CHAPTER 4

JOHAN LINDERHOLM[1*], RICHARD MACPHAIL[2], PHILIP BUCKLAND[1], SOFI ÖSTMAN[1], SAMUEL ERIKSSON[1], JAN-ERIK WALLIN[1] & ROGER ENGELMARK[1]

1. *The Environmental Archaeology Laboratory, Department of Historical, Philosophical & Religious Studies, Umeå University, 901 87, Sweden*

2. *Institute of Archaeology, University College London (UCL), 31-34, Gordon Sq., London WC1H 0PY, UK*

[*] *johan.linderholm@umu.se*

Ørlandet Iron Age settlement pattern development: Geoarchaeology (geochemistry and soil micromorphology) and plant macrofossils

ABSTRACT

Macrofossil and geoarchaeological data from a variety of contexts and periods at Vik can provide either *in situ* or proxy information on the human – environment interactions at the site through time. The aim of this paper is to discuss settlement activity patterns through time and space, with special emphasis on agriculture and animal husbandry strategies. The calcareous shell bank deposits at the site led to a reduction of the amount of analysed citric soluble phosphate and are apparently also linked to very poor macrofossil preservation. The analysis shows that farming in the pre-Roman Iron Age involved animal management and manuring of fields where naked and hulled barley were cultivated. Stock was kept in the long houses. There are also indications that animals grazed along the shore. In the Roman Iron Age there is no clear evidence of keeping livestock indoors; byre residues were instead found in house-associated waste heaps, where chemical data indicate that dung was left to ferment. Near-house Roman Iron Age waste deposits were also characterised by latrine and fish processing waste, as well as by high temperature artisan residues – fuel ash and iron working materials. Analysis of soil chemical samples indicates an increase and intensification of occupation over time during the pre-Roman Iron Age and the Roman Iron Age. Viking-medieval features were also a remarkable source for monitoring latrine, byre and industrial waste, including the secondary use of water holes and wells that supplied water to both people and animals.

INTRODUCTION

The multi-period site of Vik is characterised by a natural background geology that reflects the recently emerged pattern of coastal sediments and is composed of a number of typical settlement components, which were the focus of sampling (Figures 1a-d). Of special note is the increase in emerged land from the pre-Roman Iron Age (c. 500 BC – 0, PRIA) to the Roman Iron Age (c. 1 BC – AD 400, RIA) Periods (Romundset & Lakeman, Ch. 2; Ystgaard, Gran & Fransson, Ch. 1). Data from a variety of contexts and periods, including the Migration Period

(c. AD 400 – 575, MP), and Late Iron Age (c. AD 575 – 1030, LIA), comprising the Viking Age (c. AD 800 – 1030) and the medieval periods (c. AD 1030 – 1537, see below) can provide either *in situ* or proxy information on the human – environment interactions at the site through time. The aim of this chapter is to present our macrofossil and geo-archaeological (chemistry, magnetic susceptibility and soil micromorphology) findings associated with the settlement's constructions and activities. Other laboratories also supplied pollen and macrofossil data: we are grateful for the work done by Anette Overland and Kari Loe Hjelle, Bergen University, and Annine Moltsen, Nature and Culture, Copenhagen, respectively. Their results will not be dealt with in this paper. In this paper, we will discuss settlement activity patterns through time and space, with special emphasis on agriculture and animal husbandry strategies, and how these were applied during the various periods of occupation. The macrofossil and geoarchaeological data are discussed on the basis of the archaeological appraisal. In this paper we will examine these findings in the light of the current archaeological models for Vik (Ystgaard, Gran & Fransson, Ch. 1).

Settlement components (see Romundset & Lakeman, Ch. 2; Ystgaard, Gran & Fransson, Ch. 1) include 'constructions' (long houses, pit houses, pits, cooking pits, trenches/ditches), structures associated with the 'water management' and supply (waterholes and wells), communicating 'trackways' (sunken lanes), and activities associated with 'animal management' (presumed long house byres and other zones of dung concentrations), 'waste disposal' *sensu lato* (features fills, waste heaps, farm mounds) and 'domestic' life and 'industrial' undertakings (feature fills), as well as agriculture, which is mainly peripheral to the settlement (cultivation, stock management and grazing) (see Macphail et al. 2017; Macphail & Goldberg 2018:386-489). Previous integrated studies were carried out on the E18 Gulli-Langåker Project, Vestfold and Sea-Kings Manor at Avaldsnes, Karmøy, Rogaland (Macphail & Linderholm 2017; Viklund et al. 2013).

MATERIAL AND METHODS

The two year investigation involved 322 carbonised macrofossil samples, 9 pollen and 1632 soil survey samples (CitP and MS), and the study of 53 thin sections employing soil micromorphology and SEM/EDS. In addition, a total of 576 feature samples were analysed for fractionated P, LOI, MS, and MS550.

Macrofossil studies were carried out at MAL (The Environmental Archaeology Laboratory, Umeå University, Sweden) on samples from the 2015 excavation season at Vik, while both 2015 and 2016 samples were investigated employing soil micromorphology at UCL (Institute of Archaeology, University College London) and bulk geochemical studies at MAL. Johan Linderholm (MAL) and Richard Macphail (UCL), along with other specialists, visited the site in August 2016. Four sets of methods were applied to the samples, namely 1 and 2, palaeobotanical, and 3 and 4, geoarchaeological (Figures 1b-d, Buckland et al. 2017):

1) plant macrofossil/archaeobotanical analysis (Fields A, B and C – 2015 season). Plant macrofossils from Fields D and E - 2016 season - were not analysed by MAL, but instead by Annine Moltsen, Nature and Culture, Copenhagen, due to Norwegian university of Technology and Science NTNU purchase policies.
2) pollen analysis, mainly from Field B, because of specific questions related to the use of the area between Fields B and C. (Pollen from archaeological features in Fields A, E and D

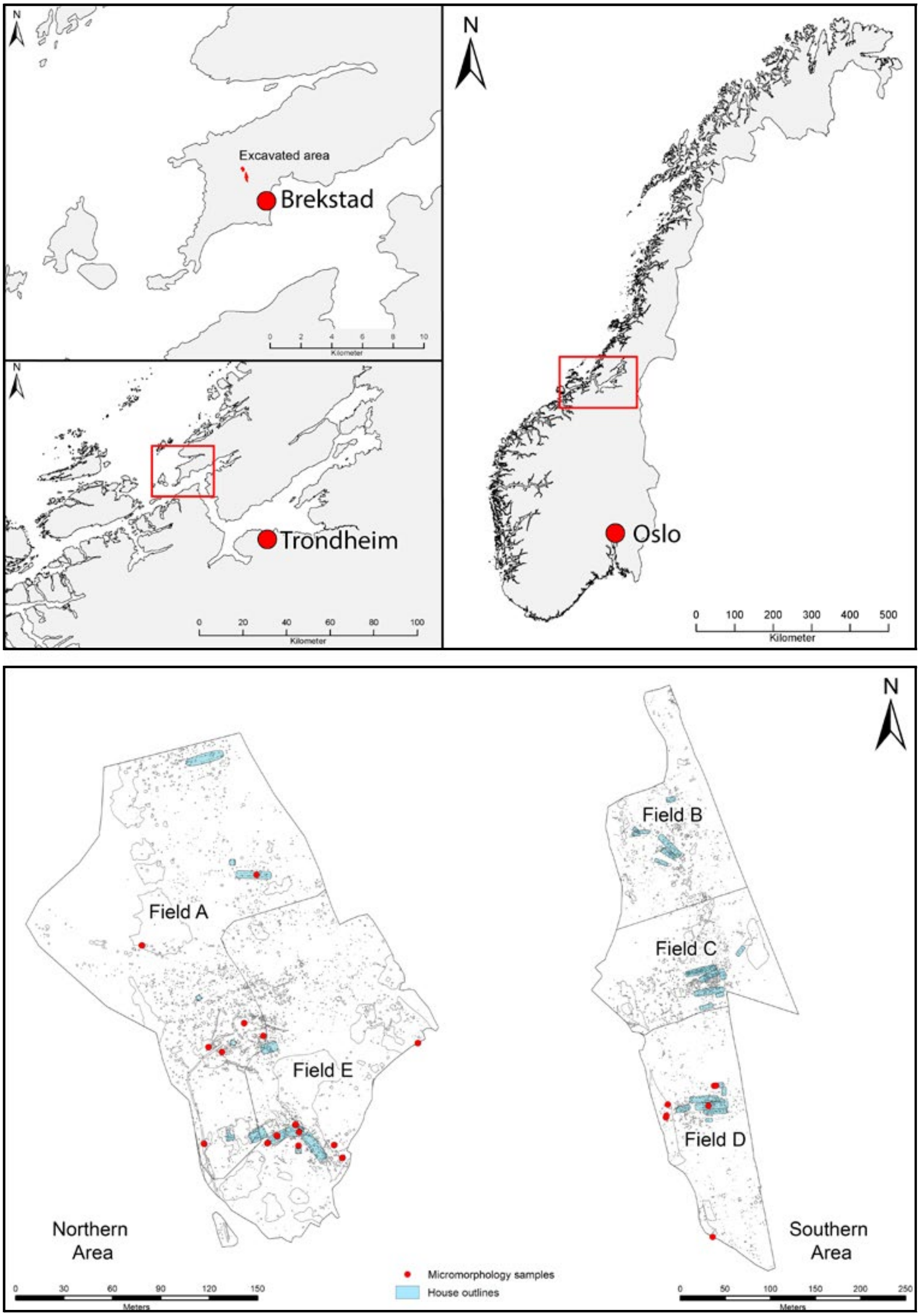


Figure 1. Location of Ørland in Norway, with the excavated area. Illustration: Magnar Mojaren Gran, NTNU University Museum.

were analysed by Bergen University, see Overland & Hjelle, Ch. 3).
3) soil chemical and magnetic susceptibility analysis (Fields A, B, C, D, and E (all Fields, 2015-2016 seasons)).
4) soil micromorphology (Fields A, D and E, which were the fields with the best conditions for micromorphology sampling – 2015-2016 seasons, Machphail 2016, 2017).

The four sets of samples were analysed as follows:

- 322 bulk samples analysed for carbonised plant macrofossils, soil chemistry and magnetic susceptibility properties, from Fields A, B and C (a small subset of 9 samples submitted for pollen analysis)
- 267 subsamples from features (where macrofossils were studied by Annine Moltsen, Nature and Culture, Copenhagen) analysed for soil chemistry and magnetic susceptibility properties (Fields D and E)
- 1632 surface survey samples analysed for soil chemistry and properties
- 53 thin section soil micromorphology samples from features, feature fills and soils were analysed.

Sampling

Sampling in connection with the excavation process was undertaken by NTNU archaeological staff, after discussion with Johan Linderholm from MAL. Bulk samples were collected from archaeological features and stored in six litre plastic buckets or three litre plastic bags. Sample size varied between 0.5 – 5.5 litres and samples were ascribed sample numbers (Prov nr). Soil survey sampling was conducted after removal of the Ap-horizon by excavator. Sampling grids were used with distances ranging from 1, 2, 5, 10, and up to 20 m depending on the archaeological contexts and need for precision. In two of the structures (Houses 2 and 4, Field C), parallel lines of samples were collected along axial lines inside the buildings.

The samples arrived in Umeå packed on pallets, and were then organized and marked with a local sample ID (MAL no). From the bulk samples, subsamples were extracted in the lab for soil chemical analysis and pollen analysis (where requested). To ensure a statistically representative subsample of the bulk samples, the material was poured out on a tray and c. 10 ml of soil representing the whole sample collected and processed separately according to analysis method (see method descriptions below). All samples were assigned a local ID and stored in a drying room at 30°C before processing.

Undisturbed soil micromorphological samples (soil monoliths) were collected employing metal boxes; these were received at the Institute of Archaeology, UCL, where they were assessed and subsampled as necessary.

Plant macrofossil analyses

Prior to analysis, samples were stored in a drying room (+30°C) to eliminate moisture and reduce the risk of mould which could prevent accurate ^{14}C dating. Sample volume was estimated before floatation and washing with water through 2 mm and 0.5 mm sieves. The resulting material (flotant) was sorted and identified under a stereo microscope (8x) with the help of MAL's plant macrofossil reference collection and reference literature (Cappers et al. 2006). Only charred/carbonised material was extracted from samples, and the amount of woody charcoal estimated at this time. (Note that non-charred material found in carbonised contexts should always be treated with suspicion as there is a high probability of it being contaminant). Material for

^{14}C analysis was extracted during identification, and weighed. Charcoal proportions, when given, were assessed in addition to any seeds and straw fragments found in the samples. Charcoal was returned to NTNU for submission to another laboratory for charcoal analysis and additional ^{14}C dating.

Plant macrofossil identifications at all levels of detail are referred to as "taxa" ("taxon" in the singular). When preservation is at its best, cereal identification can be performed at the subspecies level, such as *Hordeum vulgare var. vulgare* (hulled barley/agnekledd bygg) or *Hordeum vulgare var. nudum* (naked barley/naken bygg). With suboptimal preservation, cereals can be identified at best to the species level, e.g. *Hordeum vulgare* (barley/bygg), or at worst simply as cerealia (indet). Half cereal grains or small pieces and fragments are referred to as cerealia fragmenta. When a macrofossil looks like a particular species but lacks the species specific characteristics necessary for a 100% reliable identification, it is referred to as "cf. *taxa*" (cf. *Triticum*, means "looks like" wheat). This system is applied to all of the botanical material. Plant names are given in the text as "*Scientific/Linnean name* (English/Norwegian)".

Other material potentially of archaeological significance encountered during the macrofossil processing was also recorded and its volume or quantity estimated. This includes bones, ceramics and other small pieces of archaeological remains.

Macrofossil analyses were undertaken by Sofi Östman, Jenny Ahlqvist and Roger Engelmark, and the interpretation assisted by Philip Buckland. Radoslaw Grabowski kindly provided additional advice on the interpretation of some of the results.

Pollen analyses

Samples were treated according to the standard methodology for pollen preparation as described by Moore et al. (1991). Concentrated pollen was placed on a slide and coloured with saffron-dyed glycerine. Pollen taxa were identified under microscope using the keys of Beug (1961) and Moore et al. (1991), counted, and summarised for this report. All pollen samples derive from subsamples of nine bulk sampled archaeological features. Pollen analysis was undertaken by Jan-Erik Wallin, Pollenlaboratoriet AB/MAL.

Bulk soil chemical and physical properties

For survey samples, two parameters (Citric soluble phosphate Cit-P and Magnetic susceptibility, MS) were analysed throughout (1632 in total). A five parameter analysis routine was applied for the feature samples of the study (577 bulk samples analysed). The five parameter analysis routine has been developed and adapted for soil prospection and bulk analysis of occupation soils and features. Analysed parameters comprise organic matter (loss on ignition [LOI]) (Carter 1993), two fractions of phosphate (inorganic [Cit-P]), and sum of organic and inorganic [Cit-POI]) (Engelmark & Linderholm 1996; Linderholm 2007) and magnetic susceptibility (MS-χlf and MS550) (Clark 2000; Engelmark & Linderholm 2008). These analyses provide information on various aspects in relation to phosphate, iron and other magnetic components, and total organic matter in soils and sediments and its relationship to phosphate. (Further details can be found in Viklund et al. 2013).

Soil micromorphology

The undisturbed monolith samples were subsampled for the processing of 53 thin sections (Macphail 2016, 2017a). A wide variety of features and areas were sampled providing a broad coverage of the Vik settlement's components (Table 3). These samples were impregnated with a clear polyester resin-acetone mixture, then topped up with resin, ahead of curing and slabbing for 75x50 mm-size thin section manufacture by Spectrum Petrographics, Vancouver, Washington, USA (Goldberg & Macphail 2006; Murphy 1986 – an example is shown in Figure 6). Thin sections were further polished with 1,000 grit papers and analysed using a petrological microscope under plane polarised light (PPL), crossed polarised light (XPL), oblique incident light (OIL) and using fluorescence microscopy (blue light – BL), at magnifications ranging from x1 to x200/400. Selected features from 6 thin sections were also studied – microchemical elemental analysis using Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry (SEM/EDS) (Weiner 2010) (for examples see figures 10-11, 15-19). Thin sections were described, ascribed soil microfabric types and microfacies types, and counted according to established methods (Bullock et al. 1985; Courty 2001; Courty et al. 1989; Macphail & Cruise 2001; Macphail & Goldberg 2018; Nicosia & Stoops 2017; Stoops 2003; Stoops et al. 2010, 2018).

RESULTS AND DISCUSSION

Geological background

The Pre-Roman Iron Age occupation especially took place on relatively recently exposed marine sediments (Romundset & Lakeman, Ch. 2), which included shell-rich sand banks and 'beach rock' (Figure 2), where sands had been cemented by calcium carbonate, presumably during late last-glacial and earliest Holocene times. These calcareous deposits, and especially the shell bank deposits, have the effect of reducing the amount of analysed citric soluble phosphate and are apparently also linked to very poor macrofossil preservation (see below).

The number of preserved remains varies considerably between different areas of the site, reflecting to a considerable degree the dominating sediment types underlying the structures (Figure 3). The archaeological remains also represent structures of different sizes which have been sampled to different extents, and in different types of context (e.g. postholes, pits, hearths etc.) depending on their availability, stratigraphy and sampling strategies. Thus, comparing changes in the absolute, raw counts of macrofossil remains (Figure 3) between different areas or structures, although providing useful data for interpretation of the presence of different crops and activities, would give a false impression of changes over space and time.

Finer marine sediments, such as silty clay loams, were also introduced into the site for constructional purposes and as tracked-in material (hearth 671324 at House 24, see Figure 8 below, and pit capping 150017 in waste deposit 110297, see Figure 9 below), and this is of relict coastal pond and intertidal/coastal wetland origin (Table 1; see Overland & Hjelle, Ch. 3; Heen-Pettersen & Lorentzen, Ch. 6; Mokkelbost, Ch. 7). Silty clay of earlier formed shallow water marine origin was also found underlying beach sands in Fields B and E, and in the deepest wells (Randerz, Ch. 11, Figure 2). Such fine marine sediments have also been described from below beach sands at Heimdaljordet, Vestfold, where they have been described as 'slowstand' sediments associated with post-glacial land emergence (Kelley et al. 2010; Macphail et al. 2013). The sea and coastal environment seems to have provided important resources to the settlements through time (see below).

The location of houses in Fields C and D is clearly restricted to former shell banks. This is an unlikely random choice by the inhabitants. The reason for this may be that stabling of animals and subsequent manuring practices will benefit from the relatively higher pH-levels as the manure will "burn" and nitrification be promoted. Also, cultivation on these sediments may be less favourable

Figure 2. Aerial photo of Field D looking east and towards the present day coast. Pale areas are composed of calcareous shell sand and grey areas are composed of marine clay. Photo: 330-skvadronen. Ørland Air Base.

as they are presumably highly drained and simply rather alkaline, so it may be that the settlers made a similar choice of location as Iron Age settlements along the Norrland coast, Sweden, although here on the Norrland coast houses were placed close to blocky moraine and bedrock, while finer sediments were selected for cultivation and areas of fodder production (Liedgren 1992).

Consequences affecting the archaeological records in these areas are as follows:

1) Lower degree of preservation of carbonized material partly due to mechanical-physical weathering
2) A higher degree of oxidation of general humic/organic matter due to higher pH-levels (which means that the turnover is not comparable over the site as a whole)
3) Lower responses in the citric acid extraction due to neutralization of acid.

Pre-Roman Iron Age and Iron Age Houses

Most house data comes from post-holes and post-hole impressions (Tables 1-2, Figures 3-5). Few houses burnt down, hence the paucity of charred seeds, and some houses had short-lived occupancy and their geochemical characteristics may have been influenced by later activities. An important question

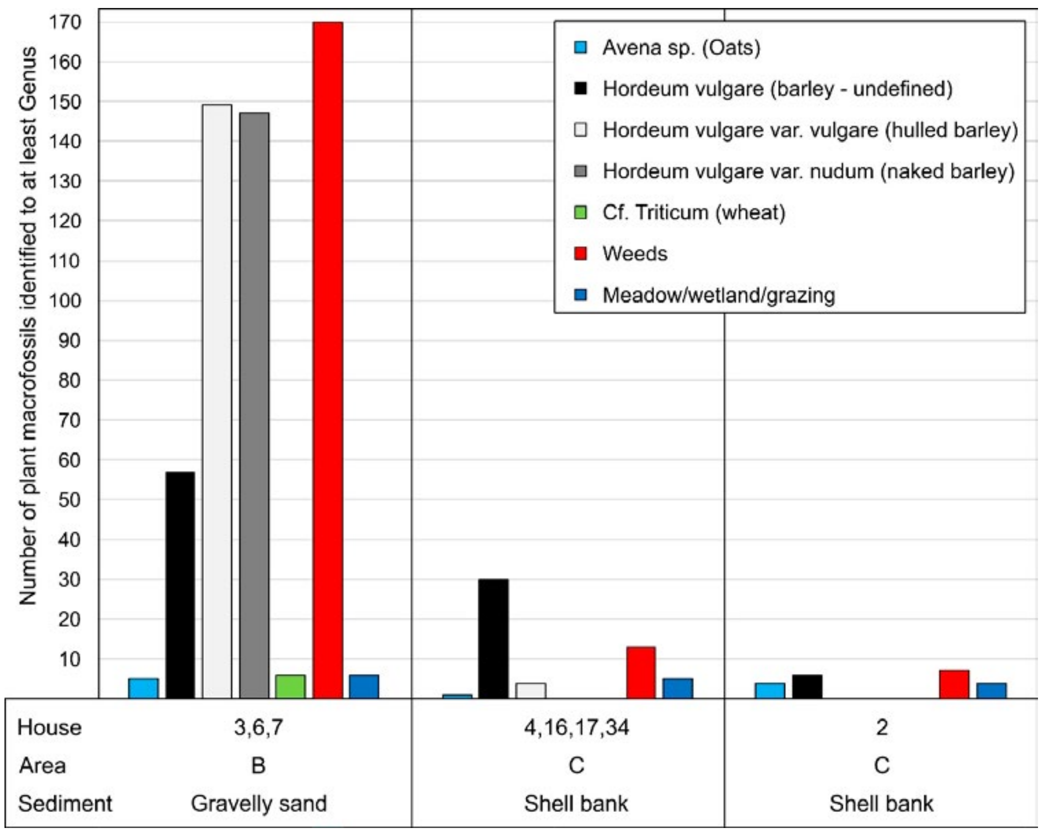


Figure 3. Summary of plant macrofossil raw counts for selected areas of the site. The figure shows selected crops individually and sum totals for seeds of weeds and meadow/wetland/grazing plants. Only well preserved remains, i.e. identified to genus or species, are included here; the relationship between these finds and unidentifiable fragments is shown in Figure 4 (Area D data are not included, as this area was not studied by the current authors – see Moltsen 2017).

Field	House	Cultivated	Weeds	Meadow/ wetland/grazing	Other
A	**1**	**1**	**3**		
B	3	6	5	0	2
B	6	16	1	0	2
B	7	805	165	6	22
C	2	96	12	6	2
C	4	141	3	0	0
C	16	23	2	0	2
C	17	56	5	2	1
C	34	54	3	3	1
Total:		**1197**	**196**	**17**	**32**

Table 1. *Sums of plant macrofossil remains per house and cultural/ecological category.*

Postholes only						
Phase	Age	House	Cultivated	Weeds	Meadow/wetland /grazing	Other
2	400 – 50 BC	3, 6, 7	72	18	0	10
3	50 - 200 AD	4, 16, 17, 34	90	6	2	2
3-4	200 – 550 AD	2	84	11	5	1
All features						
		House	Cultivated	Weeds	Meadow/wetland/grazing	Other
2	400 – 50 BC	3, 6, 7	70	20	0	9
3	50 - 200 AD	4, 16, 17, 34	90	6	2	3
3-4	200 – 550 AD	2	83	10	5	2

Table 2. *Relative abundance (%) of plant macrofossil remains per phase and area where best preservation was evident within the houses. The contents of postholes provide a comparable material to the remains found in all features (including pits and hearths) within each structure.*

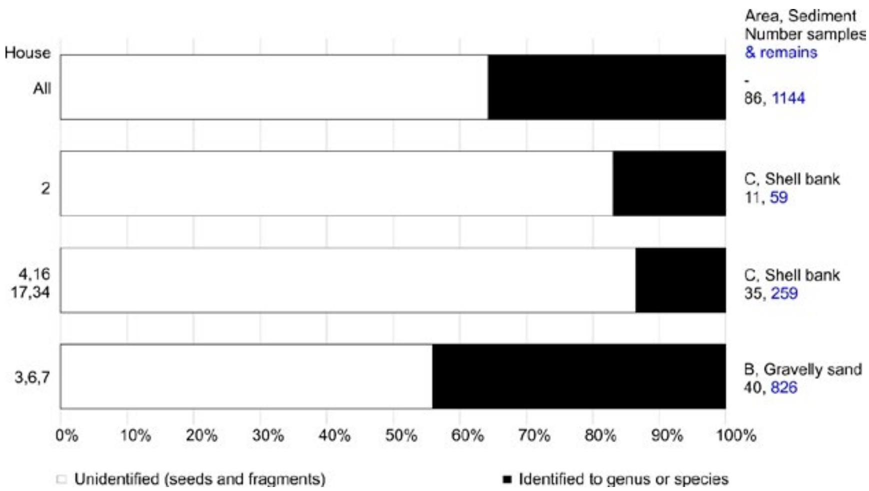


Figure 4. Relative proportion of identifiable plant macrofossil remains for three areas of the site. Total number of samples and seeds/fragments (blue) are given to the right. Fragmented remains are over-represented as several fragments may come from a single seed. House 2 data are presented separately because both shell bank and other subsoil materials affected preservation.

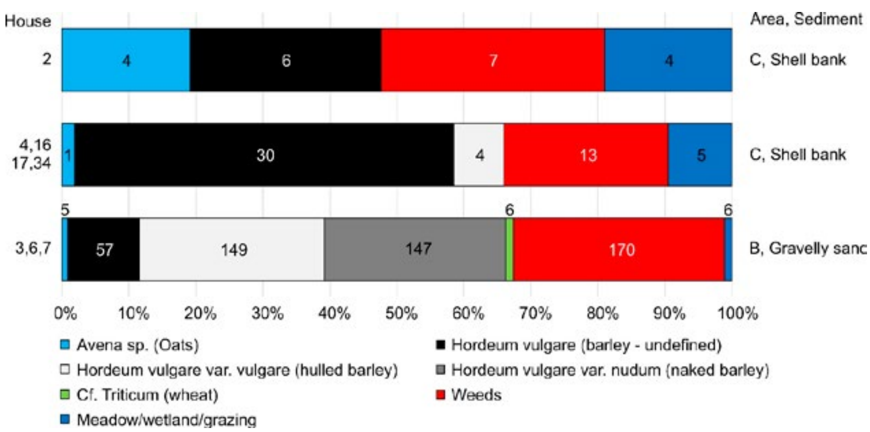


Figure 5. Relative abundance of selected plant macrofossil remains, identified to at least genus level, for three groups of houses, with number of seeds shown as numbers within or above the bar segments. Note that the number of seeds found in House 2 is too few for reliable interpretation in comparison with the other parts of the site.

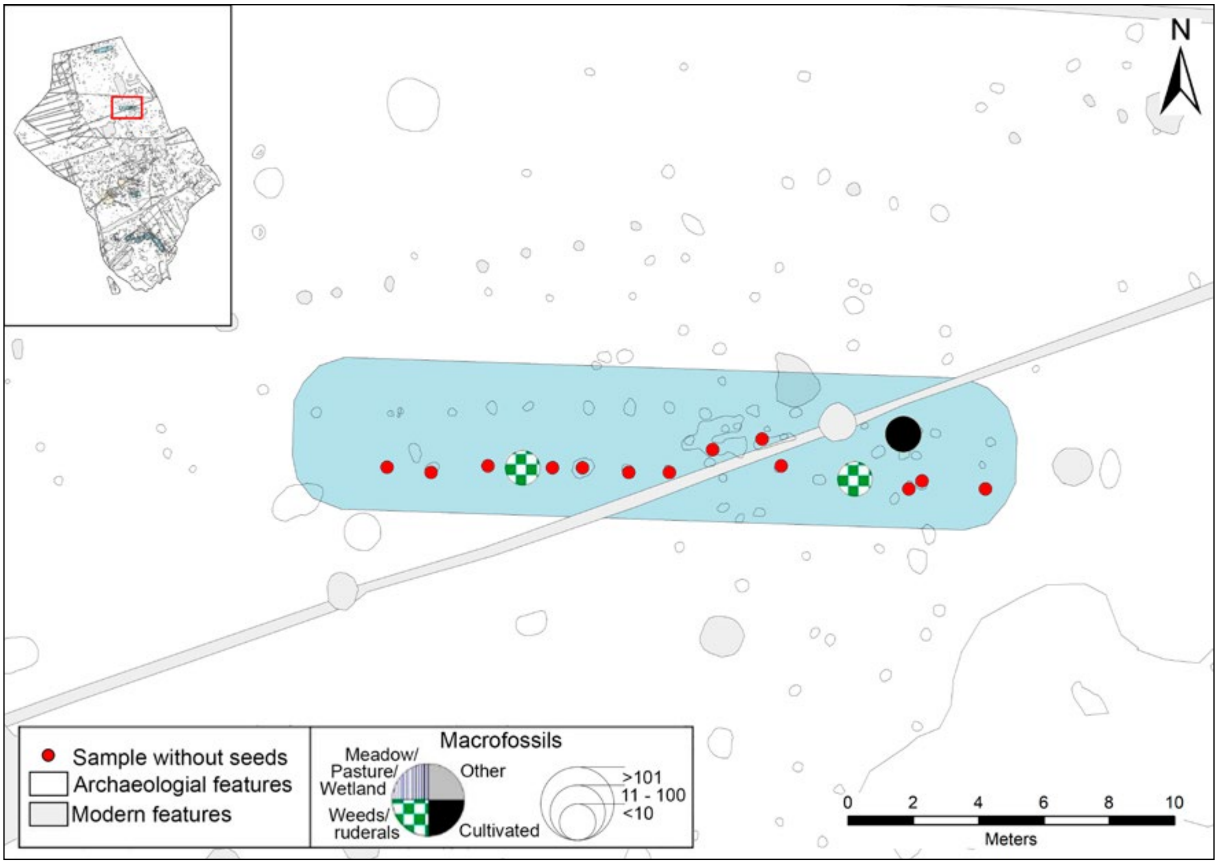


Figure 6. House 1, Field A: Relative number and proportion of plant macrofossil remains. Illustration: Magnar Mojaren Gran, NTNU University Museum.

concerning long houses of this period is whether they had internal divisions, with space for different activities, including the stalling of animals, as found, for example, in southern Sweden and in Vestfold, Norway (Engelmark & Viklund 1986; Myhre 2004; Viklund et al. 1998; Viklund et al. 2013).

Field A

House 1: In PRIA House 1, Field A, (Figure 6a-c), posthole fills in the centre of the house have a high CitP and PQuota, suggesting that this could have been the location of a byre. Unfortunately, plant macrofossil remains, consisting of a single unidentifiable cereal grain and three seeds of *Chenopodium album* (fat-hen), were too poorly preserved to support this interpretation. It is, however, noteworthy that soil micromorphology sample 149038 from floor remains 148321 in House 1 recorded amorphous organic matter of possible byre waste origin (along with the remains of a possible plank floor, Fransson, Ch. 5). Although it is assumed that long houses included a byre area (Myhre 2004) there is not always clear geochemical or macrofossil evidence of this, and posthole fills generally have a lower P-Quota – an indication of organic phosphate present – compared to 'layers' and 'pits', but the location of houses on

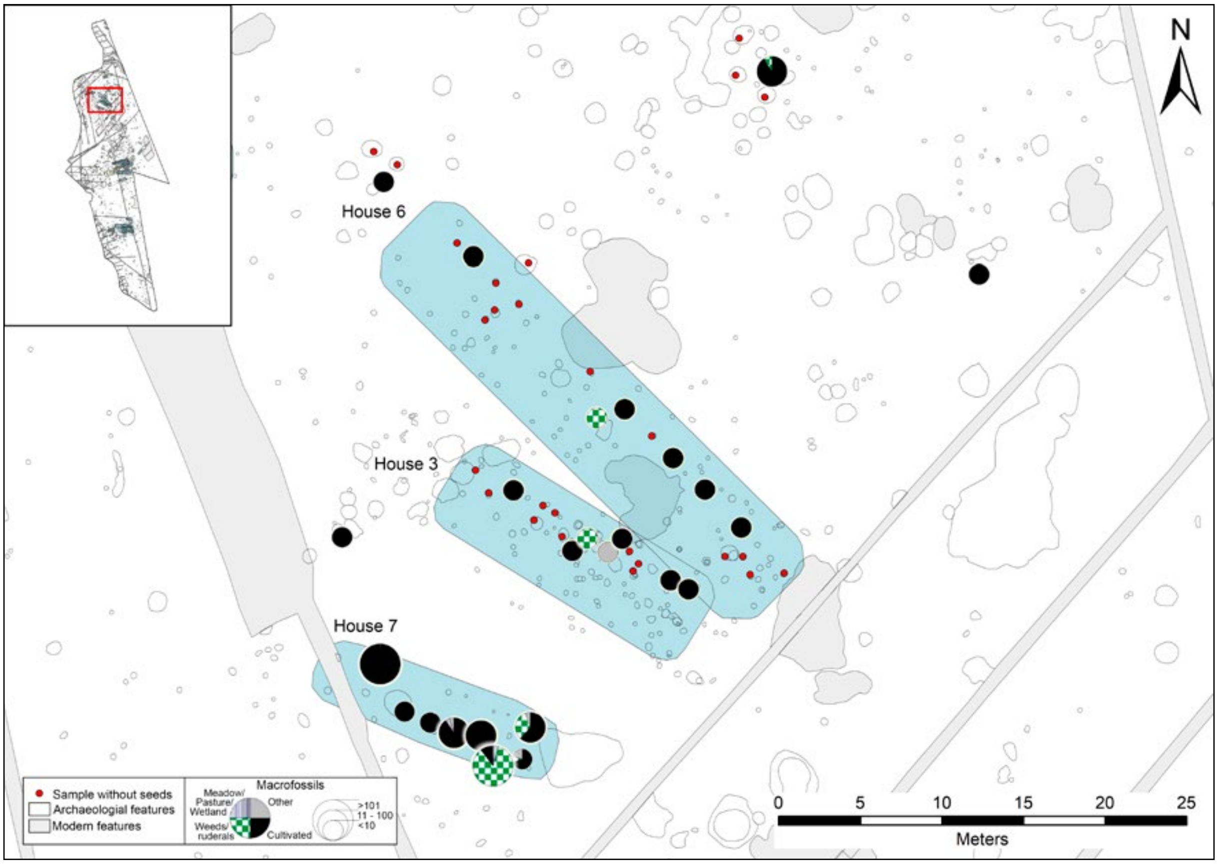


Figure 7. Houses 3, 6 and 7, Field B: Relative number and proportion of plant macrofossil remains. Illustration: Magnar Mojaren Gran, NTNU University Museum.

shell sands probably skews this finding (see below and Buckland et al. 2017).

Field B

Plant macrofossils were most abundantly preserved in Field B – the area of Houses 3, 6 and 7, dated to the pre-Roman Iron Age – because these were not located on shell sand banks (Figure 7a-c). The preservation elsewhere on the site was minimal, most likely a reflection of multiple taphonomic processes (see below) including post-depositional effects, and sampling practices (Fransson, Ch. 5). All macrofossil samples were subjected to standardized, laboratory-based processing techniques, and this should thus not have caused any differential effects between samples from different areas. The same patterns in preservation are observed over the entire site, through the whole of its period of occupation, and in the analysis results of two different laboratories (see Buckland *et al.* 2017 and Moltsen 2017). This taphonomic bias is strikingly evident in the raw numbers of macrofossils retrieved (Table 1), even when selecting only samples from house structures, which usually provide for the best preserved material.

The diversity of both crops and weeds was low in all samples, with at most five species of weed being found in any one sample (House 7; see below). It is therefore not possible to extrapolate any trends in the type of crop or cultivation and processing techniques used over time at the site.

Closer examination shows that House 7 is responsible for the vast majority of macrofossil remains on the entire site (Table 1).

PRIA House 7 is interpreted as a crop processing and possibly storage building due to the large number of cereal grains and weed seeds found. Despite better preservation in House 7, the weed assemblage is of poor diversity and highly dominated by seeds of *Stellaria media* (Common Chickweed) towards the eastern end of the building. This is a low-growing weed, the presence of which in the building suggests harvesting at a low height. High-growing weeds, including *Persicaria lapathifolia* (Pale Persicaria), were also found in the same samples, as would be expected.

The large number of weeds in the eastern end of the building, and almost pure cereal assemblages in the western end, suggest that crops were processed in the eastern end for storage in the western. Alternatively, this could represent order of crop processing, with a more refined product to the west, but storage elsewhere (Figure 7). Overall, however, House 7 seems to show that it had separate activity areas.

Considerable amounts of what was initially identified as straw were found in House 3 (Buckland et al. 2018). This material was found primarily in postholes, and at an initial stage was interpreted as evidence for cereal processing. A subsequent reassessment of the material in the light of Mooney's (2018) overview on the use of seaweed in North Atlantic contexts suggests that the material could be seaweed, which is easily mistaken for straw under poor preservation conditions. Mooney (2018) offers a range of potential uses of seaweed in an Iron Age context: as fuel, soil amendment (fertilizer), animal fodder, bedding straw. The presence of seaweed would also explain the "too old" ^{14}C dates from this context, caused by the reservoir effect on marine plants containing older carbon than the terrestrial material in the enclosing contexts.

In the case of house 3 (Field B), slightly higher P-quotas can be observed in the postholes with higher values, especially towards the eastern part of the house. This coincides with the occurrence of the straw/seaweed macrofossil finds, suggesting that the main activity/use of this house is related to animal stabling, bedding and fodder. This material may also have been stored and used for soil improvement.

The lack of significant amounts of straw in other areas of the site may be explained by the poor general preservation of macrofossils in structures or features located on the shell banks.

Field C

Although RIA House 2 is located on a shell bank, which overall has affected plant macrofossil preservation adversely, some feature fills seem less influenced by this subsoil type (Tables 1-2, Figures 3-5). Small amounts of both cereal and weed seeds were found across the house and give no clue to any house divisions, while some well-preserved chemical signatures indicate general household activities (i.e. heating and cooking) – no evidence of stalling is present.

Field D

In relationship to house construction, whilst the use of a plank floor was noted at PRIA House 1 (Area 1), a wetland clay loam had been imported to construct a hearth base in RIA House 24 in Area D, as an example of a use of coastal resource exploitation (Figure 8).

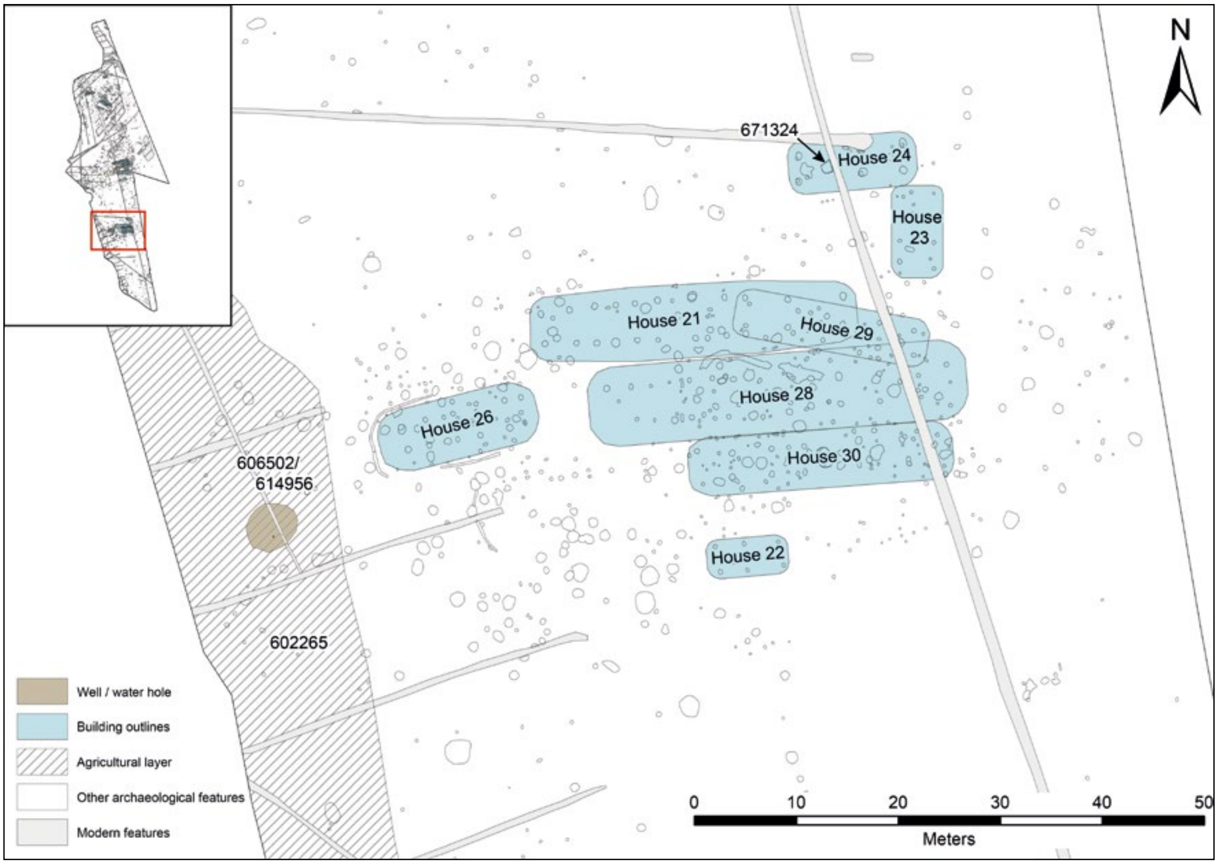


Figure 8. Field D, with micromorphology sample spot. Illustration: Magnar Mojaren Gran, NTNU University Museum.

Pre-Roman Iron Age and Roman Iron Age Houses

In conclusion, it can be suggested that although there seems to be evidence of different uses of space within the long houses for both periods, it is only in Pre-Roman Iron Age houses that there are persuasive indications of the indoor stalling of animals. It should be pointed out that changes to vegetation can also be brought into this debate concerning animal management (Overland & Hjelle, Ch. 3).

Field E

Lastly, the presence of possible phosphatised wooden floor residues in late medieval trench 215566, Field E, is noteworthy (Figure 9). In urban medieval sites in Oslo, Tønsberg and Trondheim, for example, wooden floors often became phosphate saturated, which enabled them to resist decay (Macphail & Goldberg 2018, 377-378).

Other structures

It is briefly worth noting here that there was secondary use of pits/cooking pits, and the Late Viking/early medieval (Vik phase 6) pit house (204477, 222855, Figure 9) seems to contain discarded materials, including byre waste (Figure 10; see below), and other waste including latrine deposits (see below).

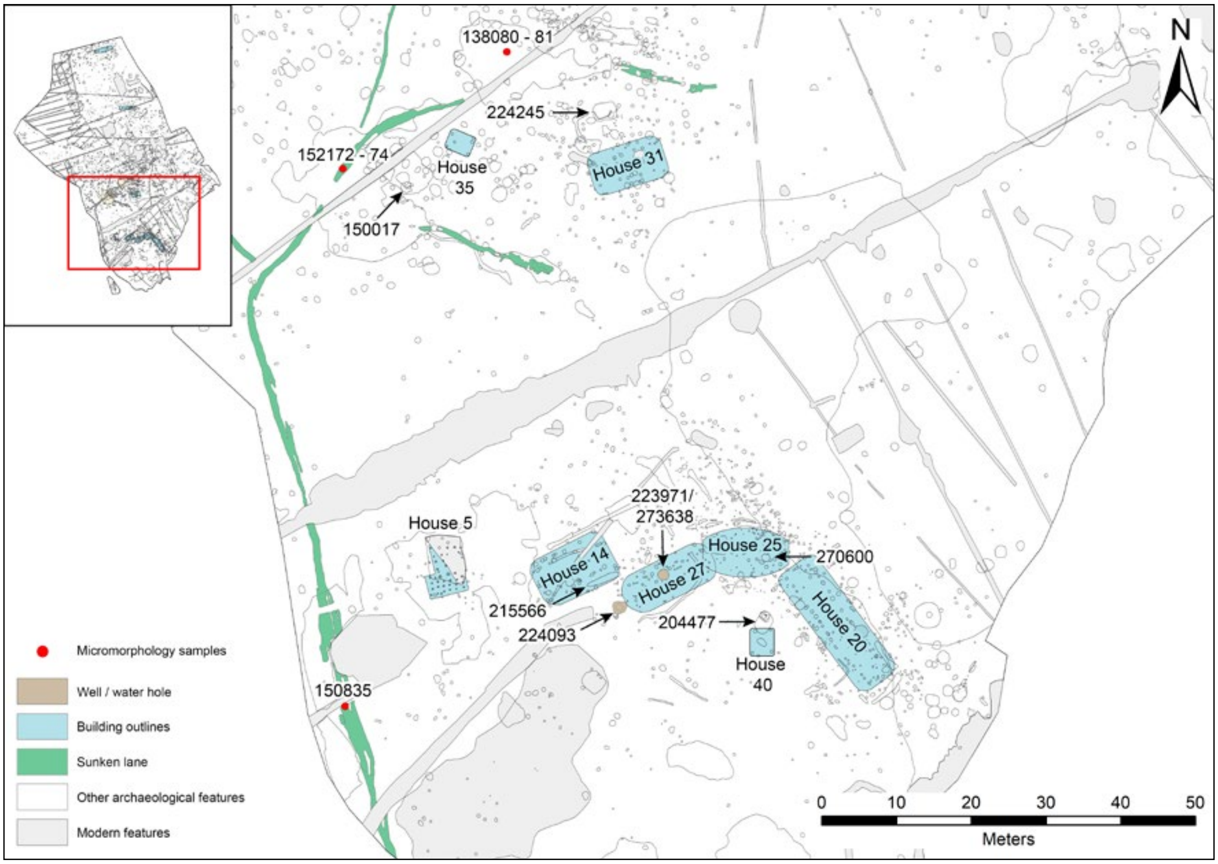


Figure 9. Fields A (north) and E (south). Illustration: Magnar Mojaren Gran, NTNU University Museum.

Hearths

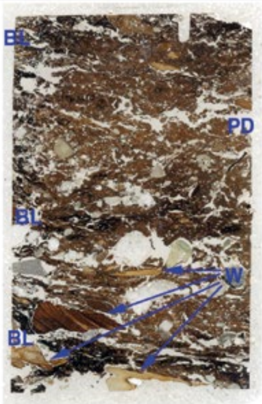
Hearths record some of the highest geochemical (Cit-P and LOI) and magnetic susceptibility (MS) values, consistent with *in situ* burning and presence of fuel ash and other use-residues. Microchemical studies of charcoal associated with some hearths also suggest that driftwood was sometimes used as fuel (see below).

Wells and waterholes

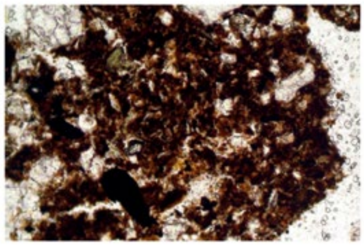
A number of wells and waterholes were investigated (see Figure 10). In addition to providing water for the population and animals, the fills themselves provide further insights into activities and the site's management, for example in their secondary fills.

In Vik Phase 3 (Roman Iron Age), some interesting results are, for example, Layer 3 in well 606502, which may have included retting waste (Moltsen 2017), while animal use of the waterholes led to sediment churning (606502, 614956, Figure 8), an impact on waterholes also suggested by Annine Moltsen (2017).

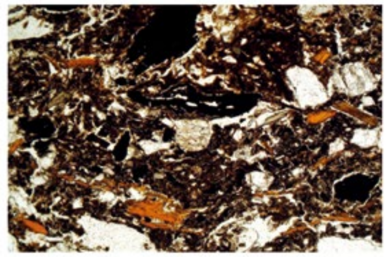
In Vik Phase 6 (Late Viking Age/early medieval period), at waterhole 273638, 223971, primary probable clean water extraction was recorded in the part of the well that was wood-revetted. Well deposits (224093; Layer 3) include wood chips of wood-working origin (Figures 9 and 10), but this could be waste from the use of wood to support the well. Waterhole



Scan of ORL224760A (Well – west – 224093; Layer 3); layered and microlaminated organic deposits, with three blackened zones (BL) testifying to strong humification episodes, a concentration of serrated wood chips ('saw dust') evidencing wood working, and possible dung rich layer (PD). Frame width is ~50mm.



Photomicrograph of ORL222861 (Pit house 204477, 222855; Layer 8); detail of organic fill, with example of humified organic matter-dominated compound ped, derived from bioworked dung-rich byre waste residues. PPL, frame width is ~0.90mm.



Photomicrograph of ORL 223011A (Waste Pit 270600, Layer 2); humic and stained deposits with concentration of fine orange-coloured probably coprolitic bone fragments, in this latrine/cess pit fill. PPL, frame width is ~2.38mm.

Figure 10. Scan from well 224093; photomicrograph from pit house 204477, 222855, layer 8; photomicrograph from waste pit 270600, layer 2.

273638 provides examples of major secondary use of such features (Figure 9). They were used for discard, and both soil micromorphology and plant macrofossil analysis found layered plant remains which had been dumped at this location, and it is interesting to note that some of these included byre residues characterised by dung spherulites (Shahack-Gross 2011).

Sunken lanes, waste disposal and domestic and industrial activities

Settlements are complex, and as an example Figures 13a and 13b demonstrate the interconnectivity of two zones in Area A and E, in part through the use of the RIA sunken lane. *In the southern zone*, with activity dated from almost all periods between the Pre-Roman Iron Age and the medieval period, where many features are CitP rich, there is an especially high concentration of CitP in RIA sunken lane sample 150835 (Figure 9), which together with evident dung residues are evidence of considerable livestock movements. *In the northern zone*, with activity dated mainly to the Roman Iron Age and the Migration period, samples 152172, 152173, 152174 also show inputs of dung, but faecal and other middening waste disposal seems more important here (138080, 138081, Figure 9). In addition, MS indicates that the northern zone is characterised by a much more marked activity area (Figure 11b); however, this pattern of evidence of pre-medieval activity may be compromised by the presence of a modern farmstead in the area (Ystgaard et al. 2018:114-118).

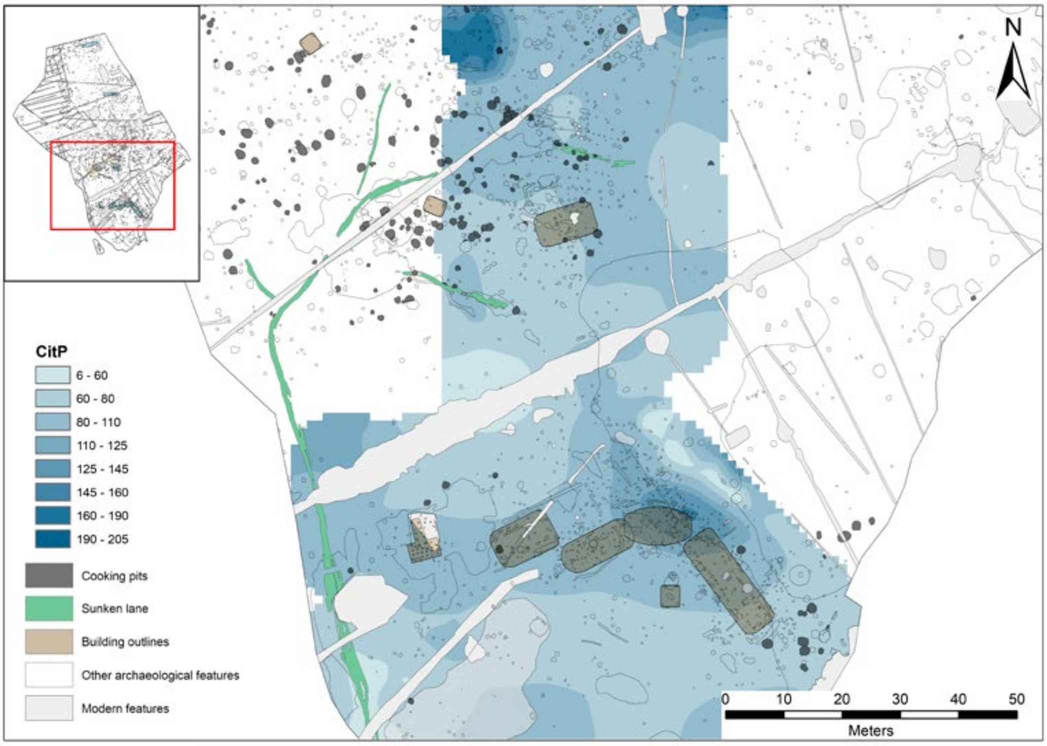


Figure 11. a: Fields A (north) and E (south), CitP surface samples. The sunken lane links southern and northern zones. Note high concentration of CitP in sunken lane (thin section) sample 150835 (cf. Figure 9) in the southern zone and possible transportation route of manure/dung/waste from the house complex. Illustration: Magnar Mojaren Gran, NTNU University Museum.

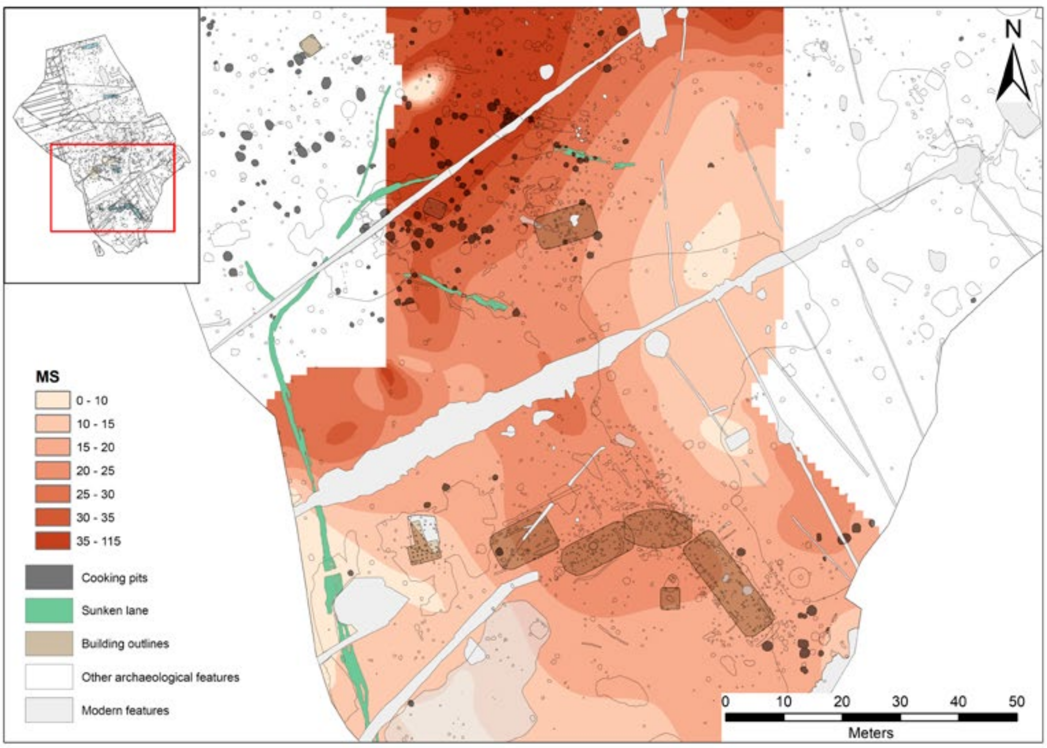


Figure 11. b: Fields A (north) and E (south), MS (magnetic susceptibility) surface samples. In this case, the greatest activity is recorded in the northern zone and is clearly linked to the abundance of cooking pits. Illustration: Magnar Mojaren Gran, NTNU University Museum.

Sunken lanes were formed by traffic, including probable livestock movements (Figures 13a and 13b), as indicated by the presence of dung residues in sunken lanes (Roman Iron Age 130000, and 217254,) and likely associated phosphate-staining, as found at other Norwegian sites such as Hørdalsåsen and Bamble, Vestfold (Macphail et al. 2017a; Viklund et al., 2013). It is also clear that at Vik livestock were also venturing across beach and wetland areas.

It can be noted that Early Iron Age 110297 and Early/Late Iron Age 106581 waste heaps, both in Field A, include both byre and household waste (Mokkelbost, Ch. 7). Pre-Roman Iron Age deposits (223022) also involved household waste disposal, with burnt material raising MS levels. Human waste is also present at the site, presumably raising general Cit-P measurements, for example at Pre-Roman Iron Age House 1 floor 148321 (Figure 6a), indicating typical poor hygiene practised in long houses (cf. Macphail & Linderholm 2017). In addition, waste heaps include latrine deposits such as at Early Roman Iron Age 110297 and Early/Late Roman Iron Age 106581. At Early Medieval pit 270600 (Figure 9) SEM/EDS was employed to analyse these concentrated cess deposits (e.g. 4.91-7.51% P; 13.8-35.7% Fe; see Figures 14, 15), which also contain fish remains Late medieval/early modern age Trench 215566 (Figure 9) also includes such human waste, demonstrating the ubiquity of such waste disposal through time. It must be remembered, however, that some faecal remains may be of pig husbandry origin; animal osteology has identified RIA pig bones (Storå et al, Ch. 8; Macphail & Goldberg 2018, 452 et seq.). It may be significant that byre waste is found in pits of RIA and a pit dating to the early medieval period – at the latter it could have been a possible seasonal deposit, possibly associated with springtime byre clearance.

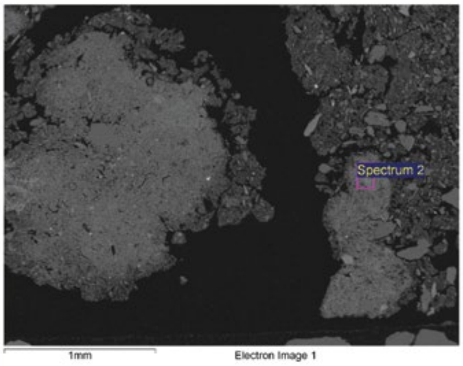
A possible Roman Iron Age pit sample (possible pit house 224245, Figure 9) was found to include both byre waste and iron use/working traces. Later (early medieval period) refuse deposits in pit 270600 (Figure 9; Fransson 2018:336), besides containing latrine inputs ('cess') demonstrating fish consumption, are equally importantly characterised by industrial and artisan activity waste (see below and Figures 19-23). Moreover, this rich pit fill records possible seasonal deposition of byre waste, as well as charcoal of fire installation origin.

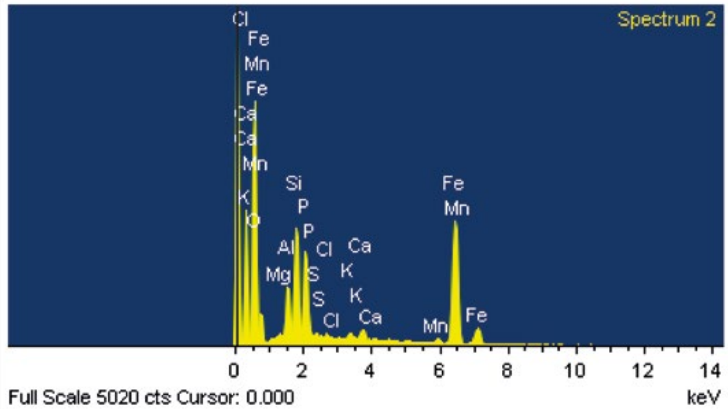
Fuel residues

Fuel ash waste which includes charcoal and wood char occurs in hearths and pits, for example, and it can be noted that SEM/EDS analysis found instances of fuel waste containing anomalously high amounts of chlorine (7.61% Cl in charcoal; max 16.6% Cl in char; RIA central hearth B24 671324; see Figure 12). Although this may possibly be a relict from salt-working, it is more likely that this records the use of driftwood, as noted at other coastal Norwegian sites (Korsmyra 1, Bud, Møre og Romsdal, Nannestad, Akerhus and Trondheim; Macphail 2017b, 2018; Macphail et al. 2016).

Remains of industrial activity

Although no evidence of non-ferrous metal working was found, likely RIA industrial activity indicators were found in pit fills. For example, indicators of iron use/working were found in pit 224245 (Figure 9), while clay-capped pit 150017 within RIA waste layer 110297 contained a heat-affected siliceous sand-rich fragment of what might possibly have been a crucible (Figure 9, Mokkelbost, Ch. 7). More significant iron working traces seem to be apparent in early medieval Pit 270600 (Layer 2) and include weathered iron fragments (63.1% Fe - ~90% Fe_2O_3), possible slag, iron-stained charcoal with 7.31-9.54%





X-Ray backscatter image of ORL 223011A (Waste Pit 270600, Layer 2); iron and phosphate-rich (latrine waste) channel infill and coating (Spectrum 2) matrix soil with little or no phosphate present.
Scale bar=1.00mm.

X-Ray Spectrum 2 of ORL 223011A (Waste Pit 270600, Layer 2); latrine waste infill with 7.51% P and 35.7% Fe. S and Mn also present.

Figure 12. Left: X-Ray backscatter image of ORL 223011A (Waste Pit 270600, Layer 2). Right: X-Ray Spectrum 2 of ORL 223011A (Waste Pit 270600, Layer 2)

Fe, fuel ash waste and a possible iron-rich furnace prill; see Figures 9 and 16-19 (cf. Berna et al. 2007). It is possible, for example, that 'cooking pit' activity could be linked to industrial processes, thus producing mapped areas of high magnetic susceptibility in the northern part of Field E (Figure 11b).

Settlement development

Settlement development can be analysed through the accumulation of phosphate over time (see Table 3 for soil micromorphological studies and phosphatic deposits in Figures 16 and 18). In terms of mapped phosphate, a good example is to compare Fields B, C and D, which comprise the best preserved settlement areas. The main phase of Field B is the Pre-Roman Iron Age while Field D is placed in the Roman Iron Age. Field C belongs to later Roman Iron Age with some Migration Period activity. In this case we have compared the chemical response of the posthole fills belonging to the different houses and areas. In Figure 13, a comparison of feature fills and surrounding surface samples are compiled into box plots. Here, a clear time gradient (from B to D to C) shows the gradual increase and intensification of the occupation over time. Differences between surface and feature samples have different explanations. In Field C (and Field D) the shell banks lower the responses in CitP, whereas the posthole fills represent 'topsoil' infills of the time, and are less affected by the underlying sediments.

It may be that the relatively low phosphate concentrations in Field B are related to this zone being a pioneering settlement before redistribution of nutrients, and that the chemical signal in the surface samples represents later phases of use. A similar signature is displayed by the magnetic susceptibility (Figure 14) where the MS intensity increases over

Settlement area	Direct and Proxy data sources	Selected Settlement Activities (animal management and waste disposal)
Constructions		
Long houses (also a pit house, pits and trenches)	Plank floors: house 1 floor 148321; Cit-P in-house concentrations Clay loam floor: house 28 floor 611987 Plank floor remains: trench 215566; plant floor coverings: well 224093 Cit-P concentrations between houses	Animal management (PRIA stabling within houses; RIA storage of dung between houses?) Waste disposal (secondary use of pit house)
Trackways		
Sunken lane(s)	Traffic, including livestock: sunken lanes 130000, 115254 and 217254, 225768; Cit-P concentrations in lane.	Animal management (coastal grazing and movements within settlement)
Water management		
Wells and waterholes (wood revetted well)	Clean water use: waterhole 273638, 223971 (and wood revetted well) Animal use: waterhole 606502, 614956	Animal management (animal use of waterholes) Waste disposal (secondary use of wells and waterholes – byre residues, flooring and plant processing residues)
Specialist domestic and industrial activities	Wood working: well 224093 Iron working?: pit 224245, pit 270600? Fuel ash (charcoal and wood char): pit 151748, pit 270600; longhouse 28 - hearth 611987. Driftwood(?) fuel: pit 151748, longhouse 24 hearth 671324 Crucible(?): pit 151748 Hearth floor: long house 28 floor 611987 Mapped high magnetic susceptibility in association with 'cooking pits'	Waste disposal (general hearth and industrial activity discard)
Waste disposal (middening)	Household debris: waste heaps 106581 and 110297	Waste disposal (waste heaps between houses)
Human waste disposal	Faecal material: Waste heaps 106581 and 110297, long house 1 floors 148321; Trench 215566, pit 270600 (fish remains)	Waste disposal (house-associated waste heaps and pit fills)
Farming		
Animal management		
Stabling	Byre residues: long houses, waste heaps, trenches 215566 and 223253; well 224093; pit 270600, waterhole 273638, 223971; pit house 204477, 222855. PRIA: Cit-P in-house concentration RIA: Cit-P concentrations between houses	Animal management (PRIA stabling within houses; RIA storage of dung between houses?; not all dung put onto fields)
Grazing (e.g. on coastal wetland?) and stock movements	Dung residues, phosphate, beach sediments and wetland soil clasts: Sunken lane(s) 130000, 115254, 217254, 225768, 276020	Animal management (coastal grazing)
Agriculture (Manured cultivation)	Manuring with household waste and dung: buried soil 141800, 107348; agricultural layers 612056, 602265 and 671676, 602265 Nitrophilous weed seeds	Animal management (manuring with dung; not all dung put onto fields – storage heaps) Waste disposal (as a form of manuring)

Table 3. *Ørland – settlement components and selected activities; soil micromorphology including SEM/EDS*

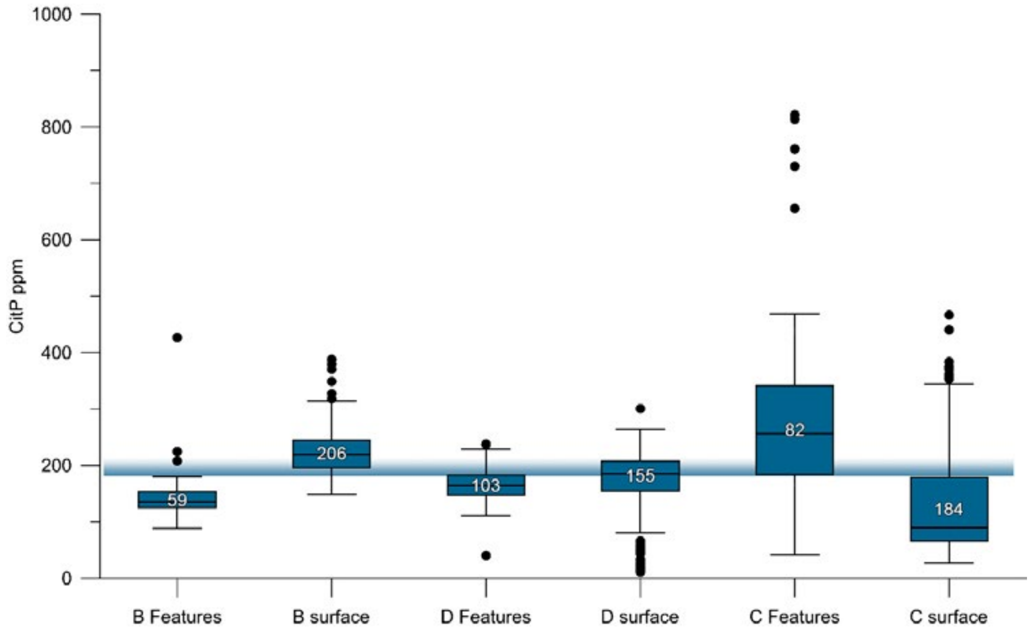


Figure 13. A chronological development based on phosphate concentrations in posthole fills and corresponding surrounding surface samples (number of samples indicated in boxes). The shaded 200 ppm level shows from where more intense enrichment starts.

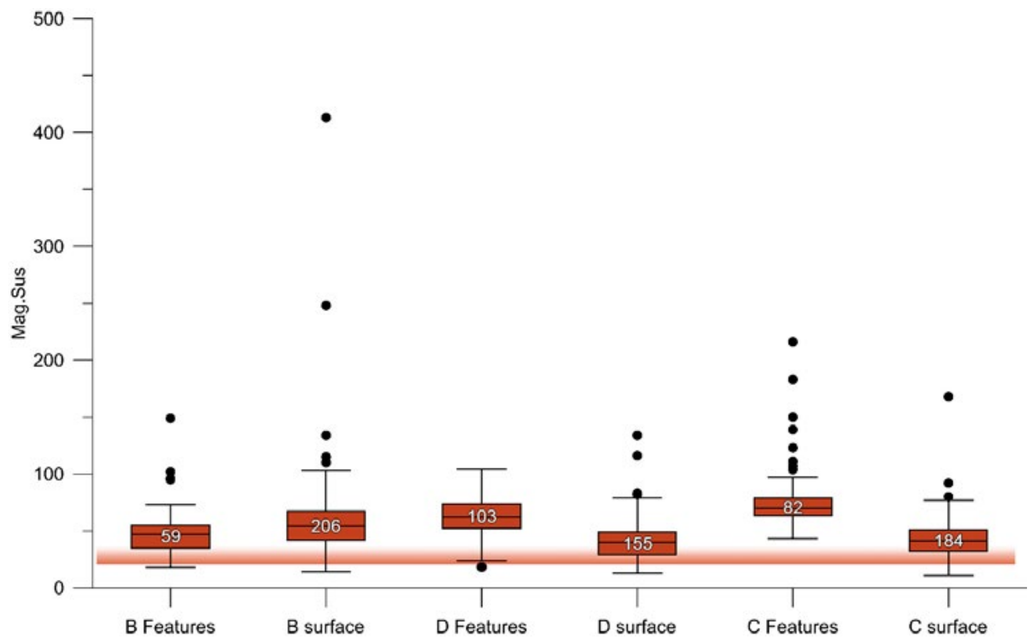


Figure 14. MS – magnetic susceptibility enhancement signal (number of samples indicated in boxes). The shaded bar represents levels from where more intense impact can be detected.

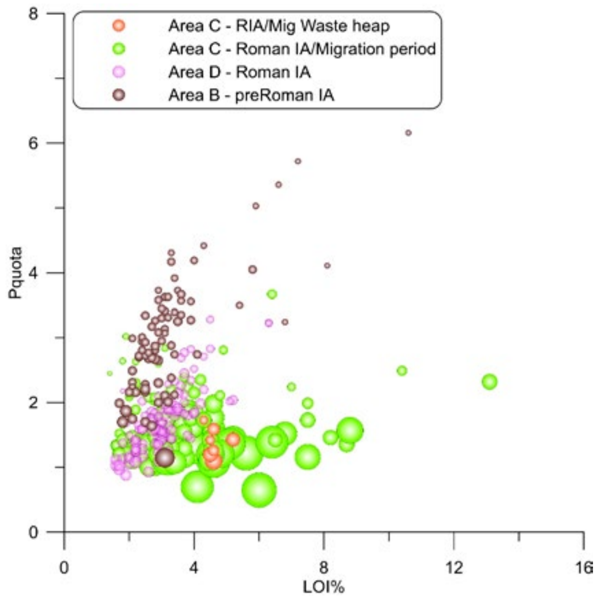


Figure 15. A chronological overview on the Pquota and Loss on ignition relationship based solely on posthole fills from house areas B, C and D. Circle sizes are relative to the CitP amount.

time, and points in the same direction as the phosphate response. It should be noted as a caveat, however, that mineralisation of phosphate in the alkaline shell banks (especially Field C) may be another factor as to why phosphate enrichment is more evident in Field B compared to the other two areas.

Lastly, Figure 15 shows the intensity of potential manuring practices and stabling. Field B shows the highest Pquotas. Either this shows that the 'virgin' soil of the area was a grassland area or that the settlement had more manure management within buildings and/or in the vicinity of houses. In fact, there are hints of this in the soil micromorphology. For example, as noted above (*Houses*) in House 1, although there is little macrofossil evidence, the soil micromorphology, CitP and PQuota data point towards a central byre. We have also noted the numerous instances of dung residues found in fills near houses across the site as a whole.

In Field C, from a large waste heap (id. 200500, Mokkelbost Ch. 7), seven bulk macro samples were collected and analysed chemically. The Cit-P range in the samples varies from 600-1300 ppm, which are quite high values, and the Pquotas varies around 1.3 to 1.8, which is significant given the high Cit-P amounts. If large amounts of dung (and household waste) were stored in this location, fermentation would lead to oxidation of organic matter increasing the Cit-P levels, and organic content would decrease, reaching levels of 4-5%. This may suggest a possible interpretation of there being a different manure management in Field C, and it could also indicate how the settlement was abandoned, with a 'precious' dung heap being left undistributed to the fields.

Agriculture

Manuring with household waste (including burnt mineral material) and dung was noted in the thin section studies of Roman Iron Age clearance cairn-buried soil layers (141800, 107348; Mokkelbost 2018:151-157) and Pre-Roman Iron Age agricultural layers 602265, 612056 and 671676 (Figure 8, Lorentzen 2018:204). This led to raised levels of biological activity. Examples of weed seeds and cereal grains were found in Roman Iron Age clearance cairn 141800, while seeds of nitrophilous plants in general may suggest manuring. As already mentioned, there is evidence of animal management which included livestock movements across the site and onto wetland grazing land.

Using the chronology of Ystgaard, Gran & Fransson (Ch. 1) we can attempt to investigate indications of changing cultivation practices and manuring levels over time by looking at discrete areas with different dates. Indications can be extracted most reliably from a combination of plant macrofossil and geoarchaeological results from posthole samples, which act as complementary proxies depending on the physical circumstances. Relative differences in sampling, preservation and size of structures also make the use of raw counts of plant macrofossils of limited comparative value on their own (see above and Figure 3). Looking at the relative proportion of macrofossil remains (Figure 4, Table 2) is therefore more useful, as raw counts alone would give an unreliable indication of differences between site areas. The possibility for differentiating between subspecies of barley (hulled and naked) is only possible in House 7 due to its better preservation, and this should not be considered as a diagnostic feature with respect to comparisons with other areas. The presence of these two subspecies together is, however, somewhat typical for the pre-Roman Iron Age (Engelmark & Viklund 2008) in southern Sweden, and is consistent with the pollen analyses carried out at Vik (Overland & Hjelle, Ch. 3). There is little empirical macrofossil data from Norway with which to compare, however, and Ørlandet thus provides important new information for mapping the development of agriculture across Scandinavia.

Settlement Patterns and organisation of resources

As suggested in Figures 13a-13b, 16-17, and in Table 3, complex patterns of activities are recorded. In addition to domestic and craft/industrial occupational activities (Figures 19-23), which included crop processing within and around houses (Figures 4-5), farming also involved management of both animals and their dung. In addition, not all domestic settlement waste was dumped – some was also added to the fields as manure. Combined soil micromorphological and chemical data suggests that there was a chronological development of animal management. For example, there are signs of animals in houses in the Pre-Roman Iron Age, but no evidence of animals in the Roman Iron Age houses. Foddering of livestock in winter and summer grazing is assumed in prehistoric Norway (Myhre 2004), but at the coastal site of Vik, because of its better climate, there are proxy indicators that during the Roman Iron Age animals grazed along the shore (micromorphological analyses in profile 223022). Animal management involving in-house foddering (PRIA) and all year grazing without the option of stalling livestock (RIA), could be consistent with interpretations of pollen data (Overland & Hjelle, Ch. 3). Other signs of resource management are collected driftwood that seems to have contributed to the settlement's fuel resources (Figure 16) and unused fodder from houses that had decayed and which was sometimes dumped into local wells and waterholes (Figure 10). The organisation of farms not only included the houses themselves, but also household and human waste disposal, as waste heaps during the Roman Iron Age (110297, 106581, Mokkelbost Ch. 7) and trenches associated with houses and rubbish pits in the Medieval period (Field E) testify. It can be noted that human waste disposal was not always 100% efficient, with traces also found in the floor of Pre-Roman Iron Age House 1. This is not, however, atypical of long houses (cf. Avaldsnes Royal Manor; Macphail & Linderholm 2017). Another important resource for any settlement is water. This seems to have been properly organised at Vik, with water for both humans and animals (Roman Iron Age waterhole 606502, Lorentzen 2018:601); wells, especially, could supply clean fresh water for human consumption and for livestock (medieval wells in Field E, cf. Fransson 2018:314-335).

CONCLUSIONS

From a methodological point of view, the studies at Ørlandet have shown that the soil/sedimentary context needs to be thoroughly accounted for in relation to analysed data. The varying taphonomy

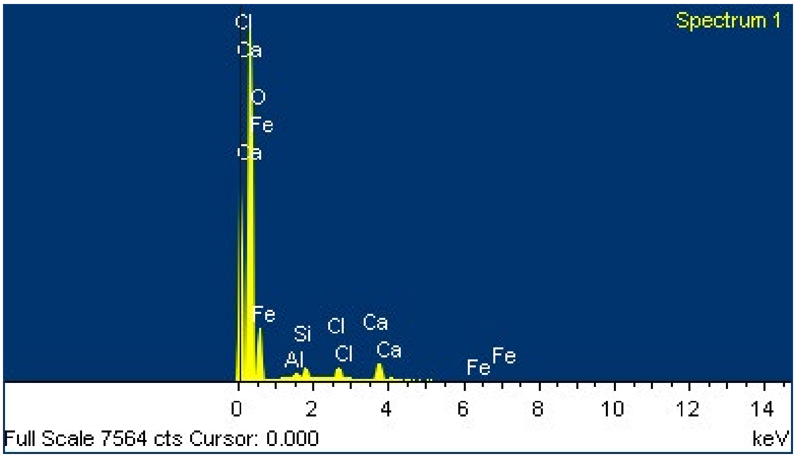
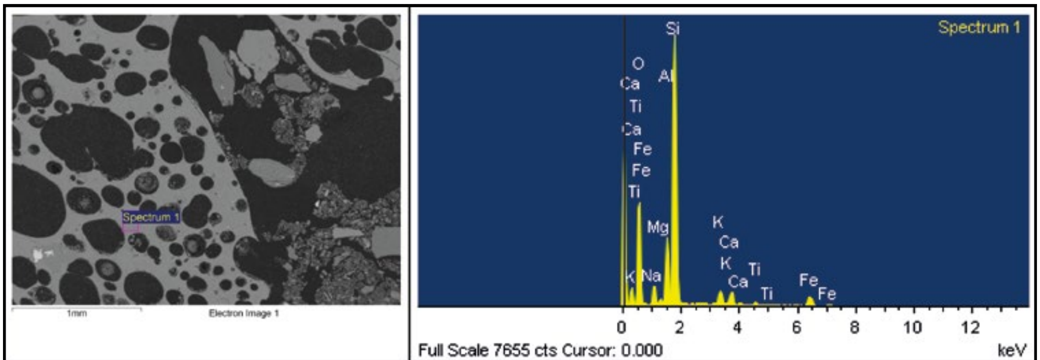
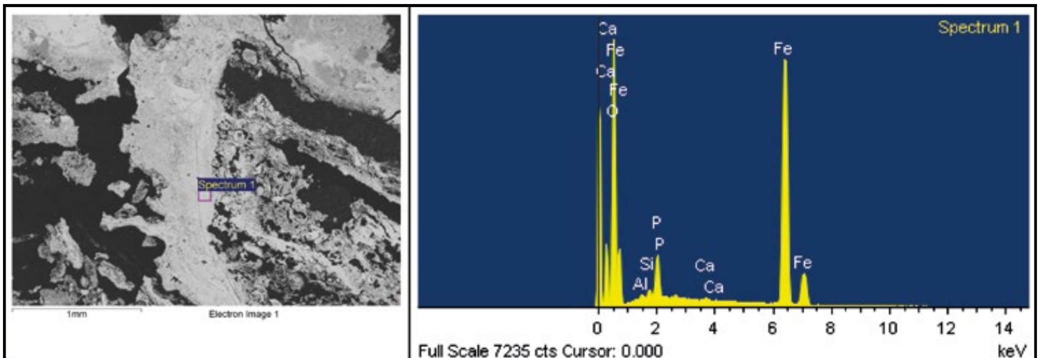


Figure 16. X-Ray spectrum of ORL616767 (Central hearth B24, 671324); wood char (fuel slag) characterised by 35.2% Ca, 16.6% Cl and 4.02% Fe.



X-Ray backscatter image of ORL223010B (Waste Pit 270600); vesicular glassy fuel ash waste. Scale bar=1mm.	X-Ray Spectrum of ORL223010B (Waste Pit 270600); vesicular glassy fuel ash waste, recording 30.6% Si.

Figure 17. Left: X-Ray backscatter image of ORL223010B (Waste Pit 270600). Right: X-Ray Spectrum of ORL223010B (Waste Pit 270600).



X-Ray backscatter image of ORL223010B (Waste Pit 270600); phosphate stained weathered remains of iron working debris. Scale bar=1mm. Figure 17. X-Ray Spectrum of ORL223010B (Waste Pit 270600); vesicular glassy fuel ash waste, recording 30.6% Si.	X-Ray Spectrum of ORL223010B (Waste Pit 270600); with 63.1% Fe - ~90% Fe2O3; 3.27% P is also present.

Figure 18. Left: X-Ray backscatter image of ORL223010B (Waste Pit 270600). Right: X-Ray Spectrum of ORL223010B (Waste Pit 270600).

of, for instance, charred botanical remains may lead to very different interpretations if this is not taken into consideration, especially when generalising and making comparisons between sites in larger geographic areas and with different soil-sedimentary situations. As has been emphasised above, the presence of calcareous shell sand and 'beach rock' adversely affected plant macrofossil preservation and accurate measurement of phosphate.

Because of different levels of preservation, palaeobotanical, physical, chemical, and soil micromorphological techniques cannot always be mutually employed on the same sample set (the full sample suite was unavailable to this team). It is quite clear, however, that it is where the study has involved multi-method interdisciplinary investigation of the same contexts that the most confident consensus interpretations have been achieved. We have therefore been able to provide some insights into how the settlement both developed and functioned. For example, the development of farming in the pre-Roman Iron Age involved animal management and manuring of fields where two subspecies of barley were cultivated (naked barley and hulled barley). During this period livestock was kept in the long houses, but there is no clear evidence of this in the Roman Iron Age, in which period byre residues are found in house-associated waste heaps, pits and trenches. It is possible that in later periods, including medieval times, byres were present and – one pit records possible seasonal byre cleaning. There is chemical data indicating that dung heaps were left to ferment in open areas (and/or in livestock enclosures within the settlement), and this suggests that not all of it was utilised in the fields. A sunken lane linked different parts of the settlement, and there are indications that animals were grazed during the Roman Iron Age along the shore. Animal management involving in-house foddering (PRIA), and all year grazing without stalling (RIA) options could also be consistent with the pollen data. Clean fresh water, especially valuable for human consumption, came from wells (at least during medieval times), whilst earlier (e.g. RIA) waterholes probably supplied both people and livestock, with stock trampling also being evident. These features also had a secondary use, as places where decayed, unused fodder/bedding from long houses was dumped. Domestic residues were disposed of in probably house-associated pits, trenches, waste heaps and disused pit houses – and included mineralised human faecal waste, containing fish remains. Burnt debris included fuel ash waste and probable iron working residues, with some fuel including likely driftwood; there are also indications that this form of settlement waste was also used on the fields.

REFERENCES

Berna, F., A. Behar, R. Shahack-Gross, J. Berg, E. Boaretto, A. Gilboa, I. Sharon, S. Shalev, S. Shilstein, N. Yahalom-Mack, J. R. Zorn & S. Weiner 2007: Sediments exposed to high temperatures: reconstructing pyrotechnological processes in Late Bronze Age and Iron Age Strata at Tel Dor (Israel): *Journal of Archaeological Science*, v. 34: 358–373.

Beug, H.-J. 1961: *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete.* Lief. 1. Stuttgart: Gustav Fischer Verlag.

Buckland, P., J. Linderholm, S. Östman, S. Eriksson, J.-E. Wallin & R. Engelmark 2017: *Environmental archaeological analysis from the archaeological excavations at Ørland kampflybase, Vik 70/1, Ørland, Sør-Trøndelag, Norway*. Environmental archaeology lab, report no. 2017-012. Department of historical, philosophical and religious studies, Umeå Universitet.

Bullock, P., N. Fedoroff, A. Jongerius, G. Stoops & T. Tursina 1985: *Handbook for Soil Thin Section Description*. Wolverhampton, Waine Research Publications.

Cappers, R.T.J., R. M. Bekker & J.E.A. Jans 2006: *Digitale Zadenatlas van Nederland Digital seed atlas of the Netherlands*. Groningen Archaeologic.

Carter, M. R. 1993: *Soil sampling and methods of analysis*. London, Lewis Publishers.

Clark, A. 2000: *Seeing beneath the soil: prospecting methods in archaeology.* New edition. London, Routledge.

Courty, M. A. 2001: Microfacies analysis assisting archaeological stratigraphy. In: Goldberg, P., V.T. Holliday & C. R. Ferring (eds.): *Earth Sciences and Archaeology*, pp. 205-239. Kluwer, New York.

Courty, M. A., P. Goldberg & R. I. Macphail 1989: *Soils and Micromorphology in Archaeology* (1st Edition). Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge.

Engelmark, R., & J. Linderholm 1996: Prehistoric land management and cultivation. A soil chemical study. In: Mejdahl, V. & P. Siemen (eds.): *Proceedings from the 6th Nordic Conference on the Application of Scientific Methods in Archaeology*, pp. 315–322. Arkæologiske Rapporter Nr. 1: Esbjerg Museum, Esbjerg.

Engelmark, R., & J. Linderholm 2008: Miljöarkeologi, Människa och Landskap – en komplicerad dynamik. *Projektet Öresundsförbindelsen*. Malmö.

Engelmark, R., & K. Viklund 1986: Järnålders jordbruk i Norrland - Teori och praktik. *Populär Arkeologi*, v. 4, no. 2: 22–24.

Engelmark, R., & K. Viklund 2008: Jordbruket i Sverige. In: Widen, B. & M. Widén (eds.): *Botanik. Systematik, evolution, mångfald.* Lund.

Fransson, U. 2018: Felt A og E, søndre del. In: Ystgaard, I., M. M. Gran, M. Mokkelbost, U. Fransson, A Heen-Pettersen, A B. Lorentzen, G. I. Solvold & E. W. Randerz: *Arkeologiske undersøkelser på Ørland kampflybase 2015-2016,* pp. 242–453. NTNU Vitenskapsmuseet arkeologisk rapport 2018:27.

Goldberg, P., & R. I. Macphail 2006: *Practical and Theoretical Geoarchaeology*. Blackwell Publishing, Oxford.

Kelley, J. T., D. F. Belknap & S. Claesson 2010: Drowned coastal deposits with associated archeological remains from a sea-level "slowstand": Northwestern Gulf of Maine, USA. *Geology*, v. 38: 695–698.

Liedgren, L. 1992: *Hus och gård i Hälsingland. En studie av agrar bebyggelse och bebyggelseutveckling i norra Hälsingland Kr.f.-600 e.Kr.* Studia archaeologica universitatis Umensis 2. Umeå universitet. Arkeologiska institutionen. Avhandling (PhD).

Linderholm, J., 2007: Soil chemical surveying. A path to a deeper understanding of prehistoric sites and societies in Sweden. *Geoarchaeology*, v. 22, no. 4: 417–438.

Lorentzen, A. B. 2018: Felt D. In: Ystgaard, I., M. M. Gran, M. Mokkelbost, U. Fransson, A Heen-Pettersen, A B. Lorentzen, G. I. Solvold & E. W. Randerz: *Arkeologiske undersøkelser på Ørland kampflybase 2015-2016* pp. 546–604. NTNU Vitenskapsmuseet arkeologisk rapport 2018:27.

Macphail, R. 2016: Ørland main air station (near Trondheim, Norway): Soil microorphology. Report for Museum of Natural History and Archaeology, Norwegian University of Science and Technology, Trondheim, Norway.

Macphail, R. 2017a: Ørland main Air Station (2016 samples), Norway: Soil micromorphology (including SEM/EDS analyses). Report for Museum of Natural History and Archaeology, Norwegian University of Science and Technology, Trondheim, Norway.

Macphail, R. 2017b: Korsmyra 1, Bud, Møre og Romsdal, Norway: soil micromorphology (including SEM/EDS), chemistry and magnetic susceptibility studies (report for Cultural history Museum, University of Olso): Institute of Archaeology, University College London.

Macphail, R. 2018: Dronningens gate 5 site, Trondheim, Norway (TA2017/14): soil micromorphology (and SEM/EDS) (report for NIKU): Institute of Archaeology, University College London.

Macphail, R. I., J. Bill, R. Cannell, J. Linderholm, & C. L. Rødsrud 2013: Integrated microstratigraphic investigations of coastal archaeological soils and sediments in Norway. The Gokstad ship burial mound and its environs including the Viking harbour settlement of Heimdaljordet, Vestfold. *Quaternary International*, no. 315: 131–146.

Macphail, R. I., J. Bill, J. Crowther, C. Haită, J. Linderholm, D. Popovici & C. L. Rødsrud 2017: European ancient settlements – a guide to their composition and morphology based on soil micromorphology and associated geoarchaeological techniques; introducing the contrasting sites of Chalcolithic Borduşani-Popină, Borcea River, Romania and the Viking Age Heimdaljordet, Vestfold, Norway. *Quaternary International*, v. 460: 30–47.

Macphail, R. I., & G. M. Cruise 2001: The soil micromorphologist as team player: a multianalytical approach to the study of European microstratigraphy. In: Goldberg, P., V. Holliday & R. Ferring (eds.): *Earth Science and Archaeology*, pp. 241–267. Kluwer Academic/ Plenum Publishers, New York.

Macphail, R. I., & P. Goldberg 2018: *Applied Soils and Micromorphology in Archaeology.* Cambridge University Press, Cambridge.

Macphail, R. I., & J. Linderholm 2017: Avaldsnes: Scientific Analyses – Microstratigraphy (soil micromorphology and microchemistry, soil chemistry and magnetic susceptibility). In: Skre, D. (ed.): *Avaldsnes - A Sea-King's Manor in First-Millenium Western Scandinavia*, pp. 379–420. De Gruyter, Berlin.

Macphail, R. I., J. Linderholm & S. Eriksson 2016: Nannestad Vicarage, cadastral number 27/1/6 – Nannestad municipality - Akershus County, Norway: soil micromorphology, chemistry and magnetic susceptibility studies (report for Cultural History Museum, University of Oslo): Institute of Archaeology, University College London.

Mokkelbost, M. 2018: Felt A og E, nordre del. In: Ystgaard, I., M. M. Gran, M. Mokkelbost, U. Fransson, A Heen-Pettersen, A B. Lorentzen, G. I. Solvold & E. W. Randerz: *Arkeologiske undersøkelser på Ørland kampflybase 2015-2016,* pp.122-158.. NTNU Vitenskapsmuseet arkeologisk rapport 2018:27.

Mooney, D. E. 2018: Charred *Fucus*-Type Seaweed in the North Atlantic: A Survey of Finds and Potential Uses. *Environmental Archaeology*, DOI:10.1080/14614103.2018.1558805.

Moltsen, A. S. A., 2017: Udvidede makrofossilanalyser fra Ørland kampflybase (report for NTNU): Natur Og Kultur.

Moore, P. D., J.A. Webb & M. E. Collinson 1991: *Pollen Analysis.* Blackwell Scientific Publications, Oxford.

Murphy, C. P. 1986: *Thin Section Preparation of Soils and Sediments.* A B Academic Publishers, Berkhamsted.

Myhre, B. 2004: Agriculture, landscape and society ca. 4000 BC-AD 800. In: Almås, R. (ed.): *Norges landbrukshitorie*, pp. 14-77. Tapir Academic Press, Trondheim.

Nicosia, C. & G. Stoops 2017: *Archaeological Soil and Sediment Micromorphology.* Wiley Blackwell, Chichester.

Shahack-Gross, R. 2011: Herbivorous Livestock Dung: Formation, Taphonomy, Methods For Identification, and Archaeological Significance. *Journal of Archaeological Science*, v. 38: 205–218.

Stoops, G. 2003: *Guidelines for Analysis and Description of Soil and Regolith Thin Sections.* Soil Science Society of America, Inc. Madison, Wisconsin.

Stoops, G., V. Marcelino & F. Mees 2010: *Interpretation of Micromorphological Features of Soils and Regoliths.* Elsevier, Amsterdam.

Stoops, G., V. Marcelino & F. Mees 2018: *Interpretation of Micromorphological Features of Soils and Regoliths (2nd Edition)*: Elsevier, Amsterdam.

Viklund, K., R. Engelmark & J. Linderholm 1998: Fåhus från bronsålder till idag. *Skrifter om skogs- och lantbrukshistoria 12.* Nordiska Museet, Lund.

Viklund, K., J. Linderholm & R. I. Macphail 2013: Integrated Palaeoenvironmental Study: Micro- and Macrofossil Analysis and Geoarchaeology (soil chemistry, magnetic susceptibility and micromorphology). In: Gerpe, L.-E. (ed.): *E18-prosjektet Gulli-Langåker. Bind 3: Oppsummering og arkeometriske analyser*, pp. 25–83. Fagbokforlaget, Bergen.

Ystgaard, I. 2018: Felt A og E, felles innledning. In: Ystgaard, I., M. M. Gran, M. Mokkelbost, U. Fransson, A Heen-Pettersen, A B. Lorentzen, G. I. Solvold & E. W. Randerz: *Arkeologiske undersøkelser på Ørland kampflybase 2015-2016,* pp.109-121. NTNU Vitenskapsmuseet arkeologisk rapport 2018:27.

Ystgaard, I., M. M. Gran, M. Mokkelbost, U. Fransson, A Heen-Pettersen, A B. Lorentzen, G. I. Solvold & E. W. Randerz 2018: *Arkeologiske undersøkelser på Ørland kampflybase 2015-2016.* NTNU Vitenskapsmuseet arkeologisk rapport 2018:27.

Weiner, S., 2010: *Microarchaeology. Beyond the Visible Archaeological Record.* Cambridge University Press, Cambridge.