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Inferring Long-term Land-use Development Through On-site Botanical Analyses at Øvre Øksnevad, Southwestern Norway

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ABSTRACT

This study analysed pollen and plant macrofossils from mainly Bronze Age and Iron Age funerary, agricultural and settlement remains, to infer local plant exploitation and long-term land-use development at Øvre Øksnevad in southwestern Norway. The results showed that deciduous woodland covered the site prior to c. 2100 BC. After this, until c. 500 BC, the vegetation became dominated by grasses/herbs, while several phases of land clearance and cultivation were identified. The main human activity on the site was c. 600–300 BC, when a settlement was established and most of the 103 cairns registered at the site were constructed. Grazing on heathland was the main land-use from 300 BC, until another short-lived settlement was established c. AD 1–200, while regular burning of the heathland occurred from c. AD 1300. The relatively short-lived settlement at Øvre Øksnevad suggests it was marginal and only used during times of high population pressure, a conclusion which is supported by the botanical evidence. This study demonstrates how comprehensive sampling for botanical remains can contribute to the understanding of complex archaeological sites, including local land-use development and human-plant interactions.

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Introduction

On-site botanical analyses, such as pollen and plant macrofossils, are often employed in archaeological investigations to reconstruct the local environment and explore human-plant interactions. Such studies contribute to the interpretation of on- and off-site activities including ritual traditions, subsistence strategies and agricultural practices (e.g. Caseldine and Matthews 1985; Dimpleby 1985; Segerström 1991).

Analysis of macroscopic plant remains often focuses on charred material, such as seeds and wood charcoal, which are usually well preserved in soils. These charred remains are generally formed during human activity, such as crop processing, food preparation and swidden agriculture, and mainly reflect local land-use and plant exploitation. On the contrary, pollen grains can travel long distances, and pollen assemblages therefore represent a mixture of the local and regional vegetation (Jacobson and Bradshaw 1981; Sugita 1994). Pollen sampling from soils and features on archaeological sites (rather than from mires or lakes located further afield) ensures that at least a part of the pollen composition originates from the immediate surroundings, and can therefore be directly linked to on-site activities. However, special attention should be paid to the soil history, as bioturbation and other taxonomic processes

may affect how the pollen and macrofossil composition is represented in the sediment column (Andersen 1979; Kelso 1994; Tipping et al. 1999).

Palaeobotanical analyses have long been systematically employed in southwestern Norway, an area where the landscape is heavily influenced by past human activities. Clearances within the deciduous woodland around 4000 BC represent the first major human impacts here (Hjelle, Hufthammer, and Bergsvik 2006; Høgestøl and Prøsch-Danielsen 2006), around the time that the Neolithic inhabitants of southern Scandinavia were making their first forays into cultivation (Sørensen and Karg 2014). Under a predominantly agro-pastoral economy from around 2400 BC, the landscape became dominated by arable fields and pasture (Prøsch-Danielsen and Simonsen 2000; Hjelle et al. 2012). Within this agricultural society, there are indications of a re-organisation of land-use from c. 500 BC, with the establishment of permanent fields and a clearer division between infield (cultivation and hay-meadows) and outfield (pastures and wood resources) (Halvorsen and Hjelle 2017; Fredh, Prøsch-Danielsen, and Jensen 2022). These millennia of human influence gave rise to a mosaic of cultivated fields, meadows and pastures, within the coastal heathland in southwestern Norway,

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although most of the small-scale pre-industrial landscape has been encroached during the last 50–100 years of modern agriculture.

The present study was carried out in connection with excavations at the multi-period site of Øvre Øksnevad (Figure 1). This complex site comprised funerary, agricultural and settlement remains from mainly the Bronze Age and Iron Age, and therefore presented an opportunity to explore the interplay between domestic, agricultural and ritual activity over several thousand years. With this in mind, a representative selection of features from the archaeological site were sampled for pollen and macroscopic plant remains during the excavation, to investigate to what extent long-term changes in land use can be inferred through on-site pollen and macrofossil sampling combined with radiocarbon dating. This paper aims to reconstruct the local land-use development and human-plant interactions in relation to the different archaeological activities represented at the site.

Material and Methods

Study Area and Archaeological Site

The study site is situated on a hill at Øvre Øksnevad, close to the town of Klepp in southwestern Norway.



Figure 1. The location of the study site of Øvre Øksnevad in southwestern Norway. Nearby towns and other archaeological sites that are mentioned in the text are also marked. Map of Norway is inserted.

It lies around 40–50 m above sea level and looks out over the Lake Frøylandsvatnet (Figure 1). The surrounding landscape is open and heavily influenced by human activity, consisting of a mixture of modern industry, residential areas and agricultural land. The climate is oceanic with relatively mild summers: the mean annual temperature is 6–8°C, and the annual precipitation is 1000–1500 mm (Moen 1999). The local area is undulating with thick Quaternary deposits, and the hill at Øvre Øksnevad is build-up of glaciofluvial sediments, mainly sorted sand and gravel, covered by approximately 40 cm of sandy till deposited during the last glacial retreat (Bergstrøm et al. 2010). The hill has previously been remodelled by recent gravel extraction, during which further archaeological remains were removed without documentation.

Excavations at Øvre Øksnevad took place in 2016 and revealed 103 cairns, three settlement areas including 6 houses, and several preserved prehistoric cultivation layers (Figures 2 and 3). Two relatively large grave mounds (approx. 20 m in diameter) were situated at the top of the hill, whereas the remaining cairns (approx. 2–5 m long) were

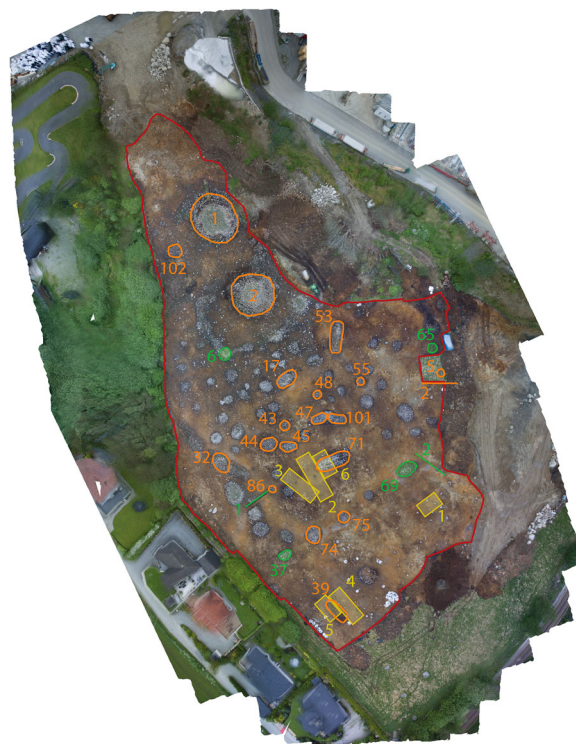


Figure 2. Aerial photo of the archaeological site of Øvre Øksnevad (within red line) after the topsoil has been removed. Green colour marks features from which both pollen and macrofossils were analysed stratigraphically: through two cultivation layers (Profile 1–2), from two cairns (Cairn 37, Cairn 65), and from two combined profiles consisting of cultivation layers with cairns on top (Cairn 69 and Cairn 6). In addition, a variety of features were analysed only for plant macrofossil analysis: yellow colour marks houses (Houses 1–6) and orange colour marks cairns/profiles.

distributed relatively evenly over the upper slopes to the south and east. Most of the cairns were circular or semi-circular, while a few were elongated. A linear stone feature was also uncovered (Cairn 6 in Figure 2 is situated within this feature), which partly surrounded one of the large grave mounds on top of the hill. The cultivation layers were found mainly on the lower terraces in depressions and in the slopes along the northern and southern edge of the hill. The settlement areas were situated in the eastern and central slopes, in three different areas, from where roughly 400 postholes along with a few fireplaces and cooking pits were uncovered. The houses were identified by two parallel rows of roof-bearing postholes with a total length of ca. 10–20 m, which is relatively short compared to other contemporary houses in the region. Four of the houses had a distinct outline with a fireplace (Houses 1, 2, 3 and 5) and two houses were more diffuse without fireplaces (Houses 4 and 6). Houses 4 and 6 were also covered by later cairns, and a few cooking pits at the site were situated stratigraphically above the cultivation layers. Finds related to the burials were scarce, although pottery was found scattered between the stones in several cairns. Potsherds were typologically dated to between 500 BC and AD 550. Some of the cairns were constructed with a central chamber, and contained fragmented pottery/burnt bone, which confirms their main purpose as markers or monuments for cremation burials (Bell and Denham 2020). In this study, we assume that all investigated cairns are for burial purposes, although it cannot be excluded that a few clearance cairns were constructed in connection with cultivation at the site.

Radiocarbon Dating

In total, 43 samples were dated (37 pieces of charcoal, 4 cultivated seeds and 2 bone fragments) from archaeological investigations at Øvre Øksnevad (Table 1). In order to produce enough radiocarbon dates for the cairns (only two cairns contained enough human bone from a burial context for radiocarbon dating) charcoal was extracted from the upper and lower parts of the cairn to retrieve a minimum and maximum date respectively. In addition, charcoal fragments were used to date fireplaces, burnt layers, cultivation layers and cooking pits. Four seeds from cultivated plants were also dated: three *Hordeum vulgare* (barley) and one *Linum usitatissimum* (flax), from three postholes and a cultivation layer. The analyses were carried out using accelerator mass spectrometry at the 14CHRONO Centre in Belfast (UBA) and Beta Analytic in London (Beta). All radiocarbon dates were calibrated using OxCal v4.4.4 based on the IntCal20 calibration curve (Bronk Ramsey 2009; Reimer et al. 2020). In addition, the summed probability function in OxCal was used to get an overview of the distribution of all radiocarbon dates from the site (Bronk Ramsey 2017).

Pollen and Multivariate Analyses

Samples for pollen analysis were extracted from six vertical sections: two profiles through cultivation layers, two profiles through cairns, and two combined profiles consisting of cultivation layers with cairns on top (Figure 2). After standard pre-treatment (Berglund and Ralska-Jasiewiczowa 1986), twenty-nine samples were analysed for the content of pollen using a light microscope (400x and 1000x magnification, including

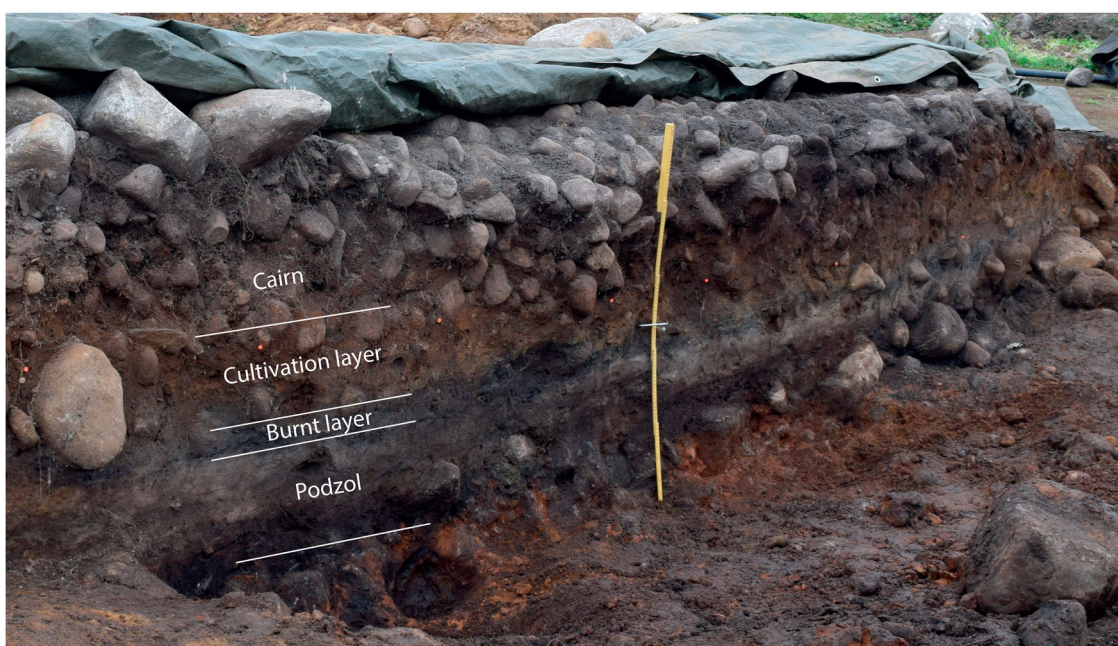


Figure 3. Picture of the vertical section of one of the analysed cairns (Cairn 6), with interpretation of stratigraphy, including layers accumulated before the cairn was constructed.

Table 1. All available radiocarbon dates obtained from the archaeological site Øvre Øksnevad, listed from youngest to oldest age.

Lab-ID (Sample ID)	Type of feature	¹⁴ C age BP	Calibrated year (2σ-range)	Sample weight (g)	Type of material
UBA34617 (295)	Cairn (Cairn 53)	120 ± 25	AD 1681-1939	0.02	Charcoal (Ericaceae)
UBA34621 (93)	Cairn (Cairn 71)	121 ± 31	AD 1676-1942	0.007	Charcoal (Ericaceae) & Seed (unidentified)
UBA34608 (258)	Cairn (Cairn 25)	148 ± 23	AD 1669- ...	0.01	Charcoal (Ericaceae)
UBA34606 (176)	Cairn (Cairn 17)	215 ± 26	AD 1644- ...	0.01	Charcoal (Ericaceae)
UBA34607 (178)	Cairn (Cairn 17)	285 ± 23	AD 1515-1660	0.02	Charcoal (Ericaceae)
UBA34612 (150)	Cairn (Cairn 34)	302 ± 25	AD 1499-1652	0.013	Charcoal (Ericaceae)
UBA34610 (191)	Cairn (Cairn 29)	440 ± 25	AD 1425-1478	0.0079	Charcoal (Salix/Populus sp.)
UBA34622 (229)	Cairn (Cairn 74)	533 ± 36	AD 1320-1444	0.02	Charcoal (Ericaceae)
UBA34613 (143)	Cairn (Cairn 36)	644 ± 33	AD 1283-1396	0.01	Charcoal (Ericaceae)
UBA34615 (339)	Cairn (Cairn 45)	661 ± 24	AD 1282-1391	0.01	Charcoal (Ericaceae)
UBA34623 (230)	Cairn (Cairn 74)	1811 ± 28	AD 132-334	0.07	Charcoal (Betula sp.)
UBA34633 (174)	Fireplace (House 2)	1814 ± 30	AD 130-330	0.0679	Charcoal (Betula sp.)
Beta457175 (172)	Posthole (House 2)	1820 ± 30	AD 130-326	0.0132	Seed (Hordeum)
UBA34631 (82)	Cooking pit (under Cairn 71)	1875 ± 30	AD 83-237	0.0625	Charcoal (Alnus sp.)
UBA34609 (257)	Cairn (Cairn 25)	1923 ± 28	AD 26-208	0.01	Charcoal (Betula sp.)
UBA34624 (10)	Cooking pit (in Profile 2)	1979 ± 32	43 BC-AD 121	0.05	Charcoal (Salix/Populus sp.)
UBA34627 (13)	Cooking pit (in Profile 2)	1989 ± 31	46 BC-AD 118	0.04	Charcoal (Betula sp.)
UBA34690 (758)	Grave context (Cairn 1)	2235 ± 32	390-200 BC	1.4	Bone (Human)
UBA34604 (382)	Cairn (Cairn 14)	2318 ± 29	451-231 BC	0.04	Charcoal (Corylus avellana)
UBA34630 (75)	Cairn/Grave context (Cairn 2)	2330 ± 31	513-233 BC	0.02	Charcoal (Corylus avellana)
UBA34628 (51)	Cairn (Cairn 71)	2337 ± 29	514-368 BC	0.128	Charcoal (Corylus avellana)
UBA34629 (57)	Grave context (Cairn 53)	2343 ± 31	537-368 BC	0.03	Charcoal (Corylus avellana)
UBA34619 (141)	Cairn (Cairn 69)	2370 ± 28	540-390 BC	0.01	Charcoal (Corylus avellana & Betula sp.)
UBA38526 (46)	Cultivation layer (Profile 1)	2373 ± 26	540-392 BC	0.0062	Seed (Hordeum vulgare)
UBA34634 (183)	Fireplace (House 4)	2415 ± 45	752-397 BC	0.0368	Charcoal (Corylus avellana)
Beta457174 (69)	Posthole (House 1)	2420 ± 30	748-402 BC	0.0076	Seed (Linum usitatissimum)
UBA34632 (137)	Grave context (Cairn 34)	2428 ± 34	750-403 BC	0.05	Charcoal (Corylus avellana)
Beta457173 (68)	Posthole (House 1)	2430 ± 30	750-404 BC	0.016	Seed (Hordeum)
UBA34620 (142)	Cairn (Cairn 69)	2431 ± 26	749-406 BC	0.013	Charcoal (Betula sp.)
UBA34618 (111)	Cairn (Cairn 60)	2433 ± 31	750-405 BC	0.05	Charcoal (Betula sp.)
UBA34691 (759)	Grave context (Cairn 33)	2435 ± 33	751-406 BC	6.09	Bone (Human)
UBA34616 (340)	Grave context (Cairn 45)	2440 ± 40	755-406 BC	0.01	Charcoal (Maloideae)
UBA34625 (11)	Cultivation layer (Profile 2)	2455 ± 30	755-414 BC	0.01	Charcoal (Corylus avellana)
Beta253732 (760)	Cooking pit (near House 2, from previous excavation)	2590 ± 40	826-563 BC	n/a	Charcoal (Alnus sp.)
UBA34602 (302)	Cairn (Cairn 6)	2702 ± 37	919-802 BC	0.0287	Charcoal (Betula sp.)
UBA38527 (48)	Burnt layer (Profile 1)	3027 ± 37	1404-1130 BC	0.0298	Charcoal (Salix/Populus sp.)
UBA34614 (144)	Cairn (Cairn 36)	3079 ± 30	1422-1262 BC	0.017	Charcoal (Deciduous)
UBA34626 (12)	Burnt layer (Profile 2)	3113 ± 31	1447-1283 BC	0.05	Charcoal (Betula sp.)
UBA34605 (383)	Cairn (Cairn 14)	3504 ± 33	1926-1703 BC	0.01	Charcoal (Deciduous) & Seed (unidentified)
UBA34611 (192)	Cairn (Cairn 29)	3538 ± 32	1956-1750 BC	0.0311	Charcoal (Betula sp.)
UBA34603 (284)	Cultivation layer (Cairn 6)	3545 ± 29	2009-1769 BC	0.0095	Charcoal (Betula sp.)
UBA38525 (286)	Burnt layer (Cairn 6)	3675 ± 33	2191-1953 BC	0.0817	Charcoal (Corylus avellana)
Beta253731 (761)	Cultivation layer (from previous excavation)	3840 ± 40	2458-2152 BC	n/a	Charcoal (Betula sp.)

Notes: The dated material was charcoal, charred seeds and human bones, which were pre-treated with HCl and NaOH. The sample weights were obtained prior to submission to the laboratories, i.e. the 14CHRONO Centre in Belfast (UBA) and Beta Analytic in London (Beta).

phase contrast), literature/key (Moore, Webb, and Colinson 1991; Beug 2004) and the reference collection at the Museum of Archaeology, University of Stavanger. The Tilia software (v. 2.0.41) was used to create pollen percentage diagrams and identify local vegetation zones by constrained cluster analysis (Grimm 1987, 1992). Linear-based multivariate analysis, i.e. Principal component analysis (PCA), was used (a short gradient length was identified) to explore the variation in pollen composition between samples using Canoco (v. 5.0). All samples and pollen taxa were included in the PCA and the pollen percentage data were square root transformed (ter Braak and Šmilauer 2012).

Macrofossil and Charcoal Analysis

A variety of features were sampled for plant macrofossil analysis throughout the excavation at Øvre

Øksnevad. In total 102 samples were analysed for macroscopic plant remains, including 7 samples analysed by Lundberg (2017). However, only the samples that contained charred plant macrofossils (78 samples) were included in this study (Supplementary material 1). Of these samples were 3 from buried soil horizons, 5 from burnt layers, 6 from cultivation layers, 4 from cooking pits/fire places, 16 from postholes, 6 from grave contexts and 31 from cairns. In addition, 7 samples contained material from two or more separate contexts. As such, these samples cannot be conclusively assigned to any one particular phase of activity at the site and are therefore not discussed further in this paper.

Samples ranged in volume from 0.5 to 8 litres, and the total volume of soil processed was approx. 200 litres. The samples were processed by water flotation. The light fraction was retained on a

0.5 mm mesh and air-dried. The samples were then sorted and plant remains retrieved for analysis. Identifications of plant macrofossils were made by comparing observed characteristics with modern reference material, along with published and digital sources (Beijerinck 1947; Berggren 1969, 1981; Anderberg 1994; Cappers, Bekker, and Jans 2006; Jacomet 2006; Neef et al. 2012). Nomenclature used in the text, diagrams, and tables follows Mossberg and Stenberg (2007).

Taxonomic identification of charcoal fragments was carried out in order to identify material suitable for radiocarbon dating. Charcoal analysis was carried out partly by an external contractor (A.J. Kirchhefer, Tromsø) and partly at the Museum of Archaeology, University of Stavanger. Taxonomic identifications were assigned by comparing suites of anatomical characteristics visible with those documented in reference atlases (Schweingruber 1990; Schoch et al. 2004; Hather 2000). Taxa with relatively short lifespans were preferentially selected for dating in order to give more accurate results; long-lived taxa such as *Pinus sylvestris* (Scots pine) and *Quercus* sp. (oak) were avoided. Taxonomic identifications of charcoal submitted for radiocarbon dating are given in Table 1.

Results

Pollen Composition in Profiles and Associated Dates

The pollen sum varied substantially between samples (from 105 to 741); in particular a few of the buried soil horizons and burnt layers showed relatively low pollen contents. Most of the pollen sequences show vertical variations in pollen content, which likely represent changes in vegetation cover over time (Figure 4). By combining all pollen samples in the PCA, three relatively distinct groups could be identified (Figure 5), which were combined to describe local pollen assemblage zones (LPAZ) as pollen samples with the same date range can be assumed to represent the same local environment. However, five samples were excluded from the LPAZ groupings as there was an overlap in pollen composition between some of the samples, in particular between samples from cultivation layers and the lower levels of cairns. The division in LPAZs was aided by the cluster analyses carried out for each pollen sequence separately.

The eight radiocarbon dates obtained from the stratigraphical sections range from c. 2100 to 500 BC, with the oldest dates obtained in the lower part of each profile (from layers with samples in LPAZ 1) and the younger dates obtained from the upper part of each profile (from layers with samples in LPAZ 3), which supports the division in LPAZs to explore the vegetation development over time. However, there was

some overlap between dates obtained from layers with pollen samples assigned to LPAZ 1 and LPAZ 2.

LPAZ 1: Woodland – *Corylus* – *Tilia*

Four pollen samples (from Cairn 6 and Profile 1) were included in LPAZ 1 (Figures 4 and 5). The samples from Cairn 6 were from a podzol sequence and from a burnt layer immediately above. LPAZ 1 was dominated by trees, characterised by high amounts of *Corylus* (hazel) and *Tilia* (lime), up to approx. 20% and 40% pollen percentage respectively. *Betula* (birch) was also common (up to approx. 50%) but this tree was not characteristic only in this zone. A few herbs were identified, such as *Melampyrum* (cow-wheats), Poaceae (grass family) and *Succisa* (devil's-bit scabious), but these taxa were rather variable between samples. *Plantago lanceolata* (ribwort plantain) was also identified in one of the burnt layers. The mean pollen composition, using all samples assigned to LPAZ 1, showed that tree pollen was dominant, comprising 86% of the total assemblage, with 4% dwarf shrubs, 4% grasses and 6% other herbs.

LPAZ 2: Herbs – Poaceae – *Betula*

Eight pollen samples (from Cairn 6, Cairn 69 and Profile 2) were included in LPAZ 2 (Figures 4 and 5). LPAZ 2 is dominated by *Betula*, Poaceae and a mixture of herbs. Common herbs were *Artemisia* (mugworts), Chenopodiaceae (goosefoot family), Cyperaceae (sedge family), *Plantago lanceolata* (ribwort plantain), *Ranunculus acris* type (buttercups), *Rumex acetosa* type (sorrel), *Spergula arvensis* (corn spurrey) and *Persicaria maculosa* (redshank). Cerealia undifferentiated (cereals), *Hordeum* type (barley) and *Triticum* type (wheat) were present in the samples from Cairn 69 and Cerealia undifferentiated from Profile 2. Combining the pollen samples assigned to LPAZ 2 resulted in a mean composition of 40% trees, 3% dwarf shrubs, 35% Poaceae and 22% other herbs.

LPAZ 3: Heathland – *Calluna vulgaris*

Twelve pollen samples (from Cairn 6, Cairn 69, Profile 1, Cairn 65 and Cairn 37) were included in LPAZ 3 (Figures 4 and 5). LPAZ 3 is dominated by the heathland plant *Calluna vulgaris* (heather), which comprises up to 75% of the total pollen composition. Poaceae was also common (up to 50%). Other heathland plants were also relatively common, such as *Empetrum* (crowberry) and *Vaccinium* type (bilberries), along with the grassland plants *Trifolium repens* (white clover) and *Plantago lanceolata*. A few grains of cereal pollen were identified in some of the profiles/cairns (i.e. Profile 1, Cairn 65 and Cairn 37). Combining the pollen samples assigned to LPAZ 3 showed a mean pollen composition of 11% trees, 3% shrubs, 55% dwarf shrubs, 25% Poaceae and 6% other herbs.

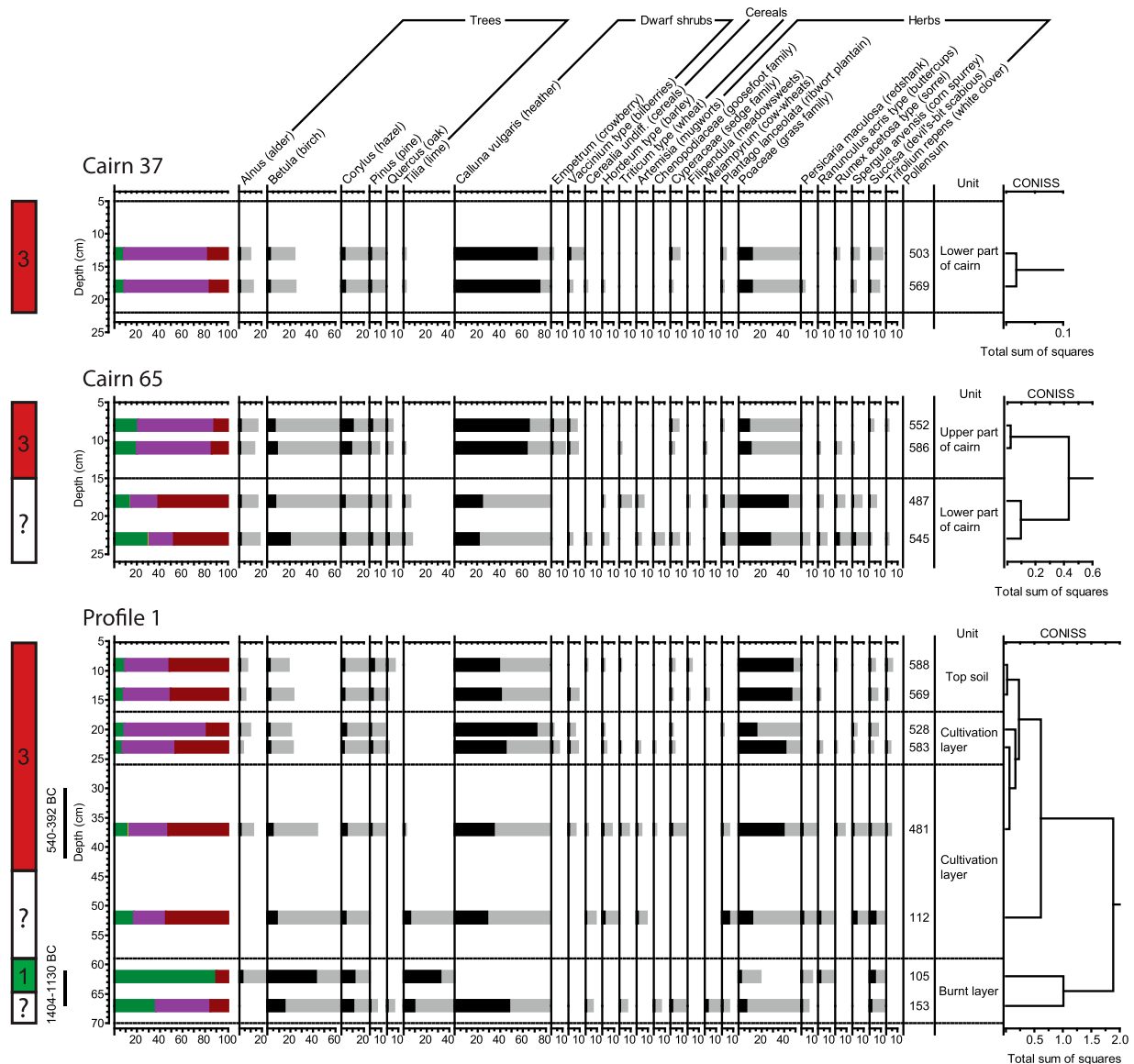


Figure 4 Continued

between soil categories, as described below (Figure 6; Supplementary material 1). Macrofossil concentration was calculated excluding charcoal fragments, and averages presented below are based only on samples which produced plant macrofossils other than charcoal. The results presented here include seven samples analysed by Lundberg (2017).

Although taxonomic identifications of charcoal were carried out on fragments to be submitted for radiocarbon dating, the results of this analysis are not discussed in detail here. As mentioned above, short-lived taxa such as Ericaceae (heather family), *Corylus avellana* (hazel), *Betula* sp. (birch) and *Alnus* sp. (alder) were preferentially selected for dating in order to avoid an 'old wood' bias in the dating results. The results therefore do not necessarily represent an accurate picture of the wood taxa present in the area and/or used as fuel at any given time. Further charcoal analysis was not carried out from the site as many samples contained too few charcoal fragments to give significant results.

Nevertheless, as Table 1 shows, charcoal fragments dated to AD 200 and earlier were generally identified as tree taxa, especially in the Betulaceae family. In contrast, the majority of charcoal fragments dated to the AD 1300 and later were identified as Ericaceae.

Most charred macrofossils were obtained from only a few postholes in Houses 1 and 2: the average macrofossil finds (not including charcoal) per litre of soil for Houses 1 and 2 respectively was 154 and 54, compared to an average of 3.5 from postholes in other Houses. The assemblage was dominated by weed seeds, mainly *Chenopodium album* (goosefoot), *Persicaria lapathifolia* (pale persicaria) and *Spergula arvensis* (corn spurry). A single posthole in House 1 contained 1760 *Chenopodium album* seeds. The postholes also contained a relatively large amount of seeds of cultivated species, mainly *Linum usitatissimum* (flax) from House 1, along with a few cereal grains including *Avena* sp. (oat), *Hordeum vulgare* (barley) and *Triticum* sp. (wheat) (Lundberg 2017).

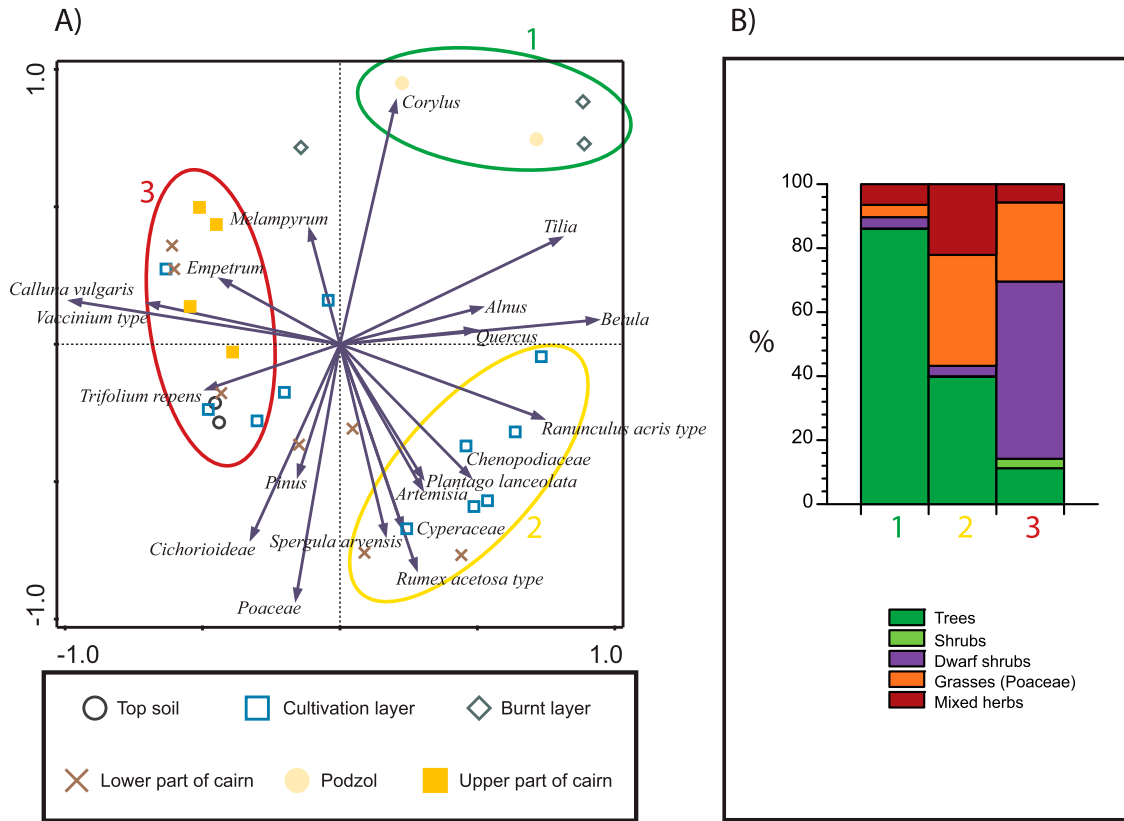


Figure 5. (A) Principal component analysis of all pollen samples included in this study, classified according to which type of soil/context the samples were extracted from. Inferred local pollen assemblage zone (no. 1–3) are also shown within ovals. (B) Mean pollen percentage for each local pollen assemblage zone (no. 1–3), inferred from the PCA and CONISS analyses.

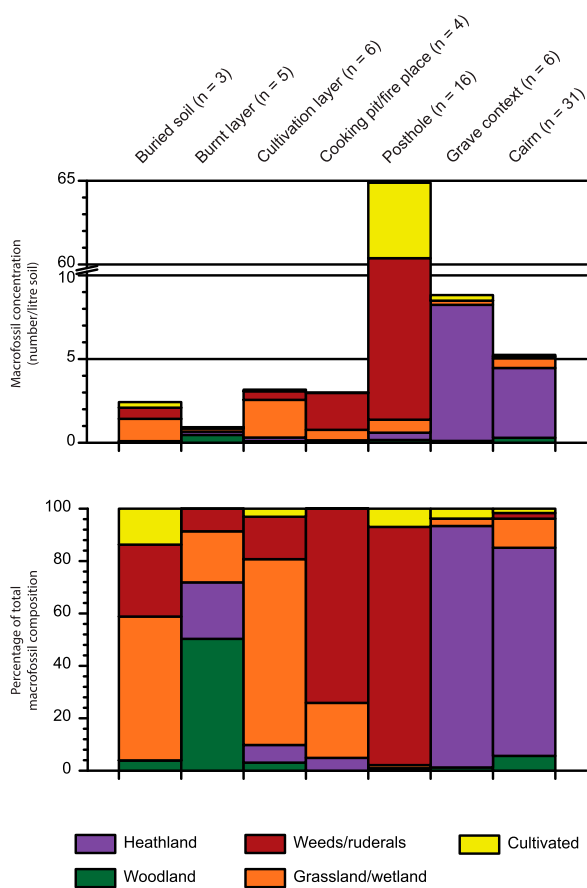


Figure 6. Mean macrofossil concentration (number per litre soil) and percent of total macrofossil composition for each group of features.

Samples from grave contexts and within cairns were dominated by seeds of heathland plants, mainly *Arctostaphylos uva-ursi* (bearberry) and *Empetrum nigrum* (crowberry), but seeds of *Rubus idaeus* (raspberry) and remains of *Calluna vulgaris* (heather) were also identified. Cairn fills produced on average 5.6 plant macrofossils per litre, while the average from grave contexts was slightly higher at 8.8.

The cooking pits and fireplaces contained mainly macrofossils of weeds/ruderals, such as *Persicaria lapathifolia* and *Chenopodium album*, as well as some grassland/wetland plants such as *Carex* (sedges) and *Potentilla erecta* (tormentil). The average plant macrofossils per litre was 3.1.

The cultivation layers contained mainly macrofossils of grassland/wetland plants, mainly Poaceae (grass family) and *Danthonia decumbens* (heath-grass). Weeds/ruderals were the second most common category, including species such as *Persicaria lapathifolia* and *Spergula arvensis*.

Few macrofossils were identified from the burnt layers (on average 1.3/litre), including the woodland taxa *Pinus sylvestris* (Scots pine) and *Sambucus nigra* (elder), and the grassland/wetland taxa *Carex* spp. and Poaceae. Charred plant macrofossils of taxa from a range of land-use types, including *Cerealia* (cereals), *Corylus avellana*, *Carex* spp. and *Rumex acetosella* (sheep’s sorrel), were found in the buried

soil layers, although find quantities here were also low, at 2.4 macrofossils per litre on average.

The plant macrofossil finds vary more significantly between context types than over time. Heathland plants were most common in cairn fills and grave contexts, where remains of cultivated plants and weeds/ruderals were rare. In contrast, the latter two groups were common in samples from houses, especially House 1 and House 2. Grassland and wetland plants were found in small quantities in all context types, but were most common in samples from cultivation layers. Macrofossils of woodland plants were rare in all context types, however occasional fragments of *Corylus avellana* nutshell attest to the continued presence and/or exploitation of this taxon throughout the occupation of the site. Of the cultivated plants, *Linum usitatissimum*, *Avena* and *Triticum* were only found in House 1, dated to c. 600 BC, while *Hordeum* was also noted in House 2, dated to c. AD 200. *Chenopodium album* appears to have been a common weed in all periods with cultivated plants. *Persicaria lapathifolia* seems to have been much more common c. AD 200, but as this is based on a large quantity of finds from a single sample in House 2, it cannot necessarily be applied to the whole site.

Discussion

Early Traces of Human Activity

The oldest pollen samples from Øvre Øksnevad date from before c. 2100 BC and likely represent the vegetation at the site before any major human impact (Figures 4 and 5). The pollen composition in these samples suggests a landscape dominated by deciduous trees (LPAZ 1), mainly *Betula* and *Corylus*, with minor components of *Alnus*, *Pinus* and *Quercus*. These taxa were common in western Norway, in particular prior to introduction of agriculture (Prøsch-Danielsen and Simonsen 2000; Hjelle et al. 2018). A fragment of charred hazelnut shell from the same stratigraphic level (Supplementary material 1) supports the presence of *Corylus avellana* in the local landscape at this time. Small quantities of pollen grains from herbs and dwarf shrubs indicate minor openings in the woodland, which was the only evidence of human activity at the site identified in LPAZ 1.

Similar pollen composition, suggesting a dominance of a deciduous woodland, was identified in two burnt layers from the site. However, one additional sample from one of these burnt layers was dominated by *Calluna vulgaris* and contained a few pollen cereal grains, and several samples contained taxa indicating pastoral activity (such as *Plantago lanceolata* and *Ranunculus acris* type) and cultivation (weed taxa such as *Persicaria maculosa*) (Hjelle 1999; Gaillard 2007; Fredh, Prøsch-Danielsen, and Jensen

2022). Macrofossils from the burnt layers, such as *Pinus sylvestris*, *Sambucus nigra*, *Carex* spp. and Poaceae, also indicate a mixture of woodland and open land. Macrofossils from woody plants probably represent trees that were burnt after clearing the land, while the herbs may either have been growing in patches of open land or incorporated during later activities. Hence, these burnt layers contained botanical remains from different types of landscapes. Probably soils of different ages were mixed during cultivation, or alternatively, fuel gathered by humans prior to burning yielded an unusual composition in some of the samples.

The dates obtained from burnt layers (c. 2100 BC and c. 1400-1300 BC) and from cultivation layers (c. 2300-1900 BC and c. 600-500 BC) suggest several phases of woodland clearance and cultivation at Øvre Øksnevad (Figure 8). The earliest phase is contemporary with the period of transition to an agricultural economy in southwestern Norway (Soltvedt 2000; Diinhoff 2005). The land at Øvre Øksnevad was probably cleared to make way for grasslands and arable fields belonging to a settlement situated nearby. This settlement must have been outside the excavated area, as no traces of settlement have been identified from this period at Øvre Øksnevad.

The earliest cultivation layer analysed contained no cereal pollen, but the layer was homogenous, cleared of larger stones and contained macroscopic charcoal. These characteristics are typical for prehistoric cultivation layers in the region (Halvorsen and Hjelle 2017; Fredh, Prøsch-Danielsen, and Jensen 2022). The layer also contained pollen from several characteristic arable weeds, such as *Persicaria maculosa* and *Spergula arvensis*, and grassland indicators, such as *Plantago lanceolata* and *Rumex acetosa* type. This pollen composition is similar to pollen assemblages from later cultivation layers (LPAZ 2). In general, cultivation layers older than around 500 BC contain relatively few pollen cereal grains, probably due to the fact that cultivation was fairly small-scale (Fredh, Prøsch-Danielsen, and Jensen 2022). A large proportion of tree pollen (mainly *Betula*) in the cultivation layers can be attributed to the fact that open land taxa are usually underestimated in pollen records (Broström et al. 1998; Sugita, Gaillard, and Broström 1999). The macrofossil assemblage from the cultivation layers contained both arable weeds and grassland taxa, which also suggests a mixture of cultivated fields and pastures. It is likely that the landscape was mainly open, with some patches of woodland remaining.

Main Activity at the Site

Most of the dates at Øvre Øksnevad were obtained from c. 600-300 BC, which suggests that the main human activity at the site was happening at this time

(Figures 7 and 8). Settlements were likely established then, and cultivation continued. The pollen composition was rather variable between samples, i.e. characterised by pollen both from grasses/herbs (LPAZ 2) and from dwarf shrubs/grasses (LPAZ 3) (Figures 4 and 5). The lower part of the profiles (generally older) dated to this interval generally contained more taxa related to human activity, such as cereals, weeds and ruderal plants, e.g. *Artemisia* and *Persicaria maculosa*, as well as more tree pollen. The upper parts (generally younger) contained more pollen from heathland plants, and indicate a slightly more open landscape. This development suggests that further woodland clearance took place when the settlement became established and that heathland developed during this relatively short time interval, while some crop cultivation was still carried out. The pollen composition was also similar between some of the different features (cultivation layers and cairns), which indicates that these overlap in time. Some of the overlap in pollen composition can also be explained by the possibility that some of the graves could have been constructed using soils containing older pollen.

The pollen data and radiocarbon dates also suggest that the grave field was related to the settlements at Øvre Øksnevad. Secure evidence of graves includes two human bone fragments that were dated to this interval (c. 600 BC and 300 BC). However, considering the large age range of some of the radiocarbon dates, it is possible that a few burial cairns were built after the settlement was abandoned. This development is somewhat supported by the general stratigraphy at the site, with the graves sometimes found on top of cultivation layers and settlement features (never the other way around). However, there were four dates from cairns

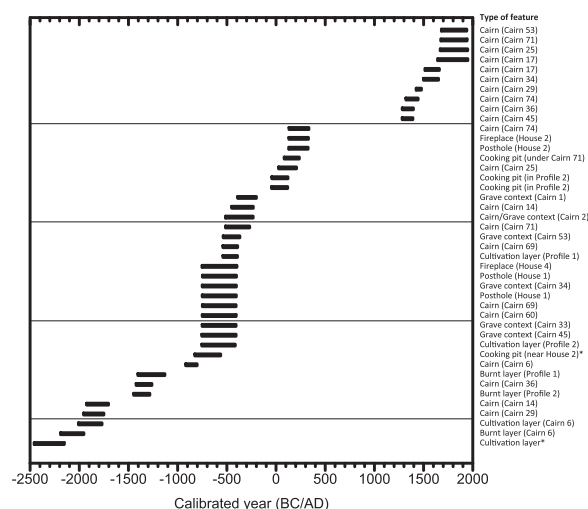


Figure 7. All radiocarbon dates obtained from the study site, shown with 2σ range and ordered according to age. Most of these dates are also presented in Bell and Denham (2020) and two dates marked with * are from a previous registration of archaeological remains at the site (Fyllingen 2008).

that were older than the ‘main activity phase’, ranging between c. 1900 and 900 BC. It is unlikely that these cairns were built without any associated settlement, and these dates should probably be considered maximum ages for these cairns. The pottery found in some of the cairns was characteristic for the period 500 BC–AD 500, which supports the hypothesis that the main activity at the site occurred at this time.

The macrofossil composition in one of the houses dated to this period (house 1), and contemporary with some of the cultivation layers found on the site, was dominated by arable weeds and cultivated plants, which suggests arable agricultural activity, possibly including crop processing taking place inside the house. The main cereal identified was *Hordeum vulgare*. The dominance of this crop is in agreement with the regional picture which shows that barley was dominant in the area throughout prehistory (Prøsch-Danielsen and Soltvedt 2011), although too few charred cereals were identified to estimate any ratios between cultivated plants. The charred flax seeds (*Linum usitatissimum*) dated from house 1 (748–402 BC) provide the oldest date so far of flax in Norway. Lundberg (2017) investigated how these flax seeds were affected by temperature (i.e. preservation characteristics) and compared their size to other flax seeds in Scandinavia, which suggested that these were most likely grown for textile fibres.

Heathland Development

Pollen from *Calluna vulgaris* was dominant in the upper part of the cultivation layers and within the cairns (dated to c. 500 BC or later), mostly assigned to LPAZ 3, i.e. characterised by heathland plants and grasses (Figures 4 and 5). In these samples, the taxa indicating open landscapes dominated but herb diversity was relatively low. This pollen composition suggests that grazing may have become dominant in the latter part of the ‘main activity phase’ and possibly continued after the settlement was abandoned. The macrofossil assemblages from grave contexts and within cairns were dominated by seeds from heathland plants, which is in agreement with the pollen record, and supports the idea that heathland developed during the main activity phase and that most of the cairns were constructed during this time period or later.

A second settlement phase was identified around c. AD 1–200 at the site, through the remains of houses along with a few cooking pits. It seems that the site was again used for settlement activities, but within a landscape dominated by heathland (Figure 8). It is possible that this settlement phase is a continuation of the previous phase at Øvre Øksnevad, but the dates available suggest a hiatus between two separate phases. There are no cultivation layers identified during this phase,

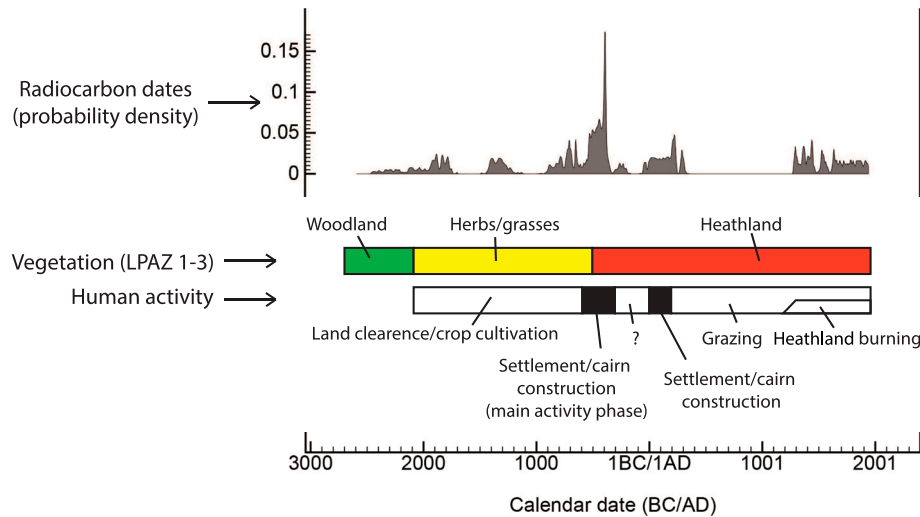


Figure 8. Distribution of all radiocarbon dates from the site using summed probability function in OxCal (Bronk Ramsey 2017), compared to the overall interpretation of main vegetation and human activity phases at Øvre Øksnevad.

which suggests a different pattern of land use in this settlement phase compared to the previous one. However, the house dated to this time interval (house 2) also contained charred seeds from cereals and weeds. These seeds indicate a continuation of crop cultivation, but this activity could have been carried out outside the excavated area. Two cairns were dated to this second settlement phase, and two graves were situated on top of postholes dated to this time period, which suggests that at least a few burial cairns were also related to this settlement.

Layers from the upper part of the sections from which pollen samples were analysed were not radiocarbon dated, but some were stratigraphically positioned above layers dated to c. 500 BC. Although these samples were dominated by heath- and grassland plants, a few cereal and weed pollen grains were also identified, which indicate crop cultivation. However, these grains could have been transported from some distance away. A few profiles showed imprints of roots penetrating into the cultivation layers below, which suggests some reforestation occurred after the settlement was abandoned, however, this potential woodland expansion was not visible in the pollen data. However, there were no radiocarbon dates between c. AD 200 and AD 1300, and no stratigraphical layers seems to have been formed, which supports a decline in human activity in this time period.

Nine of the radiocarbon dates obtained from within cairns were carried out on charred heathland plants, which provided ages that were evidently younger than the cairns. This deviation suggests charred plant material has been transported into the upper part of the graves, for example by root bioturbation, and cannot be used to date the cairns more than providing a minimum age. Nonetheless, these relatively young dates suggest human activity from c. AD 1300

to recent times, probably from burning the heathland to improve the pastures. This vegetation management practice is known in Norway from as early as 4000 BC, and is still carried out in some areas (Kaland and Kvamme 2013). However, the pollen data suggest that heathland developed during the main activity phase (c. 500 BC) and dominated the landscape most of the time until present, which is shown by the pollen content in several different types of layers. Possibly the heathland developed and was kept open by grazing (at least for some time), but the practice of regularly burning heather, shown by the dates from charred heathland plants, only started in this area around AD 1300.

The Regional Perspective and Challenges of This Type of Study

Several studies have used on-site botanical analyses for environmental reconstruction, but they commonly acknowledge that there can be some limitations (Sageidet 2005a; Overland and Hjelle 2013). Several factors affecting the stratigraphical resolution in soils have been suggested, such as physical mixing by human activity, bioturbation, selective degradation and downwash of pollen (Havinga 1984; Andersen 1979; Kelso 1994; Tipping et al. 1999). Davidson et al. (1999) rejected the downwash of pollen and suggested that bioturbation was the main agent for mixing soils of different ages. The type of soil may also be important as acidic soils and waterlogged environments are generally less susceptible to bioturbation. Consequently, most studies conclude that it is only possible to obtain a coarse temporal resolution from minerogenic soils. Such data should only be used to infer general land-use development, which reflects how we use the palaeobotanical data in this study.

In the present study, selective degradation was indicated by a large amount of *Tilia* pollen, which is resistant to degradation and is commonly overrepresented in pollen records from soils with poor preservation conditions (Havinga 1984). However, this was only identified in a few samples in the podsol and burnt layers. Mixing by human activity was of course present in the cultivation layers by arding (ploughing). However, distinct layers are still observed in these cultivation layers, and the pollen composition varies stratigraphically when analysing thicker deposits, which has previously been identified regionally (Fredh, Prösch-Danielsen, and Jensen 2022). Less bioturbation is expected in acid areas where podzols develop, such as in the present study area, but the soil conditions may have changed over time, and that some bioturbation has occurred cannot be excluded. Root penetration was however likely by heather, suggested by the relatively young dates from the cairns.

As mentioned earlier, there is not enough evidence to confirm that all cairns at the site were used for funeral practices, which is a common problem in Norwegian archaeology (Bjørlo 2020). Clearance cairns are also common in the region, which can be similar in appearance, and both types are often empty of finds. However, many cairns at Øvre Øksnevad contained shards of pottery, some with a central chamber, and a few with fragmented pottery/burnt bone, suggests their main purpose was for funeral practices. There is also evidence in Scandinavia of cairns containing a mix of ritual and practical elements, showing the complexity of differentiating the cairns from this time (Pettersson 2020). However, for the purpose of analysing the environmental history of a site, the different types of cairns can be used in a similar way, as they both work as a trap for botanical remains. The type of cairn is therefore not crucial in the type of study presented here, focusing on the vegetation and land-use development.

Another concern in the present study was the history of the soil being used for cairn construction, i.e. if the soil was accumulated successively between the stones (during and/or after construction), or if the soil was formed earlier and put between stones during construction and therefore represents an older environment. However, the development within each profile analysed showed stratigraphical differences, and the profiles were comparable to each other, previously noted at other cairn sites in Norway (Overland and Hjelle 2013; Prösch-Danielsen 1996). These observations support the idea that the soils within the cairns were formed during or after their construction, i.e. that the stratigraphy in the cairns and surrounding soils seems to be intact. Similar conclusions were drawn in relation to studies carried out at the two nearby archaeological sites Håbakken (Bysveen 1984) and Orstad (Sageidet 2009) (Figure 1).

At Håbakken, three clearance cairns analysed for pollen content showed a similar land-use development as at Øvre Øksnevad. Two pollen assemblages comparable to Øvre Øksnevad were represented (LPAZ 2 and LPAZ 3), i.e. indicating a transition from a semi-open cultural landscape to a heathland dominated landscape (Bysveen 1984). In addition, a phase dominated by coniferous pollen representing modern plantations was identified at Håbakken, including spruce that does not grow naturally in the region. This recent phase was not identified in the current study, as Øvre Øksnevad seems to have been kept open until present. This difference shows some regional variation in land use in modern times. However, no radiocarbon dates were obtained from the cairns at Håbakken, and comparisons with other sites should therefore be tentative.

At Orstad, a series of sections were analysed for pollen and radiocarbon dating along and next to an 84 m long trench across the study area, complemented by soil micromorphology and geochemical analyses (Sageidet 2005a, 2005b, 2009). The analyses at Orstad showed a dominance of deciduous woodland prior to c. 2000 BC, a land clearance followed by occasional small-scaled cultivation c. 2000-500 BC, and then the development of heathland used for grazing c. 500 BC-present. The vegetation and land use history at Orstad follows the general pattern identified at Øvre Øksnevad, but with somewhat different start time and length of the different phases. In addition, an earlier phase of pastoral activity was identified at Orstad around 3000-2500 BC.

Some of the more traditional pollen diagrams from the region, i.e. based on lake or bog sediments, show the first indication of human activity from c. 4000 BC, mainly associated with minor woodland clearances (Solem 2005; Hjelle et al. 2018). More substantial changes are observed c. 2400-2000 BC, in connection with the regional transition to an agricultural economy (Soltvedt 2000; Prösch-Danielsen and Sandgren 2003; Diinhoff 2005). This is when the first human activity is registered at Øvre Øksnevad. However, the first settlement is not identified until c. 600 BC, which is late in a regional context (Børsheim 2005). Consequently, the settlement at Øvre Øksnevad was likely established during a period of expansion, possibly in relation to the agricultural reorganisation in western Norway that started c. 500 BC, generally attributed to the establishment of the inland/outfield system and permanent fields (Soltvedt et al. 2007; Halvorsen and Hjelle 2017). The expansion of heathland at Øvre Øksnevad at c. 500 BC was also c. 300 years later than the regional pattern (Prösch-Danielsen and Simonsen 2000; Solem 2005; Hjelle et al. 2018).

Furthermore, the pollen record at Øvre Øksnevad also indicates decreased crop cultivation after c. 500 BC, which is contrary to the regional pattern

(Prøsch-Danielsen and Simonsen 2000; Solem 2005; Fredh, Prøsch-Danielsen, and Jensen 2022; Hjelle et al. 2018). It is possible that the expansion of heathland from 500 BC contributed to soil depletion that limited the possibility for crop cultivation over time. The relatively early abandonment of the settlement at Øvre Øksnevad at c. AD 200 suggests the area was mainly used during periods of high population pressure. The early Iron Age (500 BC–AD 550) is a period of expansion in southwestern Norway, and the site could have been used for occupation when needed, while normally used for less intensive activities. It should also be noted that after AD 550, the region is known for widespread abandonment, following the sixth century crisis (Gräslund and Price 2012), which could explain some of the reduced activity in later periods, when people seem to have centred around more well-established farms. Archaeological evidence from the surroundings suggests that Øvre Øksnevad was not an isolated settlement, as contemporary burial cairns and settlement activities have been identified nearby (within approx. 3 km) (Braathen 1978; Hemdorff 1987; Skauen 1997). The settlement pattern could have varied over time in relation to population variations and shifting land-use practices. The grave field at Øvre Øksnevad may also have changed its status over time due to variations in ritual practices.

Conclusions

The botanical analyses carried out in connection with the excavation at Øvre Øksnevad aided in the interpretation of the archaeological features and provided an environmental context. It was rather challenging to combine samples from different types of archaeological contexts. Although a pattern was identified, it should only be used to describe the general features in data set, rather than small variations between samples. The pollen record, in combination with the radiocarbon dates, provided the basis for interpreting the development of the site, as the pollen data showed a clear variation over time. On the other hand, the macrofossil samples generally contained few identified remains, and could therefore not be used to investigate the stratigraphic development based on a few sections alone. Instead, the macrofossil data showed a similar composition between samples from the same type of features, and was therefore used to infer environmental evidence for the time period(s) the different archaeological features were dated to.

This study has shown that prior to 2100 BC the landscape around Øvre Øksnevad was covered by deciduous trees, mainly *Betula* and *Corylus*. Minor impacts of human activity can be inferred from the dominance of these light-demanding trees that are favoured by woodland clearances, and from pollen

of herbs and dwarf shrubs that may indicate minor openings in the woodland. Between c. 2100–500 BC, several phases of land clearance followed by crop cultivation were identified. The landscape was mainly open, dominated by herbs and grasses with some minor patches of woodland remaining. Within this type of landscape, a settlement was established c. 600 BC, which started the main phase of human activity on the site, including settlement, crop cultivation and cairn construction. Heathland started to develop during main phase of human activity, and from c. 500 BC, this was the dominant land cover. The main phase of human activity seems to have been over by c. 300 BC, and the use of the area was reduced to pastoral activity. A new short-lived settlement phase was established within the heathland landscape (c. AD 1–200), although no arable land was identified in the vicinity. Regular burning of heathland was present from AD 1300. Overall, the reconstructed land-use pattern was similar to the regional development, with the exception of the last c. 2400 years, when a relatively low amount of crop cultivation was identified at the site, suggesting that the main settlement area was elsewhere. The short-lived settlement at Øvre Øksnevad suggests it was marginal and only settled during periods of high population pressure.

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Disclosure Statement

No potential conflict of interest was reported by the author(s).

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