time of recovery,[2] which was also seen for the human skeletons from the Trelleborg burial ground (Price *et al*. 2011, p. 481). The skeletal elements were identified to species, skeletal element, portion of the bone and side. The bones were sexed, aged and pathology was recorded. Age determination was based on mandibles with teeth *in situ* or isolated mandibular deciduous premolars (dp_4) or molars (M_3). Moreover, bone surface alterations such as gnawing, trampling and weathering were assessed. The weathering stage was scored according to Behrensmeyer (1978). Special focus was on man-made bone alterations, for example, burning and butchery marks. The definitions of cut mark types followed Binford (1981, p. 106ff, table 4.04). Measurements were acquired by a digital calibre, with a precision of 0.1 mm according to the definitions by von den Driesch (1976). The values for calculating height at the withers followed the guidelines recommended by von den Driesch and Boessneck (1974), although for horses May (1985) was followed.

The strontium isotope analysis

For the strontium isotope analyses of human remains, a tooth from each individual was sampled (either a deciduous molar or a permanent molar). The tooth enamel from each individual was mechanically pre-cleaned with a dental drill and subsequently repeatedly washed ultrasonically in ultrapure (MilliQ™ EMD Millipore Corporation, Darmstadt, Germany) water until the water remained visually clear. After drying, small pieces of enamel were removed by means of a small diamond blade saw and/or with chromium steel pliers. Extreme care has been taken not to sample dentin material along with the enamel. Amounts of 1–5 mg were weighted into 7 ml Teflon beakers (Savillex™ Savillex, Eden Prairie, Minnesota, USA). The samples were dissolved in a 1:1 mixture of 0.5 ml 6 N HCl (Seastar, Seastar Chemicals Inc., Sidney BC, Canada) and 0.5 ml 30% H_2O_2 (Seastar, Seastar Chemicals Inc., Sidney BC, Canada). The samples typically decomposed within 5–10 min, after which the solutions were dried down on a hotplate at 80°C. Enamel samples were taken up in a few drops of 3 N HNO_3 and then loaded on extraction columns with a 0.2 ml stem volume charged with intensively pre-cleaned mesh 50–100 SrSpec™ Sr-specific ion chromatographic extraction resin (Eichrome Europe Laboratories, Bruz, France) resin. The elution recipe essentially followed that by Horwitz *et al*. (1992), scaled to our needs. Sr was eluted/stripped by pure deionized water and then the eluate was dried on a hotplate. Strontium samples were dissolved in 2.5 µl of a Ta_2O_5–H_3PO_4–HF activator solution and directly loaded onto previously outgassed 99.98% single rhenium filaments. Samples were measured at 1250–1300°C in dynamic multi-collection mode on a VG Sector 54 IT mass spectrometer equipped with eight faraday detectors (Department of Geoscience and Natural Resources Management, University of Copenhagen). Also, 5 ng loads of the NBS 987 Sr standard gave $^{87}Sr/^{86}Sr = 0.710236 \pm 0.000010$ ($n = 10, 2\sigma$).

Results and discussion

In what follows, the investigations conducted on human and faunal bone material are presented. The human material is presented by each of the three wells. In contrast, the presentation of the animal bones is organized according to some overarching archaeozoological principles such as species distribution, taphonomy, selection of body part and species choice due to the large amount of bone material and the large species variation. Table 1 provides an overview of the representation of the human and animal remains with respect to isolated bones, joints and semi-complete skeletons in the three wells as well as other archaeological finds related to the wells. The results of the strontium isotope and radiocarbon dating are presented in Table 2 and Figure 4.

The human bone material

Well 47

In well 47, human skeletal remains of two children were found. Both skeletons were fairly complete and well preserved, though fragmented (Table 1 and Figure 5A). The remains of the two children are described as found near the bottom of the well, and it is reasonable to presume due to their completeness, as stated by Nørlund (1948, p. 42), that they were articulated when they were deposited in the well. It was also noted (Nørlund 1948, p. 42) that the bones had been exposed to fire.

This current examination found that the younger child was 4 years old (range 3–5 years), and the older child was 7 years old (range 5–9 years) based on dental development (Ubelaker 1989, p. 66), which is equivalent to previous examination (Sellevold *et al*. 1984, p. 131). We found no evidence of heat exposure of the bones as mentioned in Nørlund (1948, p. 42). Some of the bones do have a reddish brown colour which could be ascribed to heat exposure (Shipman *et al*. 1984). This is mainly evident on the tibia of the older child and some of the unfused hip bones of the younger child. However, this colouration is more likely to stem from the burial environment and the

Table 1. Census of the contents of the three Trelleborg wells showing type of deposit, context and associated finds.

	Well 47			
	Animal remains			
Human remains	Taxon	Type of deposit	Placement	Associated finds
Semi-complete skeletons of two children aged 4 and 7 years, with some fragmentation. Placed near the bottom at a depth of 2 m	Jackdaw	Single bone	All near the bottom at a depth of 2 m	A tortoise brooch, a bronze bowl, an arrow head, Slavonic pottery, two whetstones, spindle whorls and fragments of weaving weights found in the fill
	Dog	Single bones of individual 1 One heal joint and single bones of individual 2		
	Pig	Single bones of three individuals		
	Cattle	Single bones and foot joint[1] of one individual		
	Goat	Semi-complete skeleton of one individual		
	Horse	Single bones of one individual		
	Well 50			
	Animal remains			
	Species	Type of deposit	Placement	Associated finds
Fragments from the calvaria and proximal ends of a right ulna and radius from an adult individual	Swan	Single bones		Fragments of a knife, iron fragments, a quern stone, three wooden bowls, carved bowl handle, fragment of a possible sledge runner, wooden fragments and a wooden spoon placed at the bottom level
	Black-headed gull	Single bone		
	Dog	Single bones of one individual		
	Red deer	Single bones		
	Pig	Single bones of four individuals		
	Cattle	Single bones of three individuals		
	Sheep	Single bones of one individual		
	Horse	Single bones of one individual		
	Well 121			
	Animal remains			
	Species	Type of deposit	Placement	Associated finds
Semi-complete but fragmentary skulls and few postcranial parts of two children aged 4 years. Fragments from the calvaria from an adult individual	Peregrine falcon	Single bones of one individual		Fragments of pottery, semi-finished antler for combs, whetstone, bone skate and iron fragments found in upper layers of fill
	Dog	Semi-complete skeleton of one individual	On top of the children	
	Red deer	Single bone		
	Pig	Single bones of four individuals		Three belt buckles, a knife fragment and iron objects found in lower layers of fill
	Cattle	Single bones and skull, portion of vertebral column[1], right hind leg of two individuals	On top of the dog and children	
	Sheep	Single bones of three individuals		
	Horse	Single bones and portions of the neck[1], right hind leg and lower limbs[1] of three individuals		

Note: [1]Designates that based on the bone elements published by Degerbøl (1948) it was assumed that the bones had been associated; however, this could not be ascertained in the present analysis.

Table 2. Strontium isotope results from the four children.

Well no.	Tooth description	$^{87}Sr/^{86}Sr$	Error ± ppm
47 (young child)	Second deciduous molar	0.71088	21
47 (older child)	First deciduous molar	0.71023	20
121 (1)	First molar	0.71019	27
121 (2)	First molar	0.71084	13

Note: Errors reported are within-run ($2\sigma_m$) precisions of the individual runs.

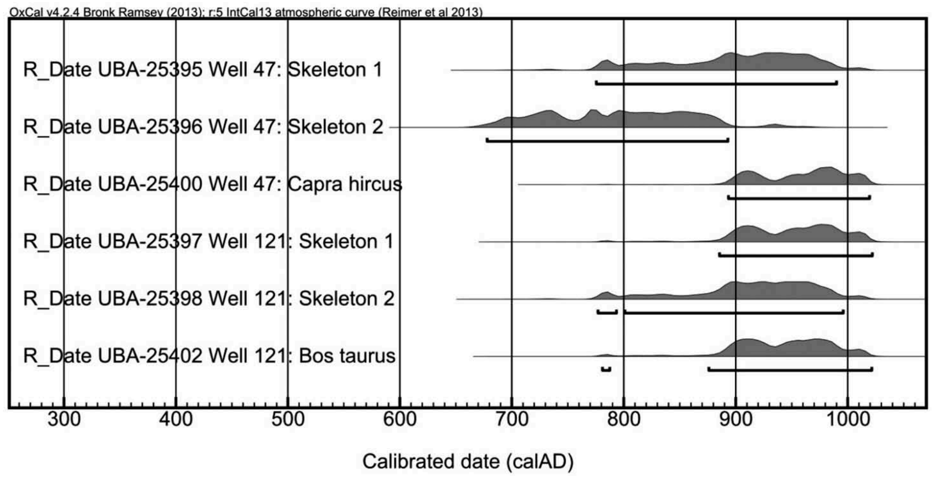

Figure 4. Radiocarbon datings from wells 47 and 121 calibrated with OxCal v4.2.3 (Bronk Ramsey 2013) and IntCal13 (Reimer et al. 2013). The three datings from well 47 indicate that the formations processes behind the depositions reach back to the eighth to the ninth century.

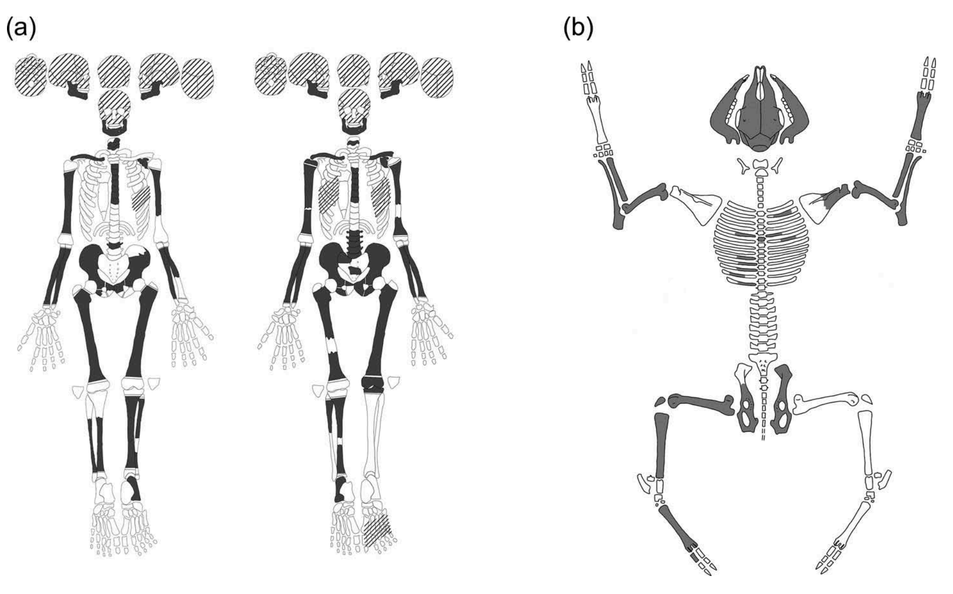

Figure 5. (A) Census of the skeletal elements present of the two children of well 47. To the left is the younger child (*c*. 4 years) and to the right the older child (*c*. 7 years). Skeletal elements that are hatched represent elements which are greatly fragmented and hence not precisely identified. (B) Census of the skeletal elements present of the young he-goat of well 47. In total, 24 bone elements were reassembled from 38 bone fragments. No butchery marks except for the possible blow to the frontal bones were observed. Basic skeletal drawing after Helmer (1987).

variation in colour between the bones is probably due to variations in the microenvironment of the well. The children were examined for growth disturbances expressed as enamel hypoplasia and Harris lines as well as cribra orbitalia which could be a sign of dietary deficiency or childhood disease (Harris 1931, Park and Richter 1953, Stuart-Macadam *et al*. 1985, Goodman and Rose 1990, Hillson 2000, Walker *et al*. 2009). The examination revealed a single Harris line on the younger child. There was no further evidence of the above-mentioned pathologies. However, diseases which are not expressed osteologically cannot be excluded. Both children had reached appropriate growth for their age. As such there are no indications of a chronically ill health.

There is no evidence of trauma, cut marks or dismemberment on any of the bones present. However, this does not mean that violence or dismember did not take place, only that there is no visible signs thereof. Several bones were broken, including the bones of the skull; however, all fractures resemble post-mortem breakage, that is, when the bones were dry. The cause of death cannot be determined.

The strontium isotope results (Table 2) of the two children fall within the Danish bioavailable range previously defined by Frei and Frei (2011, 2013), revealing that the children are most probably of local origin.

Well 50

In well 50, a few skeletal remains from an adult were found. The material only consists of nine fragments from the calvaria and an upper fragment of both lower arm bones from the right side (n = 11) (Table 1). According to Nørlund (1948, p. 244), the bones from the lower arm have been broken by force. Nørlund (1948, p. 39) further described that the bones were found in the fill of the well. According to Nørlund, the bones should therefore not be ascribed too much importance as the construction material may have been transported from elsewhere, for example, backfill in the form of sediments cleaned up from other wells or the bog area, hence containing random bone material. This is also mentioned as being the case elsewhere around the Trelleborg fortress, for example, well number 125 (Nørlund 1948, p. 41), and outside the south gate under the bridge at the inner moat (Nørlund 1948, p. 39).

Sex could not be determined from these fragments and age could not be more precise than ‘adult’. There were no signs of pathology. Further, it was found that the fractures on the ulna and radius resemble post-mortem breakage and as such have no evidence of violence.

Well 121

In well 121, human skeletal remains of two children were found. Both skeletons were well preserved though incomplete and fragmented. Skull fragments from both children were present and some few postcranial parts (Table 1 and Figure 6A). Nørlund (1948, p. 41) described that both children were complete when thrown in the well. There are no records of how the two children were found stratigraphically.

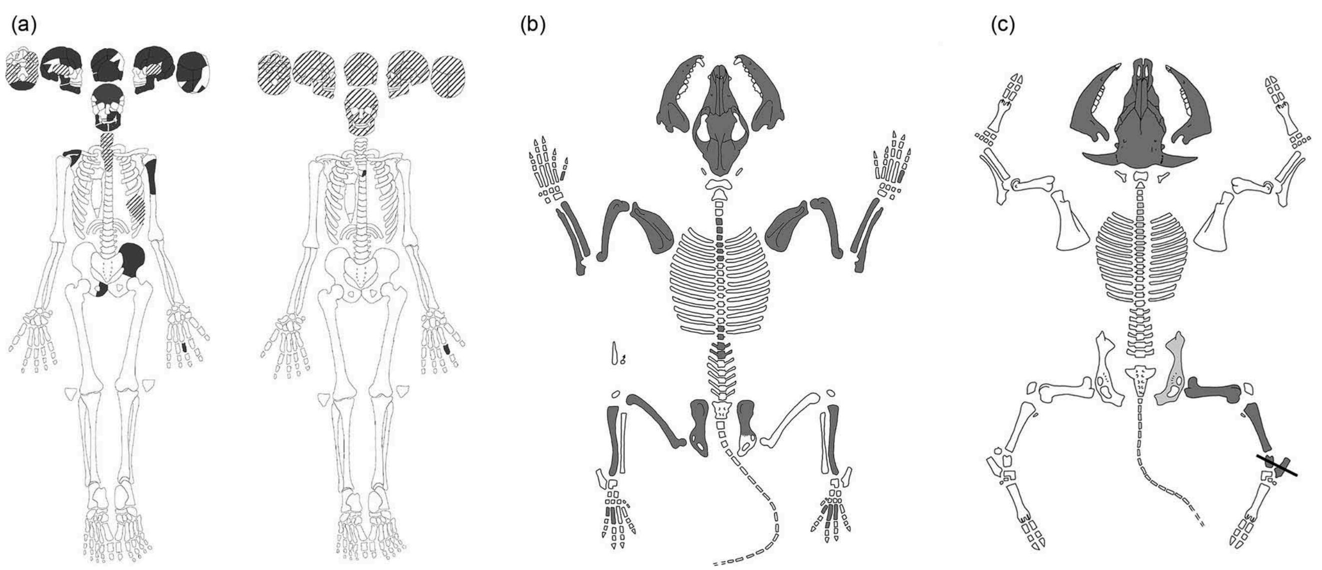

Figure 6. (A) Census of the skeletal elements present of the two children of well 121. To the left is skeleton 1 (*c*. 4 years) and to the right skeleton 2 (*c*. 4 years). Skeletal elements that are hatched represent elements which are greatly fragmented and hence not precisely identified. (B) Census of the skeletal elements of the adult dog of well 121. A total of 34 bone elements were retrieved. No bones exhibited butchery marks. Basic skeletal drawing after Helmer (1987). (C) Census of the skeletal elements of the young adult cow from well 121. The heal joint exhibited dismemberment marks (astragalus and calcaneus). Dark shaded elements were reanalysed in the present study, whereas light shaded elements were reported by Degerbøl (1948) and may have been articulated. Basic skeletal drawing after Helmer (1987).

This current examination found both children to be 4 years old (range 3–5 years), based on dental development (Ubelaker 1989, p. 66), which is equivalent to previous examination (Sellevold *et al*. 1984, p. 131). It is uncertain whether the postcranial elements are from both children as there are no indications of the postcranial bones representing more than one individual. The completeness of the children at the time of deposit cannot be confirmed from the remains preserved today. It is unknown whether the previous definition of completeness by Nørlund (1948, p. 41) differs from this assessment or whether a significant amount of bones have gone missing since the excavation. This was the case for many of the bones from the actual cemetery from the Trelleborg Stronghold (Price *et al*. 2011, p. 482). The children were examined for growth disturbances expressed as enamel hypoplasia and Harris lines as well as cribra orbitalia. The examination revealed no indications of the above. Diseases which are not expressed osteologically cannot be excluded. One of the children (skeleton 1) had in addition two teeth examined histologically in a previous study. The results reveal two periods of physiological stress within a week of birth as well as six periods the following year (Alexandersen *et al*. 1998, p. 15, 17). This is not uncommon on material of archaeological origin. There is no evidence of trauma, cut marks or dismemberment. Several bones were broken, including the bones of the skull; however, all fractures resemble post-mortem breakage, that is, when the bones were dry. There are no indications of chronically ill health. The cause of death cannot be determined.

The strontium isotope results (Table 2) of the two children fall within the Danish bioavailable range previously defined by Frei and Frei (2011, 2013), revealing that the children were most probably of local origin as concluded for well 47.

The adult bones found in well 121 consist only of two parietal fragments. Nørlund (1948) does not mention these two fragments in the publication. However, U. Møhl (unpublished sources) noted them at the Zoological Museum. It is uncertain why they were not included in the original publication. It is possible that the fragments were considered secondary deposits like those of well 50 and as such not given any further emphasis. The skeletal fragments are from an adult. Age cannot be asserted any further and neither can the sex of the individual. The edges of the fractures resemble post-mortem breakage, that is, when the bones were dry. There are no signs of pathology or trauma.

The faunal material

The three wells provided remains of seven mammalian and four avian species (Table 3). The Trelleborg site as a whole showed a preponderance of pig and cattle bones (Degerbøl 1948, p. 241). In recent excavations at Trelleborg Enge north and west of the stronghold, pigs predominated (Kveiborg and Ritchie 2013), which is in agreement with the species distribution of well 50, whereas the two other wells with children's skeletons showed a different pattern. Although whole skeletons of dog and goat inflated the number of identified specimens (NISP) counts, the minimum number of individuals (MNI) distributions still showed that dog, especially in well 47, and horse, in well 121, played

Table 3. The bird and mammal remains found in the three wells at Trelleborg as presented by taxon.

	Well 47		Well 50		Well 121		Total
Taxon	NISP	MNI	NISP	MNI	NISP	MNI	NISP
Swan (*Cygnus* sp.)			2	1			
Peregrine falcon (*Falco peregrinus*)					2	1	
Black-headed gull (*Chroicocephalus ridibundus*)			1	1			
Jackdaw (*Corvus monedula*)	1	1					
Dog (*Canis familiaris*)	11	2	3	1	34	1	
Red deer (*Cervus elaphus*)			10		1	1	
Pig (*Sus domesticus*)	12	3	16	4	22	4	
Cattle (*Bos taurus*)	8	1	21	3	13[1]	2	
Sheep (*Ovis aries*)			6	1	4	3	
Goat (*Capra hircus*)	38	1					
Horse (*Equus caballus*)	2	1	9	1	29[1]	3	
Total identified	72		68		105		245
Mammals unsp. (Mammalia sp.)	11				1		12
Grand total	83		68		106		257

Notes: NISP, number of identified specimens; MNI, minimum number of individuals.
Symmetry and ontogenetic age of the bones were considered in the MNI calculations. The faunal material published by Degerbøl (1948) with new material sorted from the human bones in 1981 and 2013 at LBA included.
[1]The number of discarded vertebrae and ribs was not informed.

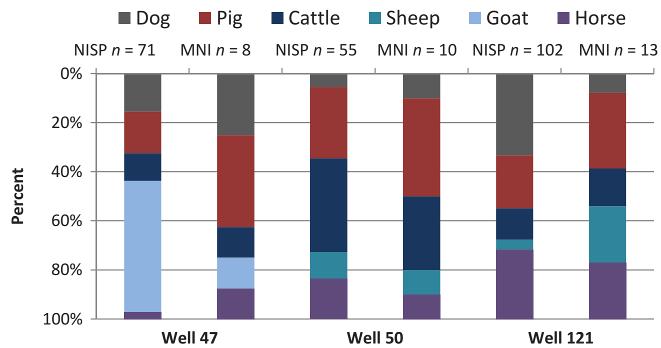

Figure 7. The relative frequencies of the domesticated mammals of the three wells at Trelleborg as shown by NISP and MNI. Data from Table 3.

relatively larger roles (Figure 7). Well structures of contemporary sites such as Tissø, Denmark, and Järrestad, Scania, Sweden, also showed higher relative frequencies of horse remains (but not dogs) as opposed to other structures at the respective sites (Nilsson 2003, table 1, p. 398, Gotfredsen *et al*. forthcoming). The age distribution of the animals in the three wells shows dog remains to be solely from adult animals, whilst the domestic livestock, especially pigs and ovicaprines and to some extent horse and cattle, were represented by young animals (Figure 8 and Supplementary Table 1).

Selection of specific body parts

Skulls and, in particular, mandibles predominate in many ritual contexts (Nilsson 2003, 2009, Magnell and Iregren 2010, p. 243). In traditional cultures, crania are connected to life-giving powers (Cooper 1993), and in Scandinavia the deposition of mandibles has been a well-known practice since the Mesolithic (cf. Noe-Nygaard and Richter 1990, Rudebeck 2010). Elk hunters of Mesolithic Europe deposited jaws and feet in a ritual pit at Popovo in Karelia (Bridault 1992) which points towards a strong symbolic value of these elements. The jaw bones may have served as a symbol of the sacrificed animals and in addition were easily transported from elsewhere to the place of deposition (Magnell and Iregren 2010, p. 243). At the entire Trelleborg site, the only intact skulls found were the goat cranium in well 47 and the dog and cow crania in well 121 (Degerbøl 1948, p. 245). Further, the wells produced two mandibles from pig, one from cattle, four damaged ones from sheep but none from horse except for two lower molars from a mandible. Skulls including mandibles may have had a symbolic significance but also represent primary butchery waste needing to be disposed of. Pigs and to some extent sheep were primarily represented by meaty parts of upper front and upper hind legs, especially in wells 50 and 121 (Table 4). Horse was represented by most body parts, whilst vertebrae and ribs were reported by U. Møhl (unpublished sources) originally to have been present. The dog and cow in well 121 were considered to have been whole skeletons by Nørlund (1948, p. 41): ‘The cow lay on top of the dog and the children, and so much was preserved of the children as well as the two animals that it was safe to say that they were interred whole into the well’ (author’s translation). It seems very likely that the dog was deposited as a whole skeleton (Figure 6B). On the contrary, the cow is assumed originally to have been deposited as a part skeleton since large cattle bones were hardly overlooked during excavation (Figure 6C).

Pre-depositional events

Very little diagenetic degradation had occurred to the bones due to the waterlogged clayey calcium-rich sediments of the wells. The three samples showed low average weathering, although bones in well 50 exhibited a slightly higher frequency of weathering and other pre-depositional damage, for example, gnawing and trampling, than bones of the two other wells, which indicate that part of the content of this well had been subaerially exposed for some time prior to deposition (Table 5).

Butchery practices and fragmentation

Except for the butchered dog bones of well 47, pig and cattle bones overall exhibited the highest frequencies of butchery marks (Table 6; for more thorough descriptions, see Supplementary Table 2). In addition, pig bones were the most fragmented with proportions of whole bones varying between 25% and 36%, whilst cattle and horse bones varied between 46–90% and 50–80%, respectively. All sheep bones occurred as fragments. Horse bones did not exhibit cut marks, although one left metatarsal from well 50 was worked cranially presumably to make a bone skate. The semi-complete he-goat of well 47 was most likely killed by a blow to the frontal bones (Figure 5B and Figure 9). The postcranial goat bones had a relatively low proportion of

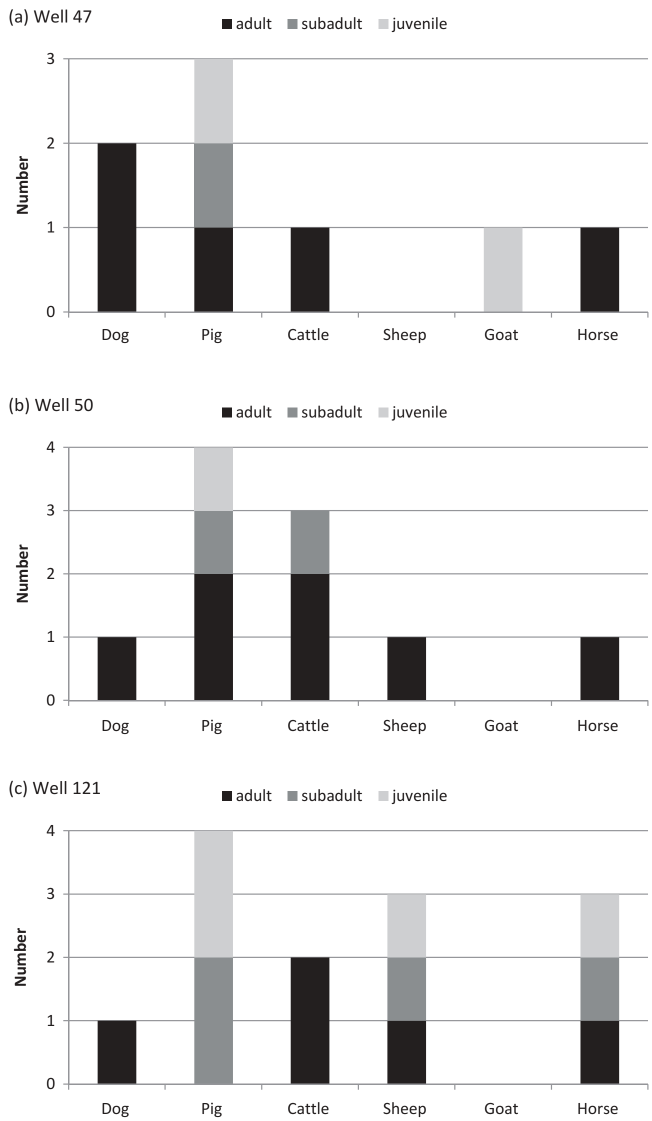

Figure 8. (A–C) Age distribution of the livestock animals of the three wells at Trelleborg as combined from dental eruptions and wear (Supplementary Table 1) and fusion data of the postcranial skeleton. Age categories follow Schmid (1972); adult: permanent teeth in function and epiphyseal lines fused; subadult: replacement of permanent dentition finished and epiphyses nearly ossified, late fusing epiphyses still open or with visible epiphyseal lines (size of the bones almost the size of adult bones); juvenile: replacement of deciduous teeth with permanent dentition and many epiphyses still unfused (size of the bones smaller than the adult bones).

whole elements, *c*. 50%, which was caused by mainly recent damage. The smooth, well-preserved bone surface and complete lack of butchery marks indicate that the meat (or some of it) may still have been attached to the bones at the time of deposition. The semi-complete dog skeleton of well 121 had intact bones without butchery traces (Figure 6B). In contrast, butchery marks were observed on more than half of the fragmented dog bones of well 47 (Table 6).

Place of deposition

Water and, in particular, wells played a central role as sacred places for people during the Iron Age (see Nilsson 2003, p. 288, 2009, p. 83). For instance, Snorre's *Edda* describes how wells were situated adjacent to the roots of Yggdrasil. One well was of particular importance and connected to the goddess or so-called Norn Urd (Carlie 2002, p. 674, Näsström 2002, p. 118). The so-called ritual shafts are structures that penetrate deep underground and form a line of communication between the living of the earth and the dead of the underworld (cf. Green 1992, p. 88). Such structures were often wells which had gone out of use, for instance, well 50 and possibly also well 121, whereas well 47 may not originally have been a well. It is, however, outside the scope of the present paper to discuss in depth the different kinds of wells or well-like structures (for ritualistic uses of wells,

Table 4. The animal remains of the major domesticates of three wells at Trelleborg as distributed by skeletal element.

	Well 47					Well 50					Well 121				
Skeletal element	Dog	Pig	Cattle	Goat	Horse	Dog	Pig	Cattle	Sheep	Horse	Dog	Pig	Cattle	Sheep	Horse
Calvarium	1			3			2				1		1		
Mandibula		2		2		1		1	1		2	1	2	3	
Caninus												2			
Premolar/molar				1						2					
Axis	1					1									
V. cervicalis											3				6
V. thoracica		1		1							5				
V. lumbalis	2										2				
Vertebra unsp.													Many[1]		
Costa		1		15											Many[1]
Scapula				1							2	2			
Humerus		1	1	2			6		1		2	2	1		1
Radius		2		2			4	3	3		2		1	1	
Ulna		1	1	2							2	5			
Metacarpus				1				2		1	2				2
Sacrum		1													
Pelvis				2		1					2		3		3
Femur	1			1							1		1		2
Patella				1											
Tibia	3		1	2			2		1		2	6	1		3
Fibula		1													
Metatarsus		2		1						3	5	2			2
Astragalus	1							6					2		1
Calcaneus	2				1		2	1		1			1		3
Tarsus															2
Metapodial II/IV															1
Phalanx 1			3	1	1			8			1				1
Phalanx 2			2							1					1
Phalanx 3										1					1
Phalanx unsp.												2			
Total	11	12	8	38	2	3	16	21	6	9	34	22	13	4	29

Notes: The faunal material published by Degerbøl (1948) with new material sorted from the human bones in 1981 and 2013 at LBA included.
[1]The number of discarded vertebrae and ribs was not informed.

Table 5. Census of bones with surface alterations shown by number and frequency.

	Gnawing						Trampling						Slight weathering			
	Well 47		Well 50		Well 121		Well 47		Well 50		Well 121		Well 47		Well 50	
Taxon	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Swan									1	100.0						
Red deer															1	100.0
Pig	1	14.3	1	12.5			2	28.6	2	25.0	1	14.9	2	28.6	4	50.0
Cattle			1	25.0	1	12.5			2	50.0					1	25.0
Total	1	1.4	2	9.1	1	1.8	3	5.2	5	22.7	1	1.8	2	2.9	6	27.3

Notes: Slight weathering designates weathering stage 1 *sensu* Behrensmeyer (1978). Frequencies were calculated from NISP counts of the re-examined sample: well 47: jackdaw (n = 1); dog (n = 11); pig (n = 7); cattle (n = 1); goat (n = 38); horse (n = 0). Well 50: swan (n = 1); black-headed gull (n = 1); dog (n = 3); pig (n = 8); red deer (n = 1); cattle (n = 4); sheep (n = 2); horse (n = 2). Well 121: peregrine falcon (n = 2); dog (n = 34); pig (n = 7); cattle (n = 10); sheep (n = 4); horse (n = 3).

see also Haasteren and Groot 2013). The widespread practice of using bogs and wetlands for ritual sacrifices and ceremonies in the early Iron Age changed through time to be settlement bound in the late Iron Age and Viking Age (e.g. Fabech 1991, p. 97, 1994, Nilsson 2003, p. 288, 2009, p. 95ff). Still, ritual depositions

Table 6. Census of bones with surface alterations inflicted by humans as shown by number and their frequency.

	Burning[1]						Cut/chop						Impact scars					
	Well 47[2]		Well 50		Well 121		Well 47		Well 50		Well 121		Well 47		Well 50		Well 121	
Taxon	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Black-headed gull									1	100								
Dog							6	54.5										
Red deer									1	10.0								
Pig			2	12.3			1	14.3	2	25.0	3	42.9	1	14.3				
Cattle			1	4.8	1	9.0			1	25.0	3	37.5			2	50.0	1	14.3
Total		0	3	4.5	1	1.0	7	12.1	5	22.7	6	10.7	1	1.7	2	9.1	1	1.8

Notes: Burning is slight burning and charring.
[1]Frequency of burning was based on NISP counts from Table 3. Frequencies of cut/chop and impact scars were calculated from NISP counts of re-examined sample see explanation for Table 5.
[2]Degerbøl (1948, p. 343) reported the majority of bones to have been subjected to mild burning; however, none of the re-examined bones could be confirmed to have been subjected to fire, hence none was recorded for well 47.

Figure 9. Skull of the *c.* 1-year-old male goat from well 47. Large parts of the forehead were missing which indicate that it was felled with a blow to the forehead before it was thrown into the well. Currently, the skull is at a permanent exhibit at the museum at Trelleborg. Photo: Anne Birgitte Gotfredsen.

continued to take place in wetland areas during the Viking Age (cf. Monikander 2010, Zachrisson 2014). At Trelleborg, the cultic rituals and disposal of waste from these acts had been carried out nearby inhabited areas, thus being in accordance with the general temporal trend. The presence of semi-complete skeletons indicates that the actual killing of the animals probably took place close to the wells, possibly within the horseshoe-shaped features (Nørlund 1948, p. 44).

The species choice

The major domesticates predominate whilst a few avian bones and red deer calvaria and antler fragments were the only remnants of wild species in the three wells (Table 3). This is in line with most Iron Age and Viking Age ritual contexts which show a preponderance of the typical livestock species (Nilsson 2009, p. 86, Magnell 2012, p. 296). In rare cases, wild species were also used (see, e.g. Magnell and Iregren 2010). Wild species and fantasy creatures were significant for identity and cultural transformations and played an important role in the *Eddas* whilst domesticates were mentioned to a lesser degree. Still, domesticated species were of particular importance in rituals at houses and farms, in wetland and at death rituals (Jennbert 2006, p. 138). Which domestic species was preferred depended on the purpose, ritual context and regional variation.

Avian species. Degerbøl (1948, p. 244f) advocated for a symbolic significance of the jackdaw wing bone in well 47 and a swan wing (ulna and carpometacarpus) in well 50. Animal body parts used in burial rituals referred to those elements that were important in the animal's relations with humans (Schanche 2000, p. 295, Fowler 2004, p. 136f); in the present case the ability to fly. The jackdaw humerus was well preserved and may have been deliberately deposited with its feathers still attached. Unfortunately, only a broken distal swan carpometacarpus exhibiting trampling traces and abrasion was retained. Thus an interpretation of a deliberate deposition of a swan wing could not be confirmed. An intact well-preserved black-headed gull ulna exhibiting possible traces of feather removal was retrieved from well 50. Furthermore, a wing and a leg bone from a male peregrine falcon in well 121 indicate that falconry was practised by members of the elite using the Trelleborg area prior to and/or during the occupation of the fortress (Gotfredsen 2014).

Dog. Whole dog skeletons and skulls occurred in bogs and wells throughout the Iron Age in present-day Denmark and Scania (Nilsson 2003, 2009, p. 89). Large pointer-sized dog skeletons found in bogs, for example, Röekillorna, Scania and Valmosen near Rislev, Zealand, were found articulated and devoid of butchery marks and therefore considered as having been deposited as whole corpses (Nilsson 2009, p. 89). Sacrificed dogs included in Danish boat-graves and weaponry bog finds, summarized by Hatting (1978, p.73, 1985, p. 11), were also reported to be large, possible war dogs, *c*. 61–63 cm at the withers. The dog in well 121 was a rather tall and slender individual, *c*. 63 cm at the withers and presumably a male (evidenced from its prominent crista sagittalis). It was healthy without pathological signs on the bones and with only moderately worn teeth, that is, at its prime. In Celtic religion, the dog was an esteemed creature with an important role in mythology and also connected to water and spring cult (Gräslund 2004, p. 171). The dog symbolized not only death but also healing and fertility (Green 1992). Furthermore, it is regarded as a general Indo-German phenomenon that dogs acted both as conductors and guards at the entrance of the underworld (Gräslund 2004, p. 171, De Grossi Mazzorin and Minniti 2006, p. 62), and in the Old Norse religion this guarding dog was named Garm (Jennbert 2006, p.138). The deposition of an entire large dog devoid of butchery traces in well 121 seems to be in accordance with the sacrificial use of dogs during the Iron Age.

In stark contrast to the whole dog in well 121 are the butchered dog joints from well 47. It cannot be stated whether the meat was actually eaten, but some meat was stripped off the bones. Consumption of dogs is a widespread practice, and even within the same society dogs may both receive ritualistic burials and serve as food (Morey 2010, p. 90). In ancient Rome, written sources described how at certain times dogs were butchered and eaten at ritual meals (cf. Wilkens 2006, p.133).

Pig. In the Old Norse mythology, the pig was associated with fertility mostly in connection with Freyr but also the female goddess Freya. The meat-producing powers of pigs was exemplified by the myth of the male pig Särimmer being slaughtered and its meat cooked each evening to feed the warriors of Valhalla (Faulkes 1995, p. 32). Moreover, pork together with horse meat was the preferred meat for consumption at the *blót* meals (Faulkes 1995). The three Trelleborg wells contained disarticulated bones of pig, primarily meat-rich portions, and all but one were from juvenile and subadult individuals close to the optimal age of slaughter. The pigs in the wells conformed to the age of pigs from the site as a whole (Degerbøl 1948, p. 249) and represent consumption waste, although a nearly intact jaw bone from a boar (well 47) may have been selected for a deliberate deposition.

Cattle. Old Norse mythology mentioned cattle in the creation myth where they gave milk to the first gods Ymer and Bure (Faulkes 1995). Thus cattle were associated with life-giving powers. Cattle, valued for their meat, milk and hide, as well as being useful draft animals, were highly estimated domesticates indicating both wealth and status. In the Trelleborg wells, cattle remains comprised firstly of assumed consumption waste; secondly, a mandible (well 50) and a part skeleton of a young adult cow including the skull (well 121). The articulated upper meaty hind leg, dismembered at the heal joint (Figure 6C), probably was deposited while still enfleshed. The cow may thus have served as a propitiatory sacrifice to the gods.

Ovicaprines. Sheep did not play a prominent role in the Old Norse mythology whilst the goat was an important mythological animal. For instance, the two male goats Tanngnjóstr and Tanngrísnir pulled Thor's chariot as described in the Gylfaginning of the *Prose Edda* by Snurri Sturluson (Faulkes 1995, p. 22). The juvenile he-goat in well 47 was, as evidenced from epiphyseal fusion data, *c*. 1 year old and thus most likely killed in spring/ early summer probably by a blow to the forehead (Figure 9). The stratigraphically close position to the two children supports the notion that the juvenile goat was a sacrificial animal. Sheep were depending on the region widespread domesticates and much more abundant than goats at Scandinavian Iron Age sites (Gotfredsen 2004, Nilsson 2009, Magnell and Iregren 2010). Sheep comprised only 4% and 11% of the domesticated mammals in wells 50 and 121, respectively. They represent meal leftovers, that is, fragments of meaty upper limb bones and mandibles which may be regarded as butchery waste. Sheep were of minor importance in culture deposits at the Trelleborg site (cf. Degerbøl 1948, Kveiborg and Ritchie 2013, diagram 15) but occurred in higher frequencies, for example, *c*. 17% at Trelleborg Enge than was evidenced from the three wells. At Tissø (Gotfredsen *et al*. forthcoming) and Järrestad, sheep were represented by lower frequencies in wells than in, for example, pit houses, perhaps because sheep had a more ordinary usage (Nilsson 2003, p. 300).

Horse. The horse played a prominent role in the pre-Christian belief system as described in the *Eddas* and evidenced in the archaeological record (Carlie 2002, Nilsson 2003, 2009, Jennbert 2006, p. 138). It was the holy animal of Odin and Freyr and closely connected to fertility. The significance of horses as an intermediary between different world realms in the belief systems of Germanic tribes was already described by Tacitus (cf. Bliujienė and Butkus 2007, p. 100). During the Viking Age, the horse was seen as a symbolic creature of transformation and passage to other worlds (Loumand 2006). Horses dragged the sun over the sky and played an important role as sacrificial animal in the *blót* meals (see Nilsson 2003, p. 301, 2009, p. 85, 89f, Magnell and Iregren 2010, p. 241, 445). According to Ström (1985, p. 177), it was the practice to select and sacrifice the best and healthiest male animals suitable for breeding, whether it were boars, stallions or bulls at the Freyr's cult or winter *blót*.

Horse bones occurred in high relative frequencies in wells and wetlands sacrificial sites but played an insignificant role at other sites (see Nilsson 2003, 2009, Magnell and Iregren 2010, Magnell 2012). In the Trelleborg wells (seen altogether), all body parts of horse occurred, that is, meatless extremities as well as meat-bearing parts. Degerbøl (1948, p. 246) considered the charred horse bones of, for example, well 47, as an indication of horse flesh being eaten. Although food leftovers from horse may have been present in well 121, such a practice cannot be ascertained in the present analysis. The horse hindlimb in well 121 derived from an unusually tall individual, *c*. 149 cm at the withers as compared to a mean of 140 cm at the site as a whole (Degerbøl 1948, p. 244, table 2). The deposition of an above-average-sized young horse (stallion?) may be interpreted as a fertility sacrifice for Freyr or Odin. In addition, well 121 provided a metatarsal from a colt killed during spring/early summer.

Conclusions

The three wells dated to the eighth/ninth to tenth centuries unearthed a variety of archaeofauna and human remains. Two wells (47 and 121) contained children's skeletons, which seem to be deliberate depositions of semi-complete skeletons or limbs. These represent to date the only Danish Viking Age wells with human remains of children. Due to post-depositional events such as heavy breakage of the children's bones and post-excavation loss of bones, it could not be stated how the children died. Additionally, the wells contained a variety of animal remains of which some represented consumption waste of livestock species being the remains of profane and/or ritual meals such as *blót* activities.

A sacrificed young he-goat in well 47 killed during spring may be seen as a propitiatory sacrifice to honour or appease Thor and to ensure fertility. The deposition of a hindlimb of a young large-sized presumed stallion and large parts of a cow placed together with the children may also be interpreted as propitiatory sacrifices, whilst the large-sized high prestige male dog may have served a dual function as a sacrifice to the gods and a conductor for the children. The sacrificed animals showed evidence of having been deposited while still enfleshed and hence, as regards the animals normally used for consumption, constituted a resource loss to the society.

The strontium isotope results of the four children found in the two wells (47 and 121) point to local provenance. However, there seems to be a pattern, as the strontium isotope results of each well pair up. Hence, the youngest child from well 47 and child from well 121 (2) have strontium isotope ratios of ~0.7108. In contrast, the oldest child from well 47 and child from well 121 (1) have strontium isotope ratios a little less radiogenic in the order of ^{87}Sr/^{86}Sr ~ 0.7102. Even though all values point to local origin, they do not seem to point to exactly the same area. It is, therefore, plausible that the children came from two different surrounding areas at Trelleborg. One could thus speculate if there is a ritual meaning that involves the sacrifice of children from certain nearby areas, which was repeated in these two wells.

Ritual wells have turned up in connection with archaeological excavations in Scandinavia. One fine example is from the royal residential complex at Lake Tissø, only *c*. 30 km north of Trelleborg (Jørgensen *et al*. 2014, p. 196, Gotfredsen *et al*. forthcoming). The use of wells as ritual sites has also been documented in earlier periods. At Lindängelund, close to the town of Malmö in southern Sweden, a number of wet areas and wells from different periods have been excavated (Carlie 2013). In a number of wells from the period 150 BC–AD 300 deposits containing remains of humans, animals, and wooden artefacts have been documented. In connection to the ritual site at

Trelleborg, it is important to note that it is closely associated with a settlement of higher status. The structure and organization of this settlement is still unknown; however, the stray metal finds indicate that we are dealing with a complex of some status. The ritual features on the promontory are not the only ones in the area. In connection with dredging of the river Tude Å, a ninth-century sword was found upstream of Trelleborg (Nørlund 1948, fig. 4). The distance to the find location for the sword is uncertain but is just outside the map in Figure 1. Undated human skeletons have been found in the bog area just east of the fortress (cf. also Nørlund 1948, p. 159). The finds so far indicate that systematic surveys and investigations would reveal further ritual sites and perhaps shape a ritual landscape similar to the one that have emerged in connection to the elite complex at Lake Tissø, where so far five contemporary ritual sites have been documented in the landscape encircling the royal residence (Jørgensen 2014, p. 137ff).

The cross-scientific analyses presented in this article demonstrate that further steps and new knowledge can be gained within an interdisciplinary collaboration between natural sciences and archaeology, particularly in order to clarify the formation processes underlying the accumulation of cultural deposits in features such as ritual wells. Apparently, they were used both for gift and communion offerings. Based on the archaeological traces of the pre-Christian religion on the Scandinavian sites, we can at least see that, in the ninth to tenth century, we had a religion which in part seems very vigorous and whose rituals seem to be firmly embedded in the mental world of the people. This is important for our understanding of the transition from the ‘pagan’ to the Christian religion.

Trelleborg constitutes an important site with regard to these power political aspects as we witness the closing of an important regional pre-Christian ritual site in connection with the construction of the fortress. A new political and military power clearly entered the regional scene and, with or without the consent of the local elite, closed down the old ritual site. We know that this event took place around AD 980. A few years ago, we would perhaps have thought that it coincided with the introduction of Christianity. However, if we look at the plan of Trelleborg we note an area just inside the northern gate where a probable stave built house is associated with one of the horseshoe features and several pits and/or postholes (cf. Figure 2). The house and adjoining features seem to respect the gate entrance and the plank-built street into the fortress. This indicates that the house and the features are contemporary with the fortress. In his publication, Nørlund (1948, p. 92f) suggested that the house could be a ‘temple’; however, he rejected this interpretation as based on too weak arguments. Instead, he called it a ‘gate house’ with an uncertain function, perhaps not least because as it is situated at the gate facing the large wet area to the north. Today new archaeological excavations indicate that Nørlund’s first interpretation could very well be correct. At the large residence at Fugledegård at Lake Tissø, the presumed pre-Christian ritual area south of the hall also in the tenth century contained a stave built house measuring 7 × 7 m (Jørgensen 2014, Fig. 7). The two buildings are not exactly similar in their construction details, but the building and the associated features at Trelleborg could very well constitute a similar ritual complex that served the Trelleborg garrison where the majority of the inhabitants with all probability not yet had converted to Christianity.

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Supplemental data

Supplemental data for this article can be accessed here.

Notes

1. During the present study, only 48% (n = 98) of the original bone sample (n = 203) published by Degerbøl (1948) could be found at the Zoological Museum–University of Copenhagen ZMUC or at exhibit at the museum at Trelleborg, Slagelse. In 1981, a small sample of animal bones (n = 53) was sorted from the human remains at LBA and sent to ZMUC. Those bones were not seen by Degerbøl. One additional peregrine falcon was reidentified from the duck bones (Gotfredsen 2014). Therefore, a total of 152 bones could be examined or re-examined in the present study. Degerbøl (1948, p. 243–45) based his publication on the bone identifications undertaken by U. Møhl, who was rather specific as regards species identification, assessment of bone element and sometimes portion of the bone, and moreover information on fusion stage and charring. Consequently, the present analysis encompass analyses regarding frequencies, age and skeletal part distributions and occurrence of charring, applied on the entire bone assemblage (n = 257). Weathering, trampling and butchery trace assessment was not undertaken by Degerbøl, and therefore, these evaluations were applied to the assemblage actually re-examined in the present study (n = 152).
2. Nørlund (1948, p. 41) stated that a skeleton of a dog and a cow was found on top of the children in well 121. However, only vertebrae, a skull and some limb bones of the cow were apparently brought back to the laboratory since Degerbøl (1948, p. 244) reported on only 13 cattle bones plus many vertebrae. Except for a dog’s axis, well 47, one from well 50, and articulated vertebrae (n = 10) of the semi-complete

dog from well 121, recovered ribs and vertebrae were not retained. Some ribs and vertebrae occurring amongst the animal bones separated from the children's skeletons at the LBA in 1981 lend support to the notion that those skeletal elements in some numbers had originally been present in the wells. U. Møhl noted in his identification lists that all bones of bird species and special mammal species such as dog and small-sized mammals were kept, whereas smaller fragments of large-sized mammals were disregarded (U. Møhl, unpublished sources). The stored animal bone assemblage of major domesticates presently kept at the Natural History Museum of Denmark gives the impression that only identifiable portions of the major long bones with articular ends and other easily identifiable portions of the main skeletal elements as well as jaws with teeth *in situ* were retained.

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RESEARCH ARTICLE

The Danish runestones – when and where?

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This article concerns the dating and distribution of Danish runestones from the eighth to the eleventh centuries. On the basis of both old and more recent investigations, the runestones are divided into five chronological periods each with their own characteristics and according to typological features regarding runes, language, style, and ornament. The majority of Danish runestones were erected within two generations after the conversion around AD 970–1020/25 and probably as a result of the stress and societal changes in connection with the advent of Christianity. The geographical distribution changed dramatically during the 400 year long runestone period and was probably due to the changing political situation. In the eighth and ninth centuries, runestones were mainly erected on Fyn, Sjælland, and Skåne. Runestones were almost exclusively erected in Jutland in the tenth century before the conversion and in the decades around the year 1000, runestones were erected in the north-eastern parts of Jutland and along the coast in Skåne. The runestone fashion died out in most parts of Denmark during the eleventh century, although on Bornholm the tradition began in the early eleventh century and came to an end within a few generations in the late eleventh century or around AD 1100.

Keywords: runestones; chronology; distribution; Viking Age

The tradition of erecting runestones in commemoration of family members, partners in business, and in rare cases oneself was initiated during the Iron Age in Scandinavia except in Norway where the tradition started as early as the Late Roman Iron Age (Imer 2011a). The tradition continued throughout the Iron and Viking Ages and lingered on into the very latest part of the eleventh century and maybe as late as around 1130 in some parts of Scandinavia. The tradition started in the eighth century and came to an end in the early eleventh century in most parts of Denmark. On Bornholm, it began in the early eleventh century, when it had practically stopped in other parts of the country, and it came to an end in the latest part of the eleventh century. Around 260 runestones were erected during the 400 year long Danish tradition in the Danish area including Skåne, Halland, Blekinge, and Schleswig. The distribution of runestones differed during the long timespan as did the number of erected stones, for example, more stones were erected after the conversion than in the previous periods. This article concentrates on the dating and the distribution of the Danish runestones in order to present an overview of the chronological layout of the Danish runestone tradition.

The method for establishing a runestone chronology follows almost the same pattern as the construction of chronologies for other types of artefacts or monuments, however, as the runestones are made of stone, methods such as radiocarbon dating and dendrochronology are excluded. The evidence of a connection between runestones and written sources forms the basis of the chronology and within this framework different typological features are used to try and fit the remainder of the runestones into an overall chronological picture. The typological features vary according to the outline of each runestone and in many cases the runestones cannot be dated very accurately. The typological features are: ornamentation, the outline of the inscription, the length of the inscription, the nature of the textual content, the typology of the runes, separation marks, and different stages and features of the language.

The following analysis is based on earlier research and adjusted to the results of new chronological improvements. The chronological studies were carried out by Marie Stoklund and some of the latest dates relevant to this article were published in 2006 (Stoklund 2006. p. 366–72). In this article, Stoklund incorporates the archaeologically or historically dated objects into a discussion of, first and foremost, the beginning and end of the runestone tradition in Denmark, the central runestones of the Viking Age (the Jelling, Hedeby and Bække-Læborg stones), and into a discussion on the appearance of the dotted runes. The following presents an overview of earlier attempts to create a runestone chronology, an outline of the present chronology based on Stoklund's work and recent investigations of the dating of the runestone material. The dates correspond with those presented in the online database http://runer.ku.dk, which has been established by runologists from the University of Copenhagen and the National

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The earliest attempt to establish a chronology for the Danish runestones was carried out by Ludvig F. A. Wimmer in the late nineteenth century in connection with his publications of the runic monuments in Denmark (Wimmer 1893-1908). According to Wimmer not less than 18 monuments could be dated historically, as they mentioned historically known persons or events. These were the two Jelling stones, the four Hedeby stones, Sønder Vissing 1, the three Hällestad stones, Sjörup, Års, two of the Århus stones (Århus 1 and 3), Kolind, Sjelle, Nylarsker 2 and Norra Åsum. These were dated to between *c*. 935 and *c*. 1010, apart from the Nylarsker stone I (dated to *c*. 1050) and the Norra Åsum stone (dated to *c*. 1210) (Wimmer, 1893-1908, p. CLXXIX). In addition to the historically datable monuments he listed a number of stones with religious inscriptions which could be placed on either side of the Conversion. Wimmer stressed that the dating of these stones was not as accurate as the historically dated monuments because the runestones contained heathen features, such as the Thor's hammer, and were not reliable in the chronological analysis (Wimmer, 1893-1908, p. CLXXX-CLXXXI). The remainder of the runic monuments was placed in relation to the historically dated stones by means of language and rune forms, which gave a relative chronology for most of the material. Finally, when none of the abovementioned features were at hand, Wimmer estimated the date of the runestones according to the general character of the inscription or the monument (Wimmer, 1893-1908, p. CLXXXIV).

Wimmer's method for building a chronology for runestones has formed the methodological basis for runestone dating and today his work stands as the pioneer work for modern runology. His dates have, of course, now been discussed and modified and other datable features such as ornament and style have been incorporated.

Danmarks Runeindskrifter (DR) (Jacobsen and Moltke 1942) included all the known runic inscriptions found in Denmark at the time. The Viking Age chronology in DR was based on Jacobsen's critique of Wimmer's perception of the historically dated runestones, which she had published as early as the 1930s (Jacobsen 1932, 1935). In her article Jacobsen only accepted six monuments as historically datable, namely the two Hedeby stones mentioning King Sigtryg, Gnupa's son, the Jelling stones, the stone in Sønder Vissing, erected by Tove, Harald Gorm's son's wife, and the Norra Åsum stone commemorating Archbishop Absalon and Esbern Mule (Jacobsen 1932, p. 104). Jacobsen included only these six historical runestones in forming the relative chronology in her article in DR on Dating and Typology (Danish: Tidsfæstelse og Typologi p. 1013–1042), in which the Jelling stones formed the most important basis. Gorm's runestone was dated to the first half of the tenth century in DR (Jacobsen and Moltke 1942, p. 79, p. 1013), whereas Harald's stone was dated to *c*. 985. The stone had to have been erected after 970, when Harald had gained control over Norway, and the passage "won for himself all of Denmark' would point to the siege of Hedeby in 983. It was concluded that the inscription must have been erected in the mid 980's as Harald died in 987 (Jacobsen and Moltke 1942, p. 77, p. 1013). Two of the Hedeby stones that Asfrid erected in memory of Sigtryg, her son with Gnupa, have to date after 934 when Gnupa, according to the historian Widukind, was defeated by the German king Henry the Fowler. In DR, the two younger Hedeby stones were the subject of an internal discussion between Jacobsen and Moltke. Jacobsen thought the stones mentioned Sven Estridsen, who reigned in the mid-eleventh century, whereas Moltke held them to be connected to Sven Forkbeard's reign.

The DR chronology was based on the abovementioned historically dated monuments and events together with the historically datable medieval inscriptions. The runic material was divided into four periods, period 2 being the Viking Age. The typological features were described on this basis and the remainder of the runic material was placed within the four periods. To the authors, it was important to stress that the classification was typological and that an inscription belonging to one period could be of the same age as inscriptions belonging to other typological periods (Jacobsen and Moltke 1942, p. 1035).

'The listing of inscriptions is not a chronological tool for dating every single inscription. Generally, inscriptions on the same stage of development will belong in the same period, but one certain type is not limited to one certain period. Archaic and new trends will always stretch over a long period, so that one inscription, which typologically speaking belongs in one period, could be contemporary with an inscription, which typologically speaking belongs in an earlier or later period.' (Jacobsen and Moltke 1942, author's translation)

Typologies will always have overlaps and smooth transitions from one phase to another as is seen in the Swedish runestone material, where overlaps between the different style groups occur (Gräslund 1998, p. 86). Gräslund's chronology is mainly restricted to the runestones of the eleventh century and takes into consideration the ornamentation and the typology along with the outline of the snake heads, Pr 1 to Pr 4 (Pr being the abbreviation of 'profile'), with which the stones were decorated. This chronology has been discussed by Magnus Källström, who argues that the absolute dates of the different style groups should be revised and that regional variation might play a role in the establishment of a chronology, as in some cases Pr 2 might be younger than Pr 4. However, Gräslund's typology seems reliable overall (Källström 2007, p. 64–75).

Despite the clear statement from the editors of DR that the defined periods were typological rather than chronological, the typology has been used in most publications since its publication (cf. Stoklund 1991, p. 289). This is probably due to being referred to as ‘periods’ rather than ‘types’ in DR even though they were typological, and also due to Jacobsen and Moltke had made an overall estimate of the timespan of the single periods.

The runestones were placed in defined periods, or phases, within the overall period 2 ‘Viking Age’: 2.1 Helnæs-Gørlev (*c*. 750 (or 800)-900), 2.2a Pre-Jelling (around 900), 2.2b Jelling (tenth century), 2.2c Post-Jelling, and Christian Post-Jelling (*c*. 1000–1050). The reason for the rather late date of the Post-Jelling type was due to the fact that Lis Jacobsen considered the Hedeby stones mentioning King Sven were erected by Sven Estridsen shortly before 1050. The runestones on Bornholm were placed in a later period, the Pre-medieval period 3. Each group was characterized with typological features describing a typological development (Jacobsen and Moltke 1942, p. 1020–30).

The oldest groups of runestones in Denmark are not ornamented and cannot be linked by any historical events. They are therefore dated by comparison with other datable inscriptions on the basis of the outline of the inscriptions, the runes and the use of language.

In DR, the oldest group of runestones was labelled group 2.1 Helnæs-Gørlev type (Jacobsen and Moltke 1942, p. 1020–22). The stones were united in one group according to the linguistic stage of the texts and it was stated that the runestone texts could sometimes show traces of preservation of older graphemes such as the ᚺ (h) and ᛗ (m) and the use of ᚼ for /a/ (Jacobsen and Moltke 1942, p. 1020). Only a few inscriptions containing these graphemes were known when DR was published and later research suggests its division into two different and most likely, chronologically separated types.

The discovery of the Ribe skull fragment in 1973 made it clear that a distinction had to be made between the use of ᚺ **h** and ᛗ **m** and the use of ᚼ **h** and ᛘ **m**. The Ribe skull was uncovered in a reliable stratigraphic context during the Ribe excavations (Stoklund 2004b:27). The skull fragment was found just above a piece of wood, dated by dendrochronology to AD 719, and just below two wooden posts also dated by dendrochronology. The posts cannot have been felled before AD 730 and 759, respectively (Stoklund 1996, 2004). The loss or deposition of the object can therefore be narrowed down to the period AD 725–750 (Søvsø 2014). There are no finds in the archaeological record using ᚺ for **h** in combination with ᛘ for **m** or the use of ᛗ for **m** in combination with ᚼ for **h**. The reading of the Snoldelev stone in DR (p. 300–301, p. 1020–21) opened the possibility that the use of ᚺ for **h** could be used with a much younger **m**-rune ᛉ, which is known from the very latest part of the tenth century onwards. However, the reading was insecurely based on the damaged last rune of the inscription, which preserved only the upper part of the left vertical line. According to the authors of DR the slanting line would suggest that the rune had the shape of ᛉ, but it is equally possible that we should read it as an m. It is therefore plausible that a distinction between the runestones which contain ᚺ **h** and ᛗ **m**, and the runestones which contain ᚼ **h** and ᛘ **m** (or in short twig inscriptions ᚽ **h** and ᛙ **m**), is chronological, although the finds that establish this chronological basis are few. This was also noted by Stoklund in various articles (Stoklund 1996, p. 200, 2004, p. 38, 2006, p. 367–68, 2010, p. 244–45), and results in the Helnæs-Gørlev group, which is labelled group 2.1 in DR, being divided into two chronological groups, labelled the Helnæs group (Stoklund 1996, p. 200) or Ribe-Snoldelev group (Stoklund 2010, p. 44–45) and the Gørlev group (Stoklund 1996, p. 200) or the Gørlev-Malt group, respectively (Stoklund 2010, p. 244–45).

We do not know the date of the simplification of ᚺ **h** and ᛗ **m** to ᚼ **h** and ᛘ **m**. We know from the Ribe skull fragment that the first two were in use in the early eighth century, Stoklund dates the Ribe-Snoldelev group to ‘somewhat after 700 with a wide margin’ (Stoklund 2010, p. 345), but exactly when the simplified 16 character futhark was introduced is still a puzzle simply because of the lack of finds. The earliest archaeologically datable find from Denmark with the new 16 character futhark is the belt end fitting from Duesminde. The belt end fitting is a Frankish product produced in the period AD 825–875 and found within the Duesminde treasure dated as being deposited in the middle of the tenth century (Wamers and Brandt, 2005). The runic inscription was added before the piece was changed from belt end fitting to pendant so the date of the inscription must be ascribed to the latter half of the ninth century or the beginning of the tenth century. This leaves us with a rather wide time span from the mid-eighth to the early or mid-tenth century when the use of rune types in Denmark is rather blurred. The 2014 discovery of a Thor’s hammer with runes from Købelev on Lolland adds another datable piece to the rare tenth century runic inscriptions on portable objects (Rasmussen *et al*. 2014). The inscription reads **hmar: is** ‘(this) is a hammer’ and has ᚼ **h** and ᛘ **m**. Other archaeologically dated inscriptions with longbranch runes are the Lindholm Høje knife shaft (ninth century) and the Århus comb (tenth century). The Lindholm knife shaft cannot be used as an argument of an early use of the simplified 16 character futhark (with the use of ᚼ **h** and ᛘ **m**), as these particular runes are not used in the inscription. The short twig runes can be dated archaeologically to the ninth century at the earliest by the Hedeby inscriptions, although these particular inscriptions seem to be rather loosely dated (cf. Stoklund 2006, p. 368). However, the comb with short twig runes from Elisenhof, Northern Germany (dated to the latter half of the ninth century) (Moltke 1985, p. 370) indicates that the short twig runes came into use during the ninth century, and as they are regarded as a further development of the simplified 16 character futhark (with ᚼ **h** and ᛘ **m**) (Fridell, 2011), it seems reasonable to suggest that the change happened somewhere around AD 800. The runestones from these two earliest periods of the runestone tradition in Denmark are quite few in number (Figures 1 and 2). They were erected in the central parts of Denmark, foremost on Fyn and Sjælland, and it is possible that their distribution is associated with the centralization of power and the pressure from the expanding Frankish Empire (Imer 2010).

The monuments are generally unornamented and frequently lacking word divisions. The inscriptions are mostly arranged in parallel order or as single line inscriptions and very short, mostly names in the nominative, name and verb without an object, names in the genitive, and the 'After NN' type. The very common tenth century type 'X erected this stone after Y' occurs only in the Helnæs inscription. The following type, Gørlev, has the same characteristics as the Helnæs type, apart from the fact that the inscriptions are

Figure 1. The Helnæs group of runestones from the eighth century. Grey dots indicate possible runestones dated to this period.

Figure 2. The Gørlev group of runestones from the ninth century. Grey dots indicate possible runestones dated to this period.

written in the standardized 16 character futhork with the introduction of ᚼ **h** and ᛘ **m**. The rare use of framing is common to both types.

Some of the runestones of the tenth century are dated according to historical events including the Hedeby 2 and 4 stones that are associated with king Gnupa in the early tenth century and the Jelling 1 stone connected to Gorm and Thyra. In DR, the Bække-Læborg stones were not counted among the historically datable runestones as it was uncertain whether the 'Thyra' mentioned on Bække 1 and Læborg, was associated with the Jelling dynasty and because the presence of a Thor's hammer on Læborg was thought to be a much older heathen trait placing the stone in an earlier phase than Jelling 1 (Jacobsen and Moltke 1942, p. 50–53). Moltke later stated that the Bække-Læborg group should be dated to after Jelling because of the layout of the inscription on the Horne stone (Moltke 1985, p. 229–30).

The inscriptions on the Bække and Læborg stones do not follow the normal pattern of inscriptions as in 'X raised this stone in memory of Y'. In the Læborg inscription Ravnunge-Tue erects the stone in memory of Thyra, his *drōttning*, and in Bække 1 it is announced that Ravnunge-Tue, Fundin, and Gnyple built Thyra's mound. If the inscriptions were intended to honour family members we would expect the normal 'X raised this stone in memory of Y' as *e.g*. Tue did in the Bække 2 inscription commemorating his mother, Viborg.[1] The textual content in these inscriptions and the fact that they are raised just south-west of Jelling serve as an argument that the stones can really be linked to the early stage of the Jelling dynasty and that the queen commemorated on the Læborg stone is Gorm's wife Thyra. As Stoklund and others before her have stated, the term *drōttning* 'mistress' is the female equivalent of *drōttin* 'lord' and it has nothing to do with 'wife','spouse', or the later generalized 'wife of the monarch' (Stoklund 2005, p. 43 with further references). In the Jelling 1 text Gorm mentions Thyra as his 'wife' not his 'queen'. This means that there is not a marital relationship between the runestone sponsor Ravnunge-Tue and the commemorated Thyra in the Læborg text and it leaves room for an interpretation of Thyra in the Læborg text being king Gorm's wife. Therefore the Bække-Læborg group should be dated to the mid-tenth century contemporary with Jelling 1.

One of the tenth century runestones refers to a grave mound (Gunderup 1) (Jacobsen and Moltke 1942, p. 179–81), dating it to the time before the conversion and a further runestone (Randbøl) was found on top of a grave (Jacobsen and Moltke 1942, p. 64–65) which probably also dates it to the time before the conversion. Randbøl is the only Danish runestone found in connection with a contemporary grave. The stones are normally unornamented with the exception of Thor's hammers on Læborg and the snake's heads on Jelling 1. Sometimes the division marks and the use of framing are outlined in such a way that they resemble a rather simplified snake's head conclusion of the inscription, e.g. Bække 2 and Randbøl. Normally, the inscriptions are arranged in parallel order or bustrophedon. Only the Horne fragment seems to be arranged in contour device (Moltke 1985, p. 229) but this is very insecure as the stone is a fragment and it might equally have been arranged in bustrophedon. Linguistic characteristics are the preservation of nominative – *ʀ*, but a development of – *ʀ* to – *r* after dental has happened. The dem. pron. **þąnsi, þansi** is not yet assimilated into the forms **þasi, þani**. *s* is preserved in the pron. *æs* (later *æʀ*) and pret. *was* (later *waʀ*), and prep. 'after' has the old short forms *aft, æft, øft* (they are later superseded by the longer form *æftiʀ*). Jelling 1 is included in this group, whereas Jelling 2 is placed on the verge of the next chronological group. The common text on the tenth century stones is 'X raised this stone in memory of Y'. The order of the inscription is dominated by vertical, parallel lines (cf. Jacobsen and Moltke 1942, p. 1023–24). These stylistic and linguistic traits are found on other runestones and are therefore included in the tenth century pre-conversion runestone tradition.

The distribution of the Pre-conversion runestones of the tenth century differs from the previous periods in that the concentration of stones has moved west with the majority of the runestones being erected in Jutland. The Glavendrup, Rønninge, and Tryggevælde stones are the only stones to have been erected on Fyn and Sjælland in this period and they are ascribed to the same group of people with the sponsor Ragnhild being the most prominent actor. Also, a few stones may have been erected on Lolland and Falster, e.g. Sdr. Kirkeby and Bregninge (Figure 3).

Regarding the chronology of the tenth century runestones, we should consider whether a very strong division between the 2.2.a Pre-Jelling and 2.2.b Jelling types is appropriate (cf. Stoklund 1991, p. 292). The Pre-Jelling type refers to a small number of around 10 runestones, *e.g*. the Glavendrup and Tryggevælde stones erected by Ragnhild and the Bække 1 and Læborg stones (Jacobsen and Moltke 1942, p. 1022–23). DR also includes Øster Løgum, Laurbjerg and Hammel, which it is suggested here to be closer to the ninth century runestones. The absence of any stylistic traits which can divide the Pre-Jelling and Jelling types is problematic and a more unified type of Pre-conversion stones covering the tenth century up until the time of the conversion, *c*. 970 is more appropriate. Some of the stones lack so many stylistic and linguistic traits that they cannot be dated as accurately and might belong to the time period after the conversion.

It is evident that the Jelling stones have played an important role in the establishment of a chronology of the Late Viking Age runestones and style history. Therefore it might be useful to briefly sum up the various

Figure 3. The pre-conversion group of runestones from *c*. AD 900–970. Light grey dots indicate possible runestones dated to this period.

Table 1. The various dates of Jelling 1.

Wimmer 1893-1908:8–17 (DRM)	935–940	Historical date
Jacobsen and Moltke 1942:77, 1013 (DR)	900–950	Historical date
Christensen and Krogh 1987	Before 958/59	Archaeological/historical/dendrochronological date
Stoklund 2000/2006	Before 958/59	Archaeological/historical/dendrochronological date
Lund 2014	Before 958/59	Archaeological/historical/dendrochronological date

Table 2. The various dates of Jelling 2.

Wimmer 1895:17–30 (DRM)	*c*. 980	Historical date
Jacobsen and Moltke 1942:77, 1013 (DR)	*c*. 985	Historical date
Lindqvist 1931:144–47, the stone cut in two tempi	*c*. 953/after Harald's death	Historical/art historical/archaeological date
La Cour 1951	960 s	Historical date
Christiansson 1953, supports Lindqvist's conception of two tempi, the last one added by Sven Forkbeard	950–990	Art historical/historical date
Christensen 1969:223–40, supports the conception of two tempi	960 s/*c*. 985	Historical date
Glob 1969:18–27, supports the conception of two tempi	*c*. 950/*c*. 985	Historical/art historical/archaeological date
Moltke 1972, all three sides of the stone cut at the same time	960–985	Runological investigation and historical date
Moltke 1976:170–172 (1985:213)	Shortly after 960	Historical date
Randsborg 1980:27	About 960	Historical date
Stoklund 2000	*c*. 962–987	Historical date
Stoklund 2006:366	*c*. 965–74 (or *c*. 985)	Historical date
Lund 2014:70	Early 960 s to late 980 s	Historical date

opinions regarding the date of these monuments. The dates of the two stones are registered as shown in the tables below (Tables 1 and 2).

These dates show that the historically fixed dates for the Jelling stones can be interpreted according to new contextual data. However, it remains clear that Jelling 1 must have been erected in the middle of the tenth century up until *c*. 960 and that Jelling 2 must have been erected sometime between the baptism of Harald in the early 960's and his death in the late 980's (Lund 2014, p. 70). Runographically or linguistically the two stones show no distinct traces which could help to place them on either side of *c*. 960 (cf. Stoklund 1991, p. 291).

The excavations in Jelling between 1976 and 1979 were of decisive importance for the chronology of the two Jelling stones. In the North mound, the remains of a grave was uncovered and pieces of wood from the grave chamber were dated by dendrochronology to 958/59 (Christensen & Krogh, 1987, p. 225f.). The grave was thought to have been built for king Gorm, who was possibly moved from the North mound to the church at the time of conversion. If the North mound was really built for king Gorm, Jelling 1 must have been erected before 958/959 (Stoklund 2006, p. 369). Although it has no importance for the chronology of the Jelling stones, it cannot be excluded that the north mound contained Thyra's grave (Lund 2014, p. 70).

The Jelling stones formed the backbone of the runestone chronology in earlier research. The date of the Post-Jelling type of runestones, which in DR was placed in the first half of the eleventh century, has relied on the date of Jelling 2. To Moltke the date of Jelling 2 was important as there has to be a certain amount of time in between the rune and language forms in the Jelling 2 inscription and the Post-Jelling type inscriptions with dotted runes and new language types. As early as 1952 Moltke agreed with Vilhelm la Cour's new date of the 960's for the Jelling 2 stone (Moltke 1952, p. 262) which allows the possibility of dating the Post-Jelling type of runestones to 25 years earlier. Using la Cour's dating of Jelling 2, Karl Martin Nielsen argued in 1970 that the Post-Jelling type was to be dated in the time between 975 and 1025. Nielsen additionally pointed out the fact that the Danish runestone texts refer to Gorm, Harald and Sven Forkbeard but that no texts refer to Canute the Great, which is notable as some of the many eleventh century Swedish (and one Scanian) runestone texts relate to men who took Canute's payment in England. This could underline the fact that the runestone fashion had come to an end in Denmark (except for Bornholm) in the 1020s (Nielsen 1970, p. 36–44, especially p. 43, see also, Stoklund 1991, p. 292, and, Stoklund 2006, p. 371).

Stoklund agrees that the absence of the runestones from the Southern Scandinavian area (apart from the younger Simris 2, which in ornament and style is influenced by the traditional Swedish runestones) mentioning Canute is significant and also believes it suggests the early ending of the runestone tradition in Denmark (Stoklund 1991, p. 293). Stoklund also continues the discussion of the date of the Hedeby stones (1 and 3) with dotted runes and compares them with the Scanian runestones with dotted runes (the Hällestad stones and Sjörup). The inscriptions on these stones could refer to the battle on the Fyris plain in the 980 s, which would aid the dating of the stones (Snædal 1985). But because of the presence of dotted runes on the Hedeby stones, Stoklund believes that they could be of the same date as the Scanian stones. She touches upon the ornamented stones by mentioning Århus 3 with the mask, which might be dated to the second part of the tenth century (Stoklund 1991, p. 291–294). Århus 3 carries dotted runes, underlining the fact that dotted runes were in use at some point during the second part of the tenth century and that the Hedeby stones should be connected to Sven Forkbeard rather than Sven Estridsen.

The chronology of the Post-Jelling type of runestones has been more and more confirmed by style history and archaeological evidence in recent years. Compared to the Swedish runestone material, the Danish runestones are rarely ornamented and dating runestones according to the ornaments was not used as a tool in the early runic corpuses. In DR, it is stated that a large number of the runestone pictures such as the large animal, the mask and the ship are so common on the Post-Jelling type that they must be characteristic for the type itself (Jacobsen and Moltke 1942, p. 1025). This means that the ornaments were not used as a foundation for dating, but that they were included as an extra indication in the relative dating of the types.

Gunhild Øeby Nielsen takes up the discussion of the ornamented runestones and their relation to chronology, referring to Signe Horn Fuglesang's work from the 1990s (Øeby Nielsen 2007, p. 40–47) in her PhD dissertation. Fourteen runestones from Denmark (fifteen including the 2011 find of a fragmented runestone in Ribe) are ornamented in the Late Viking Age styles Mammen and Ringerike (Baldringe, Bjerring, Bösarp, Jelling 2, Sjelle, Skjern 2, Västra Strö 2, Skårby 1, Århus 3, Århus 5, Sædinge, Tullstorp, Lund 1 and Hunnestad 1), which are dated to the latter half of the tenth century and first half of the eleventh century. Previous discussion of whether the Århus stones (3 and 5) have been ornamented in Mammen style (Fuglesang 1991, p. 103) or if they have elements of Ringerike style (Roesdahl and Wilson 2006, p. 214–15) are not included here as there is no doubt that the stones belong to the later part of the runestone tradition in Denmark. According to Fuglesang's work the date of the Mammen style can be based on a number of archaeologically dated artifacts. The Mammen grave with the axe head ornamented in Mammen style is dated by dendrochronology to AD 970/71 and provides us with a *terminus ante quem* for the fully developed Mammen style. A further *ante quem* date can be deduced from the Birka grave P.119 to *c*. 975. The wood panels from the north mound in Jelling, dendrochronologically dated to 958/959 show traces of the Mammen style but are not yet fully developed. This means that the Mammen style must have been created in the 960 s (Fuglesang 1991, p. 103).

Else Roesdahl and David Wilson have related the ornamented Århus runestones (Århus 3 and 5) to the Mammen and Ringerike styles and dated them to the time shortly before AD 1000. They believe that all of the Århus stones most likely belong to the time around the turn of the millennium. Furthermore, Roesdahl and Wilson argue that the Hedeby stones 1 and 3 are more likely to have been erected in the time after AD 994. Hedeby 3 is erected by king Sven in memory of Skarde, who had been 'to the west', *i.e*. England and king Sven is not recorded to have been in England before AD 994 (Roesdahl and Wilson 2006, p. 226–27). This corresponds very well with the dating of the Hällestad stones which some researchers connect to the battle on the Fyris plains in the 980's (Snædal 1985, see also Stoklund 1991, p. 293). The chronological connection between the Århus, Hedeby and Hällestad stones is important for our understanding of the dotted runes, especially the dotted **m**-rune, which seems to have no linguistic importance. It is used on the Århus 1 and 5, the Hällestad 1 and 3 stones and the Sandby 3 stone on Sjælland, which probably dates a little later than the others. The dates of the Århus and Hedeby stones form an important basis for the dating of the runestones with the dotted runes ᛂ **e**, ᚤ **y**/**ø**, and ᚵ **g**, which are an innovation in runic writing. The dotted runes ᛑ **d** and ᛔ **p** do not come into use until the earliest part of the Middle Ages and the runic coins of Sven Estridsen are the earliest evidenced examples (Stoklund 2006, p. 371). Dotting cannot have entered the orthography before the very latest part of the tenth century. This means that runestones with dotted runes (around 30 in all) are probably dated to after *c*. 980 or 990 until *c*. AD 1020. The runestones in this period are first and foremost erected in the eastern part of Jutland and southern parts of Skåne.

What we can deduce from using style and ornamentation in the chronology is that even if we exclude Jelling 2 from the foundation of the Late Viking Age runestone chronology, we would still be able to form a chronology based on the stylistic traits of the Mammen style and the appearance of dotted runes on *e.g*. Århus 3. However, Jelling 2 fits very well into the overall picture of Late Viking Age runestones with its Mammen ornamentation.

A number of new stylistic traits, runographically, linguistically as well as the physical appearance, are found on the Post-conversion runestones, although they do not all contain all stylistic traits. Characteristic is the presence of dotted runes, assimilated pron. **þasi, þani** for older **þąnsi, þansi**, *ʀ* for the older *s* in pron. *æʀ* and pret. *waʀ*, extended or assimilated form of prep. 'after' *æftiʀ, øftiʀ* or the side form *at*, crosses as ornaments, and division marks outlined as crosses. The textual content is very similar to the former Pre-conversion type (Jacobsen and Moltke 1942, p. 1025). Some of the stones are ornamented in the Mammen and Ringerike styles and the layout of the inscriptions is dominated by the contour device where the inscription follows the shape of the stone (Jacobsen and Moltke 1942, p. 1025). Some of the runes have changed their form, for example, ᛘ **m** is sometimes used instead of ᛙ, and ᚽ **s** (normally ᛋ) is used in some inscriptions. The number of Post-conversion runestones is much larger than in the previous periods making this group the most common type of runestones in Denmark. More than 100 runestones can be ascribed to this period (cf. Jacobsen and Moltke 1942, p. 1025) and the reason for this runestone boom is probably found in the societal changes after the conversion as the runestones of the late Viking Age cannot be connected to the landowning aristocracy alone. The density of runestones erected in some areas contradicts the view that the tradition was confined to the upper levels of society alone (Øeby Nielsen 2007, p. 110–116). Additionally, in the runestone texts of this period we also find merchants, seamen and brothers-in-arms. The distribution of this group of stones is concentrated in two main areas of the country, in Skåne along the coasts and the area around Lund, and the mid-eastern parts of Jutland (Figure 4).

In many cases the division of the Pre-conversion and the Post-conversion inscriptions (in DR the Jelling- 2.2b and Post-Jelling 2.2c groups) cannot be maintained.

Figure 4. The post-conversion group of runestones from *c*. AD 970–1020/25. Light grey dots indicate possible runestones dated to this period.

Stoklund is of the opinion that we should not advocate a strict division between the two as inscriptions such as Øster Alling and Rimsø (in DR typologically classified as Post-Jelling (Jacobsen and Moltke 1942, p. 147) and Jelling (Jacobsen and Moltke 1942, 152), respectively) are carved by the same rune carver and thereby should be more or less of the same date (Stoklund 1991, p. 294). Moltke did not make a clear distinction in his 1976 book but he still operated with a Jelling type, which he dated to *c*. 900–*c*. 985 and with a Post-Jelling type, which was dated according to the Hedeby stones with their innovations (Moltke 1976, p. 161). It is clear that in some cases it can be very difficult to place the runestones from the tenth century on either side of the conversion if they do not contain any characteristic traits. In these cases we must settle on a date of *c*. 900–1020/25 and this date is used in many cases in the database http://runer.ku.dk. The overall perspective however, is that the large group of post-conversion runestones have quite clear indications of belonging to a later stage of runestone erection than the Pre-Christian ones. In his 1980 book, Randsborg even suggests a further chronological division within the Post-Jelling type. He claims that runestones with texts arranged in contour device are four times as common in Scania as in Jutland, where vertical bands are found on more than half of the stones (Randsborg 1980, p. 35). The contour device is regarded as a clear typological trait for the Post-Jelling type of stones and it makes it likely that a large part of the Scanian stones are some years younger than most of the stones from the eastern part of Jutland.

The runestones on Bornholm are distinctive as the tradition began at a time when that of the rest of the southern Scandinavian area was coming to an end (Figure 5). In DR, the group was placed in period 3, a pre-medieval period dated to AD 1050–1150. This rather late date of the Bornholm runestones was presumably due to Jacobsen and Moltke dating the previous group of runestones, the Post-Jelling type, to the time period from around the turn of the Millennium to AD 1050. Period 3 in DR was dominated by the runestones on Bornholm and Sven Estridson's runic coins. Most of the stones could be separated into two chronological groups within this time period (Jacobsen and Moltke 1942, p. 1028). As mentioned above, more recent results have shown that the Post-Jelling type should be pushed back in time leaving space in the chronology for the Bornholm group of runestones to similarly be pushed back a quarter of a century to *c*. AD 1025 to 1125, and recent collaborations by Marie Stoklund and Rikke Steenholt Olesen have enhanced our knowledge on the grouping and dating these runestones. This work has resulted in the dates now available on http://runer.ku.dk. Important for the Bornholm runestones is the reference of rune types to the runic coins of Sven Estridson, which were produced in the last decade of his reign (*c*. 1065–75) (Stoklund 2006, p. 373) and similarly the ornamentation with snake heads similar to the 'run-slingor' on the eleventh century runestones of Middle Sweden. However, the lack of a link between the runestones and historical or archaeological evidence, and additionally the lack of historically or archaeologically datable runic inscriptions from the eleventh century, means that the beginning of the runestone tradition on Bornholm is still quite insecurely dated.

In other parts of the country a few runestones were erected during the late eleventh and twelfth centuries. In western Jutland the runestones in Hanning and Ådum represent a late tradition along with the now lost Allerup-sten from Fyn. The stones at Alsted, Fjenneslev, and Sandby 3 on

Figure 5. The bornholm group of runestones and the end of the runestone tradition in Denmark *c*. AD 1025–1125.

Table 3. The chronology for runestones in Denmark.

Type	Date
Helnæs group	Probably *c*. AD 700–800
Gørlev group	Probably *c*. AD 800–900
Pre-conversion group	*c*. AD 900–970
Post-conversion group	*c*. AD 970–1020/1025
Bornholm group	*c*. AD 1025–1125

Sjælland are dated to the eleventh century as well as the Tillitse stone on Lolland. The youngest known runestone is the very accurately dated Norra Åsum stone from the northern part of Skåne. It mentions archbishop Absalon and Asbjørn Mule, who are known from the historical sources. This stone must have been erected between Absalons appointment as archbishop of Lund and his death in 1201 or alternatively before Asbjørn Mule's death in 1215.

The last 40 years of research has provided us with many new results regarding the typology and chronology of the Danish runestones since the publication of DR in 1941–42. Although many of the criteria for relative dating in DR are still valid, the typology as such cannot be used without reference to the subsequent chronological studies. This article is an attempt to collate this work and the chronology of the Danish runestones is summarized in Table 3.

The Helnæs-Gørlev group is separated into two chronological groups probably at the turn of the ninth century, although finds supporting this hypothesis are still lacking. The Pre-Jelling and Jelling types are merged into one group covering the tenth century up until the time of the conversion and the Post-conversion group is moved back in time to the decades around the year AD 1000. The Bornholm group and a few other runestones in Denmark are dated to the earliest medieval period, although a few might have been erected in the twelfth century. It is important, however, to note that many runestones cannot be fitted into one of the chronological groups due to the lack of diagnostic traits. The above mentioned characteristics correspond with the dates presented in the online database http://runer.ku.dk, established by runologists from the University of Copenhagen and the National Museum of Denmark.

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Note

1. The text on this particular runestone is very difficult to grasp. Some researchers believe that two sponsors are mentioned (e.g. Barnes 2012, 146), but the general (Danish) opinion is that the text is much abbreviated, and that Ravnunge-Tue is the sole sponsor (e.g. Lerche Nielse 1993, p. 55, note; Sawyer 2000, p. 163, note 19; Imer 2011b, p. 41).

Supplemental data

The underlying research materials for this article can be accessed at http://runer.ku.dk

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RESEARCH ARTICLE

Two new denarius hoards from the island of Lolland

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Since 2009, a number of Roman denarii from the 1st, 2nd and 3rd centuries AD have been discovered on the Danish island of Lolland. Among them, two denarius hoards contained, respectively, approximately 110 and 46 coins. Previously, only few imported objects from the Late Roman Iron Age were known from Lolland, in stark contrast to the large amount of imported prestigious artefacts from the preceding Early Roman Iron Age. These denarius finds shed new light on an otherwise poorly understood time period in the region, especially with regard to the possible networks of trade and exchange in which the local population took part. As the presence of denarii in an Iron Age context is often interpreted as a sign of contacts ultimately extending beyond the bounds of present-day Denmark, this article explores the possibility that the in casu denarius finds from Lolland point to the existence of local settlements participating in the flow of elite exchange during the 3rd and possibly also 4th centuries AD.

Keywords: late Roman Iron Age; denarii; Roman coins; hoards; Lolland; exchange

Introduction

In January 2013, a hoard containing Roman denarii from the Imperial period was found on the Danish island of Lolland (Figure 1). The hoard itself contained no less than 110 coins in various states of preservation, and was located on a field owned and cultivated by the nearby Knuthenlund Manor. A year and a half later, during the summer of 2014, another hoard containing 46 well-preserved denarii was found on Lolland near the outskirts of the small settlement Hillested. Before then the only known denarii from Lolland consisted of 13 single-finds, placing the island among the Danish regions with the lowest yield of Roman coinage (Horsnæs 2010, p. 46) (Figure 2).

Because of its prominent geographical position between Zealand and the European mainland, the island of Lolland has always acted as a bridgehead facilitating cultural and material exchange between the North and the South. Traces of foreign cultural influences, and sites functioning as points of interest and commerce along the vast network of trade routes flowing through The *Barbaricum* during the time of the early Roman emperors, are thus well accounted for in connection with excavations and archaeological surveys. It is therefore no surprise that in recent years a number of new finds of Roman denarii have appeared, both as single-finds and in hoards. As of yet, no Roman coin on Lolland has been found as part of an assemblage of grave-goods, as Charon's fees or in any other context that might even loosely be interpreted as a burial (Dyhrfjeld-Johnsen 2011, p. 140ff.) The only archaeological excavation in connection with the discovery of Roman coins was conducted during the spring of 2013 on the site of the Tagesgård Hoard. Barring a few notable exceptions, the original depositional contexts of all other denarii from Lolland are unknown.

It is by no means an easy task to provide a qualified interpretation of a category of finds so complex and dynamic as the Roman coinage. Given that the total body of finds can only ever increase, it isn't a futile endeavour to attempt an analysis on a regional scale. The challenge, however, is to adjust the established perception so that it aligns itself more closely with the new material reality. In light of this, the present paper will attempt to provide an updated account of the present find-situation regarding Roman denarii on the island of Lolland.

The denarius hoards on Lolland

Denarius hoards dated to the Roman and Early Germanic Iron Age are well known phenomena from Denmark as well as the region comprising The *Barbaricum* beyond the northern fringes of the Roman Empire (Horsnæs 2010). The regional distribution of the denarius hoards within the borders of present-day Denmark is however far from uniform. One explanation for this is the varying intensity of detector surveying in different parts of the country, as well as a tendency to concentrate the effort in and around areas known for previous finds of ancient treasures. When looking at the total sum of finds however, it is quite evident that the clusters of single-finds and hoards are not merely the result of chance and happenstance in recent decades,

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Figure 1. Map of Denmark (sans Bornholm) showing the position of the island of Lolland.

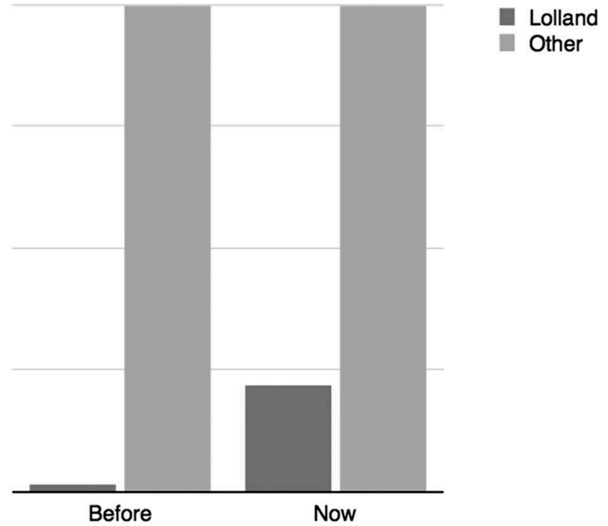

Figure 2. The changes in the amount of denarii from the island of Lolland compared to the number of roman coins found on Zealand and the islands of Falster and Møn. The omission of numerical descriptors is intentional, as the chart is only intended to show the relative rise in the number of Roman coins. The total number of known finds used in the comparison is from Horsnæs (2010, 41).

but are also rooted in the societal and regional power structures of Iron Age Denmark. Roman coins found in the context of Iron Age sites belong to the same group of imported objects including such items as glassware and -beads, as well as vessels of bronze and silver. While the function and desirability of the objects within this body of imported goods obviously differed, the channels through which the prestigious wares and Roman coins travelled from south to north were most likely the same.

The island of Lolland was until recently regarded as one of the regions of Denmark with the lowest yield of Roman coinage. Denarii were only known from scattered single-finds (four by the publication of the most recent overview of known finds, *Crossing Boundaries*, from 2010), and only a few of the base metal denominations were known (Horsnæs 2010, p. 160ff). The recent discovery of two denarius hoards as well as several denarii as single-finds thus constitutes a significant change in the known local distribution of Roman coinage (Figure 3).

The Tagesgård Hoard

The area surrounding Knuthenlund Manor, located to the north of the small town of Stokkemarke on Lolland, consists mostly of arable land and pockets of forested areas, crossed by small streams and modern roadways. The Tagesgård Hoard was discovered at the edge of a small plateau situated on the western bank of Ørby Å (Ørby Stream), a now tamed and regulated body of water leading towards the northern coastline. To the south, the small farmhouse that lent its name to the hoard (*Tagesgård* = *Tages Farm*) was easily viewable atop a hilly terrain that is known for previous wetland finds of wagon parts dating back to the Pre-Roman Iron Age (Schovsbo 1987, p. 216) as well as ring-gold from the Early Germanic Iron Age.

The hoard itself contained at least 110 denarii scattered around an area close to 140 by 90 m (Rasmussen 2013) (Figure 4).[1] A concentration of coins to the east of the area marked this as the likely spot of the original deposition. A small excavation conducted on-site during the spring of 2013 revealed a number of postholes and pits, as well as the traces of three small longhouses, of which two had a spatial overlap. Generally the remains were badly eroded, mainly due to agricultural activities. This probably also explains why no *in situ* remains of the hoard were found as well as the general lack of occupational deposits and cultural layers. The main concentration of denarii was situated in the topsoil immediately above the southern end of the easternmost longhouse (House I) (Figure 5). While this provides a possible context for the deposition of the hoard, any link between the denarii and House I is a tentative conclusion at present.

In general, the Tagesgård denarii appear to be in varying states of preservation[2] (Figure 6). While the amount of wear and tear is within the normal range of denarii from western Denmark, the level of corrosion is

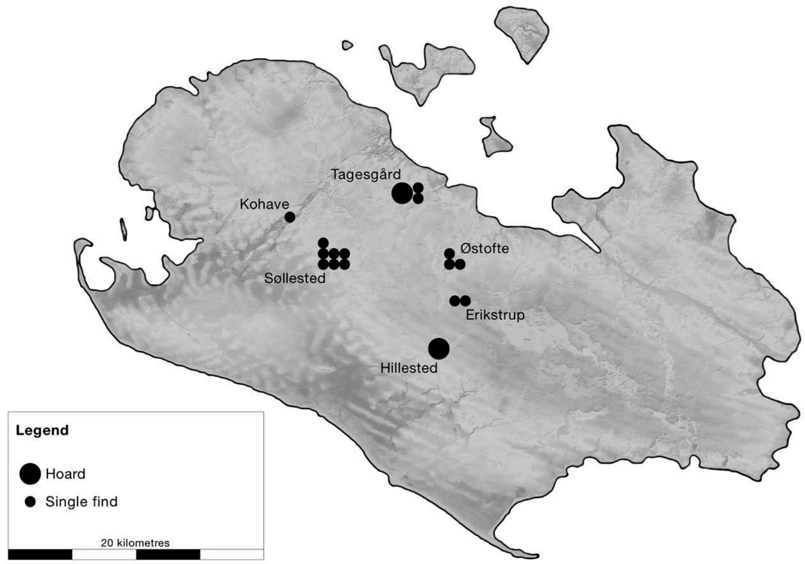

Figure 3. Cut-out of a topographical map showing the placement of all hitherto known find spots of denarii on the island of Lolland. A large circle shows the find spot of a hoard, while a small circle shows the location of a single-find. Background map, Kort & Matrikelstyrelsen.

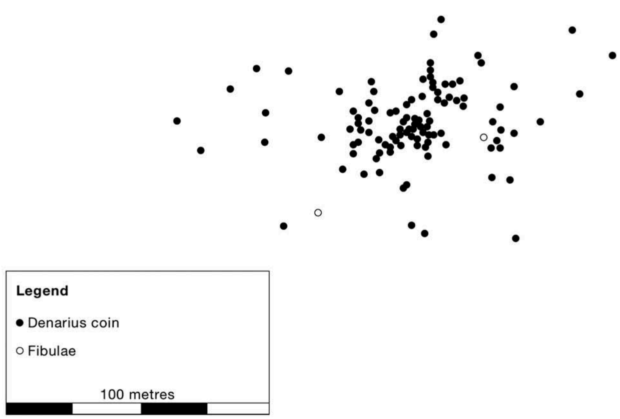

Figure 4. The Tagesgård Hoard, the distribution of denarii (status 2014).

in some instances well above the norm. The surface of several denarii in the Tagesgård Hoard is best described as having a rough and slightly corroded appearance, most likely the result of post-depositional processes connected to the slow disintegration of the original container. In addition, several scratches on the coins were clearly caused by the sand and light gravel in the plough layer.

The chronological composition of the Tagesgård Hoard spans the period from Otho to Caracalla (AD 69–211/12) (Table 1). The number of pre-Antonine denarii is low, with only two denarii from the turbulent Year of the Four Emperors in AD 69 (Otho, Vittelius) and a total of five denarii struck during the Flavian dynasty. The vast majority of denarii in the hoard were struck during the Nerva–Antonine dynasty (AD 96–192) comprising no less than 90% of the identified coins. Of these, the coinage of the emperors Hadrian, Antoninus Pius and Marcus Aurelius dominates in the assemblage with a rather large amount struck in the name of the empresses Sabina, Faustina Major and Faustina Minor. The youngest denarii from the deposit were struck during the Severan dynasty and count a single denarius from the reign of Septimius Severus as well as a denarius dated to the first year of the reign of Caracalla (*c.* AD 211–12). The Caracalla coin also provides the *t.p.q.* for the entire assemblage, signifying that the hoard cannot have been deposited earlier than during the 3rd century AD.

The area surrounding the Tagesgård Hoard has yielded few items from the Iron Age, making it difficult to provide an interpretation of the hoard and its local context. During the 2013 excavation a small number of fragmented Iron Age fibulae were found; most were within the same general area as the Roman coins, but a few were lying in a small cluster to the west. A single fragment of a two-piece fibula belonging to Almgren type VII.2 was discovered *in situ* within a small pit at the eastern edge of the excavated area. The type is usually dated back to the first half of the Late Roman Iron Age, possibly the phase C1 b in the early decades of the 3rd century AD (Ethelberg 1990, p. 36). Bearing in mind that the typical use of a fibulae might very well bring it beyond the chronological bounds of the otherwise well-defined archaeological find categories, this date does seem to coincide with the assumed time frame for the deposition of the Tagesgård Hoard in the 3rd century AD. The small cluster of fragmented fibulae to

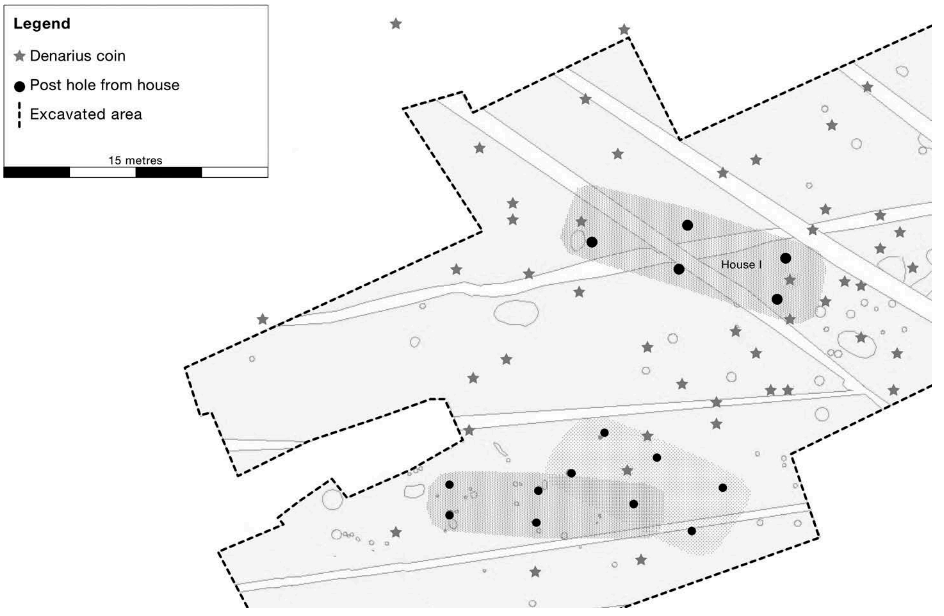

Figure 5. The main concentration of denarii from the Tagesgård Hoard and the settlement structures found beneath them. Denarii are marked with small circles; fibulae from the Roman Iron Age are marked with squares; fibulae from the Early Germanic Iron Age are marked with triangles. Background map, Kort & Matrikelstyrelsen.

the east consisted exclusively of cruciform fibulae from the Early Germanic Iron Age.

The Hillested Hoard

A year and a half after the discovery of the Tagesgård Hoard another denarius hoard, containing 46 coins, was found near the small town of Hillested at the centre of Lolland. The hoard was uncovered by detector surveying at the foot of a naturally raised area of land where an Iron Age burial ground as well as a settlement from the Roman Iron Age was discovered in the early twentieth century. A few hundred metres to the north of the find-spot a small body of water, Nordkanalen (the Northern Canal), trickles towards the southern coastline, where the mouth of the stream flows into the Fehmarn Belt. During the Iron Age, well before the draining of Rødby Fjord in the late nineteenth century and early twentieth century, it would most likely have been possible to travel by small boat or barge as far inland as Hillested and possibly beyond.

The majority of the denarii from the Hillested Hoard were found in a cluster at the southwestern edge of a large gravel pit, which was frequently used in the late nineteenth and early twentieth centuries (Figure 7). Five denarii lay approximately 50 m to the north, separated from the main concentration by an approximately 30-m stretch devoid of any finds. Towards the southwest a gradual upwards slope marked the contours of an oblong hill, constituting the single-most significant topographical feature of the area. So far 46 denarii have been found on the site – most of them scattered within an area of approximately 50 by 50 m. Due to the close proximity of the now defunct gravel pit, it is likely that some pieces of the original deposit have been removed unbeknownst to the workers at the site.

The denarii from the Hillested Hoard are all in a good state of preservation. Visible traces of corrosion on the coins are almost impossible to detect, and the amount of wear and tear is low. While this may imply that only a short period of time has passed since the destruction of the deposition, the possible removal of parts of the original hoard by gravel digging could well mask the true extent of the spread and thus skew the chronological assessment.

A single denarius struck during the reign of Domitian marks the only pre Nerva-Antonine coin in the hoard. The denarii from Nerva to Commodus dominate the assemblage, gravitating slightly towards the late 2nd century AD with a high number of denarii struck during Antoninus Pius, Marcus Aurelius and Commodus (Table 2). A single denarius struck during the reign of Septimius Severus provides a possible *t.p.q.* of the Hillested Hoard to *c.* AD 193–94, although this date is obviously preliminary and subject to change given that new findings may be unearthed in the coming years.

The Iron Age burials at the site of the Hillested Hoard were discovered in the late nineteenth and early twentieth centuries. At present, five inhumation graves are known, as well as at least 10 cremation graves in the form of urn burials: several of them furnished with exquisite grave-goods such as fine drinking horns with

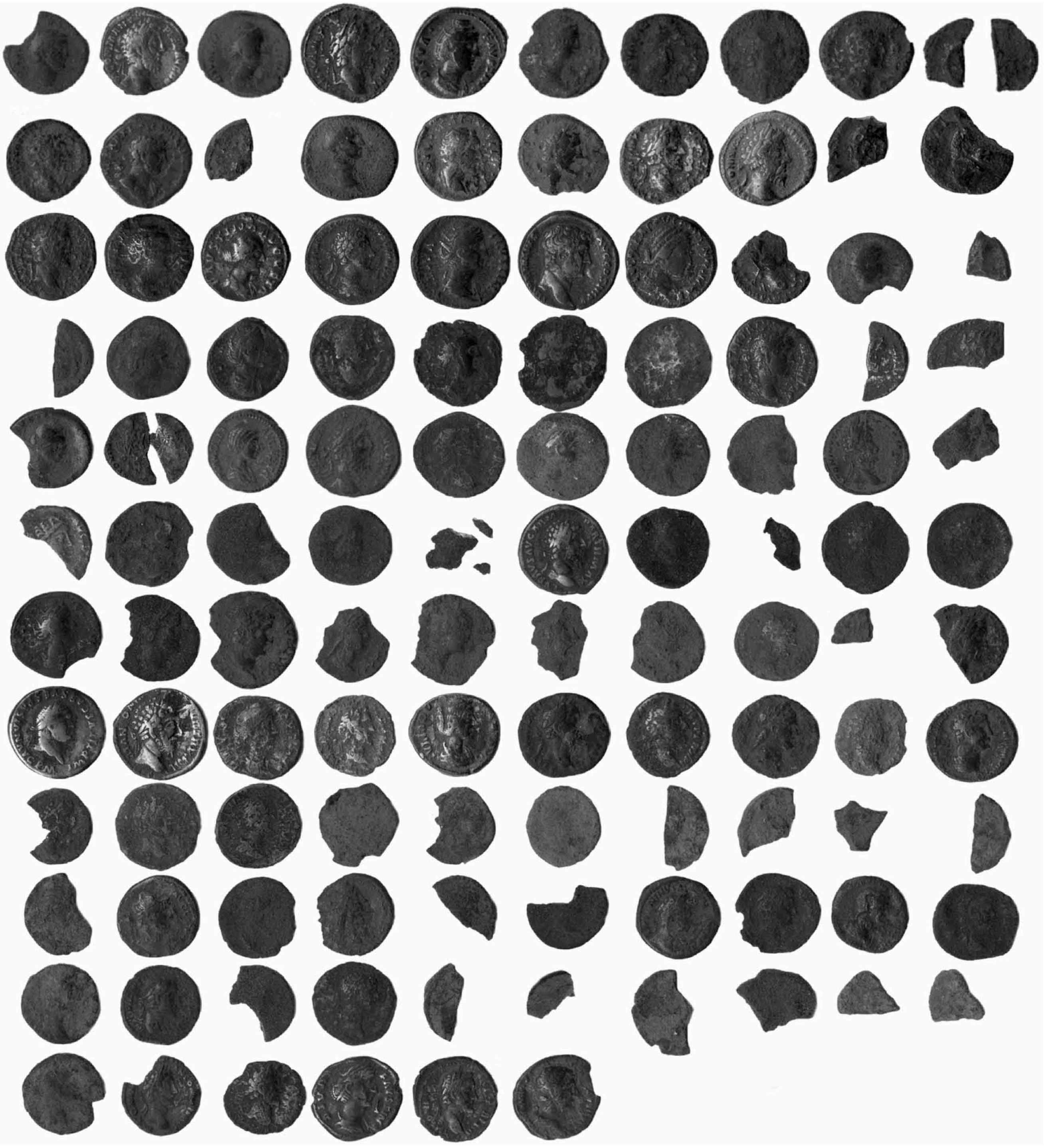

Figure 6. The Tagesgård Hoard. Not shown in chronological order. Museum Lolland-Falster.

bronze fittings as well as glass vessels, one of which has been identified as belonging to Eggers type 230 (Lund Hansen 1987, p. 419, 1995, p. 442 and 449). As the majority of these graves were found by gravel diggers, the handling of the bones and grave-goods can best be described as 'rough'. It was only through the timely intervention of local citizens and a subsequent excavation conducted by the National Museum of Denmark that any information about these early finds has survived to this day.[3] The far from fully excavated burial site at Hillested covering both cremation graves from the Early Roman Iron Age as well as inhumation

Table 1. List of denarii from the Tagesgård Hoard.

Number	Museum ID	Emperor (date AD)	RIC type
1	MLF00854x001	Otho (69)	10
2	MLF00854x019	Vitellius (69)	
2	MLF00854x096	Vitellius (69)	71 (2nd ed.)
3	MLF00854x041	Vespasian/Titus? (69–81)	-
4	MLF00854x029	Vespasian (Titus Caesar)? (72–81)	-
5	MLF00854x071	Titus (80)	25a
6	MLF00854x020	Flavian coin (Titus?) (69–81)	-
7	MLF00854x037	Titus?/Domitian? (80–82)	-
8	MLF00854x099	Trajan (103–111)	156–157
9	MLF00854x080	Trajan (114–117)	-
10	MLF00854x014	Trajan (114–117)	-
11	MLF00854x085	Trajan (98–117)	-
12	MLF00854x053	Trajan? (98–117)	-
13	MLF00854x104	Trajan (98–117)	-
14	MLF00854x067	Trajan(?) (98–117)	-
15	MLF00854x045	Trajan (98–117)	-
16	MLF00854x009	Hadrian (119–122)	122
17	MLF00854x012	Hadrian (117–122)	-
18	MLF00854x092	Hadrian (125–128)	172
19	MLF00854x098	Hadrian (134–138)	241Aa
20	MLF00854x026	Hadrian (134–138)	256
21	MLF00854x116	Hadrian (117–138)	-
22	MLF00854x100	Hadrian (117–138)	-
23	MLF00854x032	Hadrian (117–138)	-
24	MLF00854x034	Hadrian (117–138)	-
25	MLF00854x038	Hadrian (117–138)	-
26	MLF00854x086	Hadrian (117–138)	-
27	MLF00854x068	Hadrian (117–138)	-
28	MLF00854x063	Hadrian (117–138)	-
29	MLF00854x109	Hadrian (117–138)	-
29	MLF00854x040	Hadrian? (117–138)	-
30	MLF00854x066	Hadrian (117–138)	-
31	MLF00854x084	Hadrian? (117–138)	-
32	MLF00854x010-1	Hadrian? (117–138)	-
33	MLF00854x078	Hadrian (Sabina) (128–136)	-
34	MLF00854x054	Hadrian (Sabina) (128–136)	-
35	MLF00854x094	Hadrian (Sabina) (128–136)	-
36	MLF00854x064	Hadrian (Sabina) (128–136)	-
37	MLF00854x115	Antoninus Pius (149–150)	187
38	MLF00854x017	Antoninus Pius (151–152)	217(?)
39	MLF00854x076	Antoninus Pius (155–157)	250, 262 (Annona)
40	MLF00854x077	Antoninus Pius (155–157)	254, 264 (Salus)
41	MLF00854x102	Antoninus Pius (147–158)	164,180,189,196,223,267
42	MLF00854x097	Antoninus Pius (159–160)	304
43	MLF00854x021	Antoninus Pius (140–160)	-
44	MLF00854x004	Antoninus Pius (140–160)	-
45	MLF00854x105	Antoninus Pius (138–161)	-
45	MLF00854x070	Antoninus Pius (138–161)	-
46	MLF00854x008	Antoninus Pius (138–161)	-
47	MLF00854x074	Antoninus Pius (138–161)	-
48	MLF00854x016	Antoninus Pius (138–161)	-
49	MLF00854x090	Antoninus Pius (138–161)	-
49	MLF00854x048	Antoninus Pius (138–161)	-
50	MLF00854x111	Antoninus Pius (138–161)	-
51	MLF00854x036	Antoninus Pius (138–161)	-
52	MLF00854x062	Antoninus Pius (138–161)	-
53	MLF00854x113	Antoninus Pius (138–161)	-
54	MLF00854x028	Antoninus Pius (138–161)	-
55	MLF00854x031	Antoninus Pius (138–161)	-
56	MLF00854x039	Antoninus Pius? (138–161)	-

(*continued*)

Table 1. (*Continued*).

Number	Museum ID	Emperor (date AD)	RIC type
57	MLF00854x013	Antoninus Pius (138–161)	-
58	MLF00854x005	Antoninus Pius (Diva Faustina 1) (141–161)	344
59	MLF00854x114	Antoninus Pius (Diva Faustina 1) (141–161)	347
60	MLF00854x061	Antoninus Pius (Diva Faustina 1) (141–161)	353
61	MLF00854x003	Antoninus Pius (Diva Faustina 1) (141–161)	361
62	MLF00854x007	Antoninus Pius (Diva Faustina 1) (141–161)	363
63	MLF00854x033	Antoninus Pius (Diva Faustina 1) (141–161)	384
64	MLF00854x025	Antoninus Pius (Diva Faustina 1) (141–161)	384
65	MLF00854x022	Antoninus Pius (Diva Faustina 1) (141–161)	-
66	MLF00854x073	Antoninus Pius (Diva Faustina 1) (141–161)	-
67	MLF00854x035	Antoninus Pius (Diva(?) Faustina 1) (138–161)	-
68	MLF00854x006	Antoninus Pius (Diva(?) Faustina 1) (138–161)	-
69	MLF00854x010-2	Antoninus Pius (Diva(?) Faustina 1)? (138–161)	-
69	MLF00854x087	Antoninus Pius (Diva Faustina 1) (138–161)	-
70	MLF00854x089	Antoninus Pius (Diva(?) Faustina 1) (138–161)	-
71	MLF00854x107	Antoninus Pius (Diva Faustina 1)? (141–161)	-
72	MLF00854x060	Antoninus Pius (Marcus Aurelius Caesar) (140–147)	429a
73	MLF00854x059	Antoninus Pius (Marcus Aurelius Caesar) (140–161)	-
74	MLF00854x046	Antoninus Pius (Faustina 2) (161)	513d/515a/515 b
75	MLF00854x083	Antoninus Pius/Marcus Aurelius (Diva(?) Faustina 2) (146–176)	-
76	MLF00854x082	Antoninus Pius/Marcus Aurelius (138–180)	-
77	MLF00854x081	Antoninus Pius/Marcus Aurelius (cæsar?) (140–180)	-
78	MLF00854x079	Antoninus Pius/Marcus Aurelius (cæsar?) (140–180)	-
79	MLF00854x018	Marcus Aurelius (168)	183
80	MLF00854x072	Marcus Aurelius (170–171)	227
81	MLF00854x042	Marcus Aurelius (170–171)	231
82	MLF00854x049	Marcus Aurelius (175)	327
83	MLF00854x011	Marcus Aurelius (161–180)	-
84	MLF00854x050	Marcus Aurelius? (161–180)	-
85	MLF00854x093	Marcus Aurelius (Divus Antoninus) (161–180)	436
86	MLF00854x091	Marcus Aurelius (Divus Antoninus) (161–180)	436
87	MLF00854x015	Marcus Aurelius (Divus Antoninus) (161–180)	-
88	MLF00854x047	Marcus Aurelius (Lucius Verus) (163–164)	515
89	MLF00854x056	Marcus Aurelius (Lucius Verus) (165)	540
90	MLF00854x024	Marcus Aurelius (Commodus Caesar) (177)	627
91	MLF00854x023	Marcus Aurelius (Faustina 2) (161–180)	676
92	MLF00854x027	Marcus Aurelius (Lucilla) (161–180)	771
93	MLF00854x051	Marcus Aurelius (Lucilla) (161–180)	-
94	MLF00854x095	Marcus Aurelius/Commodus (possibly Crispina/Lucilla) (161–192)	-
95	MLF00854x112	Commodus (182)	45
96	MLF00854x057	Commodus (186)	129
97	MLF00854x002	Commodus (187–188)	167
98	MLF00854x044	Commodus (189)	188
99	MLF00854x101	Commodus (191–192)	254a
100	MLF00854x058	Unknown	-
101	MLF00854x075	Septimius Severus (Julia Domna) (193–196)	535–536
102	MLF00854x043	Caracalla (Plautilla) (211–212)	359
103	MLF00854x052	Unknown	-
104	MLF00854x065	Unknown	-
105	MLF00854x103	Unknown	-
106	MLF00854x108	Unknown	-
107	MLF00854x055	Unknown	-
108	MLF00854x088	Unknown	-
109	MLF00854x106	Unknown	-
110	MLF00854x069	Unknown	-

Note: The coins are listed in chronological order. RIC type is listed when known.

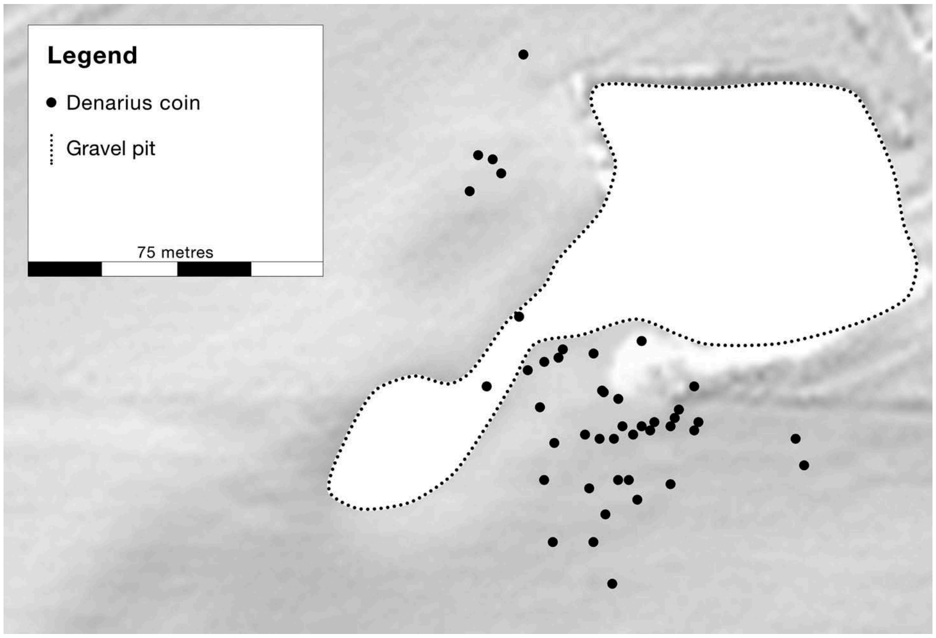

Figure 7. The Hillested Hoard, the distribution of denarii (status 2014). The location of the gravel pits is marked on the map.

graves, of which some are definitely from the Late Roman Iron Age, provides an obvious clue to the longevity of the adjoining settlement and the network of exchange in which it took part.

Denarii as single-finds

Except for the two denarii from Erikstrup found in connection with the building of the railroad between Maribo and Nakskov in the 1880s and a single Antonine denarius from Søllested, found in 1969, all denarii from Lolland have been found as a result of detector surveying. Since the search of increasingly larger areas with metal detector is becoming more and more frequent, the pace with which new finds and sites are being added to our knowledge of the past is accelerating quite rapidly. The challenge is then to preserve as much information as possible regarding the circumstances of the findings and their surroundings, knowing full well that in evaluating the importance of single-finds an understanding of context is the key.

A single republican denarius from Kohave on western Lolland was found by a detectorist in 2002 (Horsnæs 2002). While the find spot itself did not yield any supplementary material by which the original depositional context might be interpreted, the surrounding area was known for a number of settlements, burials and single-finds from the Iron Age. Among them was the Early Roman Iron Age burial site at Juellinge, situated only a few kilometres away from Kohave, at the eastern end of an old, now dried out waterway connected to the inlet of Rødby Fjord (Müller 1911, Koch 1986).

The area surrounding the present-day village of Søllested has yielded the largest number of denarii as single-finds on Lolland, total eight coins from four separate locations. An Antonine denarius was allegedly found on a field to the east of the village in 1969, but the exact find spot is unfortunately unknown. All remaining Roman coins from the area around Søllested have been found by detector surveying within the three-year period from 2009 to 2012. Four denarii, counting one Trajan, two Antonine and one Marcus Aurelius, were found in the latter part of 2009 on a field to the east of Søllested. With a distance of approximately 50 m between each of these coins, it is unlikely that they represent the remains of a hoard disturbed and scattered by agricultural processes. Another Antonine denarius was found to the west of the local church in Søllested, this time however with no auxiliary finds to indicate whether or not the site had been settled or used for other purposes during the Iron Age. The last two denarii were found lying a mere 70 m apart at the southern edge of a small forested area to the north of Søllested. One of these coins was struck under Antoninus Pius while the other had been made during the reign of Commodus and carried the image and dedication to his wife, the empress Crispina.

From the area surrounding the present-day villages of Erikstrup and Østofte, located two kilometres apart, five denarii are known from three separate locations. The two aforementioned denarii from Erikstrup were found in the

Table 2. List of denarii from the Hillested Hoard.

Number	Museum ID	Emperor (date AD)	RIC type
1	MLF01399x003	Domitian (81–96)	-
2	MLF01399x012	Nerva (96–98)	7
3	MLF01399x009	Trajan (98–117)	-
4	MLF01399x007	Hadrian (117–138)	-
5	MLF01399x013	Hadrian (117–138)	-
6	MLF01399x015	Hadrian (117–138)	-
7	MLF01399x030	Hadrian (Sabina) (128–136)	-
8	MLF01399x002	Antoninus Pius (147–148)	163
9	MLF01399x006	Antoninus Pius (138–161)	-
10	MLF01399x016	Antoninus Pius (138–161)	-
11	MLF01399x020	Antoninus Pius (138–161)	177
12	MLF01399x021	Antoninus Pius (138–161)	-
13	MLF01399x023	Antoninus Pius (138–161)	-
14	MLF01399x024	Antoninus Pius (138–161)	-
15	MLF01399x025	Antoninus Pius (138–161)	-
16	MLF01399x031	Antoninus Pius (138–161)	-
17	MLF01399x034	Antoninus Pius (138–161)	-
18	MLF01399x035	Antoninus Pius (138–161)	-
19	MLF01399x036	Antoninus Pius (138–161)	-
20	MLF01399x040	Antoninus Pius (138–161)	-
21	MLF01399x043	Antoninus Pius (138–161)	-
22	MLF01399x004	Antoninus Pius (Faustina) (138–141)	-
23	MLF01399x008	Antoninus Pius (Faustina) (138–141)	-
24	MLF01399x018	Antoninus Pius (Faustina) (138–141)	-
25	MLF01399x027	Antoninus Pius (Faustina) (138–141)	-
26	MLF01399x029	Marcus Aurelius (161–180)	-
27	MLF01399x001	Marcus Aurelius (161–180)	-
28	MLF01399x038	Marcus Aurelius/Lucius Verus (163–164)	-
29	MLF01399x005	Marcus Aurelius (Faustina) (146–176)	-
30	MLF01399x011	Marcus Aurelius (Faustina) (146–176)	-
31	MLF01399x018	Marcus Aurelius (Faustina) (146–176)	-
32	MLF01399x019	Marcus Aurelius (Faustina) (146–176)	-
33	MLF01399x026	Marcus Aurelius (Faustina) (146–176)	-
34	MLF01399x039	Marcus Aurelius? (Faustina?) (146–176)	-
35	MLF01399x042	Marcus Aurelius? (Faustina?) (146–176)	-
36	MLF01399x045	Marcus Aurelius? (Faustina?) (146–176)	-
37	MLF01399x032	Marcus Aurelius/Lucius Verus (Lucilla) (164)	-
38	MLF01399x028	Commodus (180–192)	-
39	MLF01399x033	Commodus (183)	-
40	MLF01399x037	Commodus (183)	187
41	MLF01399x041	Commodus (180–192)	-
42	MLF01399x044	Commodus (180–192)	-
43	MLF01399	Septimius Severus (193–211)	-
44	MLF01399	Unknown	-
45	MLF01399	Unknown	-

Note: The coins are listed in chronological order. RIC type is listed when known.

1880s on a field known for a previous find of a gold necklace, a gold ring and golden rods from the Late Roman Iron Age (Jørgensen and Vang Petersen 1998, p. 122; Horsnæs 2010, p. 84ff). From Østofte a single denarius struck during the reign of Marcus Aurelius (after AD 161) was found in 2009. A few hundred metres to the east of this find, two denarii were discovered by a local detectorist during the winter of 2014. One of the coins, an Antonine denarius, was well preserved. The other, however, was a heavily worn denarius from the Flavian period, possibly struck during the reign of either Vespasian or Titus.[4]

Traces of numerous settlements from the Roman and Early Germanic Iron Age have been found near Søllested during archaeological surveys and excavations, indicating that the area was densely populated during the first half of the first millennium AD.[5] While the seven denarii appear to be the only objects from the Late Roman Iron Age signalling local wealth as well as a possible link to a wider network of exchange and foreign connections, a number of prestigious objects from the Early Germanic Iron Ages seem to signify the importance of the area on a wider scale. Likewise, from the areas near the villages of Erikstrup and Østofte, a number of sites dated to the Roman and Germanic Iron Ages have previously been registered. The only known Iron Age war booty sacrifice from Lolland, Sørup, was found in connection with peat digging less than 1 km to the west of the denarii from Østofte. Despite the fact that no excavation has ever been conducted on the site of the sacrifice, the unearthed pieces of weapons and armour imply at least two depositional horizons dated to the phases B2 and C1 b, as well as a possible deposition dated to C3/D1 (Lund Hansen 1995, p. 244, Figure 9:1; Ilkjær 2002, p. 57). While the find was relatively small compared to the large weapon deposits from the Jutland Peninsula, it does point to the existence of a local centre of power, possibly the residence of a local magnate or chief.

Roman coins, Roman connections?

From the first two centuries AD, there is an abundance of evidence linking Lolland to a wider network of aristocratic connections and the exchange of prestigious goods. Several burials containing the remains of the rich and powerful individuals of the Early Roman Iron Age, interred with a selection of some of their finest and most exquisite worldly possessions, are known from the island. The princely burial from Hoby, dated to the Phase B1a and furnished with a complete set of Roman tableware as well as other prestigious goods of Roman origin, is considered one of the wealthiest graves from the Early Roman Iron Age in Northern Europe (Lund Hansen 1987, p. 193; Klingenberg 2011, p. 36). A high number of other wealthy burials from Lolland, all dated to the Early Roman Iron Age, highlights the existence of a well-connected and affluent aristocratic milieu in the first centuries AD, seemingly well positioned to take advantage of the flow of trade through the northern parts of The *Barbaricum*.

At around the time of the end of the 2nd century AD, the abundance of evidence linking Lolland to a wide network of aristocratic connections and exchange seemingly fades away. From the Late Roman Iron Age only a few wealthy burials are known, none of them remotely comparable to the burials near the chiefly centre at Himlingøje on Stevns and its surrounding environs (Lund Hansen 1995, p. 198ff; Grane 2011, p. 105ff). From the whole of Lolland, the only examples where Roman imports have been found in possible graves dated to the Late Roman Iron Age are from the sites Hillested and Toftebys Mark – both the find spot of a glass vessel of type Eggers 230 (Lund Hansen 1987, p. 411). The use of the term 'possible' in this instance stems from the fact that none of these finds were professionally excavated, and therefore doesn't quite meet the standards of documentation required by present-day researchers. However, while there is ample cause to remain doubtful as to the original context of the glass vessels from Hillested and Toftebys Mark, their presence alone does mark the two locations as being points of interest in the flow of trade and exchange in the Late Roman Iron Age.

When measured against the preceding centuries, the conspicuous lack of prestigious goods of Roman origin in the grave material from the Late Roman Iron Age on Lolland is striking. This dichotomy becomes especially apparent when one looks at the diachronic shifts in the distributional densities of Roman imports from Phase B1 to C3 within the area comprising present-day Denmark (i.e. Lund Hansen 1987, Table 2–10). With the finding of the denarius hoards from Tagesgård and Hillested, as well as the several denarii as single-finds, there is, however, cause to look at the island with renewed interest.

While the depositional dates of the denarius hoards from Tagesgård and Hillested are difficult to pinpoint with any degree of accuracy by nature of them being single-type deposits, one should not fail to consider the testimony of the archaeological surveys and excavations conducted in the vicinity of the two sites. In the case of the Tagesgård Hoard, the presence of an Iron Age settlement from the Late Roman period directly underneath the main cluster of denarii from the ploughed-up deposition does serve as a strong indication of them being contemporary. Likewise, the placement of the Hillested Hoard on a site with known grave finds from both the Early and Late Roman Iron Ages, as well as traces of a possible settlement, makes it more than likely that the coins should be situated within the same chronological frame.

The role and function played by the Roman denarii within the context of Scandinavian Iron Age Societies have long puzzled researchers, and this author professes no new enlightenment on the subject. While Roman coins were clearly valued in the Iron Age, it is equally quite apparent that the denarii set themselves apart from the other categories of Roman imports normally found as part of an assemblage of grave-goods, on the site of a settlement or in hack metal deposits. Only a few denarii have ever been found as part of a necklace or other type of jewellery, and the use of Roman coins as a Charon's fee was not widespread (Dyhrfjeld-Johnsen 2011). Even the age-old adage that the denarii probably served as one of the primary sources of silver in the Nordic region during the Roman Iron Age now seems to fail as an adequate explanation, as recent studies show little to no direct correlation between the silver in the denarius coins and the silver in local jewellery and ingots (Horsnæs 2010, p. 189). The apparent desire among the Iron Age population to preserve the denarii in their original form has led some to suggest that the coins could have played a role in the day-to-day trade and exchange of both local and foreign goods (Nielsen 1986, p. 158; Bjerg 2007, p. 122; Horsnæs 2010, p. 188ff). As the denarii are usually found on sites with a known function of centrality or with a connection to foreign trade such as Gudme on Funen or Dankirke on the west coast of Jutland, and only rarely on the sites of 'ordinary' settlements and single farms, a tentative link to the aristocratic or elite stratum of the Scandinavian Iron Age society does seem highly plausible (e.g. Horsnæs 2006, p. 563; Bjerg 2007, p. 120ff.) The high demand for prestigious foreign objects during the Roman Iron Age would almost certainly imply that something of local origin or manufacture could be traded in return. Whether this was amber or some other material, the traces have in most cases long since disappeared (Brinch 2012). The Roman denarii, by nature of them being a somewhat trustworthy unit of value, might therefore represent one of the only tangible remains of this exchange. The fact that the denarii are usually found near waterways and other nodes of transportation does provide a certain air of feasibility to the hypothesis (e.g. Korthauer 1996, p. 123ff.; Bjerg 2007, p. 113), although this obviously doesn't necessarily equate to the existence of a monetary economy within the Scandinavian Iron Age Society (Horsnæs 2006, p. 563).

This proposed link between the denarii and regional centres possibly functioning as local hubs of trade and redistribution does seem to fit the distributional pattern on Lolland. So far, all the denarius coins from the island have been found inland, along, or very near, natural corridors of transportation. The republican denarius from Kohave, as well as the hoards from Hillested and Tagesgård, was found in close connection to waterways, while the denarii from Søllested were situated in a lowland area from which easy access to the waters of Nakskov Fjord would have been possible during the Iron Age. Lastly, the denarii from Østofte and Erikstrup were all found to the immediate south of the stream of Nældevads Å, in an area also known for other finds from the Roman Iron Age and Early Germanic Iron Age.

The prevalent view is that the majority of denarii found within The *Barbaricum* did not leave The Roman Empire until the time of the 3rd century AD (Horsnæs 2010, p. 186). Except for the singular republican denarius form Kohave, nothing seems to suggest that the depositional dating of the denarii from Lolland deviates from this general trend. The occurrence of the denarii on Lolland should therefore be seen as echoes of events taking place during the 3rd or 4th century AD, during the Late Roman Iron Age and possibly the beginning of the Early Germanic Iron Age. With the finding of the two denarius hoards from Tagesgård and Hillested, as well as a number of denarii as single-finds, the position of the island in this period does appear less diminished than previously believed. As mentioned earlier, denarii are to be counted as part of the same category of imports normally thought to include such artefacts as Roman vessels of bronze and glass as well as foreign jewellery of precious metals or finely crafted glass, although they rarely appear in the same archaeological contexts, e.g. in graves (Lund Hansen 1987, p. 229). However, this difference in find circumstances does not necessarily equate to them circulating in different parts of the Scandinavian Iron Age society. Precious items placed in burials were carefully chosen to highlight the status of the deceased, and thus express a specific narrative chosen by the living. The fact that denarii are rarely found as part of an assemblage of grave-goods perhaps signifies that they were perceived as a means to achieve an end, rather than an end in and of itself.

Conclusions

The recent discovery of the two denarius hoards from Tagesgård and Hillested, as well as several denarii as single-finds on the island of Lolland, provides valuable insight into the networks of exchange and the flow of trade in the 3rd and 4th centuries AD. While the denarii do little to change the fact that the islands south of Zealand so far fail to match the wealth found in the Late Roman Iron Age burials in other parts of present-day Denmark, they do prove that the region was still a part of the networks through which foreign Roman imports were brought to Denmark and the Scandinavian Peninsula. Even if the function of the denarii in the Scandinavian Iron Age eludes us, we are left with a better understanding of the specific places where denarius coins were in circulation. The fact that the finding of denarii on Lolland has so far only occurred on sites from which easy access to the ancient northern or southern coastlines was possible tells us that the region was a stepping stone in the Western Baltic Sea during the Late Roman Iron Age.

In sum, while the amount of archaeological evidence linking the island of Lolland to the networks of aristocratic exchange during the Late Roman Iron Age is still scarce, the new denarius hoards and single-finds do outline the contours of the role played by the local settlements and social elite in the Late Roman Iron Age.

Post script. After completing the manuscript for this article three denarii were found near the village of Kettinge on Eastern Lolland. These denarii appear to be part of a hack metal deposit, containing bronze fittings and pieces of bronze and silver vessels from the Roman Iron Age and Early Germanic Iron Age.

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Disclosure statement

No potential conflict of interest was reported by the author.

Notes

1. Ten denarii were preserved only as small fragments, leaving no chance of ever reaching a proper identification. The fragmentation did not appear to be intentionally made, and was more likely caused by post-depositional processes. Given the small size of these fragments, one should at least consider the possibility that some might be the shattered remains of a singular denarius, which would then lower the total amount of denarii in the hoard.
2. Personal communication with Helle Horsnæs, curator at the Numismatic Collection at the National Museum of Denmark.
3. Two inhumation graves found during gravel digging – one containing a juvenile individual, the other an adult interred with a piece of Roman glassware of unknown type as well as three gold finger rings – were described by a local teacher in 1875–76. Three inhumation graves found in the early 1870s were unfortunately lost. The presence of cremation graves on the site, some exquisitely furnished, has likewise been attested on several occasions. In 1903, an excavation of a small cluster of urns was conducted by the National Museum of Denmark and in 1911 repeated gravel digging brought to light the remains of two urns, one of which contained the well-preserved bronze fittings from two drinking horns from phase B1 of the Early Roman Iron Age.
4. Authors note: as these two denarii were found during the final stages of the writing of this paper, it has not been possible to conduct a thorough study of them.
5. Four locations with traces of Roman Iron Age and possibly Early Germanic Iron Age settlements are known from the area surrounding Søllested. The references to these in the web-based database, *Fund & Fortidsminder*, by the Danish Cultural Heritage Agency are 070506-6, 7 and 070512-13, 16.

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BRIEF COMMUNICATION

Experiments on digging pits in pit zone alignments

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Iron Age pit zone alignments are a relatively newly recognized type of system and research has focused primarily on why the pits were dug. There are numerous proposals, although the general perception of them as a kind of defence system has not changed since it was put forward by Eriksen and Rindel in 2001. But an experimental archaeological approach is, as of yet, untested, and by asking the 'how' before the 'why' the enigmatic tracts of thousands of pit-holes can be analysed from a new angle. Thus, in this article, the focus moves from the collective pit zone alignments to each individual pit-hole and the process involved in digging same. Systematic studies of spades, attempts to reconstruct double-spades, experiments digging pit-holes and the construction and use of parts of pit zone alignments helps make it probable that the inhabitants of a village from the pre-Roman Iron Age would have been able to dig a stretch of 100 metres by 4 metres of a pit zone alignment, broadly equivalent to seven holes, in 1 day. The experiments also made it clear that the pit zone alignment did not constitute an obstacle to sheep or cattle, and that they only, under exceptional circumstances, were an obstacle to people. But most significant was the insight gained into the process of digging the holes in terms of the organization of work, which undoubtedly lay behind the excavation work

Keywords: experimental archaeology; holes; pit zone alignments; double-spades; pre-Roman Iron Age

Introduction

Experimental archaeology is a scientific method that can be used to make plausible past work processes. You could say that experimental archaeology links objects to contexts and thus populates that context, which the objects were an original part of – it rethinks a person into the material by reflecting on praxis and interpretation. Experimental archaeology has a long tradition in Denmark: in the 1870s N.F.B. Sehested conducted experiments by drilling in stone (Sehested 1884, p. 26ff.) and the civil engineer, R. Thomsen, conducted a series of internationally recognized experiments extracting iron from bog iron ore in the 1960s (Thomsen 1964, Lyngstrøm 2015). Many Danish archaeologists use those methods in their research today (Lyngstrøm 1995, Sørensen 2006, Ravn 2014) and the University of Copenhagen has taught experimental archaeology as part of its archaeology course since 1990 (Lyngstrøm 2011, p. 135ff.).

To substantiate the contemporary work processes in the construction of the pit zone alignment, we investigated how the holes were dug and the tools used, how long it took and how the tools were handled and their relation to the excavated soil. We reflected on whether or not there were differences in how different people dug and how work to dig so many holes could be organized. Only then did we take the next step and try to interpret why the pit zone alignment was constructed. Is the pit zone alignment a real barrier to people and animals – and can a pit zone alignment provide tactical advantages for an army, as that found at Hjortspring Mose is thought to express? The questions were many, but for the experiment it was the pit-hole itself that was the starting point.

Pit zone alignments

Holes in the soil are the basis for a substantial part of archaeological knowledge. It is therefore strange that archaeologists know so little about how the pit-holes were dug in practical terms: what tools were used to dig them and what considerations people had for the digging work. The pit zone alignment is the ultimate object of study when pit-holes and the digging of holes are to be examined, as it is a long tract with several thousand holes (Figure 1). Often each hole has a diameter of about 30 cm, but the size can vary between both different tracts and different areas of the same tract (Mauritsen 2010, p. 267), and despite the pit-hole's perimeter typically being a circle, some polygonal pit-holes have also been found (Eriksen and Rindel 2001, p. 17). Each hole was originally between 30 and 40 cm deep (Steen 2005, p. 17), and there also appears to be a degree of similarity between the holes within the same tract, particularly in certain areas of the same tract (Figure 2). Moreover, although the profile of the pit-holes can show some variation, most often they are cylindrical. Tracts with identical holes are interpreted as being dug concurrently and certain areas with very similar

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Figure 1. Many pit zone alignment are between 3 and 4 metres wide, equivalent to seven or nine pit-holes. Here at Liseborg close to Viborg the pit zone alignment was 3.8 metres. Photo: Viborg Museum.

Figure 2. Each hole was originally between 30 and 40 cm deep and there appears to be a degree of similarity between the holes within the same tract, particularly in certain areas of the same tract. Photo: Viborg Museum.

holes are interpreted as being dug by the same person (Steen 2009, p. 5). In several pit zone alignments, such as at Bjødstrup, it is obvious that the holes remained open after being excavated (Olesen 2009, p. 86), and other holes may even be determined as being dug during a very dry summer, as they are below groundwater level (Mauritsen 2010, p. 264). Some pit zone alignments were supplemented by another kind of pit-hole along the edge of the tract. They are deeper and may be located in pairs. Examples include Gammelbosig (Olesen 2009, fig. 9) and Risum Østergård (Steen 2005, fig. 8) where, along the tracks, staggered holes were dug in paired sets at about 4 metres distance. Many pit zone alignments are between 3 and 4 metres, equivalent to seven or nine pit-holes (Eriksen and Rindel 2001, p. 15; Rindel 2010) and the longest pit-hole tract system so far excavated is 2.3 km long (Mauritsen 2010, p. 163). Some tracts seem to have been renewed, reinforced or rebuilt (Olesen 2009, p. 87), while others seem to have been dug only once and not touched again (Mauritsen 2010, p. 271). The course of a pit zone alignment can be quite linear like the 908 metre long tract of pit-holes at Tvis Møllevej which is 4 metres wide and in long stretches is 9 pit-holes wide (Steen 2009, p. 5). However, L-form tracts are also known such as that at Lystbaekgaard which is 3.5 metres wide with seven to nine rows of pit-holes (Eriksen and Rindel 2001, p. 16). They have also been known to encircle probable contemporaneous villages (Mauritsen 2010, p. 262). The distribution of the pit-holes in each tract rarely follows straight lines, but winds its way between each other as if they are filling a particular area of the tract (Steen 2009, fig. 79) and in several pit zone alignments there are entry points, here and there, at a width of 0.5 or 1 metre (Olesen 2009, p. 83).

In Denmark about 40 pit zone alignments have been found. Most in Jutland, probably because the preservation conditions are better here than on the islands. Pit zone alignments are difficult to date, but sherds of pottery vessels were found in some individual pit-holes (Eriksen and Mauritsen 2011, p. 163). In some cases, they were so large and plenty that it may have been an entire vessel, but most often they were individual sherds (Mauritsen 2010, p. 267). The ceramics can, in several cases, like at Lystbaekgaard (Eriksen and Rindel 2001, p. 18), be dated to the early Pre-Roman Iron Age, Beckers Period I. And on Grøntoft the course of the pit zone alignments suggests that it was constructed with consideration of tussocks (Rindel 2015, fig. 2). So although the vast majority of pit zone alignments cannot be dated, some of them, at least, belong with certainty to a time when the landscape was divided in a new way and could be an expression of this strategy (Løvschal and Holst 2015).

Archaeologists first became aware of the long tracts with many holes in the 1960s when they uncovered large, contiguous areas at the West Jutland settlement excavations (Becker 1971). But most pit zone alignments were found in this millennium. Pit zone alignment research is relatively new and has focused primarily on *why* the holes were dug. Here the proposals are many: perhaps they were defensive, to control the movement of peoples and animals, cattle grids, territorial markings or they marked symbolic or cosmological limits. There have also been suggestions that they were simple fences, whose purpose was to keep animals in or out of the village (Martens 2007, p. 96). The interpretations have focused particularly on the few tapered wooden sticks that were located between holes at Brændgaards Hede. The sticks were excavated southernmost, in the inner tract, furthest out in a meadow area. They are 15–20 cm long, tapered at both ends (Mauritsen 2010, p. 267 and fig. 6) and are similar to those found in the bottom of the moats at Lyngsmose and Borremose (Eriksen and Rindel 2001, p. 13). The intense focus on the sticks has helped to maintain an overall interpretation of all pit zone alignments as defence installations or as prepared battlefields with analogies drawn to Caesar's investment at Alesia (Eriksen and Rindel 2001, p. 19; Eriksen and Mauritsen 2011, p. 163) or to chevaux-de-frise (Steen 2005, p. 23f.). The 80 metre long pit zone alignment, which ran parallel to Rammedige, has further supported this interpretation (Olesen 2003).

In this article the focus moves from the function of the pit zone alignment to the individual pit-hole and the process involved in digging a pit zone alignment. Apart from a single reconstruction, the experimental archaeological approach has, so far, been untested in pit zone alignment research and by asking *how* before *why* the enigmatic tract system of thousands of pit-holes can be analysed from a new angle.

How and why?

There can be no doubt that pit zone alignments were dug in a community and that people in this community probably worked somewhat contemporaneously. Furthermore, the pit-holes were used immediately after they were dug, that is, if the purpose of the pit-holes did not lie in the excavating process itself. In the society, there must therefore have been a consensus for where and how to dig, as well as how the pit zone alignment should lie through the countryside. Maybe having taken into account certain visual landmarks (Olesen 2009, p. 85) the alignment was allowed to grow or perhaps it stuck out and was divided into sections, as several of the most linear pit zone alignments indicate (Steen 2005, p. 18f.; Mauritsen 2010, p. 163).

After reviewing the published plans of pit-holes and pit zone alignments, the experiments focused on the most linear of them and a straight line was walked and marked with sticks every fourth step (about every 4 metres) (Figure 3). Since it is common for multiple linear pit zone alignments to close watersheds between river systems (Olesen 2009, p. 85) or lie across the landscape's lines of movement, we constructed the tract across a wheel track, which thus also became a kind of opening or passage through the tract (Løvschal and Holst 2015). The excavation work began with a chain marking pit-holes, as it seems from several excavation plans that the holes along one edge – perhaps the first holes dug – were dug quite similarly, while the remaining holes can have a more individual form and distribution (Steen 2005, fig. 5).

Several different types of spades were employed for excavation work in the early Iron Age, though they had a common factor: the blades were rarely wider than 10 cm. The spade was, thus, a tool to cut and loosen the soil with – not a tool to move earth with. It is also characteristic that none of the spade forms had a ledge, so that the foot was not used for the work. Until the early Germanic Iron Age the digging must have primarily involved the muscles of the upper body. It is perhaps only in the 500 s – a time of major technological changes in general – that ledges became a feature of spades, so that, as in the Viking and Medieval Periods, the body's entire weight could be used to advantage in the digging work (Bill and Daly 2012, fig. 2).

Around the start of the Common Era, the double-spade – with a blade on each side of the handle – was relatively common (Lerche 1985, p. 210ff.) (Figure 4). The two blades not only extended the life of the tool, they also added the function which a worn blade may have. The spade was carved from one piece of wood and usually made of oak (*Quercus* sp.). A 114 cm long double-spade from Østrup near Vognsild in Northern Jutland is C14 dated to 170 BCE (Lerche 1995,

Figure 3. The experiments focused on the most linear pit zone alignments and a straight line was marked with sticks every fourth step. Photo: Henriette Lyngstrøm.

Figure 4. Hundred of double-spades are found in Denmark and most are about 1 or 1½ metres. In the experiments we observed how the blades were worn during the digging work and therefore had to be frequently sharpened. This spade is from the collection at Vesthimmerlands Museum. Photo: Michael Nielsen.

p. 198f.), while a spade from Blegind south of Aarhus – which is distinguished by being carved from alder (*Alnus* sp.) and by being part of an archaeological context – an Iron Age road – is C14 dated to 220 BCE (Jørgensen 1991, p. 216ff.; Lerche 1995, p. 176f.). Like all tools the double-spade has a biography with conception, manufacture, use, cleaning, sharpening, storage, recycling and disposal, but its functional context is also dynamic with a manufacturing site, a workplace, a storage place and a maintenance site; there were probably quite regular routines for cleaning and maintenance (Fél and Hofer 1974, pp. 35 and 291; Gorecki 1978, p. 186). Perhaps that is why double-spades are so frequently considered by museums as casual finds from peat-cutting between the two World Wars: the bog may have been repository of spades (Lerche 1977, p. 119).

Like all hand tools double-spades were customized to the body and fit just as closely to the individual as their shoes and clothes. Spades could be very long, almost 2 metres, but most are about half as long and in the experiments we observed how the blades were worn during the digging work and therefore had to be frequently sharpened. The current length of a double-spade is rarely the original. Some are fragmented and others are dried out. Most are worn from use and not all double-spades were made with the same length. The earth and the earth's surface are, of course, of great importance to the wear and tear on the spade. In the experiments, we dug into grass-covered, slightly rocky and very clayey moraine. Therefore, the cutting edge of the spade's blade was quickly frayed, but the majority of the pit zone alignments appear on sandy soil where the wear and tear on the spade may have been different. We worked best on our knees when we cut grass-turf with the spade's sharpest edge, loosened the soil with the dullest edge and lifted the earth out of the hole with our hands or with a large ceramic sherd. In this way a double-spade could be used for almost 10 holes before it had to be sharpened. But the experience was that double-spades – after a period of adaptation – were no more difficult to dig with than modern spades (Figure 5).

Figure 5. The experience was that double-spades were no more difficult to dig with than modern spades. Photo: Henriette Lyngstrøm.

We, modern people, think it is important to know that one can dig a hole in a pit zone alignment in 6 minutes. This means that a section of four steps in length and with a total of about 35 holes could be dug at 3.6 hours. And as the spade has to be sharpened after every 10th hole, it adds an additional 22 minutes: 4 hours in total. It is also a question of whether the excavated soil is moved or perhaps spread out to blur the tract's presence. If that is done, the work will increase by at least 1 hour per section. The earth from one of the holes in the experiment weighed 11 kg, corresponding to approximately 400 kg per section. Since it is estimated that a village in pre-Roman Iron Age had between 70 and 100 people (Martens 2007, p. 96), we must assume that the inhabitants may have dug 100 metres of approximately 4 metres wide pit zone alignment in 1 day. That is 10 diggers, 1 sharpening spades, 10 pulling away soil (if that was done) and 5 responsible for the supply of food and water. Experimental archaeology is full of such examples of how long work processes take to produce results: to build a hill, grind an axe or sail a certain distance. But most often it is a completely unimportant information, partly because it is difficult – if not impossible – to compare a person's work in the early Iron Age with a modern person's work. But mostly because the perception of the concepts of 'time' and 'work' is quite different. In cultural history there are examples of many work processes where there is much more focus on the process than on the product: the process should not be completed as quickly as possible, but with as many people as possible, the right people or under special circumstances (Figure 6).

However, one issue did make sense to examine in relation to pit zone alignments: were the pits a real obstacle for animals and people? First we used a flock of sheep that repeatedly moved undisturbed over the pits. Sometimes they used the rut – other times they found foothold with ease between the pits (Figure 7). Cattle also seemed to find a relatively easy path between the pits. Future experiments will show if horses do the same and if it is possible to pull a wagon over the pit-holes. But we must conclude that pit zone alignments cannot have served as effectively as cattle grids. Next, we examined whether the pit zone alignment could be a real barrier for people. A group of people attacked and defended in various formations. Our experience was that a group of civilians who do not know each other beforehand, can remarkably quickly learn to master simple attack formations, if they are instructed professionally. And by attacking in close formation – covered with shields, the size of those found in Hjortspring – the people in the rear ranks look down and thus see the pit-holes (Figure 8). The result was that the pit zone alignment can give defenders a moderate advantage if it is placed so that attackers have to fight uphill. But a very long line requires many defenders, even if fighting is carried out differently from how we imagine today.

Figure 6. It is possible to dig a hole in a pit zone alignment in 6 minutes. This means that a section of four steps in length and with a total of about 35 holes could be dug at 3.6 hours. Photo: Henriette Lyngstrøm.

Figure 7. A flock of sheep repeatedly moved undisturbed over the pit-holes. Sometimes they used the rut – other times they found foothold with ease between the pit-holes. Photo: Henriette Lyngstrøm.

Figure 8. By attacking in close formation and covered with shields the people in the rear ranks look down and, thus, see the pit-holes. Photo: Michael Nielsen.

Results

The pit zone alignments still represent an archaeological feature type whose actual purpose is an open question and we do not know why the many pit-holes were dug. Maybe it was a strategy early Iron Age man chose when he divided the landscape and claimed his ownership to land – or maybe the purpose was the process of digging. But the experiments strongly indicate that the pit zone alignments were not used for cattle grids, nor did it work effectively as obstacles to people besides from under exceptional circumstances and only future experimental work will show the consequences if the soil is left between the pit-holes or if wooden sticks as found at Brændgårds Hede, Lyngsmose and Borremose are added.

The experiments made it probable that the people of a village from the early Iron Age may have dug a stretch 100 metres by 4 metres of a pit zone alignment in 1 day. And more importantly: we, through the process of digging the pit-holes, understood a little more of the work organization behind the process through the marking out of the line, digging the first chain of pit-holes and digging divided in sections. As the diggers had to work somewhat contemporaneously they clearly benefited from the section division with room enough to dig in they own pace and 'style', not unlike the organization of work seen on group level in the building of the Bronze Age mounds (Holst and Rasmussen 2012, p. 231ff.). The tool was the spade, prepared in advance and continuously sharpened. In such a scenario one can imagine about 10 diggers with 10 spades kneeling section by section. Beside each digger lay a skin, which they lifted the earth onto and between the sections children scurried, pulling away soil, pit-hole by pit-hole. The diggers had the chance to stretch their legs and get a sip of water every 9th or 10th hole, when they carried their spade to the person sharpening, who sat a little away with his axe.

How much wear and tear there was on the spade depended on the soil, but 5 cm per blade per section would not be unrealistic. At the same time, it was obvious that part of the process concerning laying out the tract and marking the holes to be dug differs from the rest of excavation work, thus it may have been shared between several actors: many diggers and earth-luggers, one or a few sharpeners and other persons responsible for the logistics of water, food and other necessities, which were especially necessary when digging the linear pit zone alignments that were apparently far from the contemporary settlements. In this scenario, it is not unrealistic to imagine that the people who performed the first part of the process had other skills or powers than those who performed the second part. It is not necessary that both working parties worked at the same pace or directly and consecutively. And one can also imagine that the first part was ritualized on a higher level or was imposed on more jurisdictions, than the later one and perhaps therefore took longer and had actors that we are unable to see in the archaeological material. They may have been participants in processions or ceremonies. By examining *how* the pit-holes were dug, we took a little step closer to understanding the organization of the work and the complex diversity to which the enigmatic tracts with thousands of pit-holes bear witness.

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