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Burnt grain and crop cleaning residues: an archaeobotanical contribution to the understanding of 3rd–6th century AD longhouses in Jutland and Funen (Denmark)

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ABSTRACT

This paper uses the composition and spatial distribution of carbonised archaeobotanical material from postholes to identify and delineate agrarian and household activities within settlements. The paper presents the analyses of seven houses/farmsteads dating to the 3rd–6th century AD, which were excavated on four separate sites: Flensted, Skovby Nygård and Gedved Vest in east-central Jutland, and Odensevej on the island of Funen.

To infer settlement activities from the distributions of carbonised plant macro remains, the paper defines the various stages of plant processing and carbonisation circumstances. It also discusses assumptions about plant processing sequences and the formation of charred plant assemblages that were made during the analysis.

The results show that the distribution of charred plant macro-remains can assist in the identification and delineation of spaces with different functions. The presented cases identify the locations of dwelling spaces, spaces where processed crops were stored and/or used, and spaces where fine sieving of grain was performed. The results also show a similarity between the analysed houses, which suggests the existence of a regional tradition of ordering household space. These patterns also confirm assumptions about mid-1st millennium houses previously made on the basis of other archaeological evidence.

1. Background: archaeological understanding of the use of space in late Iron Age houses in Denmark

Settlements from the 2nd to the 5th century AD in present day Denmark are characterised by farmsteads with a main longhouse which was adjoined by one or more smaller buildings (outhouses). Regularly these farmsteads were surrounded by fences, and in some cases the fences also appear to have been covered by a roof. These so-called *saddle-roof* enclosures would have been open to all sides except the one with the fence.

The typical late Iron Age longhouse is understood to have been a multifunctional building (Figure 1). Unfortunately, much less is known about the internal ordering of longhouses during the middle of the first millennium AD, than those of the preceding early Iron Age where many well-preserved sites have provided ample evidence about indoor activities (summary in Webley, 2008).

Longhouses from the 3rd to the 7th century AD varied in length from approximately 15 to more than 60 metres but were almost always between 5 and 6 metres wide. The houses were mostly oriented east-west with two centrally located entrances (facing north and south). Dwelling areas (*i.e.* spaces for food preparation, eating, other household activities, and probably also sleeping) are occasionally indicated by the presence of hearths and artefacts associated with domestic activities. They tend to be situated to the west of the central entrances. Byres are occasionally indicated by the presence of traces of animal stall partition walls. These stalls were mostly situated to the east of the entrances. The function of the small ancillary houses is in most cases unknown, but

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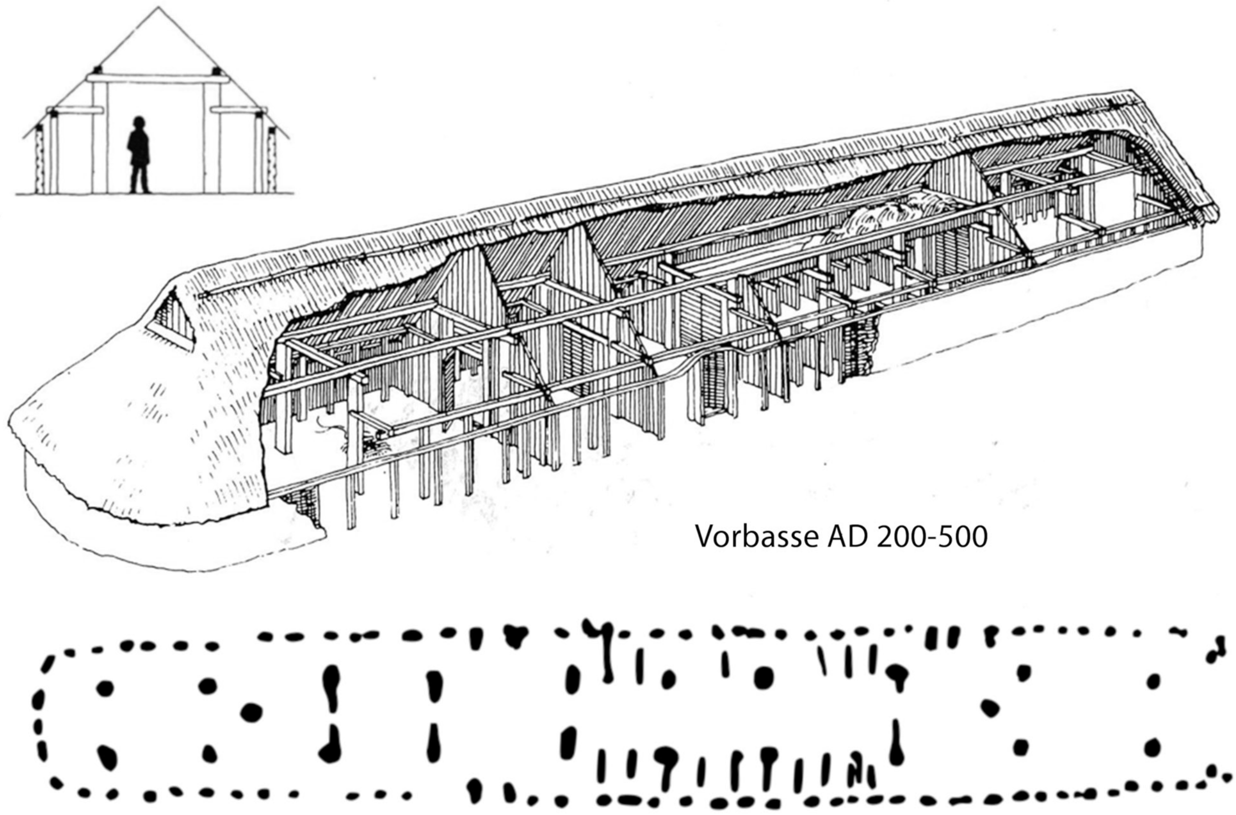

Figure 1. Plan and hypothetical reconstruction drawing of a late Iron Age longhouse at Vorbasse in Jutland (after Hedeager and Kristiansen, 1988, p.139).

they are often assumed to have been used for agriculture or crafts and are commonly termed "economy buildings" (DK: *økonomibygning*) (Hedeager and Kristiansen, 1988, p.142; Hvass *et al.*, 1988; Ethelberg, 2003, p.226; Jensen, 2003, p.214; Mikkelsen and Nørbach, 2003, p.23; Herschend, 2009, p.236).

From the earlier Scandinavian Iron Age (c. 500 BC–AD 100) a significant number of houses with preserved floor layers, pavements and artefact spreads have been encountered over the last hundred years; especially in the west of the country where a combination of less intensive agriculture and aeolian movement of sand have acted as factors for excellent preservation. Through these finds, detailed inferences about the use of domestic space have been possible (see comprehensive summary in Webley, 2008). For the later Iron Age, the paucity of artefacts, preserved floor layers, and architectural traces indicative of function makes interpretation of the internal arrangement of late Iron Age houses more difficult, especially in the many cases where no hearths or animal stall walls are present. This has, over the years, led to attempts at using various natural scientific approaches, such as soil phosphate mapping and plant macrofossil analysis, to provide additional insights. The use of these methods is still at a stage of evaluation by the broader archaeological community. This makes the dissemination of promising examples important.

2. Aims and organisation of the paper

The main aim of this paper is to illustrate the potential contribution that archaeobotanical analysis of carbonised plant macro remains can make to the understanding of late Iron Age longhouses. Furthermore, the paper aims to provide a broad outline of the key principles and assumptions that underpin analysis of charred macrofossil distributions in houses. This is done in the hope of making the approach more accessible to colleagues outside of archaeobotany, especially those who regularly excavate settlements and are responsible for the collection of samples.

The aims are pursued in three steps. Firstly, in the theory section (Section 3), the formation, circulation and preservation of carbonised botanical material is explored. The focus lies on cereal crops and arable weeds since these categories of plant material make up the majority of all archaeobotanical finds from late Iron Age settlements (excluding charcoal). The method and material of the study are presented in Sections 4 and 5 respectively. In Section 6, the patterning in the botanical record from each case study is presented and interpreted within the framework established in Section 3. Lastly, in Section 7, the broader implications of the results for understanding 3rd–6th century habitation are discussed.

3. Theory: the formation, circulation and preservation of carbonised plant remains on settlements

3.1 The *chaîne opératoire* of plant processing

Botanical material can become preserved by carbonisation if it is exposed to the right combination of heat (usually 250–500°C) and low-oxygen conditions (Miksicek, 1987). Once carbonised, such material is no longer biologically degradable but can still be damaged and fragmented through mechanical action.

In archaeology, preserved plant remains are rarely studied as individual finds, but rather as *assemblages* sampled from natural or cultural deposits. While often used for understanding cultural phenomena such as the use of domestic space, and hence acting as (micro-) artefacts of human behaviour, botanical assemblages have some properties which make them different from other forms of material culture. Assemblages of charred plant remains are not *manufactured* in the same way as most artefacts but are instead assembled (sorted, mixed, accumulated) due to processes related to the procurement (harvest/gathering), sorting, cleaning, storage, preparation, consumption and discard of plant resources. Since these processes tend to follow a specific order they can be understood as botanical *chaînes opératoire* (operational sequences) of plant use (Hillman, 1984; Jones, 1984; Viklund, 1998).

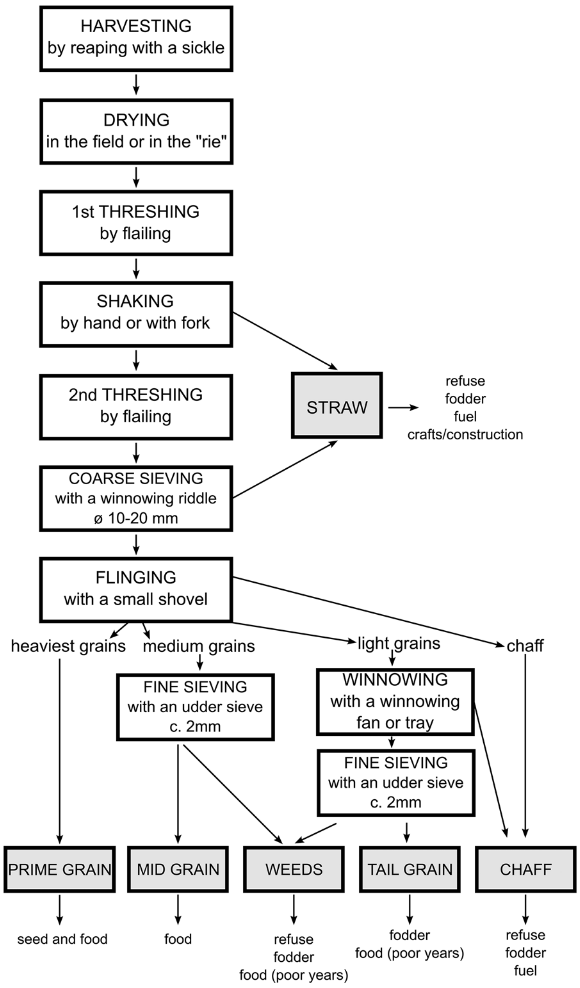

Figure 2. A schematic summary of historical (late 19th/early 20th century) hulled barley processing in Sweden (after Engelmark, 1989, p.183).

On Iron Age settlements in Scandinavia, cereals and weeds make up the majority of all carbonised plant macro remains (excluding charcoal). The operational sequences of these plant categories are therefore the most relevant for understanding the use of space.

From historical sources in Scandinavia, and ethnographic documentation in regions where pre-industrial agriculture was still practiced in the recent past, we know that the processing of cereals usually required 30 or more separate steps (see summary example in Figure 2) (Erixon, 1956; Brøndegaard, 1978; Hillman, 1984; Jones, 1984). This degree of detail is, however, rarely traceable archaeologically, and practitioners of Scandinavian archaeobotany tend to work with simplified sequences such as: 1) harvest, 2) threshing, 3) coarse and fine cleaning, 4) storage, 5) consumption and 6) various forms of discard (*e.g.* Engelmark, 1989; Henriksen and Robinson, 1996; Viklund, 1998; Mikkelsen and Nørbach, 2003; Grabowski, 2013).

In general terms, it can be said that three main changes will occur in the composition of cereal assemblages meant for consumption during processing. Firstly, the ratio of non-edible to edible parts of cereal plants will decrease as non-edible parts are separated from the grain. An example of this is the breaking of the ears with a threshing flail and removal of the straw, glumes and rachises by sieving, flinging and winnowing. Secondly, the ratio of weed seeds to grain will also decrease as weeds, which are unwanted in both food and seed, will be sorted away with different techniques. Because all sorting relies on size and/or weight, weeds with weights and shapes similar to those of grain will be the last to be removed. Thirdly, small and large cereal grains may be sorted into batches of different size (Hillman, 1981; 1984; Viklund, 1998; Stevens, 2003; Fuller *et al.*, 2014). From historical records we know that grain was sorted into categories from the very best, known as *prime grain*, which was used for sowing, through mid-grain, which was used as food, to the smallest, the so called *tail grain*, which was regularly mixed with straw and chaff and given to animals, but could also be consumed by people in lean years (Erixon, 1956; Engelmark, 1989; Larsson, 2017).

Ethno-archaeological *middle-range* studies such as the one by Jones (1990) provide real-life demonstrations of the changes in botanical assemblages that occur over the course of an operational sequence. Using ternary graphs, Jones has been able to show that assemblages from different processing stages have distinct ratios of grain to weeds to rachises (Figure 3a). Such modern data is useful for interpreting archaeobotanical assemblages, but as Jones rightly points out, we must be aware of possible differences in the handling of different crop species (her study concerned barley and naked wheat). Furthermore, the precise composition of botanical assemblages at specific points during processing may vary

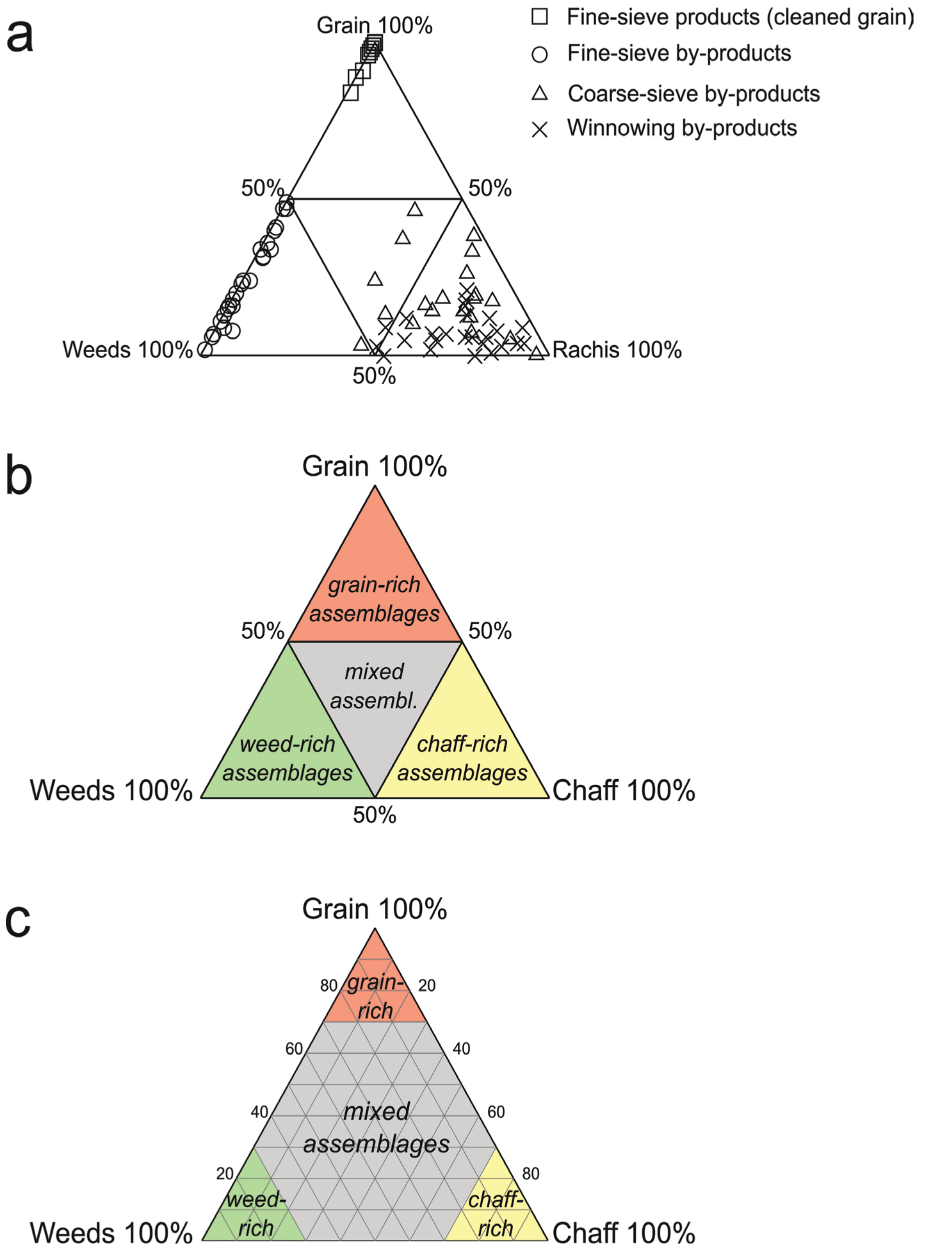

Figure 3. Ternary graphs as a tool for categorising charred archaeobotanical assemblages: a) the real-life compositions of botanical assemblages from different stages of crop processing from 20th century Greece (after Jones, 1990); b) an often-used general categorisation into grain-rich, weed-rich, chaff-rich and mixed assemblages (after Veen van der and Jones, 2006); and c) the categorisation used in this study, with the cut-off points for non-mixed categories set stricter than in b.

from one community to another, or even between individual farmers (Jones and Halstead, 1995) due to differences in agricultural habits and different concepts of what the desired product is supposed to be. For these reasons, some studies use a simplified categorisation of the botanical record into grain-rich, weed-rich and chaff-rich assemblages when comparing samples, features, houses and sites (Jones, 1985; Veen van der and Jones, 2006; Figure 3b).

Because the activities which create differently-composed archaeobotanical assemblages tend to be performed in different parts of a settlement, the inference of the operational stages of botanical assemblages can offer clues about the functions of spaces. Identification of cleaned grain can, for example, help delineate storage areas; concentrations of chaff and rachises can define threshing areas, *etc.* (*e.g.* Maier and Harwath, 2011; VanDerwarker *et al.*, 2015).

3.2. The carbonisation event and deposition of carbonised plant macro remains in postholes

A precondition for inferring the operational context of an assemblage is defining the nature of the carbonisation event, and how the material may have become deposited in posthole fills. Often a posthole will contain more than one fill (Engelmark, 1985). The *primary fill* was intentionally packed around the post to keep it in place. Presumably it consists mainly of the topsoil and subsoil that was dug out in preparation for the raising of the post. The primary fill tends to be either devoid of carbonised plant material or, in the case of multi-phased settlements, it may contain material from preceding habitation phases. Sampling of the primary fill is thus not relevant for studying the structure to which the posthole belongs. The *secondary fills* are the deposits which made their way into a posthole during or after use.

This infilling will have begun already during the use of the house as the posts decomposed and soil and other matter from the surrounding floor layers fell in. After a house was abandoned, disassembled or destroyed, for example by a fire, more material may have made its way into the posthole. Any resulting hollows presumably quickly filled up with matter from the immediate proximity of the post.

Concentrations of carbonised material per litre of (secondary) posthole fill can be an indicator for whether a house is burnt or unburnt but need to be evaluated carefully as they may be misleading. This is partly due to chance. We must not forget that archaeological postholes are merely the lowermost "stumps" of the original features. The parts of the postholes closest to the original floor surface have in most cases been destroyed by biological activity in the topsoil and/or hundreds of years of land use. It is often difficult to establish to what extent these remnants represent the original situation.

Carbonisation itself can occur at many steps during plant processing, but some stages will probably be over-represented since they involved the use of fire or were performed near fires (Hillman, 1981; 1984; Engelmark, 1989; Viklund, 1998). Carbonisation, moreover, may have occurred on a small scale during everyday activities or be due to accidents where large volumes of material became carbonised all at once (Hillman, 1981; 1984; Engelmark, 1989; Viklund, 1998). In unburnt houses, we can theorise that deposition of charred material should mainly have occurred around fireplaces or in refuse collection areas. The resulting archaeobotanical assemblages should in these cases be seen as 'palimpsests' of many individual actions over longer periods of time. If, on the other hand, a house burned down, carbonisation would have become possible anywhere in the house and plants which normally run little risk of being exposed to heat could have become preserved. The resulting archaeobotanical assemblages from such cases will reflect a shorter time span in the history of a building, showing something akin to a "photograph" of what was in the house at the time of the fire. A signal from the preceding sporadic "everyday" carbonisations will in these cases still be embedded in the assemblage, but studies in southern Scandinavia indicate that house-fire carbonisations outnumber everyday charring to such an extent as to make the latter invisible (Henriksen and Robinson, 1996; Viklund, 1998; Gustafsson, 2000; Henriksen, 2003; Moltsen, 2011; Grabowski and Linderholm, 2014).

Concretely, the difference between burnt and unburnt houses should be visible both as differences in the concentrations of burnt material (grains, seeds, charcoal) per litre of sampled soil, as well as differences in distribution (Figure 4). Unburnt

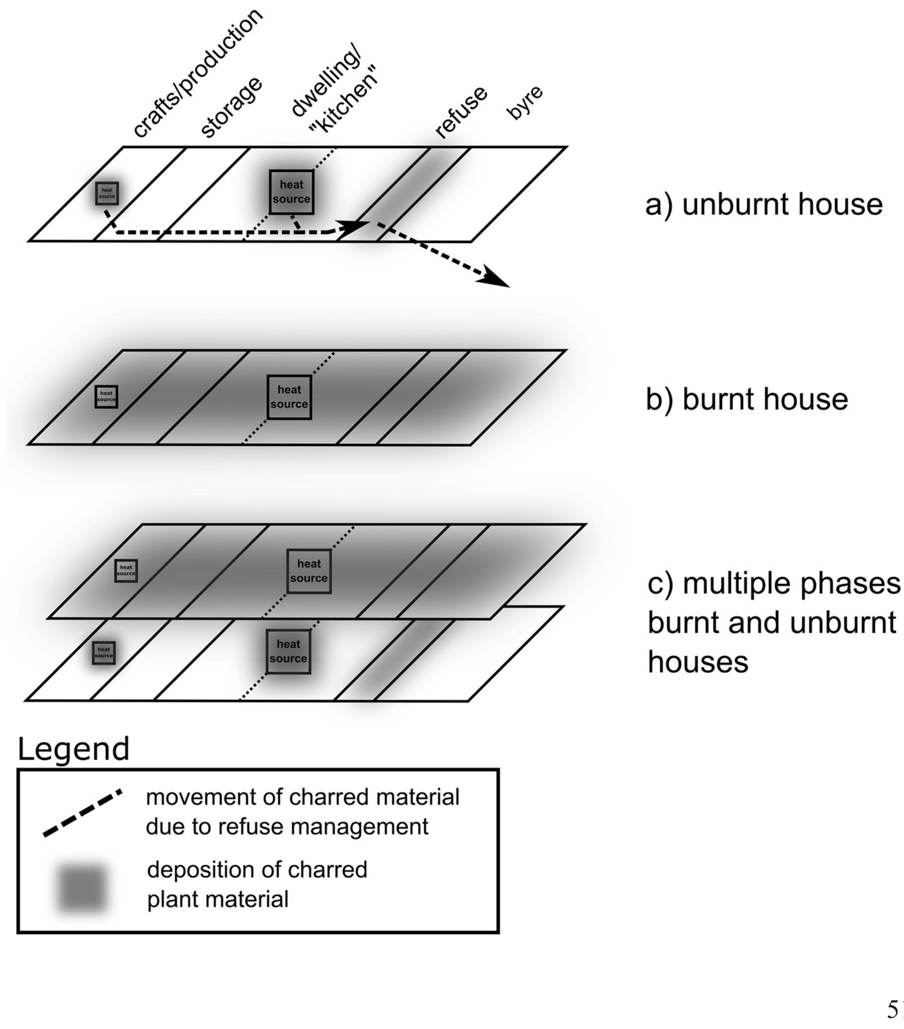

Figure 4. Schematic representation of the expected pattern of deposition of carbonised plant material in burnt and unburnt houses.

houses should show an uneven distribution with "peaks" in some areas, while in burnt houses, where all plants (including the house structure) could carbonise, charred material should be present in every part of the house.

Some final considerations to take into account are that houses may have been only partially affected by fire, or that they may have been burnt down intentionally for functional (clearance) or symbolic (abandonment ritual) reasons. In both cases, they may have been emptied or modified beforehand.

4. Material and method

4.1. The analysed house remains

A total of twelve structures have been analysed, distributed over seven farmsteads on four sites in east-central Jutland and Funen. A summary of the houses, their dating and references to the excavation reports is provided in Table 1. Common to all cases, and underpinning their relevance for this study, was that the houses were comprehensively sampled, with material gathered from *all* segments of each house (see Figures 6–9).

House K5 at Flensted, K1 at Skovby Nygård and A11312 at Geved Vest are all single phased constructions with no overlap of other habitation phases. The southern end of house A11320 at Gedved Vest was overlapped by a smaller structure, but this structure has, by means of ^{14}C-analysis, been established as younger. Its postholes did not intersect those of A11320. The risk of contamination is considered as negligible. All of the mentioned houses are assumed to have been the main longhouse within their respective farmstead except for K1 from Skovby Nygård. This house was situated just outside a large farmstead enclosed by a saddle-roof fence. It seems, however, to have been too large for an ancillary "shed". Furthermore, a well-preserved, high-quality, imitation of a Frankish drinking vessel was found in the house, possibly indicating a domestic or ritual setting.

The most complex site is Odensevej (Figure 9), where samples derive from both longhouses and outbuildings. The site also contains three distinct phases (phase 2, 3 and 4; phase 1 was situated outside the area of this study) of which the latter two were enclosed by saddle-roofed enclosures. The enclosure was unfortunately not sampled. The structures of the later phases were constructed over those of the earlier ones but there is only one instance where two postholes intersect.

4.2. Sample preparation and determination of botanical material

All botanical material was extracted by flotation and collected with <0.25 mm sieves or nets. The samples were inspected under stereo microscope and the botanical material was determined with the help of reference literature and modern comparative collections.

Table 1. Summary of the analysed houses and the field interpretation about whether the houses are burnt or unburnt. All radiocarbon dates are shown as cal. 2σ.

House	Date	Presumed burnt/ unburnt before analysis	Number of samples (analysed volume)	Original excavation and archaeobotanical report/ publication
Flensted House K5	^{14}C: AD 240–381 ^{14}C: AD 260–416 ^{14}C: AD 260–421	Unburnt? No traces of fire	18 (70 litres)	(Grabowski, 2015a; Schifter Bagge, 2016)
Skovby Nygård House K1	^{14}C: AD 336–533 ^{14}C: AD 405–575 ^{14}C: AD 382–536	Not interpreted	6 (25 litres)	(Jensen, 2013; Grabowski, 2015b)
Gedved Vest House A11312	^{14}C: AD 417–570 ^{14}C: AD 406–556 ^{14}C: AD 412–545	Not interpreted	13 (66.5 litres)	(Hansen, 2012; Grabowski, 2013; 2014a)
Gedved Vest House A11320	^{14}C: AD 352–537 ^{14}C: AD 411–543 ^{14}C: AD 352–537	Not interpreted	7 (31 litres)	(Hansen, 2012; Grabowski, 2013; 2014a)
Odensevej phase 2 (longhouse house K1 and ancillary building K12)	^{14}C: AD 135–340	Limited traces of fire, unknown whether from house fire or use of hearth(s)	15 (73 litres)	(Christensen and Hansen, 2008; Grabowski, 2009; 2014b)
Odensevej phase 3 (longhouse K2 and ancillary buildings K4 and K6)	Stratigraphy: later than phase 2, earlier than phase 4	Unburnt, no traces of fire	18 (81.5 litres)	(Christensen and Hansen, 2008; Grabowski, 2009; 2014b)
Odensevej phase 4 (longhouse K3 and ancillary buildings K5 and K7)	^{14}C: AD 411–543 ^{14}C: AD 433–604	Clear traces of fire	26 (110 litres)	(Christensen and Hansen, 2008; Grabowski, 2009; 2014b)

4.3. Data processing

The categorisation of houses as burnt or unburnt and the inference of the probable stage of operation of the botanical material, following the concepts outlined in Section 3, has been pursued with the following approach:

- Comparison of the archaeobotanical results to relevant observations made during excavation/post-excavation (summarised in Table 1).
- Comparison of the concentrations of carbonised material in the posthole fills. Because charcoal in burnt houses can also originate from the structure itself, charcoal and grains/seeds/chaff are calculated separately (Table 2).
- Comparison of the ratios of cereal grain to weeds to chaff with the help of ternary graphs (Figure 5). The criteria for categorising the assemblages have been set somewhat stricter than in, for example, van der Veen and Jones (2006). Assemblages are categorised as grain-rich, weed-rich or chaff-rich if they contain 70% or more of a single crop plant component (Figure 3c).
- Visualisation of the distribution of carbonised material in space, overlain on house plans. One plan shows the distribution and concentrations of charcoal, the other the distribution and concentrations of seeds/fruits/grain (Figures 6–9). On the second plan, the symbols are colour coded with red for grain-rich, green for weed-rich, yellow for chaff-rich, and grey for mixed assemblages, *i.e.* the same colour codes as in Figures 3c and 5.
- Where enough intact/non-deformed grain was present in both grain-rich and weed-rich assemblages, comparison of the grain sizes from different presumed processing stages (Figure 10). The dimensions of the grains were measured from calibrated photographs with the ImageJ software (Anon. n.d.).

5. Results and interpretation of spatial patterns

5.1. General composition of the botanical material from the houses

The carbonised material in the analysed houses consists mainly of grain and arable weeds/ruderals. The most numerous crop is hulled barley (*Hordeum vulgare* s.l. var. *vulgare*). Rye (*Secale cereale*) is also present and may have been either intentionally grown or present as a weed (Mikkelsen and Nørbach, 2003; Robinson *et al.*, 2009; Grabowski, 2014b). At Odensevej, there is also a smaller presence of bread wheat (*Triticum aestivum* subsp. *vulgare*). Oat is also present, but the sporadic finds are assumed to derive from wild oat (*Avena fatua*). The weeds are dominated by nitrophilous annuals with goosefoot (*Chenopodium album*) and pale persicaria/redshank (*Persicaria lapathifolia/maculosa*) accounting for most of the finds. It is assumed that these plants were growing in the fields with the grain and were unintentionally brought in with the harvests.

5.2. One unburnt and one burnt house at the nearby sites of Flensted and Skovby Nygård

Houses K5 from Flensted and K1 from Skovby Nygård provide the most easily interpretable records in relation to the theory outlined above. They also appear to be each other's opposites in terms of formation of the archaeobotanical record. Table 2 and the ternary graph (Figure 5) show house K5 to have the lowest concentrations of both charcoal and grains/seeds. Most of the samples fall in the category "grain-rich",

Table 2. Minimum, mean and maximum concentrations of charcoal and other plant macro-remains (mainly grain and seeds/fruits) in the analysed houses.

	MACRO REMAINS (n/l)			CHARCOAL (ml/l)		
	min	avg	max	min	avg	max
Flensted, K5	0	1.7	6	0.2	4	12.5
Skovby Nygård, K1	1	59.9	194.9	5	14.4	28
Gedved Vest, A11312	0	16.9	50.6	2.2	14.9	40.2
Gedved Vest, A11320	2	22	100.9	15	23.6	40
Odensevej, phase 2						
longhouse	1	15.5	47.8	1.8	4.5	10
outbuildings	0	0.2	0.3	0.2	1	2.4
Odensevej, phase 3						
longhouse	0.2	11.5	76.3	0.1	1.9	6.5
outbuilding N	0.2	0.8	2.2	7.4	11.5	20
outbuilding S	0	0.6	2	1.6	3.2	5
Odensevej, phase 4						
longhouse	0	150.4	801.6	3.6	43.8	160
outbuilding N	0	7.1	33.4	0.8	3.6	7.6
outbuilding S	0	0.1	0.2	0.2	4.1	10

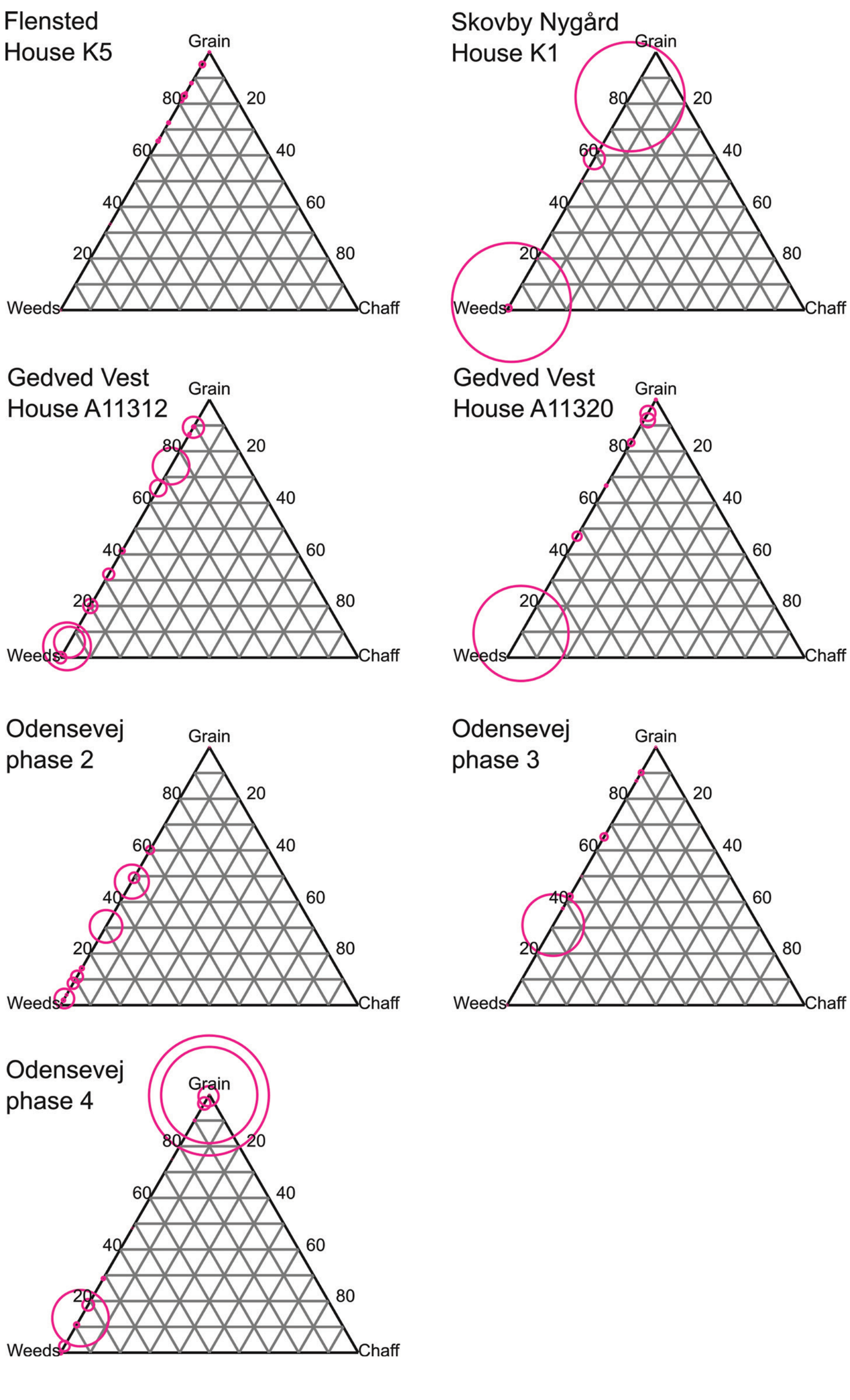

Figure 5. Ternary graphs showing the ratios of grain to weeds to chaff as well as the total concentration of material (size of circle) in the samples from the analysed houses. The circles showing the concentrations are to scale for all graphs except Odensevej, phase 4, where the size has been reduced to fit inside the Figure. For summary data of the concentrations of carbonised material see Table 2.

but it is important to emphasise that we are dealing with only handfuls of kernels per sample. Interestingly, both the grains/seeds and the charcoal show a clear spatial trend (Figure 6), with higher concentrations around the entrances (marked with arrows on the plan) and in the western half of the house. Hardly any material is present in the postholes of the eastern third of the house. Seen within the framework of the theory outlined in Section 3, this indicates an unburnt house, probably with the hearth situated to the west of the entrances. The fact that material was also found in the entrance area may indicate that this was the route along which burnt refuse was transported (swept?) out of the house. House K1 from Skovby Nygård, in contrast, shows charcoal concentrations on average four times that of K5 and the second highest concentrations of macro remains of all the analysed houses. The ternary graph (Figure 5) shows that the botanical material is mainly present in two postholes and consists of one grain-rich and one weed-rich assemblage, while the

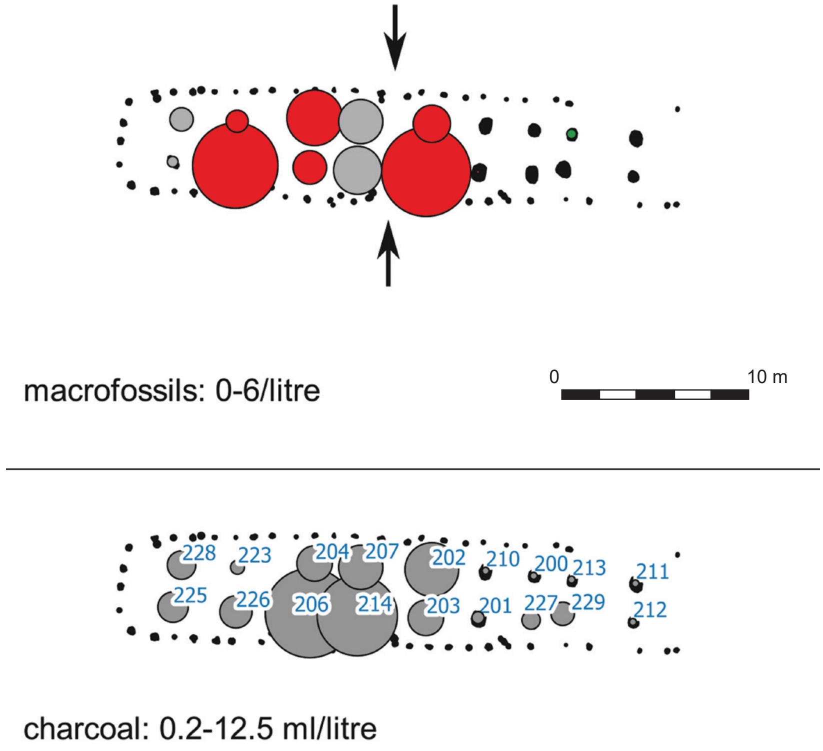

Figure 6. Spatial distribution of grain/seeds (above) and charcoal (below) in House K5 at Flensted. The symbols showing the concentrations of grain/seeds are colour coded with red for grain-rich assemblages, green for weed-rich assemblages, yellow for chaff rich assemblages and grey for mixed materials (*cf.* Figure 3). The charcoal overlay also shows the sample numbers. GIS-data courtesy of Skanderborg Museum.

spatial distribution map (Figure 7) shows that the weeds and grain are present in the opposite ends of the house, with the grain in the west and the weeds in the east. It is unlikely for such large amounts of grain or weed seeds to carbonise from everyday activities. This, in combination with the high concentrations of charred material indicates that this house burnt down.

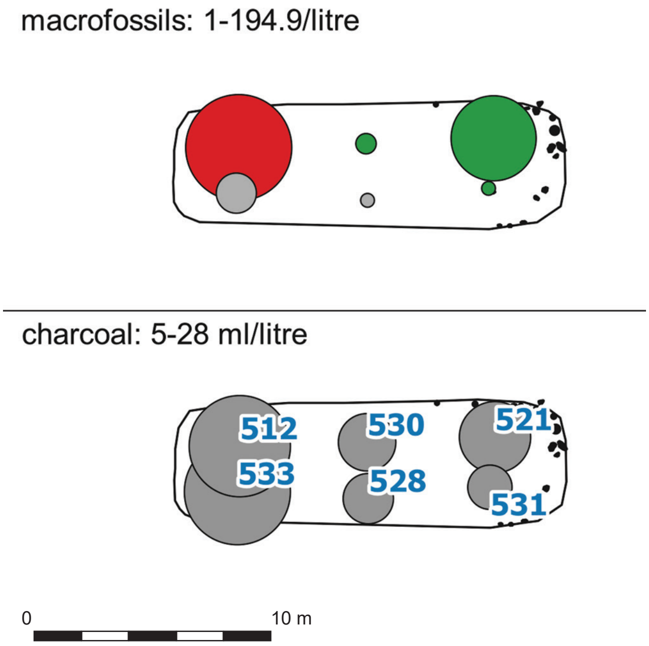

Figure 7. Spatial distribution of grain/seeds (left) and charcoal (right) in House K1 at Skovby Nygård. The symbols showing the concentrations of grain/seeds are colour coded with red for grain-rich assemblages, green for weed-rich assemblages, yellow for chaff rich assemblages and grey for mixed materials (*cf.* Figure 3). The charcoal overlay also shows the sample numbers. GIS-data courtesy of Skanderborg Museum.

5.3. Two similar houses at Gedved Vest

Houses A11312 and A11320 from the site of Gedved Vest were situated close to each other. The ^{14}C-data makes possible that they were contemporaneous, but they may also represent two habitation phases on the same spot. No hypothesis of whether the houses were burnt or unburnt was proposed before the analysis. The concentrations of charcoal in both houses are comparable to K1 from Skovby Nygård, while the amounts of grain and weed seeds are lower, but still distinctly higher than at Flensted. The ternary graphs (Figure 5) for these houses show similar patterns where the largest assemblages in each house are, just like at Skovby Nygård, to be found opposite to each other in the categories grain-rich and weed-rich assemblages, while the smaller assemblages are mixed. Another striking similarity is the spatial distribution of the material (Figure 8). In both houses, the grain-rich assemblages are situated in the NE-end, while weeds are concentrated in the centre of the house. This pattern seems clearer in House A11320, but this is partly due to the cut-off point of the categorisation as the mixed (grey) assemblages in the north-east of A11312 fall just outside the range for "grain-rich". Following the same logic as for K1 at Skovby Nygård, these houses are interpreted as burnt. The even distribution of charcoal throughout the houses seems to support this assumption. There are no obvious "peaks" and the pattern may thus reflect charcoal from the house structure itself.

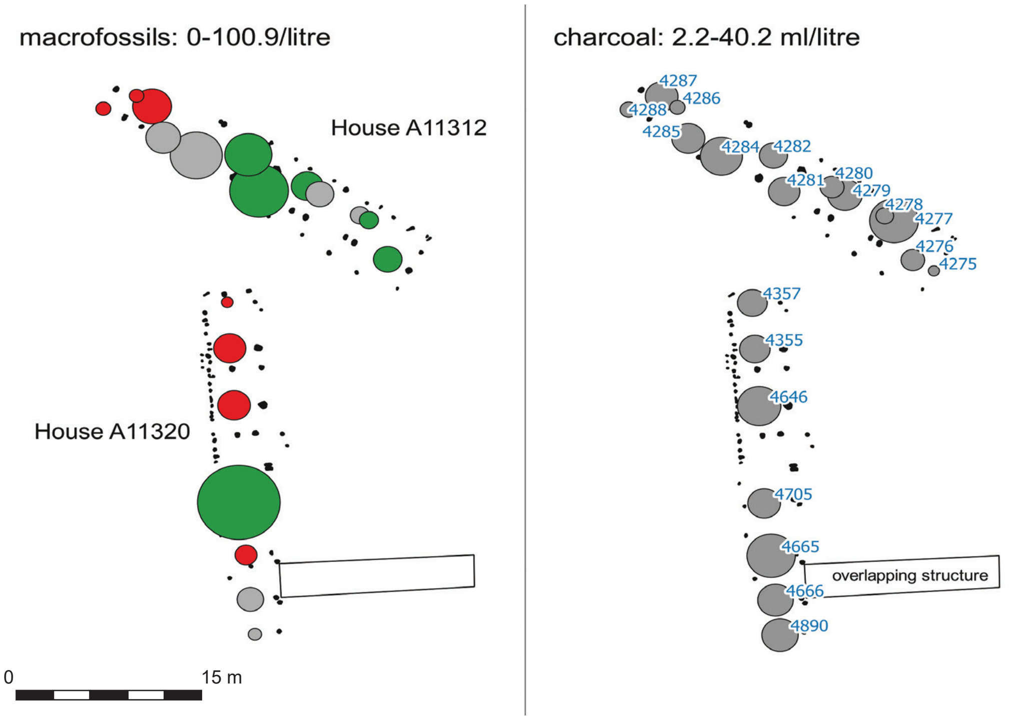

Figure 8. Spatial distribution of grain/seeds (left) and charcoal (right) in houses A11312 and A11320 at Gedved Vest. The symbols showing the concentrations of grain/seeds are colour coded with red for grain-rich assemblages, green for weed-rich assemblages, yellow for chaff rich assemblages and grey for mixed materials (*cf.* Figure 3). The charcoal overlay also shows the sample numbers. GIS-data courtesy of Horsens Museum.

5.4. A three phased farm at Odensevej

This site is the most complex of the ones included in this paper because the three construction phases are superimposed on top of each other. However, in only one case did a feature from one phase (phase 3) intersect (barely) a posthole belonging to a previous one (phase 2). These postholes were qualitatively compared but showed no obvious similarities indicative of contamination. The latest phase (phase 4) showed traces of extensive fire. The middle phase (phase 3) showed no evidence of burning, while the earliest phase (phase 2) did show some higher presence of burnt materials, but less prominently than in phase 4 (Christensen and Hansen, 2008).

Starting with the latest phase (phase 4), the botanical analysis seems to confirm the excavator's interpretation of this house being affected by fire. The concentrations of charred material (Table 2) are the highest of all included in this paper and the individual samples can clearly be categorised as either grain-rich or weed-rich (Figure 5). The distribution of this material in space (Figure 9) is recognisable. Just as at Gedved Vest, there is a concentration of grain in the west and a concentration of weeds in the east. Notable, also, is that the outbuildings show much lower content of carbonised material than the longhouse. This probably means that only the longhouse was affected by fire.

The results for the middle phase are also consistent with the field observations that this was an unburnt house. The concentrations of carbonised material are low, and the assemblages are mixed. The longhouse shows a higher presence of both charcoal and grains and seeds in its western section, and little material in the east. This distribution is similar to the one observed in the presumably unburnt house at Flensted. One of the outbuildings of phase 3 shows higher concentrations of charcoal than the longhouse, but not as high as those in the houses which have so far been presumed as burnt. This house may have fulfilled a function in the handling of burnt refuse from the longhouse, or it may have contained its own fireplace.

The earliest phase (phase 2) is one with more contradictions. The concentrations of both charcoal and grain and seeds are overall low which should indicate an unburnt structure. However, while most samples are mixed, there is also a group of weed-rich assemblages distributed clearly in the central and eastern part of the house. In accordance with the theory outlined at the start of the paper, it is difficult to envisage why larger amounts of weeds would become deposited in just one part of a house unless it had burnt down. Furthermore, the distribution of both seeds and grains and charcoal is even throughout the length of the house, which would be consistent with a house fire. Balancing these observations against each other seems to point towards this phase of Odensevej as also having been burnt, but for some reason the concentrations of charred material in the postholes remained low, and the assemblages became more mixed than in the other burnt houses. The fact that phase 2 was the earliest habitation phase may perhaps explain some of the contradictory evidence. The constructional similarities between the phases of Odensevej

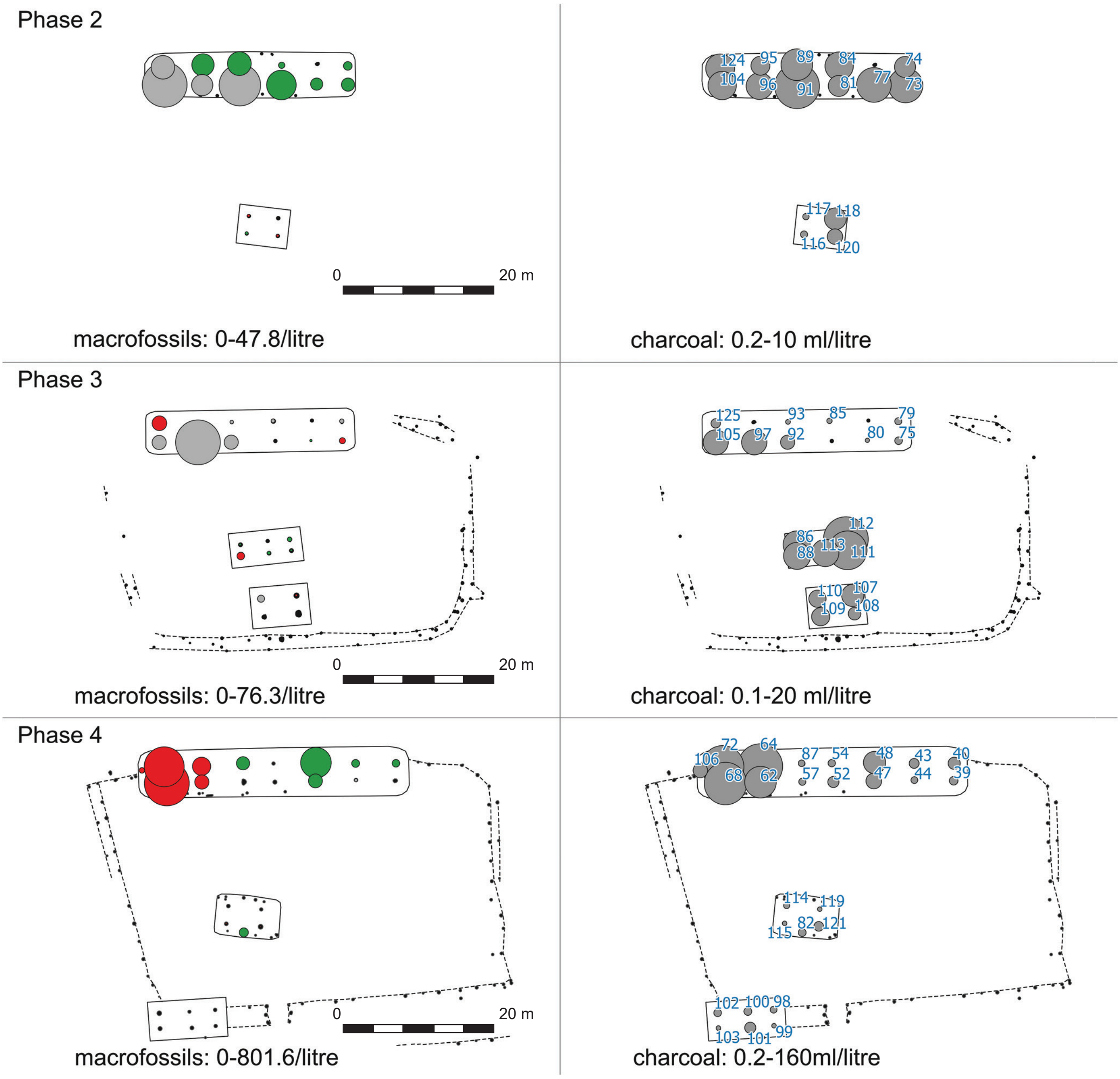

Figure 9. Spatial distribution of grain/seeds (left) and charcoal (right) at a three phased farmstead at Odensevej. Phase 2 (top), phase 3 (middle) and phase 4 (bottom). The symbols showing the concentrations of grain/seeds are colour coded with red for grain-rich assemblages, green for weed-rich assemblages, yellow for chaff rich assemblages and grey for mixed materials (*cf.* Figure 3). The charcoal overlay also shows the sample numbers. GIS-data courtesy of Odense Museum.

and the consistent placement and alignment of the various farm elements seem to indicate a strong continuity of habitation without significant hiatuses. This probably means that phase 3 was constructed immediately after the suggested fire of phase 2. It is perhaps possible that the immediate re-utilisation of the area and the building of a new farmstead may have disturbed the charred material lying on the ground, resulting in more mixed assemblages. It is also possible that construction activities, such as levelling of the ground, affected the flow of carbonised material into the posthole fills. A final explanation could be that the house was intentionally burnt to clear the area, perhaps after it was emptied and/or partly deconstructed, in which case there would have been less material to carbonise.

5.5. Grain measurements as supporting evidence for the inferred processing stages

A final piece of botanical evidence are the sizes of the cereal grains themselves in assemblages categorised as either grain-rich or weed. Logically, grain recovered from weed-rich assemblages should be smaller than that in the grain-rich assemblages of the same house.

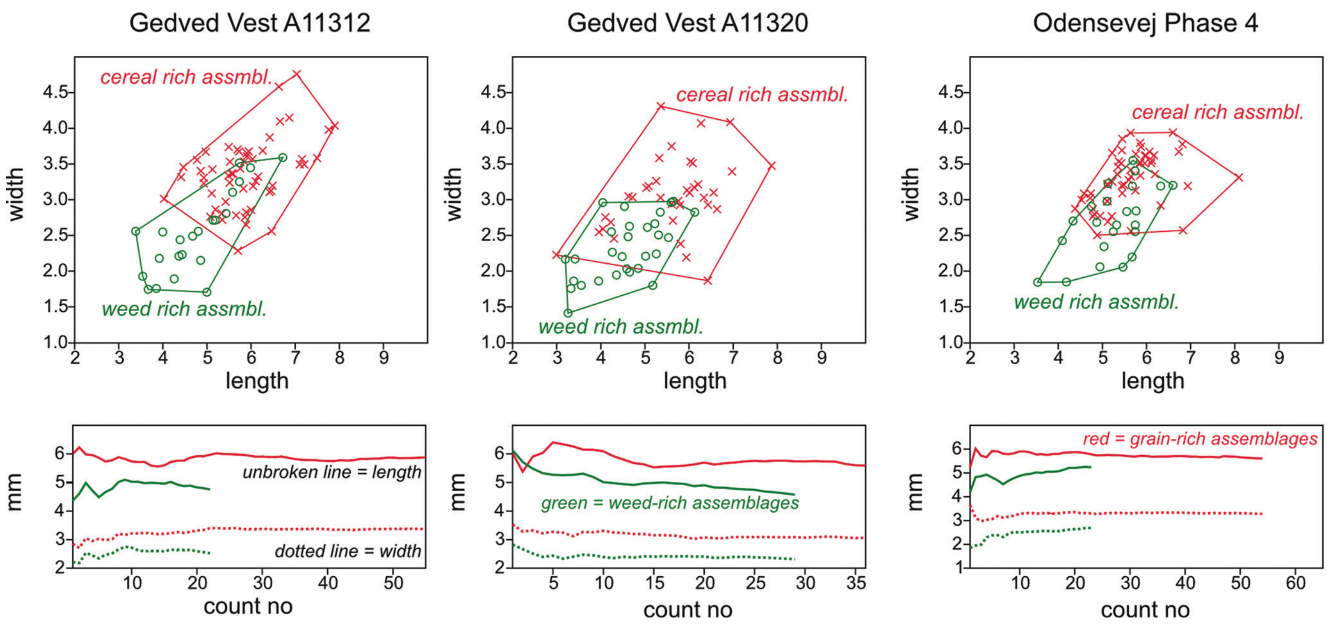

Figure 10. Grain sizes of hulled barley (Hordeum vulgare var. vulgare) from grain-rich and weed-rich assemblages at Gedved Vest, houses A11312 and A11320 and Odensevej, phase 4. Top row shows scatter plots of the individual measurements while the bottom row shows the cumulative mean for the lengths and widths from each type of assemblage.

In this paper only the grain sizes for the two houses of Gedved Vest and phase 4 of Odensevej were measured. In the other cases there was insufficient intact grain in the weed-rich assemblages to attempt a comparison. The only cereal which was sufficiently present to allow for comparison was hulled barley.

The results (Figure 10) show that there is a fair amount of overlap between the assemblages and that the sample sizes in some cases (particularly for the weed-rich assemblages) could have been larger since the cumulative mean graphs have not attained a flat line. Still, the overall trend is obvious. In all three cases the average length and width of grain in grain-rich assemblages is around 1 mm or more larger than that of the corresponding weed-rich assemblage. These results thus seem to confirm the interpretation of A11312, A11320 and phase 4 of Odensevej as outlined above.

6. Discussion

6.1 Designated space in late Iron Age houses

As seen from the results, 3rd–6th century houses display a binary pattern of distribution of carbonised plant macro remains. This may indicate that the houses were divided into at least two main spaces with different functions. Such interpretation is consistent with the established archaeological understanding of these structures (see Section 1). Because this pattern has also been observed at numerous other sites in Denmark and southern Sweden (Viklund, 1998; Henriksen, 2003; 2007; Andréasson, 2008; Andreasen, 2015; Jensen, 2015; 2019), we are possibly seeing the botanical reflection of a widespread and well-established tradition of ordering space.

In houses which are presumed to be unburnt, the twofold division of space is seen as concentrations of charred material in one half of the house and an absence of the same material in the other. The assemblages in these cases generally show a mixed character and low total concentrations of charred remains. This would be consistent with small-scale and fairly random carbonisations during everyday activities. The peaks in charred material may reflect the locations of household hearths.

In houses which seem to have been burnt, the image provided is sharper; the west/north-west sections of the houses show sizable grain-rich assemblages, which could derive from the storage of cereals. It is unknown whether this is large-scale storage of entire harvests or of smaller batches brought into the house before consumption. Large assemblages of arable weeds occur to the east/south-east of the house centre. Also notable is that the weed-rich assemblages tend to cluster in one or two pairs of postholes. This could mean that grain cleaning occurred either in a separate room or in a designated corner of a larger space. Both these alternatives are sensible as it is known from historical sources that pre-modern grain cleaning released hazardous amounts of dust and mould into the air which over time could lead to a condition known as threshers-lung. This health problem is mentioned already in medieval Danish texts and may well have been recognised also during the late Iron Age (Mårtensson and Svala, 1998; Rylander and Schilling, 1998).

6.2. Processing but not threshing?

In south Scandinavian overviews of Iron Age farming, it is regularly suggested that the threshing of cereals was performed inside houses (Jensen, 2003, p.218; Näsman,

Figure 11. Depiction of the threshing of grain with flails in the Luttrel Psalter (mid-14th century). Based on the results of this study, it appears that threshing in the 3rd to 6th century AD was not performed inside the longhouses but may have been performed outdoors. Source: Wikimedia Commons, image in public domain (CC0 1.0).

2009, p.103), for example by Näsman, who writes that: "as was observed by the Greek explorer Pythaeas [of Massalia] already in the 4th century BC, threshing was performed indoors". Viklund (1998) also refers to historical records of indoor threshing when interpreting Iron Age houses. In this study, however, no chaff-rich assemblages have been observed. The weed concentrations in the houses, as understood through the lens of ethnographic comparative data (see Section 3.1), seem rather to reflect the fine sieving of grain, which is a processing stage that occurs after threshing. This could partly be an effect of preservation. Rachises, straw and glumes are more easily destroyed by fire than grain and the seeds of some weedy species (Boardman and Jones 1990). However, since chaff does occur in other contexts from roughly this period (*e.g.* in drying kilns, Grabowski, 2015b), poor preservation cannot fully explain the absence of such remains in the houses.

In England, where comparison of grain, weed and chaff-rich site assemblages has a longer history, the absence of early processing stages has sometimes been interpreted as an indication of "consumer sites" which got partly processed grain from "producer sites" (see Veen van der and Jones, 2006 and the summarised debate therein). In a Nordic setting, such interpretation would contrast against the current understanding of mid-1st millennium economy, where farmsteads are assumed to have predominantly functioned as independent productive units engaged in the full spectrum of crop and animal husbandry (Hedeager and Kristiansen, 1988; Hvass *et al.*, 1988; Jensen, 2003; Holst, 2010; Hansen, 2015). It is therefore more likely that that the absence of remnants from the early processing stages means that these phases of processing were performed in ways and locations which have made them archaeobotanically less visible or less likely to be sampled.

6.3. Stalling but no fodder?

In northern Sweden, some 700–900 km north of the case studies of this paper, several analyses of burnt down Iron Age longhouses have revealed concentrations of the seeds/fruits of grasses (Poaceae), rushes (*Juncus* spp) and sedges (Cyperaceae) in what is presumed to have been the byres (Engelmark, 1981; Ramqvist, 1983; Wennberg, 1985; Viklund, 1998). These finds have been interpreted as evidence of the storage and use of fodder for winter-stalled animals. Similar finds are absent in the houses of this study and appear to be generally rare in houses from southern Scandinavia. This could indicate that fodder was stored more rarely or in different ways in the south than in the north. This should, however, not be seen as contradicting evidence for the presence of byres in houses with animal stalls, or where phosphate studies indicate their presence. The key difference may rather have been in the nature of the stalling. Animal fodder may, for example, have been stored outside of the longhouses where it may not have been extensively exposed to fire, for example in the outbuildings or under the roofed enclosures. Climate may be another factor. In southern Scandinavia it is usually possible to practice grazing throughout the year without any harm to the animals. In fact, Zimmermann (1999) lists numerous reasons for why prolonged stalling is unhealthy for both people and animals. Possibly, the animals were only brought into the stalls at night or for short periods of the year and got most of their fodder outdoors (*cf.* discussion in Kveiborg, 2009). In northern Sweden the thicker snow cover usually prevents grazing for several months of the winter, which may have resulted in different solutions for stalling and fodder storage.

6.4. Acknowledging ambiguous results

The results of the analysis of phase 2 of the Odensevej site (Section 5.4.) have already been mentioned as more ambiguous than those of the other cases. The concentrations of charred material point to this being an unburnt farmstead, while the distribution pattern and assemblage composition indicates a fire. In Section 5.4., this is discussed as a possible effect of an assumed immediate re-utilisation of the area for another phase of habitation. On a similar note, in Section

3.2, where the principles of this study are described, it is noted that chance will always have been a factor in how the postholes of houses filled up with material and how they became preserved for posterity.

A more nuanced way of framing the unpredictability of posthole fill formation is to acknowledge that the postholes have unique, diverse and complex "biographies". Theuws (2014, p.319) has schematically outlined more than a dozen ways in which posts may have been "retired": among others, through variations of demolition, where posts were either broken off above ground or completely dug out, or by abandonment, where posts were allowed to slowly rot away. At Butser Ancient Farm an unexpected result of a study was that the posts of an experimental round-house rotted away at ground level after only a few years, leaving the rest standing flatly on the ground, but still steadily due to the weight of the roof (Reynolds, 1994). Since the postholes in this case were "sealed" early during the lifespan of the house, the material therein was found to reflect only the earliest stages of house use. We must assume that the way in which a house suffered "wear and tear", and how it was abandoned, has an influence on the formation of botanical posthole records.

One last complexity is that studies have occasionally indicated intentional, possibly ritual/symbolic, depositions of charred macro remains in postholes (Regnell, 1997; Jensen *et al.*, 2010). Such depositions would also have affected the concentrations of charred material. Considering these possibilities, it would seem that some ambiguity will always be a part of analysing settlement remains.

While the complexity described above could be perceived as discouraging rather than inspirational for the spatial analysis of plant macro-remains and other small artefacts, the situation can also be a starting point for qualitative interpretations of specific and unique events. The idea of a fire in phase 2 of Odensevej, followed by immediate re-building of a similar, but also larger and more substantial farmstead on top of the old one, is largely speculative. It does, however, also tell a very human story of the ups and downs of domestic life in the past.

6.5. Multidisciplinary integration

This paper has focused on the contribution that archaeobotanical analysis can make to the understanding of the use of settlement space. The limited methodological scope of this paper is partly because the presented houses did not provide much other evidence about the use of space. It has, moreover, been pursued intentionally as a demonstration of the level of detail which can be attained through botanical analysis alone.

A more complete understanding of the use of space can, however, only be achieved through solid integration of available archaeological methods. Any single proxy for the human use of space is bound to quickly reach a "ceiling" beyond which few meaningful inferences can be made. This can be illustrated with the distribution of grain-rich assemblages in the western/north-western ends of the houses presented in this paper. Are these traces of a smaller-scale presence of grain brought into the house for cooking, or did these segments of the longhouses also function as the cereal stores of the farm? The latter could have been feasible, for example, on a loft above the dwelling area (*cf.* discussion in Rowley-Conwy, 2000). Only by engaging in multiproxy studies, where several methods with overlapping abilities to infer past activities, but different ways in which they are limited by archaeological fragmentation, can a more complete understanding of the use of space be achieved.

Botanical analysis of house features is ideally suited for integration into smarter ways of excavating and analysis. Even when the use of space is not the main aim of a study, house features must regularly be sampled for datable material. The screening of samples for organic material for radiocarbon dating can thus also double as an inventory of suitable contexts for spatial analysis. Another advantage is that botanical analysis relies on the use of standardized sieve mesh sizes, which are also useful for collecting other materials (bone, pottery, wall daub, *etc.*). In many ways this method is preferable to hand collecting during excavation, since it is consistent and does not miss even smaller finds. Some of the effort involved in collecting botanical material can therefore be offset by making it double as the main retrieval procedure for artefacts in posthole fills.

In my experience, the main challenges in improving the archaeobotanical analysis of settlements, as well as integrating plant macrofossil analysis into multidisciplinary projects, is less a problem of methodology than one of project design and logistics. This is positive, because once all the actors within a project understand each other, projects can be rapidly improved.

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