CHAPTER 3

ANETTE OVERLAND
Department of Natural History, University Museum, University of Bergen, Norway
kari.hjelle@uib.no
KARI LOE HJELLE
Department of Natural History, University Museum, University of Bergen, Norway

Vegetation development at Ørland, and in the region, from c. 260 BC to the present

ABSTRACT
The vegetation history at Ørland is based on pollen analysis of a local bog (Ryggamyra), and several archaeological contexts, such as cultivation layers and plow mark, a refuse/cesspit, and wells and waterholes. Ryggamyra reflects important activity periods, in the Pre-Roman Iron Age and Roman Iron Age, where barley was cultivated and areas with herbaceous grasslands existed in connection with settlement areas. In comparison, pollen analysis from lake sediments (Eidsvatnet) reflects a larger region. Eidsvatnet covers the period c. 260 BC to the present, during which three periods of more intensive human activity can be identified, when forest is cleared, grass-dominated vegetation increases, and outfield grazing areas are established. These periods are the Roman Iron Age and Migration Period (c. AD 1-540), parts of the Viking Age and Early and High Middle Ages (c. AD 900–1360), and recent times (from AD 1600 onwards). In both pollen profiles, Eidsvatnet and Ryggamyra, the Merovingian period represents a period with structural changes in landscape utilization and perhaps less human activity overall. Ørland has largely been characterized by marshes and wetland areas through the past, dominated by Cyperaceae. On the drier main ridge, where settlement areas existed in the Pre-Roman Iron Age and Roman Iron Age, and again in the early medieval period, the pollen profiles indicate a completely open landscape with herb-rich grassy vegetation and cultivation of barley and wheat. The increase in heather from the Late Viking Age to the early medieval period is seen in Ryggamyra and is reflected in the archaeological deposits, indicating utilization of heathlands for whole-year grazing. Pollen analysis also suggests local production/use of hemp and increased use of wheat in medieval times. The area around Eidsvatnet seems to be influenced by the late medieval depression and Black Death, with the increase in coniferous woodland and reduced outfield grazing activity.

INTRODUCTION
Archaeological excavations at Ørland Main Air Base, carried out by NTNU Science Museum 2014–2016, revealed settlements from the Bronze Age/Iron Age transition through the Early Iron Age, followed by a new phase of settlement in the Late Viking Age/Middle Ages. At the transition Early/Late Iron Age, the archaeological data are scarce. The highest activity seems to have been during Pre-Roman and Roman Iron Age, with several house remains, cooking pits and different deposits reflecting farm settlements. Pollen samples were collected from archaeological contexts including cultivation layers, plow marks, refuse/cesspits, wells and waterholes. The aims of the pollen analysis were to provide knowledge on environment, natural conditions,

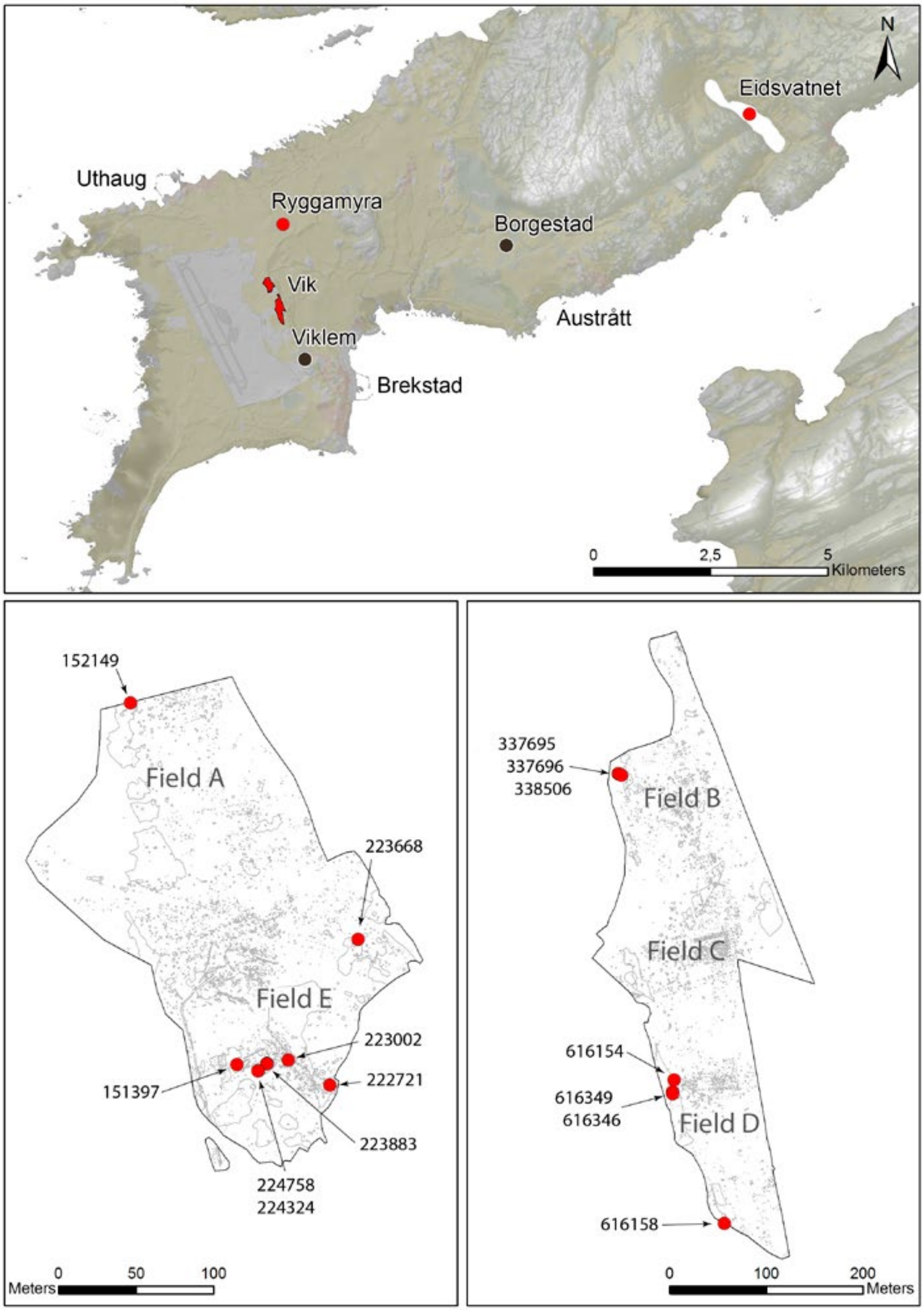


Figure 1. Localities for pollen analysis. Eidsvatnet (lake), Ryggamyra (bog) and archaeological contexts in excavation Field A (152149), Field D (616154, 616349/616346, 616158) and Field E (223883, 224758/224324, 222721, 223002, 223668), (See Buckland et al. (2017) for pollen analysis of 151397, 337695, 337696, 338506). Map: Magnar Mojaren Gran, NTNU University Museum.

landscape development, settlement and farming economy at Ørland. The investigation also included pollen analysis of a local peat profile, Ryggamyra, and sediments from the lake Eidsvatnet (Fig. 1). Ryggamyra represents a local palaeobotanical archive, which will reflect the development of the environment and landscape at Ørland, as well as human impact on the local vegetation and landscape. Pollen analysis of sediments from Eidsvatnet, which is situated approximately 10.5km from Ryggamyra and the archaeological excavation areas, will provide the regional setting for landscape and vegetation development. Earlier studies from Ørland include analysis of pollen samples from bogs at Borgestad and Veklem. At Borgestad, c. 5.5km east of the excavation area, the development of an open cultural landscape with cultivation and grazing in the Late Bronze Age and Early Iron Age, is indicated (Solem 2009). Pollen analysis from a small bog at Veklem close to Ørland church reveals an open landscape from the Late Bronze Age (Berglund & Solem 2017). At that site, cultivation is documented from the Middle Ages whereas grazing was found from the Iron Age. Also a few pollen samples previously analyzed from Field D at Vik (Engtrø & Haug 2015) indicated open arable fields and grasslands in Pre-Roman and Roman Iron Age. Except for these investigations, all made in relation to archaeological projects, no investigation of the vegetation history at Ørland has earlier been carried out. However, the Holocene vegetation history is well documented at the island Frøya, c. 44km west of Ørland (Paus 1982). Contemporary with the settlement at Ørland, open heathlands managed through grazing and burning characterized the landscape of Frøya. On the islands outside Ørland (incl. Tarva), there is evidence of at least 300 years of managed heathland (Kaland & Kvamme 2013). Coastal heathlands represent a human-induced vegetation type developed and maintained through burning and grazing (Kaland 1986, 2014). They are found in an oceanic climate, giving possibilities for whole-year grazing. In historic time, they have characterized the western coast of Norway, but the development spans over several thousand years and shows large variations along the coast (Kaland 1986, Prøsch-Danielsen & Simonsen 2002, Tveraabak 2004, Hjelle et al. 2010, 2018). Ørland is located within the coastal heathland belt, and our study gives new information on their history in relation to settlement in this part of Norway.

MATERIAL AND METHODS

Samples and radiocarbon dates

The sediment core from Eidsvatnet (63.7388N, 9.8375E, 64ha, Fig. 1) was collected by NGU (Geological Survey of Norway) (Romundset & Lakeman Ch. 2). Pollen samples (volume $1cm^3$) were collected at NGU, every 0.5cm continuously through the core. Loss-on-ignition was done on the sample directly below the analyzed pollen sample. The isolation of the lake is radiocarbon dated to c. 2200 cal. yr BP while two dates from the top of the core (838–839cm, Poz-86900/86901) gave modern age (Table 1). Based on the radiocarbon dates (Table 1) and the age 1950 given to the upper dated level, an age-depth model is presented (Fig. 2). Sediment stratigraphy is shown in Table 2. Eidsvatnet is located 10.5km east of the archaeological excavation areas.

The bog Ryggamyra (id 282408, 63.7185N, 9.6355E, 4ha, Fig. 1) is situated on the central ridge of the peninsula which first became exposed above sea level around 2400 years ago (Romundset & Lakeman ch. 2), and is situated c. 1000m north of the archaeological excavation areas. A bog monolith was extracted and subsampled for pollen analysis (sample volume $1cm^3$) and loss-on-ignition in the laboratory at the University of Bergen. Radiocarbon

Lab. ID	C^{14}-age, calibration (2σ)	Depth (cm)	Dated material
Eidsvatnet. Depth: from water surface			
Poz-86900	137.67±0.33 pMC ('percent modern carbon')	838–839	Wooden twig
Poz-86901	140.44±0.35 pMC ('percent modern carbon')	838–839	Terrestrial plant fragments
Beta-467912	480±30 BP, Cal. AD 1409–1451	851–852	Terrestrial plant fragments, chironomids
Beta-467913	1160±30 BP, Cal. AD 774–967	864–865	Wood fragment
Beta-467914	1520±30 BP, Cal. AD 428–608	877–878	Wooden twig
Beta-469526	1780±30 BP, Cal. AD 138–333	884–885	Seed
Poz-86867	1705±30 BP, Cal. AD 253–400	885–886	Terrestrial plant fragments
Poz-86868	2130±30 BP, 349–53 Cal. BC	896–897	Terrestrial plant fragments
Poz-86869	2125±30 BP, 346–53 Cal. BC	899–900	Terrestrial plant fragments
Poz-86870	2170±30 BP, 359–118 Cal. BC	902–903	*Betula* fruit and leaf fragment
Ryggamyra (282408). Depth: from peat surface			
Beta-474786	620±30 BP, Cal. AD 1292–1400	79–80	Terrestrial plant fragments
Poz-1116326	1045±30 BP, Cal. AD 901–1029	110-111	Terrestrial plant fragments
Beta-451876	1150±30 BP, Cal. AD 773–970	120–121	Terrestrial plant fragments
TRa-11515	1440±20 BP, Cal. AD 584–649	129–130	Terrestrial plant fragments
Beta-451877	2340±30 BP, 506–367 Cal. BC	153–154	Terrestrial plant fragments
Field A (152149). Depth: from base of monolith			
Beta-474785	850±30 BP, Cal. AD 1152–1260	34.5–48.5	Charcoal
TRa-11514	2005±20 BP, Cal. 46 BC–AD 53	20–28.5	Charcoal, *Alnus/Betula*
TRa-11513	2300±20 BP, 404–361 Cal. BC	9–20	Charcoal
Sample ID	**C^{14}-age, calibration (2σ)**	**Context ID**	**Dated material**
Field D			
801906	1845±20 BP, Cal. AD 88–236	616349, 616346	Wood, *Alnus*
	Four cooking pits below context c. 350 Cal. BC–Cal. AD 50. Two cooking pits dug into context c. Cal. AD 80–240	616158	Charcoal
Field E			
223913 TRa-11402	916±14 BP, cal. AD 1046–1165	223883, (223995)	Wood
222847, TRa-11094	935±15 BP, Cal. AD 1034–1154	223002	Charcoal
223321, TRa-11101	950±20 BP, Cal. AD 1026–1155	223002	Charcoal
223323, TRa-11102	890±20 BP, Cal. AD 1046–1214	223002	Charcoal
223348, TRa-11117	1020±25 BP, Cal. AD 970–118	223002	Charcoal
222635, TRa-11308	1120±15 BP, Cal. AD 890–975	222721	Charcoal
222344, TRa-11361	2195±20 BP, 360–198 Cal. BC	222721	Charcoal
222789, TRa-11307	2205±25 BP, 361–201 Cal. BC	222721	Charcoal
223669, TRa-11122	2215±30 BP, 371–202 Cal. BC	223668	Charcoal
224815, TRa-11066	960±20 BP, Cal. AD 1020–1121	224324, 224758	Wood

Table 1. *Radiocarbon dates for Eidsvatnet, Ryggamyra and archaeological contexts associated with pollen analysis. Calibrated from OxCal v4.2.4 (Bronk Ramsey 2013, Reimer et al. 2013).*

dates are given in Table 1, and an age-depth model is presented in Figure 2. Peat stratigraphy is shown in Table 2.

From the archaeological excavations, a monolith from prehistoric agricultural soils was extracted in Field A and subsampled for pollen analysis in the laboratory. In Fields D and E pollen samples were taken directly from profile walls during archaeological investigations (Fig. 3). For samples taken in archaeological contexts, ages are based on radiocarbon dates from these contexts or stratigraphic relationships to dated contexts (Tabell 1, Overland & Hjelle 2017, Ystgaard et al. 2018:51).

Laboratory work

In the laboratory, samples for loss-on-ignition were dried at 110˚C for 24 hours and ignited at 550˚C for 6 hours. All pollen samples were processed using the methods described in Fægri and Iversen (1989) with acetolysis and HF-treatment. Pollen identification followed the key in Fægri and Iversen (1989) with additional use of Beug (2004) and the pollen reference collection at UiB. For identification of non-pollen-palynomorphs (NPP) several sources were consulted (Geel 1978, Pals et al. 1980, Geel et al. 1981, van der Wiel 1982, van Dam et al. 1988, van Smeerdijk 1989, Geel et al. 2003, http://nonpollenpalynomorphs.tsu.ru/index.html). The pollen diagrams are plotted using Core 2.0 (Natvik & Kaland 1993), where black curves/histograms are showing percentage values and yellow curve/histogram show this value ×10. All pollen data are calculated on the basis of ΣP (total terrestrial pollen), while the percentages of spores, aquatics, algae and other microfossils are based on ΣP + X, were X is the constituent in question. Some taxa are omitted from the diagrams, and complete diagrams as well as detailed methodology, results and interpretations, are presented in Overland and Hjelle (2017). Beate Helle (University Museum, UiB), did the final editing of pollen diagrams.

Data analysis

Vegetation cover in Ørland peninsula was estimated using the Landscape Reconstruction Algorithm (LRA, Sugita 2007a, 2007b). Due to differences in pollen production and dispersal among species, the relationship between the plant abundance in the vegetation and the pollen percentage in a sample is not one to one. LRA accounts for these differences and a better representation of vegetation cover is obtained by using LRA than is given by only pollen percentages (e.g. Hellman et al. 2008, Sugita et al. 2010, Poska et al. 2014, Hjelle et al. 2016). LRA consists of two models: REVEALS, which estimate the regional vegetation cover within a radius of 50 to 100km surrounding the investigated site (Sugita 2007a) and which we applied on the data from Eidsvatnet, and LOVE which combines the regional vegetation cover with pollen data from local sites (Ryggamyra and samples from the excavated fields) to reconstruct the local vegetation (Sugita 2007b). The pollen samples from Eidsvatnet and Ryggamyra were grouped into the agreed Vik archaeological phases (Ystgaard, Gran & Fransson Ch. 1) and hundred-year periods based on ages estimated in the age-depth models (Fig. 2). To carry out these reconstructions, pollen productivity estimates for taxa included in the analysis are needed. In Ørland, eight tree taxa (*Alnus*, *Betula*, *Corylus*, *Fraxinus*, *Picea*, *Pinus*, *Quercus* and *Ulmus*), two shrub taxa (*Juniperus*, *Salix*) and ten open-land taxa (*Artemisia*, *Calluna*, Cerealia, Cyperaceae, *Filipendula*, *Plantago lanceolata*, *P. major*, *P. maritima*, Poaceae, *Rumex acetosa*-type) with available pollen productivity estimates were included in the analysis. The same pollen productivity estimates as those found to give a good approximation of the vegetation cover in western Norway (Hjelle et al. 2015) were used. These estimates are based on data sets from Norway (Hjelle & Sugita 2012), Denmark (Nielsen 2004) and mean values from Europe (Mazier et al. 2012). The programs REVEALS.v5.0.win64.exe and LOVE.v4.7.1.exe (both Shinya Sugita, unpubl.) were

Depth (cm)	Layer	Description of layer	Troels-Smith (1955) classification system for unconsolidated sediments
Eidsvatnet, Bjugn			
835–881	6	Gray/brown, laminated silt and clay with organic remains. Inorganic bands at 838 cm, 850,5 cm, 875 cm and 876 cm.	As1-, Ag2+, Ga+, Ld1-, Nig2, Strat3, Elas2, Sicc2, LimS3
881–884	5	Brown/gray, laminated silt and clay with organic remains.	As1-, Ag2+, Ga+, Ld1, Nig2, Strat3, Elas2, Sicc2, LimS3
884–888	4	Brown/gray, laminated silt and clay with some macrofossils.	As1-, Ag2+, Ga+, Ld1, Dl/Dh/Dg/Th/Tl/Tb+, Nig2, Strat3, Elas2, Sicc2, LimS3
888–902.5	3	Gray-brown, laminated silt and clay with organic remains.	As1-, Ag2+, Ga+, Ld1-, Nig2, Strat3, Elas2, Sicc2, LimS3
Ryggamyra, Ørland			
75–58	6	Fibrous, less decomposed peat.	Th/Dh4^{1}, Tb+, Ld+, Nig3, Strat0, Elas2, Sicc2, LimS0
75–109	5	Fibrous, bands of light brown to yellow peat with twigs and moss.	Th/Dh/Tb4^{1}, Tl/Dl+, Ld+, Nig3-, Strat+, Elas2+, Sicc2, LimS0
109–120	4	Loose, fibrous peat, with woody twigs. Brown/yellow bands.	Th/Dh/Tb4^{2}, Tl/Dl+, Ld+, Nig3-, Strat+, Elas2, Sicc2, LimS0
120–130	3	Compact, fibrous, less decomposed peat. Brown/yellow bands.	Th/Dh/Tb4^{1}, Ld+, Nig3-, Strat1, Elas2, Sicc2, LimS0
130–155.5	2	Dark brown, fibrous, somewhat decomposed silty peat.	Ld2$^{2-3}$, Th/Dh/Tb2^{3}, Ag+, Nig3+, Strat1, Elas2, Sicc2, LimS1

Table 2. *Description of lake sediments in Eidsvatnet, Bjugn, and peat in Ryggamyra, Ørlandet. Depth refers to cm below water/peat surface.*

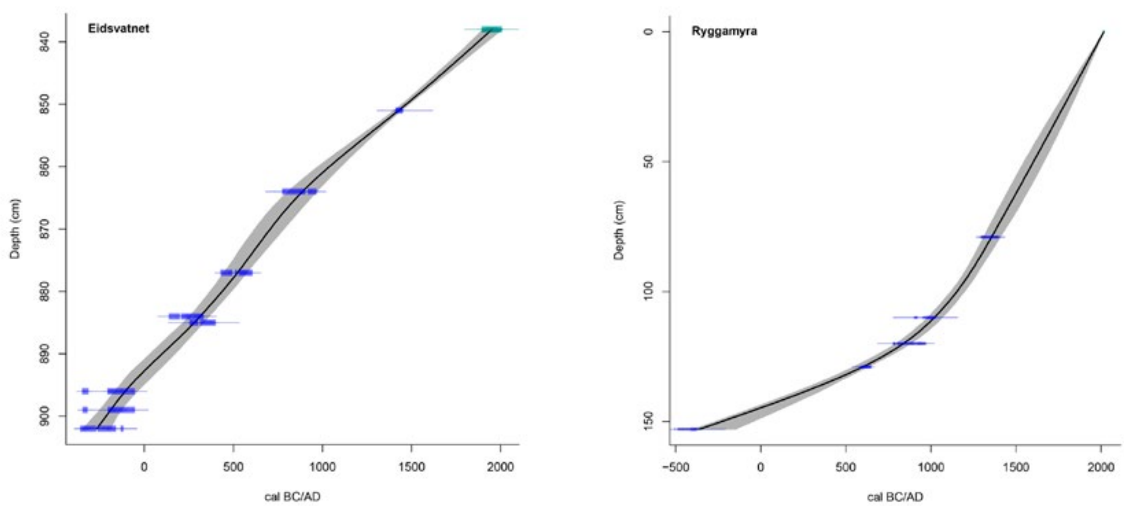


Figure 2. Age models, Eidsvatnet and Ryggamyra. Smooth spline in Clam, R-code for classical age-depth modelling version 2.2 (Blaauw 2010). Calibrations by IntCal13 (Reimer et al. 2013), using 95 % probability.

applied. The wind speed was set to 3m/sec., and the regional vegetation to 50km. The relevant source area of pollen (RSAP) – the area in which the vegetation cover can be reconstructed using LOVE (cf. Sugita 1994, 2007b) – differs between a radius of 800 and 2200m for different periods in Ryggamyra. RSAP for the excavated fields is estimated to a radius of 300m in most cases, but also to 2200 and, in one case, 4400m. The resulting cover estimates were compared to estimates using a fixed RSAP of radius1500m, and only small differences appeared (not shown). In the hundred-year periods for Ryggamyra, 1500m was used applying the program LOVE.v5.1.win64.exe (Shinya Sugita, unpubl.).

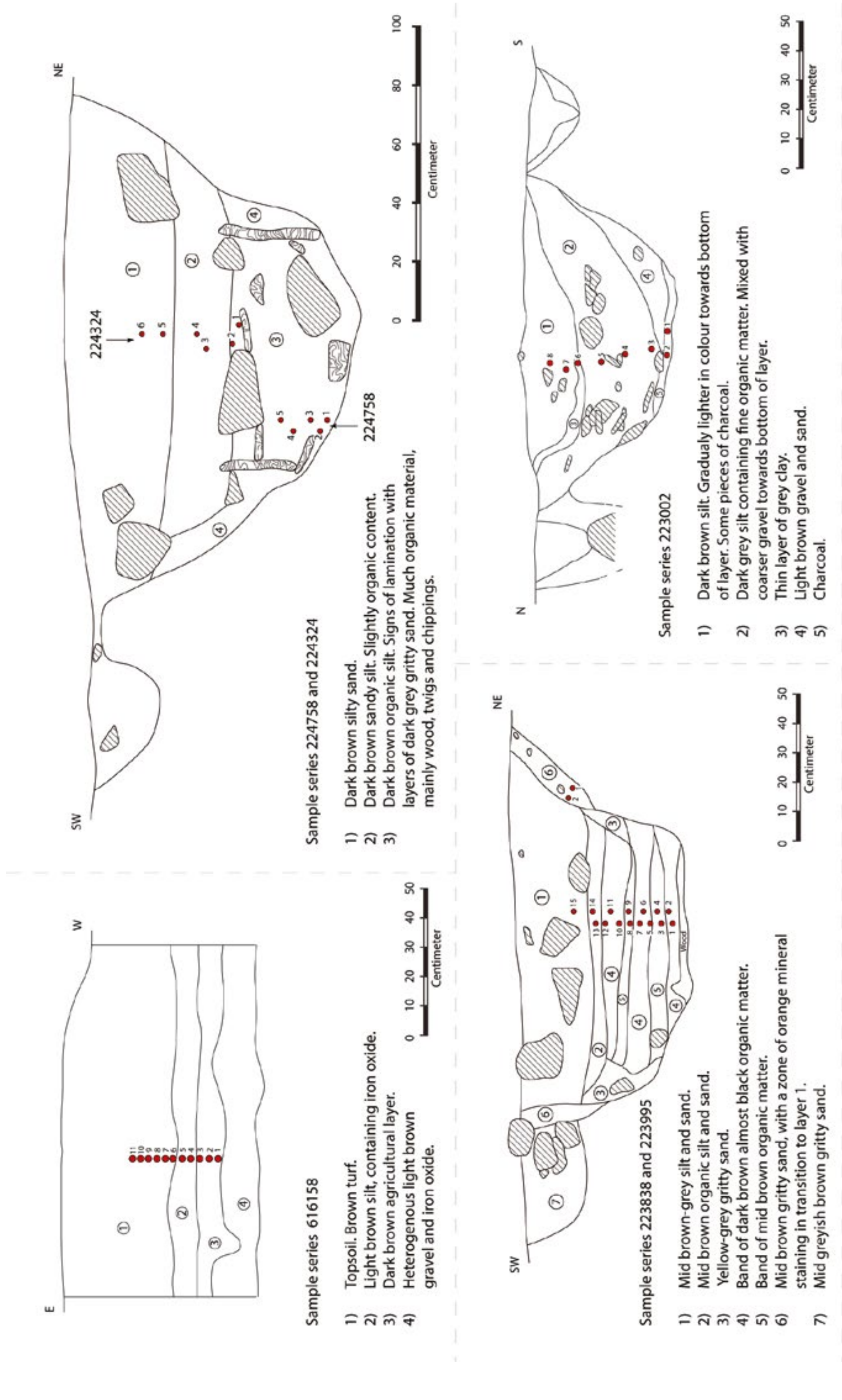
The overall pattern in the pollen data from Ørland was investigated by gradient analysis within the program Canoco for Windows 4.5 (ter Braak and Smilauer 2002). The data revealed a short gradient (< 2.2) using Detrended Correspondence Analysis, and Principal Component Analysis (PCA) was carried out. Initial analysis of the total data set separated the samples from Eidsvatnet from all other samples. This reflects the different basins/deposits analyzed. Analyses of two different data sets are shown in the present paper. PCA of the samples from Ryggamyra, Fields A, D and E reflects similarities and differences between the off-site data from the bog and the on-site data. Eidsvatnet is included as supplementary data in this analysis. To get a more detailed picture of the pollen composition in different archaeological contexts and phases, PCA using only the pollen samples from the excavated areas was carried out. For both data sets, the pollen/spore percentages were square-root transformed prior to analysis. In the PCA-plots, pollen-types are abbreviated, while full names are given in Appendix I.

RESULTS AND INTERPRETATION

The pollen diagrams from Eidsvatnet and Ryggamyra (Figs. 4–5) are zoned based on changes in the respective pollen data through time (E1–E7 and R1–R5), and shown in relation to the archaeological phases Vik 2–Vik 9. The pollen samples from archaeological contexts are presented in relation to sampled layer and archaeological phase within the respective areas (Fields A, D and E, Figs. 6–8). The vegetation cover is reconstructed for the different Vik phases (Fig. 9), with Vik 7 separated in two due to large changes in the pollen composition in Eidsvatnet within the period AD 1250–1850. Additionally, reconstructions in hundred-year intervals were carried out (Fig. 10). Finally, the pollen data are summarized in ordinations (Figs. 11, 12) where the analyzed context is illustrated together with the Vik archaeological phase.

Pre-Roman Iron Age – Migration Period, c. 400 BC–AD 550 (E1–E2, ≈R1), Vik 2 – Vik 4

The area surrounding Eidsvatnet was partly dominated by woodland, mainly *Pinus*, *Betula* and *Alnus*, partly by open grasslands (Poaceae), indicated both in the pollen percentage diagram (Fig. 4) and in the reconstructed vegetation cover (Fig. 9 and 10). In sheltered areas more demanding trees like *Quercus*, *Fraxinus* and *Ulmus* were most likely present (cf. Holten 1978). In the bottom part of the Eidsvatnet diagram (E1) representing the PRIA, the openness of the vegetation is likely to be affected by isolation processes, and the estimated tree cover in Vik 3 is probably more representative of the openness of the regional landscape. Throughout the period the area was grazed and cereals were cultivated. During the Late Roman Iron Age, woodland clearance took place resulting in less than 40% woodland cover between AD 300 and AD 500. Peaks in *Juniperus*, Poaceae and herbs are probably connected to intensification in outfield grazing and expansion of hay meadows. *Cannabis/Humulus*-type is recorded in the Roman Iron Age (see discussion).


Sample series 616158
1) Topsoil. Brown turf.
2) Light brown silt, containing iron oxide.
3) Dark brown agricultural layer.
4) Heterogenous light brown gravel and iron oxide.
Centimeter
E
W
Sample series 224758 and 224324
1) Dark brown silty sand.
2) Dark brown sandy silt. Slightly organic content.
3) Dark brown organic silt. Signs of lamination with layers of dark grey gritty sand. Much organic material, mainly wood, twigs and chippings.
224324
224758
SW
NE
Centimeter
Sample series 223838 and 223995
1) Mid brown-grey silt and sand.
2) Mid brown organic silt and sand.
3) Yellow-grey gritty sand.
4) Band of dark brown almost black organic matter.
5) Band of mid brown organic matter.
6) Mid brown gritty sand, with a zone of orange mineral staining in transition to layer 1.
7) Mid greyish brown gritty sand.
SW
NE
Wood
Centimeter
Sample series 223002
1) Dark brown silt. Gradualy lighter in colour towards bottom of layer. Some pieces of charcoal.
2) Dark grey silt containing fine organic matter. Mixed with coarser gravel towards bottom of layer.
3) Thin layer of grey clay.
4) Light brown gravel and sand.
5) Charcoal.
N
S
Centimeter

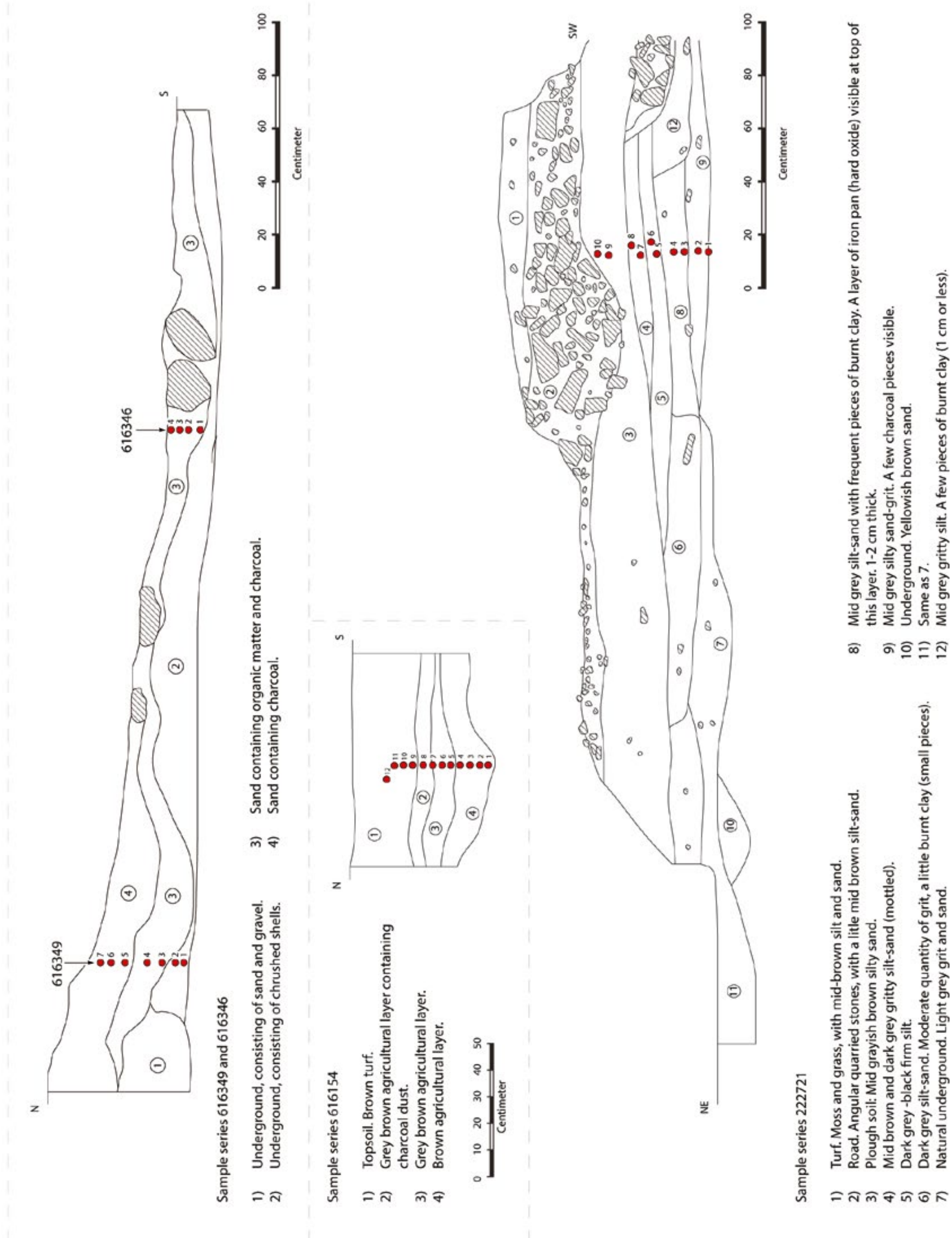


Figure 3. Profile drawings for contexts with pollen analysis at excavation Field D and E. Pollen sample number refer to id in PCA plots. Illustration: Magnar Mojaren Gran, NTNU University Museum.

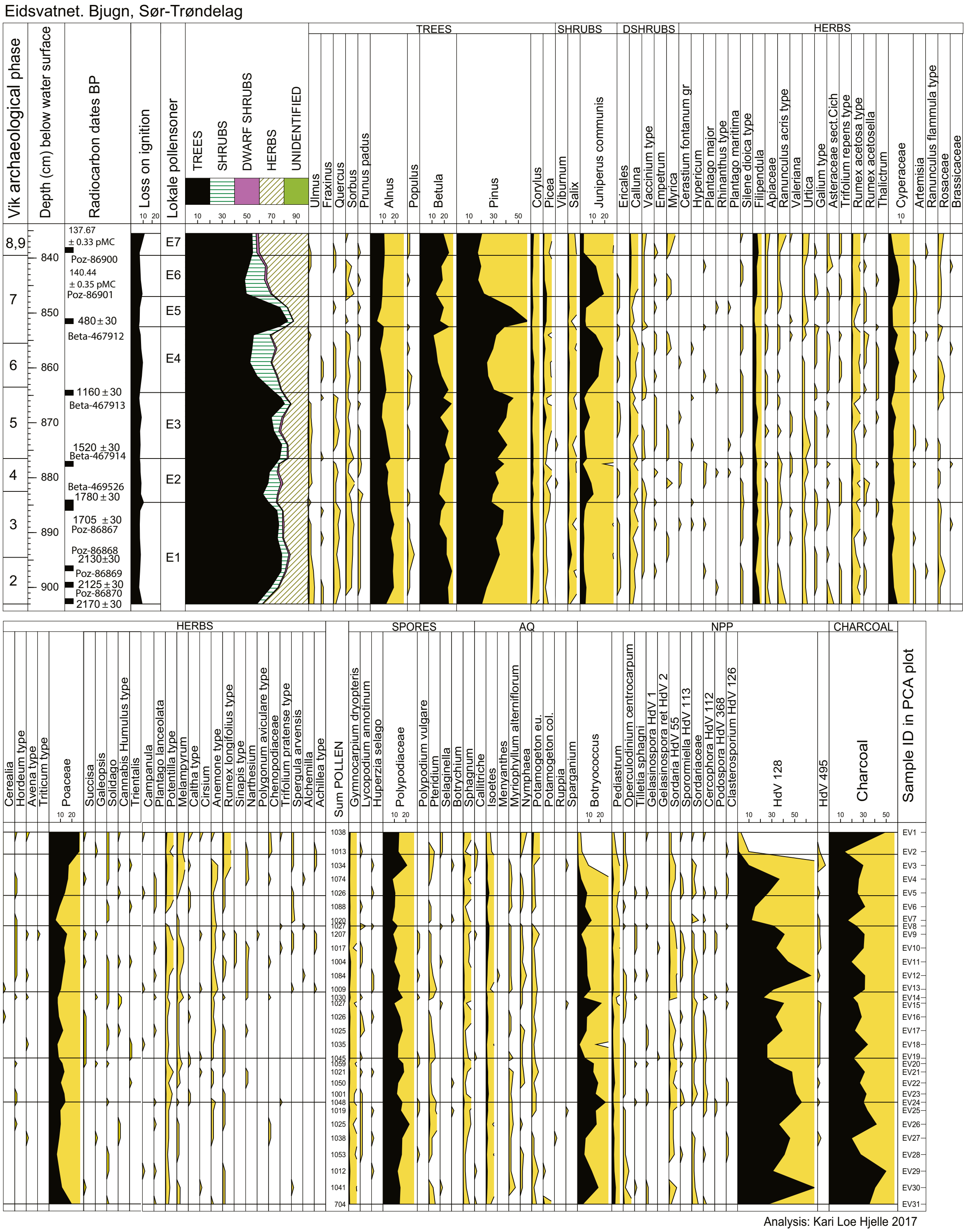


Figure 4. Percentage pollen diagram for Eidsvatnet. Some taxa are omitted from the diagram. Complete diagram presented in Overland and Hjelle (2017).

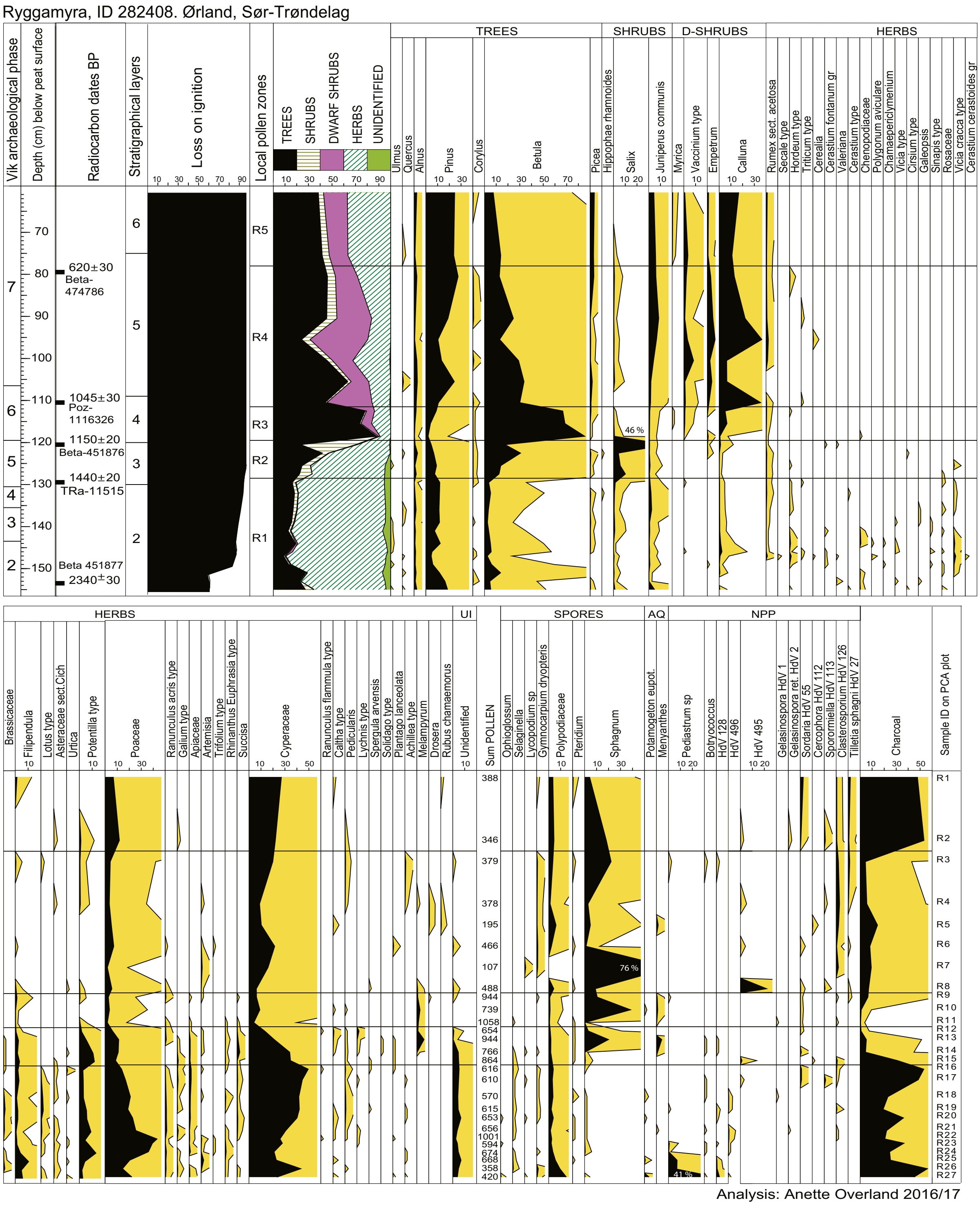


Figure 5. Percentage pollen diagram for Ryggamyra. Some taxa are omitted from the diagram. Complete diagram presented in Overland and Hjelle (2017).

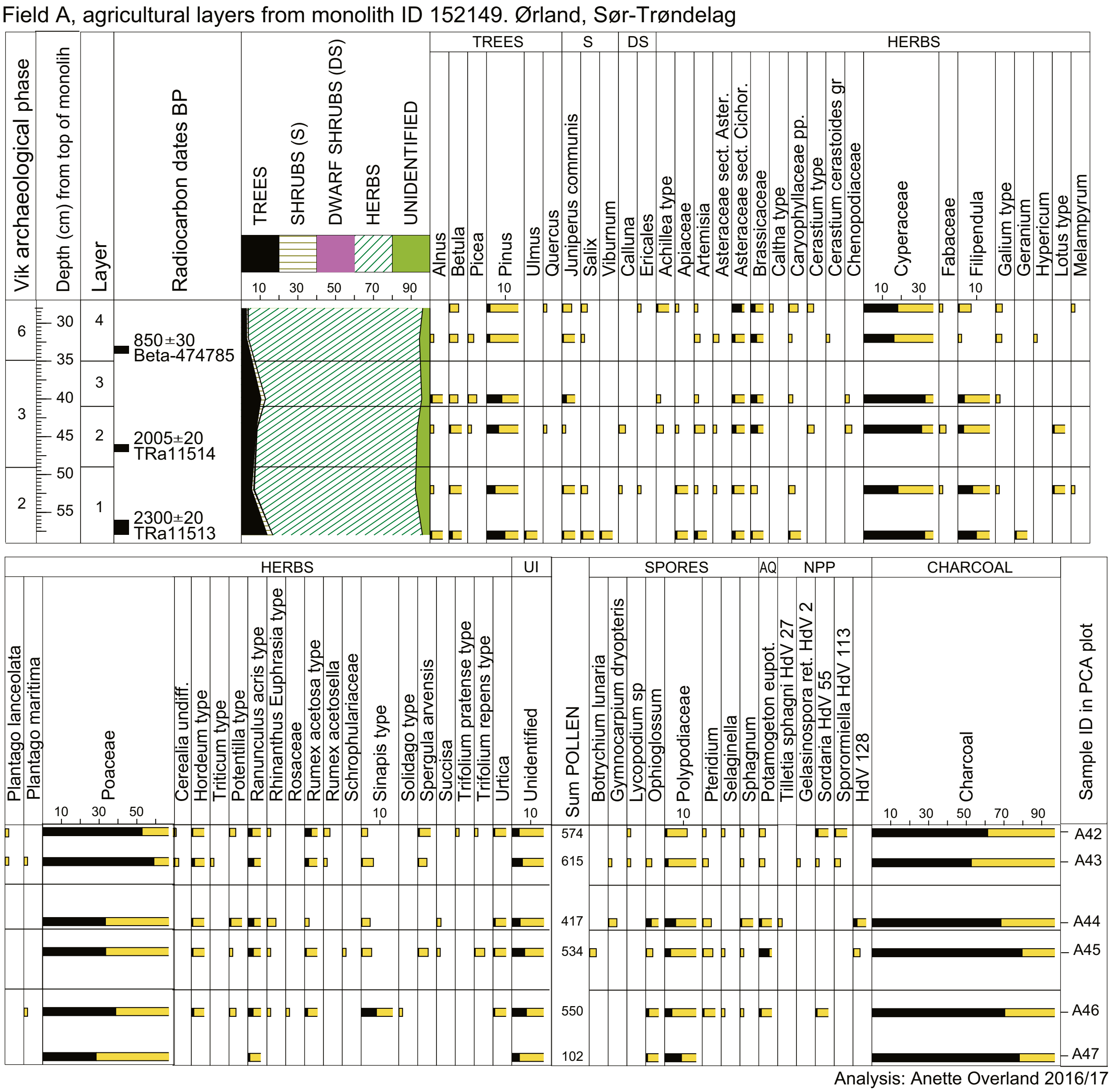


Figure 6. Percentage pollen diagram for agricultural layers in Field A. Some taxa are omitted from the diagram. Complete diagram presented in Overland and Hjelle (2017).

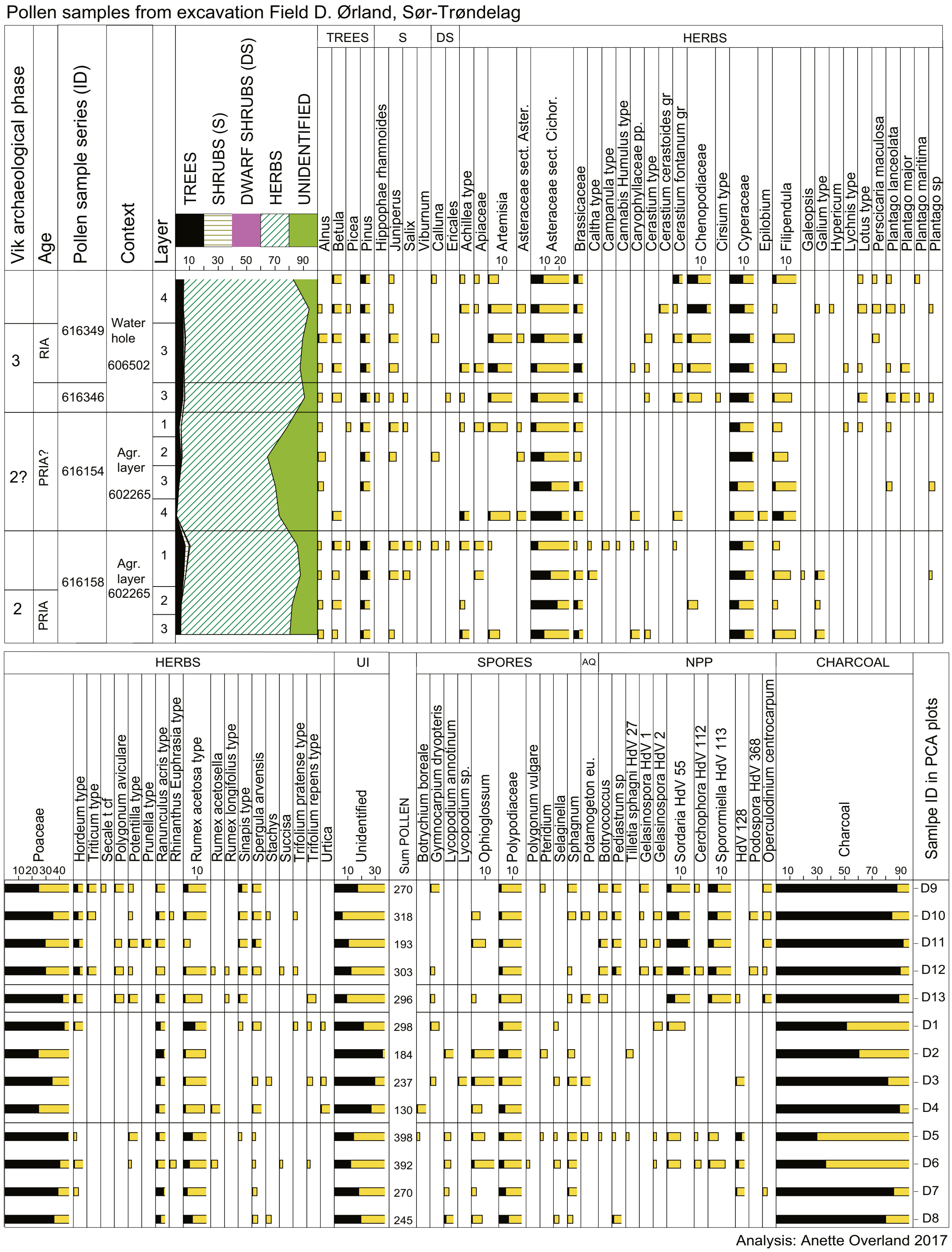


Figure 7. Percentage pollen diagram for Field D. Complete diagram presented in Overland and Hjelle (2017).

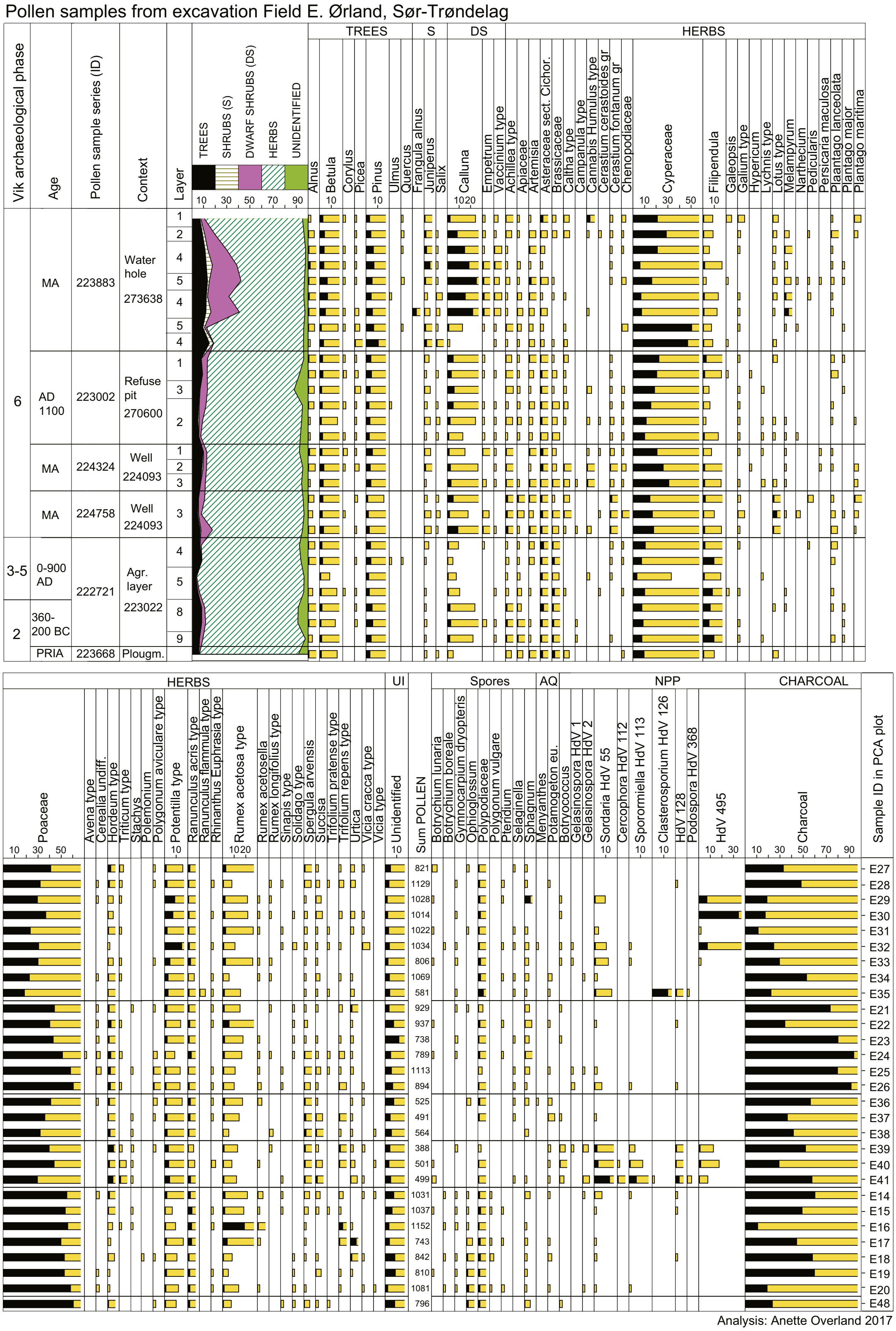


Figure 8. Percentage pollen diagram for Field E. Complete diagram presented in Overland and Hjelle (2017).

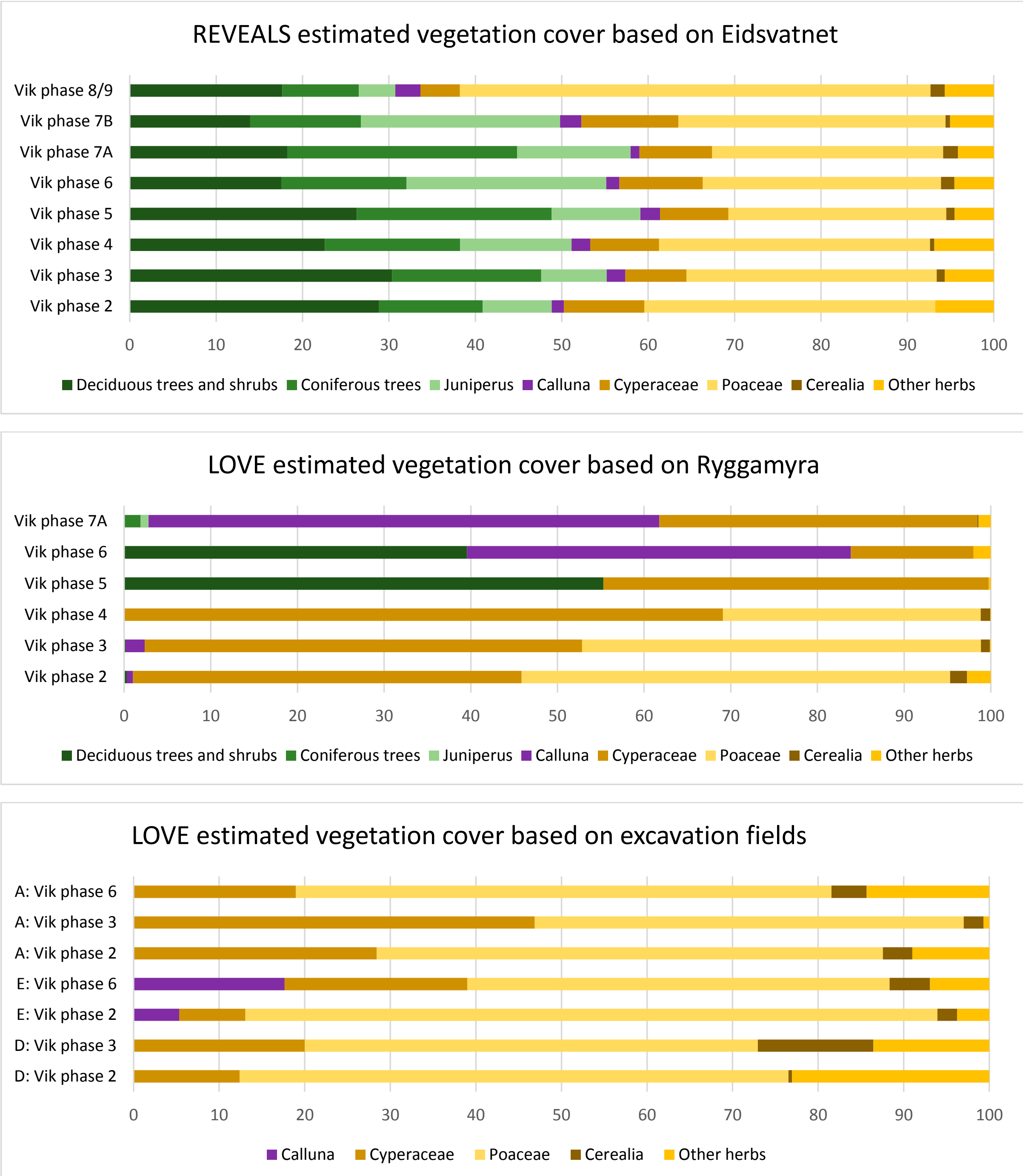


Figure 9. Estimated vegetation cover using the Landscape Reconstruction Algorithm (Sugita 2007a, b). Regional and local vegetation cover based on pollen data combined into Vik phases. Vik phase 7 has been separated in two (see text). Pollen data were only available for three phases from the excavation areas.

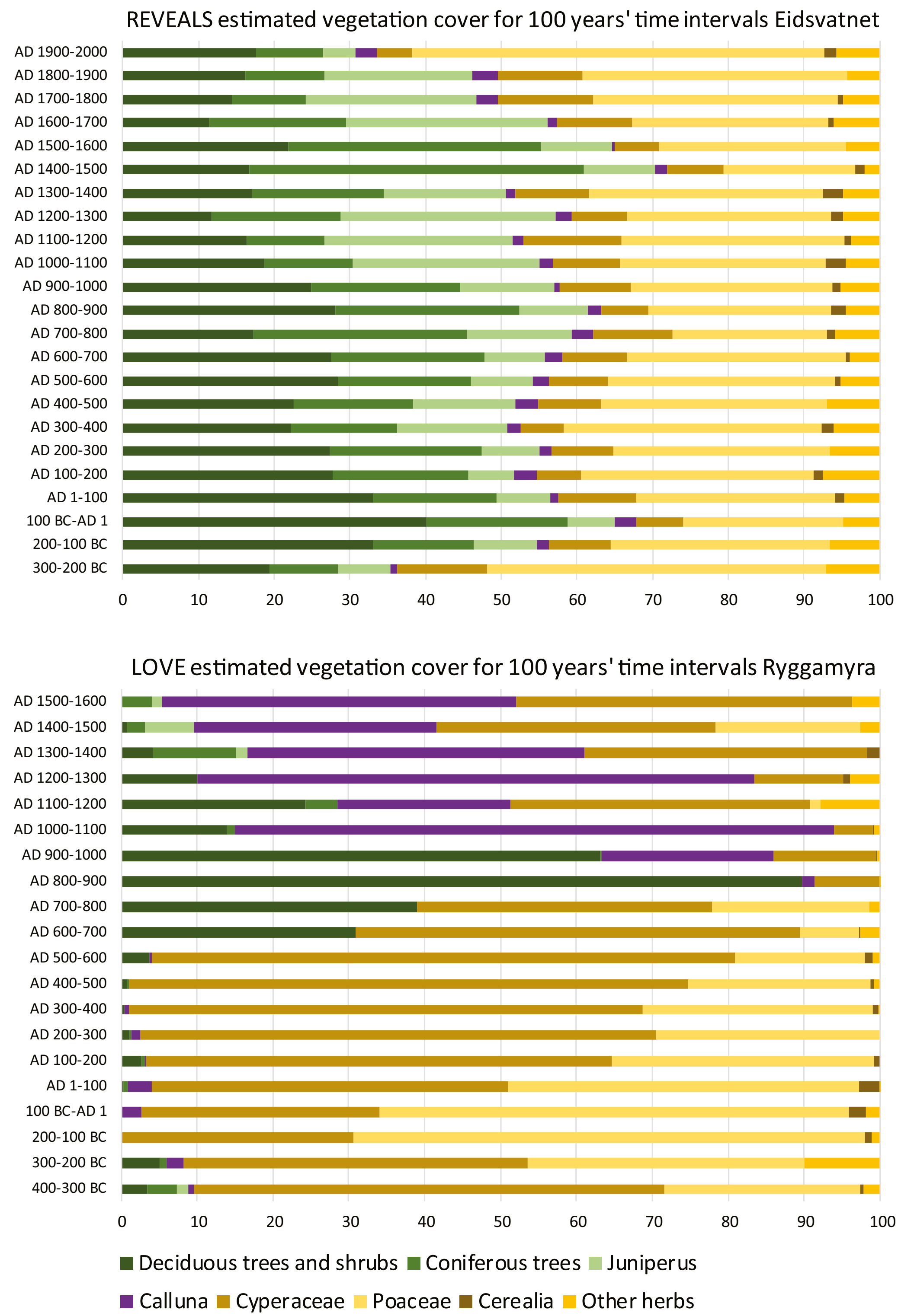


Figure 10. REVEALS and LOVE estimated vegetation cover in hundred years' time intervals, Eidsvatnet and Ryggamyra.

Locally in Ørland the peat profile Ryggamyra (R1) suggests presence of an open Cyperaceae-rich wetland (Fig. 5). Ryggamyra was situated close to farmed landscapes reflected by records of *Hordeum*-type and *Triticum*-type, as well as a range of ruderal and grassland taxa, and the charcoal values are high. During the Pre-Roman Iron Age (Vik 2) there was a farm in Field B and cooking pits in Field A, and in the Roman Iron Age (Vik 3) there were farms in Fields A, C and D. The estimated cover of cereal fields was at its highest in the Early Roman Iron Age (Figures 9, 10), followed by increased cover of sedges (Cyperaceae). In the end of R1 (Vik 4) there is an increase in coprophilous fungi (*Sordaria* HdV-55, *Sporormiella* HdV-113) suggesting increased grazing activity at and around Ryggamyra (Geel et al. 2003, Mazier et al. 2009, Cugny et al. 2010, Davies 2019). The farm settlement in Field D was abandoned in this period (Vik 4).

Agricultural soils (monolith ID 152149) from Field A (Fig. 6) are associated with Vik 2 and Vik 3. Pollen samples and reconstructions (Fig. 9) suggest moist grassland during Vik 2 (layer 1) with species such as Cyperaceae and *Filipendula*, in addition to Poaceae, Asteraceae sect. Cichorioideae, *Ranunculus acris*-type, *Rumex acetosa*-type, Caryophyllaceae, *Galium*-type, *Potentilla*-type and *Rhinanthus/Euphrasia*-type. *Hordeum*-type is present in all samples. Ruderal taxa of frequently disturbed soils associated with agriculture (Chenopodiaceae, *Artemisia*, Brassicaceae, *Sinapis*-type, *Rumex acetosella*, *Spergula arvensis*) are also present, as well as *Urtica*, a taxon related to nitrogen. The aquatic herb *Potamogeton eupotamogeton* reflects local wetlands. Both *Ophioglossum* and *Botrychium lunaria* that are associated with lime rich soils, and *Plantago maritima,* may be associated with seashore vegetation. The pollen profile from Field A represents cultivation and grazing activity.

From Field D, pollen samples associated with agricultural soils (pollen series 616158 and 616154 from context 602265) from Vik 2 (and possibly later), and a water hole/well (pollen series 616349 and 616346 from context 606502) associated with the settlement during Vik 3, were investigated (Fig. 1, Fig. 7). Pollen samples from the agricultural soils are characterized by grassland herb pollen (Poaceae, Cyperaceae and Asteraceae sect. Cichorioideae). Preservation of pollen is exceptionally low, with as much as 10–35% of total pollen sum representing corroded, unidentified pollen grains, typical for agricultural soils. *Hordeum*-type is present in some pollen samples, and *Cannabis/Humulus*-type is present in layer 1 (id 616158). Taxa indicating frequently disturbed soil and agriculture are Brassicaceae, *Spergula arvensis*, Chenopodiaceae, *Sinapis*-type, *Rumex acetosella*, *Galeopsis* and *Artemisia* (Behre 1981), while grassland indicators include *Ranunculus acris*-type, *Rumex acetosa*-type, *Galium*-type, *Achillea*-type, *Plantago lanceolata, Trifolium repens*-type and *T. pretense*-type (Hjelle 1999). Coprophilous fungi *Sordaria* (HdV-55), *Cercophora* (HdV-112), *Sporormiella* (HdV-113), and *Gelasinospora* (HdV-1) suggest use of manure/grazing animals, and green alga (*Pediastrum*, *Botryococcus*) and HdV-128 suggest open, mesotrophic-eutrophic waters (Geel 1976, Geel et al. 1981), possibly associated with manure and farm animals. The dinophyceae cyst *Operculodinium* suggests presence of salt water. The ferns *Ophioglossum* and *Botrychium boreale,* on the other hand, are associated with lime rich grasslands/seashore vegetation, while taxa related to nutrient-poor heathland/bog (*Cyperaceae, Juniperus, Calluna, Lycopodium annotinum, Selaginella*) and aquatic environments (*Potamogeton eupotamogeton* and *Caltha*-type) are present, suggesting a varied local environment.

The pollen samples from the water hole in Field D, Vik 3 (Fig. 7) are characterized by relatively high values of *Hordeum*-type, and ruderal taxa of frequently disturbed soils and agriculture (*Triticum*-type, Chenopodiaceae, *Artemisia*, Brassicaceae, *Sinapis*-type, *Rumex acetosella*, *Persicaria maculosa*, *Polygonum aviculare*, *Spergula arvensis*). The samples are also characterized by grassland indicators (Poaceae, Cyperaceae, Asteraceae sect. Cichorioideae, *Ranunculus acris*-type, *Rumex acetosa*-type, Apiaceae, *Potentilla*-type, *Plantago lanceolata*, *Achillea*-type). Presence of *Plantago major* probably suggests trampling. Also present are relatively high values of some of the coprophilous fungi, *Sordaria* (HdV-55), *Cercophora* (HdV-112), *Sporormiella* (HdV-113), *Podospora* (HdV-368) and *Gelasinospora* (HdV-1). The greenalga *Pediastrum* and *Botryococcus* suggest nutritious water, and dinophyceae cyst *Operculodinium* suggests salt water. Microscopic charcoal values are high.

Altogether the pollen samples from Field D suggest an open landscape near the settlement where barley and hemp may have been cultivated (see discussion). There is presence of both calcareous coastal vegetation, as well as nutrient-poor wetlands, which both may have been grazed. An open, grassland-dominated landscape with cereal fields is also evident from the LOVE-based reconstructions (Fig. 9). Aquatic algae also suggest supply of nutritious water, partly brackish, and coprophilous fungus spores are probably related to farm animals and use of manure.

From Field E, pollen samples associated with two water holes/wells, one refuse pit, and agricultural layers including plow mark were investigated (Fig. 1, Fig. 8). The plow mark (pollen series 223668, context 223669) was associated with Vik 2, whereas the agricultural layers (pollen series 222721, profile 223022), were most likely associated with Vik 2–5. The pollen samples (Fig. 8) are generally characterized by herb pollen, mainly Poaceae, but also Cyperaceae, and in some samples from the agricultural layers *Filipendula, Rumex acetosa*-type, *Trifolium repens*-type and *Urtica* are well represented. Other grassland indicators include *Achillea*-type, Asteraceae sect. Cichorioideae, *Ranunculus acris*-type, *Plantago lanceolata* and *Potentilla*-type. Taxa indicating disturbed soil and agriculture are *Artemisia*, Brassicaceae and *Spergula arvensis*, which are frequently registered, and Chenopodiaceae, *Rumex acetosella*, *Galeopsis, Sinapis*-type and *Polygonum aviculare,* which are present in some samples. *Hordeum*-type is present in all samples, while *Triticum*-type and *Cannabis/Humulus*-type are identified in layer 5. *Ophioglossum* is well represented in all samples, and also *Botrychium lunaria*, *Botrychium boreale* and *Polemonium* are registered in some samples, all species associated with lime-rich soils (shell-sand). Some coprophilous fungi (Sordariaceae) are registered.

Field E was generally associated with agriculture (barley), and open grassland vegetation (cf. also the reconstructions, Fig. 9). In the Pre-Roman Iron Age, Vik 2 (plow-mark and agriculture layer 8, 9), the area is associated with both heather, most likely on wet and acid environments, and brackens (and herbs) of lime-rich soils, suggesting a variety of pollen sources. This may suggest grazing animals on outfields (both heathland, and seashore environments) and/or nearby heathland (Mølnhaugen?). Micromorphology suggests that layer 9 represents a farmyard (household waste and manure; Macphaile 2017), probably associated with a settlement nearby in the PRIA. Layer 5 suggests increase in grassland, possibly associated with mowing. Also *Cannabis/Humulus*-type is recorded, in addition to barley and wheat. This is a wet site, possibly due to bedrock with sparse soil cover, guiding surface water from Mølnhaugen, and subsequently forming iron pan (post-depositional processes). In layer 4, the representation of barley increases. Layers 4 and 5 are disturbed (see archaeological report), so there is a chance that these changes in vegetation represent younger periods.

Merovingian – early Viking Age, c. AD 550–900 (≈E3 and R2), Vik 5

During the Merovingian Period there is increase in woodland surrounding Eidsvatnet (E3, Fig. 4), but farming activity is still present, indicated by records of Cerealia and possibly *Cannabis/Humulus*-type. The estimated tree cover indicates increase in both conifers and deciduous species with around 10% on a regional level from AD 500 to AD 600 and a further increase from AD 800 to AD 900 (Fig. 10).

At Ørland the peat profile Ryggamyra suggests a natural succession from the minerotrophic wetland to raised bog (R2), in which *Sphagnum* and a succession of shrubs (especially *Salix*, but also *Betula,* incl. *Betula nana*), dwarf shrubs and bog taxa play a role (Figs. 5, 9, 10). There is probably still farming activity with grazing and cereal cultivation in the area (*Hordeum*-type, *Pl. lanceolata*, coprophilous fungi), but throughout the period charcoal is declining, as is input of minerogenic material (LOI-curve), suggesting less activity. This fits well with the archaeological results from Vik, with no settlement recorded during Vik 5. The bog may have formed part of outfield grazing areas (see discussion), but the estimated local tree/shrub cover >90% AD 800–AD 900) indicates that the grazing pressure was too low to prevent shrub/woodland development.

Late Viking Age and Early/High Medieval Period c. AD 900–1250 (≈start of E4, R3 and early R4), Vik 6

The period is characterized by woodland clearance surrounding Eidsvatnet (*Pinus, Betula, Alnus*), with maximum opening of the woodland AD 1100–1200, and an increase in *Juniperus* and Poaceae, most likely related to expansion of outfield grazing areas (Figs. 4, 10). Herb taxa indicative of grazing and mowing increase in representation or are recorded for the first time, e.g. Poaceae, *Rumex acetosa*-type, Asteraceae sect. Cichorioideae, *Potentilla*-type, *Thalictrum* and *Achillea*-type (Hjelle 1999). There are more or less continuous records of the cereal *Hordeum*-type, and also records of *Avena*-type, *Triticum*-type and *Cannabis/Humulus*-type. The period is characterized by an open landscape (nearly 70% open) with outfield pastures, but also infields with cereal cultivation and mown meadows.

The record from Ryggamyra (Fig. 5) suggests a peat bog dominated by shrub vegetation (incl. *B. nana*) and dwarf shrubs (*Calluna*). The marked increase in *Calluna* with maximum cover AD 1000–1100 (Fig. 10) together with coprophilous fungi (*Sordaria* HdV-55) suggest that the bog formed part of outfield grazing areas. Local hydrological changes and reduced minerogenic input may have provided suitable habitats for expansion of *Sphagnum*. The high variations in percentage of *Sphagnum* in R3 and R4 may be caused by local peat disturbances such as grazing activity.

In agricultural soils from Field A (Fig. 6, layer 4), there is a marked increase in Poaceae, together with Asteraceae sect. Cichorioideae and *Rumex acetosa*-type. There is a decline in Cyperaceae compared to Vik 3, which may suggest drier conditions, and possibly mowing (Hjelle 1999). There is also a drop in charcoal that may indicate changed farming practice. *Triticum*-type is present and grasslands with cultivated fields are indicated in the reconstructions (Fig. 9).

Locally at Vik a farm is established in Field E (Vik 6). The pollen samples associated with the medieval period (Vik 6, and Vik 7?) in Field E relate to contexts from wells (pollen series 224758 and 224324, context 224093), a water hole (pollen series 223883, context 273638) and a refuse/cess pit (pollen series 223002, context 270600) (Fig. 1, Fig. 8).

The pollen samples from the water hole (pollen series 223883) can be interpreted through four phases (Fig. 3) according to micromorphology

(Macphaile 2017). Pollen samples E35 and E34 in the bottom represent the "use phase" of the water hole; pollen samples E33 and E32 represent "redisposition of byre material", probably after the water hole fell into disuse; pollen samples E31–E29 represent "naturally deposited, thin laminations" also after disuse of the locality as a water hole; and pollen samples E28 and E27, from mineral soil, may be associated with much later activity. This interpretation fits well with the pollen record (Fig. 8). During the "use phase" the surrounding area is probably wet. Cyperaceae dominates, and there is presence of *Clasterosporium* (HdV-126), a fungi growing on *Carex* (Cyperaceae). Also the green algae *Pediastrum* and NPP HdV-128 suggest open water. Some coprophilous fungi (*Sordaria* HdV-55 and *Podospora* HdV-368) are registered, indicating some pollution by animal dung. The "byre material", which according to micromorphology is represented by coppice (Macphaile 2017), may be of *Betula*, *Frangula alnus* and *Calluna* (Fig. 8). The samples associated with redeposited byre material have particularly high values of *Calluna*, *Melampyrum* and *Potentilla*-type, which may reflect outfield heathland grazing. Pollen samples representing "natural laminations" are associated with *Calluna*, *Juniperus*, *Potentilla*-type, a peak in the moss *Sphagnum*, and fungi (NPP) HdV-495 that are associated with the heathland grass *Molinia caerulea*. The deposit suggests reduced local activity, i.e. laminated organic deposits and less micro-charcoal, but the pollen record also indicates continuing grazing activity and cultivation (*Hordeum*-type and *Tritium*-type) nearby. The pollen samples from layer 1 and 2, which may be associated with much later activity, are characterized by higher values of *Hordeum*-type and *Cannabis/Humulus*-type.

Pollen samples from infill in a well (pollen series 224758 and 224324) probably reflect the local environment in the period after the well was in use. Pollen series 224758 has a strong representation of *Calluna* and grazing indicators *Cerastium fontanum* gr., *Achillea*-type, *Lotus*, *Trifolium repens*-type, *Plantago maritima*, and cultivation indicators such as *Hordeum*-type, *Triticum*-type and *Spergula arvensis* (Fig. 8). The samples also have strong representation of coprophilous fungi *Sordaria* (HdV-55), *Cercophora* (HdV-112), *Sporormiella* (HdV-113) and *Gelasinospora*, as well as the green algae *Botryococcus* and fresh water algae HdV-128. This suggests that pollen series 224758, which relates to the earliest stages of infill in the well, represents deposition during a period with presence of animal dung and nutritious water. The well may have been used as water source for farm animals in the early stage of infilling, but has probably also received household waste, latrine and byre material. This is in accordance with the interpretation of the macrofossil record. There has been open water, but also dry periods and infill of animal dung and refuse (Moltsen 2017). In the later stages (pollen series 224324) presence of *Hordeum*-type and coprophilous fungi are much reduced, but *Cannabis/Humulus*-type is regularly recorded, suggesting a change in local environment/activity.

The pollen samples from the refuse/cess pit (pollen series 223002) are likely to mainly contain pollen grains from deposited waste, and also local ruderal herbs associated with the settlement (Fig. 8). The pollen samples are characterized by Poaceae, grassland herbs and ruderal taxa, which in general may relate to byre/stabling debris, supporting the interpretation of the micromorphology (Macphaile 2017). *Hordeum*-type is also well represented, and both *Triticum*-type and *Avena*-type are recorded, which most likely reflect household waste or latrine deposits (cf. Macphaile 2017). The charcoal values are high, which may have different sources, but according to micromorphology reflects industrial (iron working) traces.

The landscape in general reflects an open environment (Fig. 9, assuming that pollen in the different deposits reflects the surrounding vegetation in phase 6), where herb-rich grasslands and ruderal herbs associated with settlement dominate the excavation areas, together with cultivated fields. *Hordeum* is well represented, and *Cannabis/Humulus*-type is regularly identified, probably reflecting locally grown crops, unless imported (see discussion). Heathlands had developed in the vicinity in this period, probably reflecting outfield grazing.

High/Late Medieval and Early Modern times, c. AD 1250–1850 (≈end of E4–E6, R4 and R5), Vik 7

There are significant changes in vegetation cover surrounding Eidsvatnet during Vik 7 (Fig. 4). In the period c. AD 1380–AD 1550 (E5) there is reforestation involving particularly *Betula* and *Pinus*. At the same time there is a drop in *Juniperus*, *Calluna*, Poaceae and Cyperaceae, and in microscopic charcoal. Using hundred-year intervals indicates that the main increase in regional tree cover (>25%) took place from AD 1400 to AD 1500 (Fig. 10). This may be related to less farming activity in the late medieval depression period and in the aftermath of the Black Death (AD 1349). *Hordeum*-type is recorded in the start of the zone, and also ruderal species like *Artemisia* and *Spergula arvensis*. Some increase in *Urtica* may indicate expansion of fallows.

At Ørland, reflected by Ryggamyra (R4 and R5), there is local outfield grazing activity in this period. Estimations of local vegetation cover using hundred-year intervals indicate increased shrubs/trees cover AD 1300–1400, followed by clearance and expansion of grasslands (Fig. 10). There are records of Cerealia, *Hordeum*-type, *Triticum*-type and ruderal species (Fig. 5), most likely spread from nearby settlements. From c. AD 1400 the charcoal curve suggests increased human activity around Ryggamyra, probably related to heathland burning. A new expansion of heathlands and bogs is estimated to have taken place after AD 1500.

Surrounding Eidsvatnet there is significant woodland clearance after AD 1550 (E6, Fig. 4), and an increase in shrubs, dwarf-shrubs and herbs relating to open fields, pastures and meadows (*Juniperus*, *Calluna*, Cyperaceae, *Filipendula*, *Melampyrum*, Poaceae, *Potentilla*-type, *Ranunculus acris*-type, *Rumex acetosa*-type). There are records of *Cannabis/Humulus*-type and *Hordeum*-type, and ruderal species like *Spergula arvensis*, Chenopodiaceae and *Artemisia*. Coprophilous fungi (*Sordaria* HdV-55, Sordariaceae) are also recorded. The regional landscape is most likely a mosaic of outfield pastures/heathlands and infields with cereal cultivation and mown meadows during this period, with an estimated tree cover of <30% after AD 1600. Locally at Ørland, pollen data from the last part of Vik phase 7 is lacking.

Modern, c. AD 1850–present (≈E7), Vik 8 and 9

Around Eidsvatnet there is an increase in Poaceae and a reduction in *Juniperus*, suggesting better representation of infield meadow areas, reflecting intensification in land-use practices surrounding Eidsvatnet (Fig. 4, 9, 10). There are also changes in representation of algae (*Botryococcus*, *Pediastrum*) and HdV-128.

Summary of the data revealed through gradient analysis

Combining pollen data from Ryggamyra and the excavation area in one gradient analysis, with the samples from Eidsvatnet positioned passively on the PCA-plot, reveals the difference between various deposits and contexts analyzed (Fig. 11). The first axis differentiates between samples characterized by cereals, ruderal species (e.g. *Artemisia*, Brassicaceae, *Spergula arvensis*), grasses and other grassland taxa (e.g. *Ranunculus acris*-type, *Rumex acetosa*-type), on

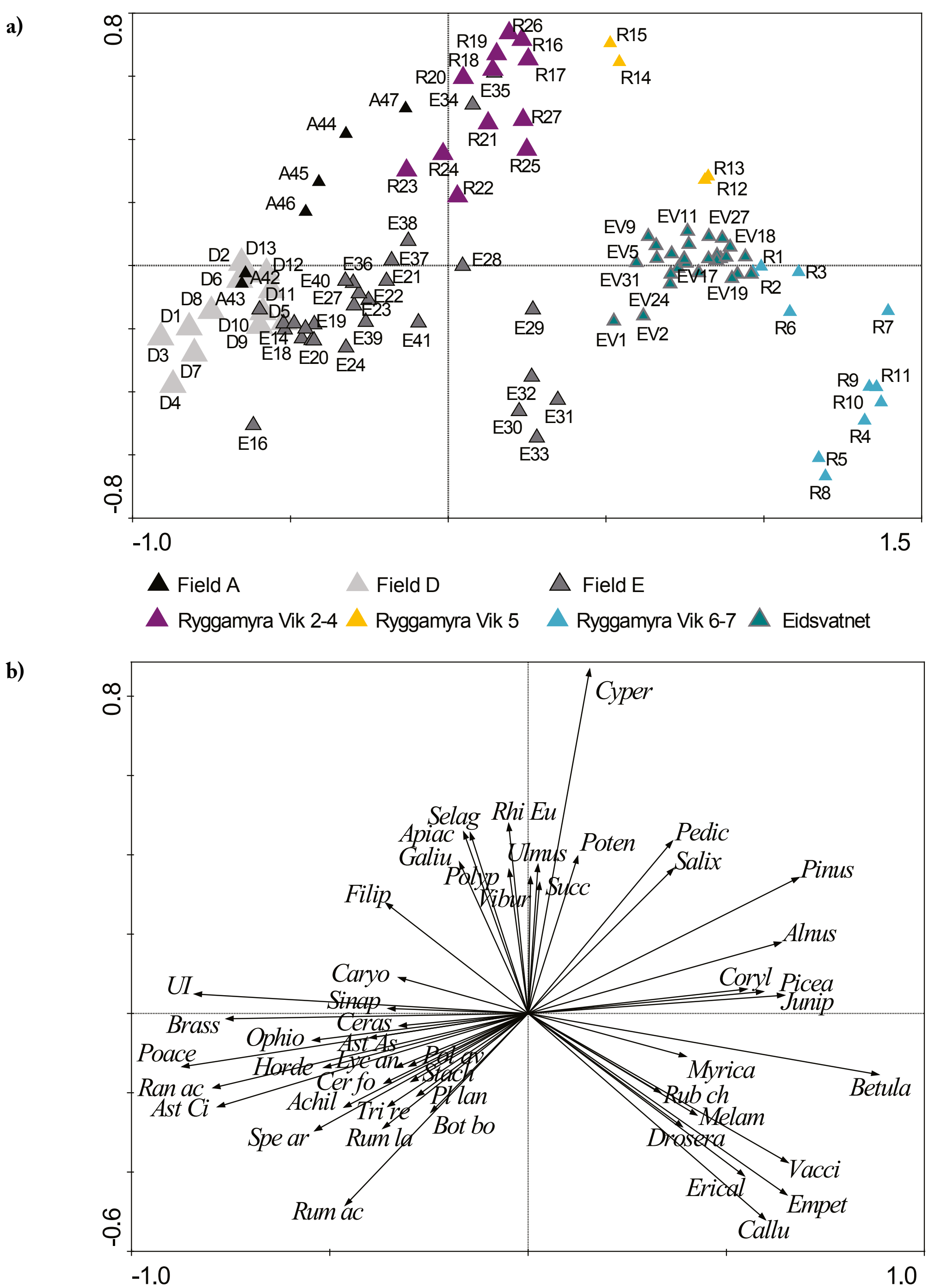


Figure 11. Principal Component Analysis (PCA) showing the main gradients based on pollen samples from archaeological contexts and Ryggamyra, Ørlandet. Samples from Eidsvatnet are treated as supplementary (passive) data; a) samples, numbers referring to sample id in pollen diagrams (Figs. 6–8), and b) selected pollen types. See Appendix I for abbreviations of names.

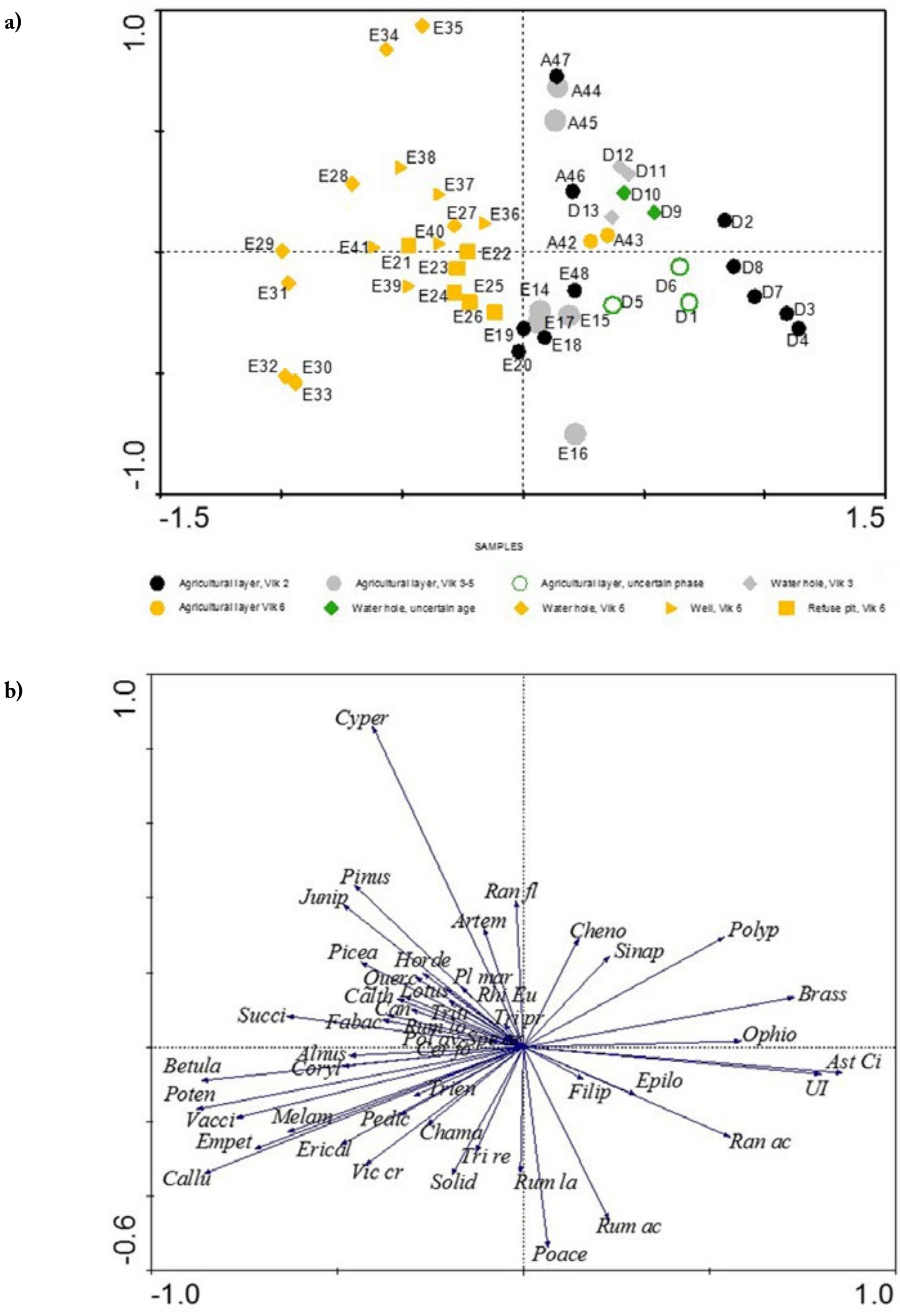


Figure 12. Principal Component Analysis (PCA) showing the gradients in the pollen data from archaeological contexts; a) samples, numbers referring to sample id in pollen diagrams (Figs. 6–8), and b) selected pollen types. See Appendix I for abbreviations of names.

the left hand side, and samples with higher values of heathland, outfield grazing and woodland taxa (e.g. *Calluna*, *Vaccinium, Juniperus, Betula, Pinus*), on the right hand side. Samples having high values of Cyperaceae are found at the top of the plot. Nearly all samples from the excavated areas are found to the left. Some samples from Field E are found more to the right in the plot, due to their high values of *Calluna.* Samples from the Early Iron Age phases from Ryggamyra (Vik 2–4) are quite similar to samples from the excavated areas, especially to samples from the waterhole and refuse pit, Vik 6, and also to samples from Field A having high values of Cyperaceae. Vik phase 5 from Ryggamyra, with its high values of *Salix*, differs from all other samples and represents a transition between the older phases (Vik 2–4) and Ryggamyra (Vik phases 6, 7), characterized by dwarf shrubs (e.g. *Calluna*). Eidsvatnet is found in the tree-dominated part of the plot, with the increased human impact in the top of the diagram separating the two topmost samples (Vik 8–9) from the older phases. The first axis explains 39.8% of the variation in the data, the second axis 12.5%.

The PCA plot showing samples from the excavated fields (Fig. 12) indicates that samples from the same context and archaeological phase are most often placed in the vicinity of each other. Moreover, the plot separates samples from water hole, well and refuse pit in field E (Vik 6) on the left hand side, from all other samples to the right. Unidentified pollen grains are positively correlated to the first axis (right hand side of the plot), reflecting a high degree of corroded pollen grains in agricultural soils. Asteraceae sect. Cichorioideae and Brassicaceae are also found on this side of the plot, whereas most taxa, including cereals, are found on the negative side of the first axis. This may reflect increased use of cereals in Vik 6 compared to earlier periods. More likely, however, this reflects better preservation conditions for pollen grains in the rather moist deposits from Vik 6 (water hole, well and refuse pit), in combination with the fact that pollen grains from cereals most often follow the harvest/crop (cf. Vuorela 1973, Krzywinski & Fægri 1979, Hall 1989), rather than being dispersed on the site of cultivation. Grassland taxa such as Poaceae, *Rumex acetosa*-type and *Trifolium repens*-type are found on the negative side of the second axis (bottom of the plot), whereas Cyperaceae is found on the positive side of this axis. The first axis explains 30.6% of the variation in the data, the second axis 12.7%.

DISCUSSION

Vegetation types and natural conditions at Ørland

The excavated areas at Ørland became dry land around 2400 years ago (Romundset 2017), and were in prehistory most likely dominated by wetland areas with poor drainage. At some stage the wetland developed into a variation of Atlantic blanket bog (Skogen 1965, Moen et al. 2011). The development from minerotrophic wetland to ombrotrophic blanket bog can be seen in Ryggamyra from the Roman Iron Age, a change that may be caused by a combination of several factors, both involving human impact and climatic change (see below). Drainage schemes in the last few hundred years have transformed the landscape in Ørland completely, towards modern fields and grasslands (Berger 2001). Skogen (1965), who gives an outline of contemporary vegetation in Ørland, describes the landscape in 1961 as heavily influenced by human occupation and animal grazing. The remnants of natural vegetation types could only be found in patches, in the most remote beaches, the steepest rocky outcrops, and the wettest ombrotrophic bogs.

In the present pollen analysis there are pollen-types related to variations of dry herb-rich grasslands, some of which may be related to lime-rich soils and shell-sand, or dry rocky outcrops. These include species like *Trifolium repens*, *Rhinanthus/Euphrasia*, *Galium, Lotus corniculatus, Vicia cracca*-type, *Campanula rotundifolia, Achillea millefolium,* Apiaceae (e.g. *Carum carvi*), *Potentilla*-type, *Leontodon autumnalis, Polemonium, Plantago lanceolata, Cannabis/Humulus, Ophioglossum* and *Botrychium lunaria*. Some species may also exist in dry heathlands, as on the island Tarva outside Ørland (Fremstad & Nilsen 2000). The heathland vegetation on these islands today represents the scanty remains of a former, and much more widespread, vegetation type and management that existed along the coast previous to the introduction of modern farming (Kaland & Kvamme 2013).

The woodland at and near Ørland has contained both coniferous (pine and spruce) and deciduous species. In the sheltered south-facing Rusaset/Reitan area, including the south-facing Fosenheia, there are thermophilous trees (*Corylus* and *Ulmus*) (Holten 1978), that most likely represent remnants of more extensive woodlands (Skogen 1965). In the pollen data species like *Corylus*, *Ulmus*, *Quercus, Viburnum, Frangula alnus* and *Humulus lupulus* (https://www.artsdatabanken.no) may have originated in and around these areas.

Representation in our data

The history of the vegetation at Ørland is based on a pollen diagram from the bog Ryggamyra and pollen data from settlement contexts, such as agricultural layers, water holes, a well and a refuse pit. The local vegetation dominates the pollen composition both at Ryggamyra and in the agricultural fields, but they also receive pollen from a larger area and an estimated relevant source area of pollen (RSAP) (Sugita 1994) of up to a radius of around 2000 m is in accordance with studies from cultural landscapes elsewhere (e.g. Nielsen & Sugita 2005, Poska et al. 2011). Based on our estimates, the pollen data from agricultural fields mainly reflect the archaeological excavation areas, whereas Ryggamyra reflects a larger area including the excavated areas. The size of the RSAP varies with the size of vegetation patches in the landscape and the spatial distribution of taxa; the larger the patch size and lower the species evenness, the larger the RSAP (e.g. Bunting et al. 2004, Hellman et al. 2009a, b).

Pollen samples from Eidsvatnet were analyzed with the aim of putting the vegetation development at Ørland into a regional context, and also for the purpose of carrying out local vegetation reconstructions at Ørland using the Landscape Reconstruction Algorithm (Sugita 2007a, b). Eidsvatnet is a large lake, probably reflecting the vegetation in an area of radius up to 50–100km. This means that the lake gives a regional pattern of the vegetation development, including the Ørland area, but with higher impact on the pollen assemblages from the landscape surrounding the lake, as well as from Austrått with its important medieval farm, situated between Ørland and Eidsvatnet.

Two assumptions for the Landscape Reconstruction Algorithm – no plants should grow on the sampling point and pollen should be wind dispersed (Sugita 2007a, b) – are not met in our data. Both Ryggamyra and agricultural fields have local vegetation that may be overrepresented in the reconstructions. Moreover, human activity may be an important pollen dispersal agent for samples from archaeological contexts. Nevertheless, while being aware of this source of error, we have included samples from archaeological contexts in order to get a potential indication of the importance of the various vegetation types through time. We assume that the pollen composition is dominated by wind-dispersed pollen from the local vegetation, and that the potential plant material that is anthropogenically deposited brings pollen that has originated in the local vegetation.

Farming and resource utilization at Ørland

Due to sea level changes the last 2400 years (Romundset 2017) local environment and resource exploitation at Ørland has changed throughout prehistoric and historic times. Pollen records from various contexts, areas and time phases can cast light on these local changes in vegetation development, landscape and resource exploitation. The peat profile Ryggamyra represents an archive of local activity in the area and forms the oldest palynological record directly associated with farming activity in Ørland. Ryggamyra shows the presence of open sedge rich wetland/fen, situated close to farmed landscapes during the Pre-Roman and Roman Iron Age (Vik 2 and 3) where the fen's catchment received run-off direct from farming activity. This was the main period of the farming settlement at Vik (Fransson Ch. 5, Heen-Pettersen & Lorentzen Ch. 6). Barley was cultivated in the catchment area of Ryggamyra, and animals most likely grazed both in wetland areas and drier seashore grasslands. Prehistoric settlements at Ørland, with associated agricultural fields and herb-rich grazed grasslands, were most likely situated on areas with the most favorable drainage and in more or less totally open landscapes. This is reflected by excavation Fields A, B and E in the Pre-Roman Iron Age (Vik 2), and in Fields A, C and D during the Roman period (Vik 3) (Engtrø & Haug 2015, Ystgaard et al. 2018). Pollen samples from agricultural soils, plow marks and water holes from the settlement sites reflect farming activity, where barley was the main crop cultivated (also see Engtrø & Haug 2015). During Vik 2 and Vik 3 the seashore was much nearer than today (Romundset 2017), as reflected by the regular occurrence of salt water indicators (*Operculodinium*) in pollen samples (Field D). Otherwise, saltwater indicators may reflect animal grazing on the seashore, which is also likely. Spores of adders-tongue (*Ophioglossum vulgatum*) were regularly recorded in the pollen records in Fields D and E, in contexts relating to Vik 2 and Vik 3. Adders-tongue is a fern related to lime-rich beaches and grasslands, often found in salty soils (Mossberg & Stenberg 2014), and is today recorded on Storfosna, west of Ørland (https://www.artsdatabanken.no). The fern is sensitive to competition (Mossberg & Stenberg 2014). Another fern, moonwort (*Botrychium*), is recorded in the pollen record in Fields A, E and D, and has also been present at Ryggen (near Ryggamyra) until recent (Skogen 1965). Both ferns are relatively rare species and can today be found on remote beaches. Previously, both species may have found a niche in traditionally managed grazed and mowed grasslands, where they were able to expand and thrive due to removal of competitive grasses by grazing animals and mowing (cf. Losvik 1993). Their pollen record may therefore reflect a landscape of traditionally managed grasslands and meadows with minor/moderate manuring at Vik during phases Vik 2 and Vik 3. Mowing is generally connected to development of the scythe in the Late Iron Age (Solberg 2003). However, the species composition connected to traditional hay meadows (Losvik 1993, Hjelle 1999) seems to appear at least from the Pre-Roman Iron Age in western Norway (Hjelle 2005), supporting the view that hay meadows may have existed also at Ørland during Vik 2 and Vik 3. The presence of longhouses (Fransson Ch. 5, Heen-Pettersen & Lorentzen Ch. 6) also indicates the stalling of animals and the need of winter fodder, probably gained through the cutting of grasslands.

The regional development as reflected around Eidsvatnet was dominated by woodland and open grasslands, with patches of heathland and cereal cultivation during Vik 2–4. Compared to the data from Ørland, there were probably areas further east that were covered by woodland, whereas the western part of the peninsula was open. This is also supported by the data from Borgestad (Solem 2009) and Veklem (Berglund & Solem 2017). Records of hemp/hops (*Cannabis*/*Humulus*) are associated with the Roman Iron Age around Eidsvatnet. In Scandinavia local hemp retting is suggested from c. AD 1–400 (Larsson & Lagerås 2015), and it is possible that hemp was grown in the Eidsvatnet region. Otherwise hops are naturally present in sheltered south-facing rocky outcrops in South Trøndelag (Skogen 1965). In the Late Roman Iron Age and Migration period, the regional farming activity intensified, with woodland clearance, which also involved *Ulmus* and *Quercus* woodland, and with increased grazing. Earlier pine-dominated woodland may have become outfield pasture: grassland with juniper, and heathland. This regional development of extensive areas of grazed outfield from the Migration Period is parallel to the local development in Ørland. The Migration Period (Vik 4) is interpreted as a period of less activity at Vik (Heen-Pettersen & Lorentzen Ch. 6), where Field D was no longer in use as a settlement site, while the settlements at Fields A, C and E were abandoned in the Merovingian period (Vik 5). There are suggestions of an increase in grassland, and possibly of mowing (cf. Hjelle 1999) related to pollen series 222721 (Field E), and also records of barley, wheat and hemp/hops suggest continuous farming activity in the area. Around Ryggamyra there was less activity, reflected by a drop in charcoal values and in minerogenic run-off from human activity (LOI near 100%). While Ryggamyra during Vik 2, 3 and 4 was within the catchment area of infield farming, Ryggamyra from Vik 5 onwards was situated within the outfield grazing area. Ryggamyra underwent a natural succession from minerotrophic wetland to raised bog with heathland vegetation, maybe due to reduced minerogenic run-off from human impact and/or local hydrological and/or regional climatic changes. This development may be a consequence of local sea-level changes (Romundset 2017, Romundset & Lakeman Ch. 2) that may have impacted on settlement patterns. Changing settlement patterns most likely also resulted in reorganization of infield and outfield areas, and impacted on local resource utilization.

A steady increase in regional woodland takes place in Vik 5, but farming activity is still present. The vegetation development around Eidsvatnet, as in Ryggamyra, suggests a "period of change" at the transition to the Merovingian period. This may be associated with structural changes in society, which may again be influenced by climatic changes perhaps related to volcanic eruptions (Solberg 2003, Myhre 2004, Büntgen et al. 2016). At Ørland the changes in settlement patterns (Ystgaard, Gran & Fransson, Ch. 1) may be linked to sea level changes (Romundset 2017), which most likely impacted hugely on harbor facilities and exploitation of marine resources. Again, changing settlement patterns and sea level changes most likely influenced the trophic status in wetlands and bogs, which could partly be responsible for development of ombrotrophic peat-bogs that became suitable for outfield grazing. The change from wetlands to ombrotrophic peat bog in Ryggamyra need not indicate a reduction in overall human impact at Ørland, but may reflect changes in settlement patterns and exploitation of outfield resources. The estimated increase in tree cover regionally seems to have had minor effect on the regional cover of heathlands.

In the last part of the Late Iron Age woodland clearance on a regional level took place, with expansion of outfield grazing areas with, in particular, juniper (Vik 6). The period is characterized by an open landscape with outfield pastures, but also by infields with mown meadows and cultivated fields. This expansion may be connected to increased activity, for instance around the manor Austrått, a substantial farm situated c. 4.5km from the excavated areas, and mentioned in the Islandic saga literature. There are burial mounds from the Viking period at the manor area, indicating that the manor itself may trace its roots back to the 10th century or before (Andersen & Bratberg 2005).

Within the excavation area, spores of the fern adders-tongue (*Ophioglossum*) are recorded with much less frequency during Vik 6, than before. This may again be a consequence of sea-level changes and a larger distance to this fern's optimal habitat, but it may also be a consequence of intensified farming with highly manured infields. Pollen assemblages relating to mowing (Hjelle 1999) are indicated in Field A (monolith id 152149), which may suggest hay production. Increased use of manure, indicated by coprophilous fungi (Geel et al. 2003, Mazier et al. 2009, Cugny et al. 2010, Davies 2019), to promote grass production and higher hay yield, would have been of disadvantage to the small fern adders-tongue. Parallel to intensified infield production in Vik 6 there was outfield exploitation involving grazed heathland vegetation. Ryggamyra, during Vik 6, formed part of outfield grazing areas marked by expansion in *Calluna* cover and presence of coprophilous fungi. Palynological investigations in Aukra, situated c. 170km southwest of Ørland also suggest expansion in heathland development in the Late Iron Age and the medieval period, connected to changes in settlement pattern (Hjelle & Solem 2008, Hjelle et al. 2013). Utilization of coastal heathlands seems generally to be important in this period, as well as the expansion of heathland management into new areas (e.g. Kaland 1986, Tveraabak 2004, Hjelle et al. 2010, 2018). This is also most likely linked to the increased representation of heather in pollen samples from the archaeological contexts in Field E (refuse pit, wells and waterholes). Increasingly, wetlands may have turned into ombrotrophic peats with heather vegetation, which were used as outfield grazing. Locally at Ørland this development may have been triggered by hydrological changes in association with sea-level changes.

During Vik 6 a farm is established in Field E, and pollen records from wells, water holes, and refuse pit reflect the local activity and vegetation associated with this farming activity. The refuse pit is deposited during the time of the farm, and reflects an open farmyard with abundant ruderal species and grasses. Barley is very well represented and may be connected to household waste or latrine material (see Macphail 2017). Pollen samples from another well in Field E (pollen series 224758) have slightly elevated values of wheat, and in the same layer macro fossil of cornflower (*Centaurea cyanus*) was recorded (Moltsen 2017). Macro remains of *Centaurea cyanus* are recorded in Trondheim from the medieval period (Sandvik 2006:210) and their presence at Ørland may suggest import of cereals for consumption and/or for sowing. Increased contact with Trondheim and the outside world is very likely considering Ørland's position along the gateway to Trondheim (cf. Ystgaard, Gran & Fransson Ch. 1). The source of pollen grains such as cereals found in household waste and latrine material may be locally cultivated or be the result of trade. The presence of Cerealia pollen grains also in agricultural layers and around Eidsvatnet shows that local cereal cultivation took place. As in previous phases, barley (*Hordeum*) seems to have been the most important cereal in Vik 6. The presence of oats (*Avena*) and wheat (*Triticum*) indicates that these were also cultivated, and wheat may have been more common at Ørland in Vik 6 than before. A seed of flax (*Linum usitatissimum*) (Moltsen 2017) documents the presence and probable cultivation of flax at Ørland, but is not recorded in the pollen samples. Pollen of flax is rarely found in cultivation layers and may well have been cultivated at Ørland, in spite of its absence in the pollen record.

The regional landscape during Vik 7 was most likely a mosaic of outfield pastures and infields with cereal cultivation and mown meadows. A significant reforestation (pine and spruce) and a reduction in outfield areas are visible around Eidsvatnet c. AD 1360–1550. This may be a consequence of population depletion during the Black Death (c. AD 1350; Lunden 2004). At Ørland, as reflected by Ryggamyra, there was local outfield grazing activity until the 14th century, with records of Cerealia, barley, wheat and ruderal species, most likely spread from nearby settlements. From c. AD 1400 the charcoal curve suggests increased human activity around Ryggamyra. This could relate to summer farm activity, which is well known from late historical times (Schøning 1910). The increased charcoal could also relate to heathland burning. Finally, in historical times, farmsteads (husmannsplasser) were established in outfield areas in Vik (Berger 2001).

During Vik 7 there may also have been local hemp production or import, unless the pollen type reflects naturally grown hops (pollen series 616158, 224324 and 223883). Pollen grains of hemp and hops are difficult to separate, and are often grouped together in the same pollen-type. Pollen grains of hemp have somewhat larger pollen grains than hops, but the sizes often overlap (Beug 2004). According to Fægri & Iversen (1989) the pollen grains of hops are below 20μ in diameter while pollen grains of hemp are above 20μ, but according to Beug (2004) hops can be up towards 24μ, and hemp > 25μ. In the pollen samples from Ørlandet the pollen grains have a diameter of up towards 29μ, and may represent hemp. Historical sources indicate production of hemp in Ørland c. AD 1770 (Schøning 1910).

The manor at Austrått had an expansion period from about AD 1500 (Andersen & Bratberg 2005). A significant woodland clearance is visible around Eidsvatnet from c. AD 1590 and a regional forest cover comparable to that of recent time was established between AD 1600 and 1700. This is in accordance with historical sources that point to a lack of woodland and the introduction of peat as a source of fuel from c. 1600 at Ørland (Schøning 1910). In Field D there is an increase in pollen types connected to hay meadows, suggesting an increase in mowing, which has been important in Ørland historically (Rian 1986). In early modern times large drainage schemes transformed outfield commonage in Ørland into infield meadows and fields (Berger 2001).

CONCLUSIONS

The vegetation history of Vik, Ørland is based on a pollen diagram from the bog Ryggamyra, spanning the period from c. 500 BC to recent times, and pollen data from a variety of settlement contexts at Vik dating to Pre-Roman Iron Age, Roman Iron Age, and the early medieval period. Pollen analysis suggests that Ørland throughout its past has been largely characterized by open landscapes of marshes and wetland areas, with poor drainage, and that herbaceous grasslands and barley cultivation existed in connection with farmed landscapes and settlement sites at Ryggen during Pre-Roman Iron Age and Roman Iron Age. Barley was cultivated and animals grazed both in wetland areas and drier, lime-rich seashore grasslands.

Pollen samples from the lake Eidsvatnet, further east, were analyzed to give a regional context to the vegetation development at Ørland. Eidsvatnet covers the period from c. 260 BC to recent times, and reflects areas of woodland and open grasslands, with patches of heathlands and cereal cultivation during Pre-Roman Iron Age and Roman Iron Age. Around Eidsvatnet three periods of more intensive human activity can be identified, when forest is cleared, grass-dominated vegetation increases, and outfield grazing areas are established. These periods are the Roman Iron Age and Migration Period (c. AD 1–540), parts of the Viking Age and Early and High Middle Ages (c. AD 900–1360), and recent times (from AD 1600 onwards).

The Migration Period is interpreted as a period of less activity at Vik, Ørland. At this time Ryggamyra underwent a natural succession from minerotrophic wetland to raised bog with heathland vegetation. This can be a consequence of interrelated environmental factors involving changing sea levels and changing settlement patterns. The vegetation development at both Eidsvatnet and Ryggamyra suggest a period of change at the transition to the Merovingian period, which may be associated with structural changes in society influenced by climatic changes.

In the last part of the Late Iron Age Eidsvatnet suggests woodland clearance on a regional level, with the expansion of outfield grazing areas. This period is characterized by an open landscape with outfield pastures, but also by infields with mown meadows and cultivated fields. Parallel to intensified infield production at Ørland in the late Viking Age and early medieval period, there was outfield exploitation involving grazed heathland vegetation (Ryggamyra), a development also reflected in the archaeological contexts at Vik.

Presence of pollen from cornflower in a medieval context at Ørland may suggest import of cereals for consumption and/or for sowing. Increased contact with the outside world is likely considering Ørland's position along the gateway to Trondheim. As in previous phases, barley seems to have been the most important cereal in Middle Ages. Pollen analysis also suggests local production/use of hemp and increased use of wheat in the medieval period.

The regional landscape in the late medieval period was most likely a mosaic of outfield pastures and infields with cereal cultivation and mown meadows. Eidsvatnet seems to record the late medieval depression and the Black Death, with the increase in coniferous woodland and reduced outfield grazing activity. At Ørland, as reflected by Ryggamyra, there was local outfield grazing activity until the 14th century, with records of undifferentiated cereals, barley, wheat and ruderal species, most likely spread from nearby settlements. From c. AD 1400 the charcoal curve suggests increased human activity around Ryggamyra, which could relate to summer farm activity, and/or heathland burning.

The main vegetation development and interpretation of the pollen data was summarized through gradient analysis showing similarities and differences between samples from the archaeological contexts, the bog and the lake. Landscape openness reconstructions further contributed to the identification of periods of high and low human activity at and around Ørland, with decrease and increase in tree cover, respectively. These analyses revealed a high degree of correspondence with the number of radiocarbon dates from archaeological contexts, opening up new potentials in the collaboration between archaeology and pollen analysis in environmental and landscape research projects.

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APPENDIX

Pollen-types with abbreviations used in figures, Norwegian names from Lid & Lid (2005), and common English name from www.linnaeus.nrm.se/flora.

Pollen-type (abbreviations used in Fig. 11, 12)	Norwegian name	Common English name
Achillea-type (Achil)	prestekrage/ryllik	oxeye daisy/yarrow
Alchemilla	marikåpe	lady's mantel
Alnus	or	alder
Anemone-type (Anemo)	hvitveis	wood anemone
Apiaceae (Apiac)	skjermplanter	umbellifer family
Artemisia (Artem)	burot	mugworth
*Asteraceae sect. Aster (*Ast As*)*	kurvplanter	composite family
Asteraceae sect. Cich (Ast Ci)	svæve-type	composite family (dandelion-type)
Avena	havre	oats
Betula	bjørk	birch
Betula nana	dvergbjørk	dwarf birch
Botrychium boreale	fjellmarinøkkel	-
Botrychium lunaria	marinøkkel	moonwort
Brassicaceae (Brass)	korsblomster	crucifer family
Callitriche	vasshår	water-starwort
Calluna (Callu)	røsslyng	heather
Caltha-type (Calth)	bekkeblom	marsh-marigold
Campanula	blåklokke	bluebell
Cannabis/Humulus-type (Can)	hamp/humle	hemp/hops
Caryophyllaceae (Caryo)	nellikfamilien	carnation family
Cerastium cerastoides gr.	arve	mouse-ear
Cerastium fontanum gr. (Cer fo)	arve	common mouse-ear
Cerastium-type (Ceras)	storarveslekten	mouse-ear
Cerealia	korn	cereals
Chamaepericlymenum	skrubbær	dwarf cornel
Chenopodiaceae (Cheno)	melder	amaranth family
Cirsium	tistel	thistle
Corylus (Coryl)	hassel	hazel
Cryptogramma (Crypt)	hestespreng	parsley fern
Cyperaceae (Cyper)	halvgress/starr	sedge family

Pollen-type (abbreviations used in Fig. 11, 12)	Norwegian name	Common English name
Drosera	soldogg	sundew
Empetrum (Empet)	krekling	crowberry
Ericaceae (Erical)	lyngordenen	Heather family
Fabaceae (Fabac)	ertefamilien	pea family
Fagus	bøk	beech
Filipendula (Filip)	mjødurt	meadowsweet
Frangula alnus	trollhegg	alder buckthorn
Fraxinus	ask	European ash
Galeopsis	då	hemp-nettle
Galium (Galiu)	maure	bedstraw
Geranium	storknebb	crane's-bill
Gymnocarpium dryopteris	fugletelg	oak-fern
Hippophaë rhamnoides (Hippo)	tindved	sea-buckthorn
Hordeum-type *(Horde)*	bygg	barley
Huperzia selago (Hup se)	lusegras	fir clubmoss
Hypericum (Hyper)	perikum	St. john's-wort
Juniperus (Junip)	einer	juniper
Lotus-type *(Lotus)*	tiriltunge	common bird's-foot trefoil
Lychnis-type	hanekam/tjæreblom	ragged-robin/sticky catchfly
Lycopodium annotinum (Lyc an)	stri kråkefot	interrupted clubmoss
Melampyrum (Melam)	marimjelle	cow-wheat
Menyanthes	bukkeblad	bog bean
Montia	kildeurt	blinks
Myrica	pors	bog myrtle
Myriophyllum alterniflorum	tusenblad	alternate water-milfoil
Narthecium	rome	bog asphodel
Nymphaea	nøkkerose	white water-lily
Onagraceae/Epilobium	mjølke	willowherb
Ophioglossum (Ophio)	ormetunge	adders-tongue
Oxalis	gaukesyre	sorrel
Parnassia	jåblom	grass-of-Parnassus
Pedicularis (Pedic)	myrklegg	lousewort
Persicaria maculosa	hønsegress	redshank

Pollen-type (abbreviations used in Fig. 11, 12)	Norwegian name	Common English name
Picea	gran	spruce
Pinus	furu	pine
Plantago lanceolata (Pl lan)	smalkjempe	ribworth plantain
Plantago major	groblad	broadleaf plantain
Plantago maritima (Pl mar)	strandkjempe	sea plantain
Poaceae (Poace)	gress	grasses
Polemonium	fjellflokk	Jacob's ladder
Polygonum aviculare (Pol av)	tungress	knotgrass
Polypodiaceae (Polyp)	sisselrotfamilien	ferns
Polypodium vulgare	sisselrot	polypod
Populus	osp	poplar/aspen
Potamogeton col.	tjønnaks	pondweed
Potamogeton eupot.	tjønnaks	pondweed
Potentilla-type *(Poten)*	tepperot/myrhatt	tormentil/marsh cinquefoil
Prunella-type	blåkoll	selfheal
Prunus padus	hegg	bird cherry
Pteridium	einstape	bracken
Quercus (Querc)	eik	oak
Ranunculus acris-type *(Ran ac)*	engsoleie	meadow buttercup
Ranunculus flammula-type (Ran fl)	grøftesoleie	lesser spearwort
Rhinanthus/Euphrasia-type *(Rhi Eu)*	engkall/øyentrøst	yellow-rattle/-eyebright
Rosaceae	rosefamilien	rose family
Rubus chamaemorus (Rub ch)	molte	cloudberry
Rumex acetosella (Rum la)	småsyre	sheep's sorrel
Rumex longifolius-type (Rum lo)	høymol	northern dock
Rumex sect. *acetosa (Rum ac)*	engsyre	common sorrel
Ruppia	havgras	tasselweed
Sagina	småarve	pearlwort
Salix	selje/vier	willow
Saxifraga oppositifolia-type	sildre	purple saxifrage
Schrophulariaceae	maskeblomsterfamilien	figwort family
Scilla-type	blåstjerne	squill
Secale	rug	rye
Sedum	bergknapp	stonecrop

Pollen-type (abbreviations used in Fig. 11, 12)	Norwegian name	Common English name
Selaginella (Selag)	dvergjamne	lesser clubmoss
Silene dioica-type (Sil di)	jonsokblom	campion
Sinapis-type *(Sinap)*	sennepslekten	charlock, mustard
Solidago (Solid)	gullris	goldenrod
Sorbus	rogn	rowan/mountain-ash
Spergula arvensis (Spe ar)	linbendel	corn spurrey
Sphagnum	torvmose	peat moss
Stachys (Stach)	svinerot	woundwort
Succisa (Succ)	blåknapp	devilsbit
Thalictrum	frøstjerne	meadow-rue
Tilia	lind	lime
Trientalis (Trien)	skogstjerne	chickweed-wintergreen
Trifolium pratense-type	rødkløver	red clover
Trifolium repens-type (Tri re)	hvitkløver	white clover
Triticum-type *(Triti)*	hvete	bread wheat
Ulmus	alm	elm
Unidentified (UI)		
Urtica	nesle	nettle
Vaccinium-type *(Vacci)*	bærlyng	blueberry/lingonberry
Valeriana	valeriana	valerian
Verbascum	kongslys	mullein
Viburnum (Vibur)	krossved	guelder-rose
Vicia cracca-type *(Vic cr)*	fuglevikke	vetch
Vicia-type	vikke	vetch